Data infrastructures and digital labour: the case of teleradiology

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Statement of Authentication

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in full or in part, for a degree at this or any other institution.

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List of abbreviations

ABR – American Board of Radiology

ACR – American College of Radiology

DICOM – Digital Imaging and Communications in Medicine

HIPAA – The Health Insurance Portability and Accountability Act

HIS – Hospital Information System

HL7 – Health Level 7

NEMA – National Electrical Manufacturers Association

PACS – Picture Archiving and Communication System

RANZCR – the Royal Australian and New Zealand College of Radiologists

RCR – the Royal College of Radiologists

RIS – Radiology Information System

Abstract

In this thesis, I investigate the effects of digitalisation in teleradiology, the practice of outsourcing radiology diagnosis, through an analysis of the role of infrastructures that enable the transfer, storage, and processing of digital medical data. Consisting of standards, code, protocols and hardware, these infrastructures contribute to the making of complex supply chains that intervene into existing labour processes and produce interdependent relations among radiologists, patients, data engineers, and auxiliary workers. My analysis focuses on three key infrastructures that facilitate teleradiology: Picture Archiving and Communication Systems (PACS), the Digital Imaging and Communication in Medicine (DICOM) standard, and the Health Level 7 (HL7) standard. PACS is a system of four interconnected components: imaging hardware, a secure network, viewing stations for reading images, and data storage facilities. All of these components use DICOM, which specifies data formats and network protocols for the transfer of data within PACS. HL7 is a standard that defines data structures for the purposes of transfer between medical information systems. My research draws on fieldwork in teleradiology companies in Sydney, Australia, and Bangalore, India, which specialise in international outsourcing of medical imaging diagnostics and provide services for hospitals in Europe, USA, and Singapore, among others. I argue that PACS, DICOM, and HL7 establish a technopolitical context that erodes boundaries between social institutions of labour management and material infrastructures of data control. This intertwining of bureaucratic and infrastructural modes of regulation gives rise to a variety of strategies deployed by companies for maximising productivity, as well as counter-strategies of workers in leveraging mobility and qualifications to their advantage.

Complementing knowledge derived from fieldwork, my analysis draws on the official documentation of the DICOM and HL7 standards as well as early military documents and current technical studies on PACS. Studying teleradiology practices shows that the work of radiologists and other non-medical employees, such as transcriptionists, is highly regulated through PACS, particularly by means of its workflow management function and its capacities for formatting, storing and transmitting medical data. PACS and DICOM introduce temporalities of labour determined by the movement of data between systems and this technical processuality becomes a guiding principle in the organisation of workflows. Additionally, radiologists are subject to restrictions stemming from national healthcare systems and professional organisations that regulate who can diagnose patients in different countries. As teleradiology companies set offices in multiple locations, hire radiologists from different nationalities, and provide

services for a number of countries, workers need to navigate regulations determined by both infrastructural and juridico-political constraints.

The design of PACS and DICOM partially integrates labour regimes established by nation states and professional associations by including options for incorporating state requirements concerning radiology diagnosis within the workflow. These systems provide the ability to automatically assign cases and tag data in ways that adhere to national healthcare protocols that set parameters for defining, documenting, and monitoring the performance of medical procedures. However, such technological measures do not subsume the role of traditional political regulations. Instead, they generate a field of technopolitics that reinterprets and intersects with state regulations of medical professionalism and labour mobilities. Significantly, PACS, DICOM, and HL7 enable the establishing of new teleradiology initiatives, both international and national, and the inclusion of patients from marginalised communities into digitalised healthcare. Data infrastructures also alter radiology supply chains by introducing subjects whose role is to directly support the transfer of data in order to speed up the process of diagnosis and help maximise the productivity of radiologists. These inclusions point to the role of digitalisation in building relations of interdependence among inclusion, control, and extraction and show how data infrastructures become incorporated within strategies for labour intensification and the exploitation of patient data.

The thesis consists of five chapters. In the first one, I analyse the infrastructures of expertise formed through the intersection of licensing, national and international jurisdictions, and the processes of bordering and self-regulation within the radiology profession. I argue that these conditions of the regulation of radiology expertise are formative for the hierarchies within teleradiology labour and the technologies for labour intensification which become incorporated within data infrastructures for data and workflow management. The second chapter focuses on the workflow management in teleradiology, which is central for the organisation of labour productivity in the industry. I also examine the hierarchies between workers that develop within the teleradiology supply chain and trace how the interdependence between data management and labour management evolves. The third chapter analyses the digitalisation and standardisation of medical images through the DICOM standard and shows how these processes reshape the relationship between visualisation, control, and subjectivity. In the fourth chapter I trace the development of PACS and how data management and organisation are structured through its two main components - the archive and the secure network, arguing that these two elements show the role of the materiality of digital data in shaping practices of labour control. Finally, in the fifth chapter, I examine the politics of interoperability and data ontologies through the case of the healthcare data standard HL7 used in Hospital Information Systems and Radiology Information Systems.

The thesis integrates theoretical work in digital media studies, political economy, and science and technology studies with close reading of technical documents on DICOM, HL7, and PACS. I adopt this approach not only as a way to interrogate the political effects produced through the intersection of material infrastructures and the social and historical contexts within which they operate but also as a method for constructing the conceptual apparatus of my analysis. My research shows that material technologies for organising data are part of a complex ecosystem of political technologies and logistical techniques that works through modulating the properties of environments, flows, bodies, and territories. The data infrastructures that facilitate teleradiology both solidify and undermine historically developed modes of labour management in healthcare. In turn, the digital workflows and information extraction that these infrastructures enable become integrated in strategies of algorithmic control that subjects of teleradiology supply chains experience through both coercion and consent.

Contents

Introduction

A few years ago, while living in Sofia, I managed to walk nose first into a glass door and, with a bruised nose, headed to the doctor to check if there was anything broken. I went to the local polyclinic, a remnant from the time of free public healthcare; it now lay half-empty with different private practices housed in the individual offices. I walked into the quiet old building and received a referral for x-ray from an elderly doctor, who thought I was overly cautious. He scribbled a note for the radiographer. I went to the upper floor, where an equally old female radiographer, dressed in a white apron, looked at the piece of paper in my hand, let me in; she adjusted the heavy x-ray machine and a few minutes later handed me the x-ray in the corridor before pointing to the office of the radiologist. There the radiologist, a man in his 50s, read the image on the light box; while I was sitting next to him, he told me that my nose is fine, and handed back the x-ray. Sometimes radiologists would ask me about symptoms and my history of other illnesses, for instance pneumonia, in case I was referred for a lung x-ray. But this time none of this was necessary and the radiologist did not even write a note back to the general practitioner doctor (GP) who referred me. I strolled out with the x-ray in hand and later that evening I jokingly exchanged x-ray selfies with my friend, Veronika. She got my not broken nose, I got her infected lungs from the year before. The x-ray film had become a souvenir, there was only a handwritten scribble in one corner that vaguely identified Veronika, if one even managed to decipher it. Other than that, the image was completely unhooked from the clinical context of its production and interpretation.

I start with this little story to illustrate the differences in the practice of radiology that have been brought about through the digitalisation of medical images and the introduction of remote radiology diagnosis (teleradiology). If I replay this incident in the context of the practice of teleradiology, which I analyse in this dissertation, then the scenario is completely different. Let's imagine that instead of being in Sofia, I was in Sweden. Here, I go to a hospital that has a contract with Omniscan Teleradiology, which is one of the teleradiology companies from my fieldwork. This hospital does not use a film x-ray machine. All radiography modalities are digital, including the one used to take the x-ray of my nose. When the GP issues a referral for an x-ray, they would do this through the local Hospital Information System (HIS). HIS is a digital information system used in medical institutions to manage admissions, referrals, finances, and patient records. Another subsystem integrated into HIS is the Radiology Information System (RIS), which is used to specifically manage referrals to the radiology department. The referral will be sent directly to the radiography department; it will include the details of the GP, my patient details, and the type of exam to be performed. RIS will be connected to the Picture Archiving and Communication System (PACS) that is used for storing and transferring medical images. The digital radiography modality, the machine used for taking the x-ray, will be linked to both of these RIS and PACS systems. The digital radiography machine is manufactured to conform to Digital Imaging and Communication in Medicine (DICOM), which is the key industry standard for digital medical images in radiology and teleradiology.

DICOM sets physical parameters for the digital images: from greyscale to pixels as well as what other information should be included in the image format, how it should be formatted, and how the images can be transferred between modalities and information systems. All standard digital images in radiology are DICOM images. This is a special format that can be opened in PACS, while on a regular Microsoft Windows or Apple OSX operating system it appears as a zip folder. One of the functionalities enabled through this standard, DICOM modality worklist, enables the x-ray machine to automatically pull out patient details and the exam details from the referral filed in HIS and RIS (National Electric Manufacturers Association 2015b). Thus my details from the referral will be automatically included in the DICOM file. I will not receive a copy to bring to the radiologist. Instead, the DICOM file will be automatically uploaded in PACS and assigned to a radiologist. In the case of the Swedish hospital I am hypothetically visiting, the DICOM image will be assigned to one of the radiologists from the Omniscan Teleradiology company that has taken on the functions of the local radiology department. The radiologist who reads my image will be based in their Sydney office, but because this teleradiology company shares a cloud-based PACS with the Swedish hospital, the hospital will receive this image almost instantaneously. As soon as the image is processed by the x-ray machine, it will be uploaded in PACS as a DICOM image. The radiologist in Sydney will have the necessary credentials to diagnose the images from this Swedish hospital. When the radiologist reads the image and writes a report, this report will then be sent back to the Swedish hospital via PACS and conveyed to me by the GP who had written the referral.

Teleradiology represents the convergence of trends in contemporary healthcare and professional labour that link the increased digitalisation of different aspects of medical practice with the possibilities for globalisation and outsourcing of care and expertise. Teleradiology, where radiology images are outsourced, (often abroad) for diagnosis, entails the development, assembling, and use of a complex set of infrastructures that enable the transfer of visual and textual patient data, impose technical and procedural standards, and facilitate the management of labour. By focusing on the way these infrastructures develop, their political underpinning and genealogy, and the way they are employed in the exercise of control over labour, I offer an analysis that shows the ways in which techniques of managing and regulating expertise and professional work are all incorporated within the development of digital infrastructures. I suggest that the development of teleradiology and the different subjectivities and relations that it brings about can best be understood as produced through the intersection of two different regimes of infrastructural organisation, namely professional expertise standards and specialised digital infrastructures. The intersection of these two regimes of labour regulation in teleradiology shapes the ways in which teleradiology workers, both radiologists and administrative staff, is included within the practices and hierarchies that are developed to sustain intensified productivity. These two regimes of regulation, that is professional licensing and digital standards, have some things in common; they both generate logics of inclusion and exclusion in the practice of teleradiology, hierarchies between different workers, and specific technologies for labour intensification. There is a difference however, in the way these two regimes function and the ways in which they have developed. This arises from different histories of control and productivity that I set out to explore in my analysis of teleradiology practice.

Standards and structures for ensuring professional expertise in teleradiology have a significant importance for making this practice possible. The very premise of international teleradiology, which I am studying here, is that companies make use of different economic, political, and temporal geographies in order to offer radiology services that are either cheaper or which cover the nighttime hours, or both. In this context, professional standards and regimes of certification have a crucial role in ensuring that this business model can function. The radiologists working for these companies diagnose patients who are located in other countries and this cross-border dimension of the practice puts much stronger emphasis on the regulation of their work. Teleradiology practice involves both physical and virtual labour migration (Aneesh 2006). While some radiologists migrate to a new place in order to work in teleradiology, others stay in their country of origin but become partially incorporated within the regimes of regulation of a foreign country's medical practice. In this context of remote cross-border labour, professional licensing requirements play an important role in regulating such mobilities.

The digital standards used in teleradiology on the other hand, construct a different regime of management of labour. This is a regime that simultaneously enables transfers and mobilities and at the same time imposing technological control on these mobilities and on the labour of teleradiologists. The size of the files, the time it takes for them to load, the sequence of actions that are prescribed by data standards and set procedures, all create a context of technoscientific control. Teleradiology practice is dependent on these standards and digital systems that make the transfer of data and the organisation of labour possible. This second point, that is the role of medical data standards and digital systems in enacting modes of labour management, is my main focus in analysing the role of these standards and digital systems in teleradiology.

Teleradiology and the condition of mediated labour

Teleradiology itself is not a practice that has been extensively studied in social sciences. One of the reasons for this perhaps is the fact that it is a highly specialised industry that has not entered the popular imagination in the same way clinical trials and genomic research have. But it is nevertheless a practice that is far more common and closer to our everyday experiences than other recent developments in the medical field. This wide adoption of teleradiology is probably leading to the paradox that it is an object of research that is simultaneously exotic and very mundane. The scarce research in social sciences and cultural studies that focuses on teleradiology specifically, examines some of the experiences of radiologists working in this industry. Ari Goelman who conducted a doctoral study based at Massachusetts Institute of Technology (MIT) on the outsourcing of nighttime (nighthawk) teleradiology from the USA to Sydney, Australia, adopts a human geography approach, focusing on the role of space and place in the practice (Goelman 2005a), the implications of outsourcing for labour productivity and accuracy of diagnosis (Goelman 2007), and the way digital media use has been shaping and has been shaped by these remote spatial practices (Goelman 2005b).

Goelman's work on teleradiology is situated within the study of outsourced labour and the role of digital technology in its mediation, which has been the focus of a number of other studies coming from MIT. Frank Levy, Goelman's supervisor and co-author, whose research focuses on the offshoring and outsourcing of labour, published a series of articles that examine the implications of outsourcing for job security, job losses, and deskilling of radiologists in the United States (Levy and Goelman 2005; Yu and Levy 2007, 2010). This series of studies by Levy and his colleagues take the effects of outsourcing on the labour market in the outsourcing country as a starting position and analyse the impact that this has on the professional labour of radiologists. These authors analysed the debates within the USA and Singapore radiology communities at the time, along with their reaction to the outsourcing of imaging diagnostics to India, the push towards rules for certification in international teleradiology, and the reasons why radiology is less vulnerable to deskilling and the displacement of jobs from the Global North to the Global South. This focus of research positions teleradiology within the general context of outsourcing as an international practice that leads both to the globalisation of industries and to weakening the position of labour in developed economies.

The above research in labour markets and professional power provides a valuable context for my own study of teleradiology. What I show in my analysis however, is that the notion of professional expertise and power itself should not be uncritically accepted as a force that protects the interests of labour. This is partly because infrastructures for the licensing of professional expertise involve diverse actors who enact regulations on different scales through national institutions, professional bodies, individual healthcare entities, and international organisations. The role of professional licensing does not just have the sole purpose of restricting and regulating the practice of teleradiology. The imperatives for maintaining professional competences through sustained and diversified practice posed by radiology associations can also be paradoxically appropriated by teleradiology companies to strengthen the incentive for radiologists to join outsourcing companies.

Selma Venco (2012) similarly analyses the practice of teleradiology in the context of international outsourcing and the new international division of labour. Her research on teleradiology companies in Brazil that provide medical imaging diagnostics for hospitals in Portugal, uses a world systems perspective to show how lower-paid Brazilian doctors are employed as a way for healthcare capital to profit from international wage inequalities. Venco analyses the teleradiology outsourcing chain by extending an argument about the obliteration of time and space through the globalisation of capital which she sees as further accelerated by the use of information and communication technology (ICT), and concludes that even professional labour like radiology is not immune to being displaced and devalued. Venco builds on a tradition of Marxist analysis of the globalisation of capital in search of cheap labour, which Immanuel Wallerstein (2004) conceptualises through the dichotomy between a core of capitalist state-colonisers and a periphery of non-capitalist or developing regions from which the capitalist core extracts value and resources. Venco's research shows how past colonial dependencies and cultural affinities are reactivated through the practice of outsourcing. In her case, Brazilian hospitals build outsourcing relations not only with Portugal but also with Angola, another former colony of Portugal, from where images are processed. Venco's study, although presenting an initial entry into the field, shows hints of some of the topics I develop throughout my dissertation; she mentions the way for instance in which the Brazilian company sees its outsourcing contracts with Portuguese hospitals as the gateway to other radiology markets in Europe. Her study thus touches upon a larger argument in the social sciences, about the way supply chains function and the kinds of relations they enable across borders.

The anthropologist Anna Tsing, who has written on supply chains in Southeast Asia, coins the term "supply chain capitalism" (2009, 2011), in reference to the specific condition of globalised capitalism. Tsing challenges the world-systems theory of Wallerstein, arguing that what is specific to the expansion of capitalism is that it reaches for new territories of extraction but without necessarily aiming to universalise and homogenise them. Instead, capitalism takes advantage of cultural differences, margins, and liminalities. Extracapitalist relations therefore are not entirely subsumed under capitalism but are, rather, put in its service. Tsing's research in summary highlights the heterogeneity of supply chains as they penetrate new places. While Tsing does not focus on the technical infrastructures used for sustaining and managing supply chains, she does touch upon the issue of mediation in the way capitalist and power relations radiate from the centres of supply chains to their peripheries, and draws attention to the resistance and subversion that these relations encounter. In this way, Tsing's analysis elucidates the materiality of power relations within which international capital intervenes. My research focuses, however, more closely on the infrastructures that sustain and enable teleradiology outsourcing chains. Through this analysis I demonstrate that these digital infrastructures used for the transfer of medical data and images play a central role in shaping practices of control and labour intensification in teleradiology.

The focus on infrastructures allows me to examine the role of digital media in enabling and regulating the practice of teleradiology. Digital technology is an essential element that makes outsourcing possible in many ways; for instance, it enables information transfer, remote work, and it has introduced tools to monitor and increase the productivity of labour. Research on the role of Internet Communications Technology (ICT) in outsourcing and managing labour is abounding in recent decades; a large part of this has been dedicated to investigating the emergence of new forms of labour or transformation of existing ones and in the process introducing the concept of "digital labour". Ursula Huws for instance, who writes extensively on outsourcing and digital labour, argues that the rise in digitally mediated labour leads to a qualitative change in the condition of labour by increasing precarious employment, workplace surveillance, and allowing companies to easily move countries and to use this ease of mobility to negotiate lower wages and undermine labour protection (Huws 2014). Huws suggests that the new conditions of labour lead to a new material and political characteristic of its subjects, calling these new subjects the "cybertariat". She also notes the importance of restructuring business functions for the enabling of outsourcing and the efficient management of geographically dispersed production processes (Huws et al. 2009, Huws 2014). The compartmentalising of business processes into business functions is a key mechanism enabling, on one hand, the management of labour and, on the other hand, the establishment of operations that make outsourcing possible. Huws (2006) sees the development of value chains (used often as synonymous with supply chains but focusing more on the production of value across the multiple stages of production and delivery) within a historical lineage conceptualising the political economy of capital from Adam Smith onward. She also offers important theoretical insight into the relationship between the organisation of supply chains and outsourcing, on one hand, and the long standing practices of scientific management, on the other. Huws suggests that a key development enabling the global rise of outsourcing has been the management technique of separating business processes into discrete business functions that can be performed separately but controlled centrally by the company and that this practice builds on the tradition of scientific management from the early 20th century.

In my work I offer an analysis of another key mechanism for the management of value chains - the workflow. While Huws explores the effects of separating functions as a strategy for labour control, my focus on workflow organisation puts primary emphasis on the integration of different processes, tasks and roles, in an attempt to achieve interoperability. This approach helps highlight the ways in which the management of data and the management of labour are interconnected. It also sheds light on the hierarchies and dependencies among different workers in teleradiology. Tracing the genealogy of the teleradiology workflow to the scientific management studies of Frank and Lilian Gilbreth, I show that there is a distinct line of enquiry that places the theories and methods of labour management and organisational structure within attempts to organise material control over labour productivity. It does so through manipulating different elements of the media within which flows of data and labour take place.

Materiality constitutes an important part of the analysis of digitally mediated labour and the objects and subjects that form the chains of interoperability and transfer of information. In the study of radiology and medical practice, numerous scholars have explored different aspects of the materiality of ICT-mediated practices. For example, some scholars from the medical sciences employ ethnographic methods and methods from Actor-network theory (ANT) to discuss the way radiologists (Karasti, Reponen, Tervonen, and Kuutti 1998) and radiographers (Larsson, Aspelin, Bergquist et al. 2007) use PACS in their daily practice. This type of research into the digital systems used in radiology and teleradiology builds on a tradition in the study of technology and its social role and situatedness. This scholarly work done on digital technology in organisational settings draws on Bruno Latour's Actor-network theory and his work on uncovering the ways in which practices and knowledge are produced and shaped in an environment of complex and shared agency between human and non-human actors (see Latour 2005, Latour and Woolgar 1986). Also following on Latour and others, much of this work draws on the science and technology studies (STS) tradition. Catherine Pope, Susan Halford, Joanne Turnbull and Jane Prichard (2014), for example, talk about cyborgisation of healthcare workers in their study of the implementation of an automated decision support system for emergency care. Their study, which focuses on non-professional healthcare workers who handle emergency phone calls in an UK hospital, suggests the development of hybrid practices is shaped by the interactions between humans and machines.

The idea of cyborgisation triggered by the adoption of digital health technologies, is present also in two of the prominent researchers in digital healthcare, namely Nelly Oudshoorn (2020) and Deborah Lupton (2012), with regards to the relationship that patients have with digital medical technology. Lupton revisits the concept in later work, arguing that a more appropriate term of post-cyborg needs to be adopted instead for the analysis of contemporary digital health because of the way humans are absorbed into new data landscapes (Lupton 2015, 2016). Nelly Oudshoorn, however, espouses a different approach in her work on labour in telemedicine settings, where she focuses on issues of invisibility, gender, and control (Oudshoorn 2011). One of the key lines of Oudshoorn's research on telemedicine workers, who are non-professionals and nurses responding to phone calls, is the notion of script, which she uses to distinguish between the ways in which different digital systems used in the workplace affect the work process and decision making.

The concept of a script, that underpins the functionalities of digital technology but also applies to the social rules and scenarios of human action, is one of the key notions in the work of Lucy Suchman on human-machine configurations. In this work, she also analyses the role of the interface as a locus of translation between different scripts (Suchman 1987). The link between materiality and control, which Suchman and Oudshoorn both develop through the concept of underlying scripts, underscores the role of the medium in the organisation of labour. Their premise for analysis lies in the argument that scripts determine the functionalities of digital technologies, and also, through their interaction, the effect that they have on the actions of humans working with them. One of the restricting aspects of such STS informed research is its focus on small scale interactions and attention to the role of the interface as a technology and as a situation of encounter. While it is possible to infer some conclusions about how digital technology changes labour processes and relations from observing how people use this technology and how their practices are changed by its introduction, the point of encounter between the worker and the machine is only one small section in a complex chain of actors and technologies of production and control that define the effects of digital systems. A more critical approach that brings together issues of materiality and political and economic power, arises from research in media studies, critical management studies, and labour studies that uses notions of algorithmic governance (Amoore and Raley 2017; Aneesh 2009; Aradau and Blanke 2018), algorithmic management (Beverungen 2019; Irani 2015a, 2015b), or algorithmic control (Wood, Graham, Lehdonvirta et al. 2019). The difference that these studies bring in comparison to the STS approach is the political genealogy of control that they incorporate into the analysis. This situates the new forms of control exercised through digital technology within the history of the development of scientific management and bureaucracy as forms of command and organisation, that arise with the birth of modernity and capitalism. Studies on algorithmic management also place less weight on the interface as an object of study and a focal point of control in socio-technical infrastructures. On the contrary, algorithmic control is seen as a complex and systemic amalgam of quantification, calculation, categorisation, and what Aneesh Aneesh (2009) calls "algocracy" - the path of action predetermined by algorithms that workers need to comply with.

While in my analysis I adopt a similar approach of historically situating the structures of control through digital technology in teleradiology, my focus goes beyond the issue of quantification and calculation that dominates research on algorithmic management. Instead, I suggest that control is exercised through a more complex configuration of the materiality of digital technology. It is not only determined by algorithms and quantification, but also through other means of organising digital media such as data formats, ontologies, and architectures. The significance of these other means of organising and exercising control in teleradiology lies in tracing the continuities and discontinuities between digital infrastructures and past histories of control and organisation in healthcare and healthcare labour. What I show through my analysis, is that digital technologies of control and intensification of labour build on a long history of entanglement between media and the management of labour productivity.

Infrastructuralisation of radiology

In the following chapters I trace the ways in which the interconnectedness of data management and labour management is playing out in the practice of teleradiology and how this leads to the digital infrastructuralisation of the practice. This process of infrastructuralisation involves the increased and diversified role of technology and the increased articulation of political and economic relations of power and accumulation through technological tools. Infrastructuralisation does not simply mean more technology in the practice of teleradiology; it also entails initiatives aimed at accelerating integration and interoperability across different technological systems, coordinated standardisation, and the growing adoption of technological tools within frameworks of political and economic control. This last point, which touches on the entanglement of technological and politico-economical control, refers both to the ways in which digital infrastructure absorbs past practices of control as well as the ways in which technology generates its own political context and relations and transforms the existing context and relations. The enmeshment of politics, sociality, and technology also means that the possibilities for agency and the political role of subjects are shaped in both response and opposition to the operation of infrastructures. Paul Edwards (2019) refers to these processes of mutual articulation as infrastructuration, building on Anthony Giddens' theory of structuration (1984). All these processes build on the specific characteristics and role of infrastructure in the practice of teleradiology.

Infrastructure is a concept that has such a high provenance in disciplines like anthropology (Anand, Gupta, and Appel 2018; Dalakoglou 2017; Harvey and Knox 2015), science and technology studies (Bowker and Star 2000; Kornberger, Bowker, Elyachar et al. 2019; Star 1999; Law 1990), media studies (Parks and Starosielski 2015; Peters 2015; Rossiter 2015, 2016; Starosielski 2015), urban studies and human geography (Graham and Marvin 2001; Larkin 2008, 2013), critical security studies (Amoore 2018), and even international relations (Mayer and Acuto 2015), that it has acquired a wide array of meanings and theoretical uses. The heterogeneous provenance of infrastructure as an object of study and a theoretical concept for analysing the entanglement of technology and social life, make the study of infrastructure inherently interdisciplinary; my own research builds on this interdisciplinarity. What makes my approach distinctive, however, is the emphasis on both technology and political economy, which I adopt as a means of opening up questions of infrastructure and its relation to labour and subjectivity.

This diverse adoption of infrastructure as a theoretical concept and an object of study leads to a complex picture of how infrastructure is analysed in relation to, and as part of, social and political life. One distinct line of analysis can be traced back to the work of Lewis Mumford (1934), who reads infrastructure as a political matrix through which social relations are organised. Mumford coins the concept of "the megamachine" as a model of the way in which power relations and the role of individual subjects in industrial capitalism are moulded in the image of factory machinery. The idea that infrastructure participates in shaping political organisation by providing new models of control, categorisation, and connectivity or exclusion, is also part of the conceptual underpinning of the more recent works of Keller Easterling (2014) and Benjamin Bratton (2016). Easterling sees infrastructures - not just physical ones but also soft infrastructures like the international ISO standard - as part of the forming of what she sees as a new order of governance that she calls "extrastatecraft". The close entanglement of extrastatecraft with infrastructures is based on the way in which technological and technocratic solutions generate wider political practices. These solutions change the possibilities of enacting the political and then become replicated across the globe, imprinting on the materiality of social life which Easterling calls "spatial software". Benjamin Bratton, albeit working on a different scale and more concerned with geopolitics, also analyses the role of infrastructure as a matrix of political organisation. He uses the notion of "the stack" from the Open Systems Interconnection (OSI) model as a way to discuss the emerging reorganisations of political order on different levels from the urban to the planetary. These more conceptual works analyse infrastructures as generative of social and political structures, but they are not always attentive to the ways, in which subjectivity can take part in shaping and sabotaging infrastructure. Nonetheless, they underscore the role of infrastructure in maintaining political power and supporting the spread of imperial and capitalist projects and show that a core underpinning of the way infrastructures function is through their drive towards universalisation; this is precisely why they are so tightly linked with the projects of modernity, colonialism, and capitalism (Bear 2020; Larkin 2013; Mitchell 2002; Rossiter 2015, among many).

Anthropological studies on infrastructure, such as those by Brian Larkin (2008), Nikhil Anand (2017), and Dimitris Dalakoglou (2017), put more emphasis on the way infrastructures are incorporated in social life and how they shape and are in turn shaped by social practices. While Larkin, Anand, and Dalakoglou all pay attention to the materiality of infrastructures, they each analyse the ways in which their production and use involve the interaction of different subjects (both individually and as groups) with this materiality, and how this interaction affects them in different ways. Notably, Anand (2017) introduced the concept of hydraulic publics which captures how infrastructures can also be objects of and conduits for political demands and struggles around access to public utilities in urban space. Other writers have similarly pointed out that infrastructures can be instrumental in enacting politics of exclusion and segregation through the material built of public spaces (Graham and Marvin 2001; Law 1990). Brian Larkin meanwhile, writing about media production and piracy in Nigeria, shows that alongside the monumental large-scale infrastructural projects supported by state institutions and capital, subjects who are seemingly deprived of control over the usage and reproduction of media and technology can generate their own parallel infrastructures that mimic and parasitise on the established socio-technical structures.

Writing about infrastructure is not simply a positivist exercise of uncovering technological facts but, more than that, a theoretical and methodological choice to approach the way that practices and relations are constructed and grounded in the materiality of our social worlds (what Sohn-Rethel (1978) and Geoffrey Bowker (1995) refer to as "second nature"). As Susan Leigh Star and Geoffrey Bowker remark, infrastructure is contextual and a matter of position and approach to social reality (Bowker and Star 2000). Beyond the obvious technological aspect of teleradiology, talking about infrastructure and labour in this practice allows for analysis focused on the way DICOM, HL7, and PACS all participate in the construction and historical transformation of complex social systems for data transfer and the management of labour. Focusing on the systemic character of infrastructure generates an important inflection in the research on socio-technical systems which stresses the complexity of infrastructures, their mutual dependence and their embeddedness. Bowker and Star point out that infrastructures involve the combination and coordination of different tools that are subsumed under a unified framework of epistemology and control (ibid. 34). An infrastructure is not necessarily monolithic, centralised, and public (despite arguments to the contrary; see Plantin, Lagoze, Edwards, and Sandvig 2018) although the appearance of being such can be part of its aesthetics (Larkin 2013). Thus, it is the progressive mutual integration of DICOM, HL7, and PACS that allows me to talk about infrastructuralisation of teleradiology, rather than the assumption of centralisation and public utility.

In science and technology studies (STS) the study of infrastructure is linked to the idea of uncovering what lies beneath the seemingly obvious relations and practices that constitute social worlds. Bowker's (1994) notion of "infrastructural inversion" (a concept that is methodological and theoretical at the same time) reveals an initial presumption in the study of sociotechnical systems: they are material and technological structures that are hidden in plain sight while underlying our everyday lives. Studying sociotechnical systems means shifting the focus and bringing them into the spotlight. This tension between being invisible and foregrounding the material possibility of a number of social practices, is present in the case of DICOM, HL7 and PACS as well. These standards and systems have become so fundamental for teleradiology that their technological characteristics and presence disappear into everyday work processes. And part of the reason for this disappearance is the universality and smoothness that standards aim to achieve. For example, the DICOM viewer - the software used by radiologists to open and read DICOM images, which constitutes a central part of PACS - represents one of the components of teleradiology infrastructure that is most noticeable by radiologists, being the interface between PACS and the doctors. However, there is a tendency adopted by software manufacturers to standardise the interface, that is the icons and their position on the screen. This makes it easier for doctors to work on different software systems, smoothing the disruptions that can occur from switching between disparate interfaces, a disruption that would otherwise force the radiologists to notice the distinct materiality of different systems. Standardisation and standards are fundamental elements of how infrastructures function, whether this be as formal institutionalised standards such as DICOM and HL7, or through other informal ways of developing means of mutual intelligibility and interoperability; the alignment of graphic interfaces is one such example from teleradiology.

Recent research in media studies also stresses the historical nature of infrastructures and highlights the possibility to think of infrastructures and infrastructural relations across different media. John Durham Peters' work on media (2015) is one such example; he traces the conceptual and technological origins of different media technologies to research on marine biology, meteorology, and to the basic elements of fire, air, water, and earth. Louise Amoore (2018) offers an equally fascinating historical account of the development of cloud technology, linking it to earlier research on cloud chambers in physics. This research, similarly to the contributions in the volume *Signal Traffic* edited by Lisa Parks and Nicole Starosielski (2015), offers an approach to infrastructure building on the methods of media archaeology (Huhtamo and Parikka 2011; Parikka 2010), and situates contemporary technology within the historical context of cultural and scientific ideas that have influenced its development.

In my analysis of teleradiology I identify a few key features of what infrastructures are and what they do. Infrastructures are "matter that enable the movement of other matter […]; things and also the relation between things" (Larkin 2013: 329), they enable transfers and mobilities. The use of software and hardware systems, data standards, and web and cloud technology makes possible mobilities without which teleradiology would not be possible. These infrastructures enable the transfer of medical patient information, the remote work arrangements which create the conditions for virtual labour mobility; they also become the prerequisites for the physical mobility of radiologists who settle in different time zones in order to cover nighttime shifts in countries for which they provide diagnoses. However, DICOM, HL7, PACS, and infrastructures in general, function not merely by enabling mobilities but more saliently by making some mobilities possible while impeding other ones. These can be physical mobilities, as in the case of teleradiologists moving countries, data mobilities in the case of medical images and patient records, but they can also be changes in the status and the condition of subjects and objects. One such example is the infrastructures of expertise that regulate the recognition of professional expert status of radiologists within state borders and internationally.

Teleradiology labour is subjected to specific technologies of management that arise from the ways in which healthcare expertise is construed and regulated. Professional licensing, credentialing, and rules for remote practice form an important part of the way teleradiology labour is managed by defining the scope and validity of radiology expertise. These aspects impose rules for the inclusion of certain professionals, conditions for their membership, and distinctions between members and non-members. I examine the complex logics behind professional licensing as part of the infrastructures that mediate the status of radiology labour, the hierarchies between professionals, and the possibilities for transborder mobilities and remote work.

Professional licensing and the politics and institutions involved in maintaining and regulating it constitute a part of what Lisa Parks and Nicole Starosielski call "soft infrastructural forms" (Parks and Starosielski 2015: 20) which include intangible structures of control such as rules, conventions, and protocols. The mechanisms of professional licensing govern the mobility of labour in ways that differ from the logic of the main technology exercising control over labour mobilities, that is, the state border. This is not performed through the institutions of state border control but instead through the mechanisms of professional self-regulation. This logic of professional membership as means of bordering develops in a complex relationship to the institution of the nation state - something that I explore in more detail below. The regulation of expert practice in teleradiology follows a logic that is not homogeneous and monolithic but, rather, allows professional membership to operate across different scales and intersect with different regimes of control of labour.

The rise of professions and their role in the modern state are subject to multiple studies, from Weber's work on rationalisation and bureaucratisation of society onward (2019; see also Ritzer 1976). The development of professions, professional expertise, and professional associations are part of a process of transformation of modes of governance and relations within society that builds on different tendencies in the development of modern state power. On one hand, professionalism and expertise, in particular medical expertise, constitute an important part in the development of the relationship between knowledge and power. This characterises what Foucault (2012) calls “disciplinary society”, in which the systematic and scientific collection of data about the population becomes integral to the art of governing. Professional expertise constitutes an important aspect of this development and also the way that practices and conduct are shaped on a large scale as part of modernist projects of nation states (Mitchell 2002, Rose 1993). This entanglement of professional expertise puts radiology, and teleradiology practice into a close relationship with the apparatus of the nation state and the control and care over populations that it exercises. As I show in the analysis of the effect of professional licensing regulation on possibilities of cross-border teleradiology, this connection between nation state, population, and the healthcare profession plays an important role in the way teleradiology is managed. It is foregrounded in the role healthcare plays in national economies - not in the sense of specific businesses, but in the sense of taking care of the needs and productivity of national populations. For instance, this link is especially notable in the way deficits of radiologists are conceptualised in professional literature as a relation between the general health of the population and the number of radiology graduates available to provide medical services.

This embeddedness of healthcare and radiology within national economies not only has implications for international outsourcing strategies but it also leads to hierarchies between workers, which complicate the notion of expertise and how it operates in remote work and outsourcing. I demonstrate this later in the dissertation by analysing the relationships between Indian-certified and US-certified radiologists. These hierarchies and the regulation of who can diagnose certain images based on certification, are encoded in PACS used in teleradiology. They also become tied to the regulations for personal and health data provenance imposed by different countries. The workflow management function of PACS allows companies to pre-set rules for distributing cases among radiologists, in order that each of the doctors only receives the patient images they are certified to diagnose. PACS also allows for the incorporation of a 2-tier diagnostic process whereby studies undergo a preliminary and a second read by radiologists. This is an option used to maximise the productivity of US-certified radiologists who do the second reads in Indian teleradiology companies, after the images are already diagnosed by their Indian-certified colleagues. In teleradiology practice the infrastructures of expertise governing the possibilities for labour mobility are tightly linked to the regulations of data mobility whereby technological conditions, such as the location of servers and the anonymisation of personal information, become prerequisites for exercising radiology across borders.

Professional licensing functions as a technology of self-regulation and self-governance that claims autonomy from the institutions of the state (Starr 1982). It does not work through the mechanisms of the state, but instead imposes rules through membership consensus; this is a technology of liberal governance that defines a large number of extrastate organisations including standard setting bodies and professional associations. The technologies of self-regulation and autonomy develop in the process of defining different professions and through the boundary-making distinctions that arise from these developments. This is a process that involves multiple considerations and actors and means that while healthcare expertise is intrinsically linked to the modern nation state and its apparatus, its regulation of professional healthcare expertise is construed and governed through a complex configuration of actors and institutions.

The mechanisms for radiology licensing and credentialing entail different scales and considerations of inclusion and exclusion. In the USA for example, the regulation of professional radiology practice involves state-specific licensing as well as a process of hospital credentialing, that creates a contractual dependency between the doctors and the hospital institution. These considerations are linked to the growing need to manage risks and liabilities in the medical industry, which is an imperative that is transferred onto teleradiology practice with implications for its work arrangements. Risk, liability, and the management of the deficit of radiologists all emerge as the primary mechanisms for constructing complex and fragmented regimes of expertise management that regulate the way that labour subjects are included within teleradiology workflows.

Another key feature of infrastructures is that they involve interaction, collaboration, and antagonism between different actors. This applies both in the processes of establishing infrastructures and in their continuous functioning and maintenance. If we take as an example the medical data standards that I discuss in this dissertation, their initial development is the consequence of strategic collaborations between industry, professionals, and state actors. DICOM, HL7, and PACS have been instrumental for the development of digital imaging in radiology from its beginnings in the 1970s and 1980s and nowadays teleradiology is virtually impossible outside DICOM and PACS. This interdependence partly arises from the history of development of the DICOM standard which is initiated by radiography modality manufacturers in the USA and the American College of Radiology (ACR). This partnership meant that all medical imaging equipment would be produced in conformance with this standard and is the main reason for the wide acceptance and use of DICOM.

This ubiquitous dominance of DICOM means that all digital radiology images are DICOM images and all the hardware and software used for reading these images needs to be DICOM compliant. The processes of digitalisation and standardisation of radiology have led to the strong dependencies between the standards for imaging data and other healthcare data, the digital systems for image acquisition and transfer, and the institutionalised practice of teleradiology. This is a dependence that plays out in the material organisation of how teleradiology functions as a labour and diagnostic practice; the history of co-development of DICOM and PACS leads to their mutual interdependence (Mildenberger, Eichelberg, and Martin 2020; Mustra, Delac, and Grgic 2008; Pianykh 2008). DICOM developed in the early 1980s as an initiative of the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA). This is a partnership that aims to ensure that the technology for medical imaging satisfies the requirements of the radiologists and that there is a common standard for the images produced by different proprietary imaging modalities (Horii 2005). This initial partnership sets the parameters within which DICOM and PACS form the basis of a process of standardisation and infrastructuralisation of radiology, leading to increasing interconnectedness and embeddedness of technological standards and technological systems (also, see Bowker and Star (2000) who show this tendency in the development of technological standards in other areas). DICOM, on its end, has become integrated with HL7 in joint crossovers of the two standards aimed at harmonising them. These crossovers have since been further incorporated within and harmonised with another key technological standard for digital infrastructures developed by The Institute of Electrical and Electronics Engineers Standards Association (IEEE). Besides leading to easier transfer between different systems, these processes of harmonisation also increasingly mean that non-compliance with the standards leads to inevitable exclusion which, in the case of DICOM and HL7, is enacted through the impossibility to transfer and store a file. The increased use of smartphones by medical staff for instance, to take pictures of symptoms and attach them to a patient's record, poses such a problem of incompatibility since these images are non-DICOM compliant (Ridley 2011).

In the course of their development and use, however, the standards outlined above accrue increasing significance and entanglement with different actors. They become conductive to new relations and to drawing new actors in. For example, the healthcare data standard HL7 becomes a way for governments to articulate and exercise their control over an endlessly diversifying field of digital health technology. At the same time, new actors are drawn into the development, implementation, and use of HL7 standard; this includes software developers, mobile app developers, companies entering the digital healthcare scene such as Google, Microsoft and Apple, as well as petty entrepreneurs and mediating subjects who are incorporated within networks of transmission and control as a way of bridging infrastructural gaps or building on the existing practices of mediation between state, capital and populations.

During my fieldwork, while all the companies were using DICOM-compliant software and hardware, not all were using HL7 compliant systems. HL7 is not integrated within hardware systems the same way that DICOM is, which therefore makes it possible to send and receive information about patients and compile patient records without using this standard, or even without fully using HIS (Health Information System) for that matter. So, alongside the integrated HIS-RIS-PACS solution, some hospitals were using a makeshift combination of Microsoft Word documents and Skype for the transfer of information. Foreign medical tourists were sending their radiology images via Whatsapp for diagnosis and planning the treatment before they arrive, thus constituting a parallel unstable and fractured infrastructure where images, data, and labour do not move smoothly across technological systems, but instead rely on the mediation of humans. AbduMaliq Simone (2004) coins the concept of "people as infrastructure" to refer to such instances of fragmentation of infrastructure, whereby humans step in and compensate for discontinuities and malfunctioning of existing technological systems and serve as the elements that enable mobilities, exchanges, and circulations. In these instances of "people as infrastructure", identity, culture, and different forms of dependencies are employed to organise the socioeconomic flows of goods and money, as well as the arrangement of the power relations and social conventions that sustain these flows. In the case of teleradiology, we can see these types of infrastructures and infrastructural roles and relations emerge through functions incorporated in the teleradiology workflow; they can be seen for example in the role of loaders, who load the images to compensate for the technological lag of downloading and opening large image files.

The role of mediators is another example of an infrastructural role that becomes integrated within teleradiology practice and which demonstrates how different types of infrastructural arrangements can build on each other. Mediators, whose role in teleradiology is to ease the penetration of digital radiology infrastructures into different communities and enable the transfer of information, are both crucial and ambiguous figures. They often are embedded within existing infrastructural arrangements through which power and value permeate society. This is the case with the accredited social health activists (ASHA) who are female health mediators in rural areas in India and whose role is to ease the access of healthcare initiatives into remote communities and help include the local population in them. ASHAs have been enlisted as an important element of the teleradiology infrastructure in India whose role is to ensure that people use the teleradiology services and to lead by example making their own bodies the first line of contact between the digital radiology infrastructure and the local community. ASHAs show how teleradiology infrastructure comes to grow on top of another type of infrastructural arrangement that Michael Mann (1984, 2008) calls "the infrastructural power of the state", referring to the institutions, roles, and functions through which sovereign power radiates and reaches different territories and populations.

These existing infrastructural arrangements, which do not necessarily fit the image of infrastructure being an assemblage of technological systems, are important for understanding how DICOM, HL7 and PACS function. Part of the way teleradiology infrastructures function is the way they absorb, transform, or replace existing relations and modes of control and management of flows. While their primary technological purpose is to enable the transfer of medical images across different systems and to ensure standards for the properties of these images, they do much more than that. DICOM, PACS, and HL7 together, and each of them individually, also capture and standardise administrative and labour processes in healthcare practices that become integrated within the properties of the files exchanged in teleradiology. The digitalisation of teleradiology practice thus offers a unique perspective on the relationships and dependencies between digital data and labour. These dependencies are visible in the way key data standards are structured. Taking the example of DICOM and HL7, these two standards are grounded not just in file properties but also in rendering production and administrative processes. They show the complex interdependence between labour and data management while also participating in the processes of the digital infrastructuralisation of radiology.

Infrastructures develop historically on the basis of existing technologies of mediation and control, absorb some of their features, and modify the way that control is exercised both through their materiality and medium and through the social relations they foster. Thinking through infrastructure allows for understanding the relationship between past and present practices of infrastructural relations on one hand, and the standards, software, and hardware we see in teleradiology, on the other. These continuities and dependencies do not necessarily mean that parts of older physical infrastructures are kept within the new ones. Sometimes, as is the case with teleradiology, what is preserved in some form within the new infrastructure is a logic of arrangement and control. These residual logics carry on across different media and DICOM, HL7, and PACS show us how the medium of the digital incorporates and transforms these logics. This means that while teleradiology practice and the digital infrastructures that enable it are relatively new phenomena, the way they function as technologies of control, organisation, and intensification of labour is situated within a genealogy of techniques of management exercised in the field of healthcare. Infrastructure often builds on previous material and political technologies; this is something that I show in this dissertation by analysing different modes of flow regulation and labour management that foreground the development of workflow management, which is the central principle of interconnection in teleradiology systems. The notion of workflow and the practice of workflow management bring together two important aspects of teleradiology infrastructures - their use in the management of both data and labour. I trace the principles of workflow management back to early 20th scientific management and the work of Frank and Lillian Gilbreth who conducted important work on work movement optimisation in hospitals and other work settings and used flowchart diagrams in order to visualise and improve labour processes.

In the context of healthcare, the development of workflow management also finds its predecessors in the standardisation of patient records. This had two important implications; firstly for the reorganisation of work in the clinic and secondly for attempts to improve the efficiency of hospitals healthcare labour through the organisation of architectural and institutional spaces inside them. I argue that these different principles of managing the productive environment of healthcare institutions exhibit a sustained and complex preoccupation with the control of flows of different elements and media that produce value – namely information, labour, paper, and air. This complexity is reflected in the architecture of the digital systems used in teleradiology, PACS, which combine the hardware and software functions for archiving, transmission, and network connectivity. This practice links together the transfer of data with the involvement of labour in different parts of the diagnostic process and it is one of the principles of data management in DICOM and HL7. It organises the teleradiology diagnostic process into sequences of actions that can be performed remotely and coordinated via PACS and HIS. The workflow is a principle in labour and data management that I trace back with an analysis that shows affinities between standardisation, data, and labour. This relationship between the management of data and the management of labour are thus linked to the material and organisational modification of work environments in ways that increase productivity and control. and that point towards the connections between media and organisation (Beverungen, Beyes, and Conrad 2019).

Infrastructures also need to be understood through the materiality of their medium. In other words, the digitalisation of healthcare and its effects need to be understood beyond the notions of increased speed, quantification, and subsumption of labour. The ways in which the digital medium is changing how control is exercised, is at least partially happening on account of the logic of data categorisation and architecture within the medical data standards. Yuk Hui (2016) sees digital media as constructing its own ontology of the digital object and traces the intellectual conversations and affinities between ontology and logic as philosophical disciplines and as principles of organisation of digital data. He argues that beyond the binary as a material logic of the digital we are also faced with the additional dimension of new ontological realities that are constructed through the categorisation of digital data and the relations between digital objects. His work shows importantly that understanding the effects and role of digital infrastructures entails understanding the specific ontologies and logics that underpin the organisation of data. I argue that the Digital Imaging in Communication in Medicine (DICOM) and Health Level 7 (HL7) standards confirm the significance of data ontologies and reveal the emergence of new principles of relating, categorising, and organising that affect how labour processes are structured and how labour subjects are understood. The process through which DICOM and HL7 are capturing administrative and production processes and the implications of this process for labour are connected to the link between media and organisational aspects of digitalisation in teleradiology. An underlying principle of the two standards is their reference to "real world" objects, actors, and relations. These "real world" objects, actors, and relations represent institutional roles and processes in healthcare that are integrated in DICOM and HL7 as the elements of a digital data standard. As Hui (2016) points out, digitalisation, in its current, semantic web context, entails a process of ordering and contextualising digital data into ontologies of objects, events, and relations that render a picture of the world. HL7 is especially representative of this entanglement of digital media and organisation.

The developers of the Reference Information Model (RIM) in version 3 of HL7 draw explicit inspiration from the notion of John Austin's speech acts (1975) constructing a data ontology where all organisational practices and planning are rendered as recorded speech acts. This is a model that links the capture, documentation, and transfer of information to the standardisation and digitalisation of organisational processes (Health Level Seven International 2004b; Vizenor and Smith 2004; Vizenor, Smith, and Ceusters 2004). There are two implications from this characteristic of HL7: firstly, that its increasing adoption transforms the organisation of healthcare into an information recording system; and secondly that HL7 builds on and further develops standards for the organisation of healthcare practice and its recording. Contrary to the distinctions between algorithmic management and bureaucratic management made by some scholars (see Aneesh 2009), these data standards incorporate and expand on principles of bureaucratic control and management. By this, I mean that there are continuities between the organisation and representation of labour processes and organisational structures that can be traced in the architecture of digital medical data and its standardisation. This is an argument that once again speaks to the relationship between media and organisation (Beverungen, Beyes, and Conrad 2019). Adrian Mackenzie (2006) points out for instance, that digital document structure and the functionalities of the interface in the Microsoft Word format follow the conventions of how an actual office operates. I argue that the structure of healthcare data standards and the functionalities of the software used in teleradiology practice similarly draw on a specific history of management and organisation in healthcare that brings together organisational and technological control. This specific understanding of what infrastructures are and do in the context of teleradiology has strong groundings in the methodology I use for researching and analysing the practice.

Methodology and design

This project brings together two aspects of teleradiology practice, namely global labour and digital standardisation, each of which poses a methodological challenge on its own. Both aspects challenge the notions of visibility, containment, and exhaustiveness in social research methods in different ways. While the dispersed work locations in teleradiology prompt considerations about the limits of the field, studying digital standards and systems is in itself a methodological challenge. The focus on labour and standardisation and the ways in which digital infrastructures enforce labour control and transform labour practices leads to two methodological decisions for this project. Firstly on a practical level, I combine ethnography with the analysis of technical documentation and specialised radiology literature. Secondly in terms of method, I weave together the ethnographic observations and interviews with the analysis of standards documents and genealogical analysis of the way that these standards build upon past technologies of control. This is a methodological choice that aims to capture the relationship and dependencies between the subjective experiences of different radiologists and the structures and apparatuses that contextualise their work. Anna Tsing (2010) calls this type of contextualising of ethnographic observations "worldling", which provides the political and historical background of on-site observations. Digital standards and infrastructures and the regimes of professional licensing collectively provide the apparatuses that shape localised subjectivities and also show how different experiences are related to and dependent on each other (Feldman 2011).

Martha Lampland and Susan Leigh Star (2009) write in their introduction to *Standards and their stories*, that standards are often considered to be a boring object of research, while adding the wonderful anecdotal detail that they called their research group (which also included Marc Berg and Geoffrey Bowker) "The Society of People Interested in Boring Things". Star and Lampland continue to elaborate that the reason why standards are considered boring is because they tend to be integral parts of infrastructural systems and, as part of infrastructures, have the quality of disappearing into the background and not being immediately noticed as part of social and political processes. This invisibility poses a methodological challenge: does studying infrastructures mean analysing their effects on social life, the process of their development, or the infrastructure as a technological object of research. Neoinstitutionalists for example, are concerned with the ways in which standards set rules of conduct and organise the interactions of groups of people (see, for instance, Ponte, Gibbon, and Vestergaard 2011), while approaches grounded in the science and technology studies (STS) tradition analyse the way standards recreate reality and the way we perceive the social world (see Berg and Bowker 1997). This versatility in the way that standards can be studied has partially arisen from the complex ways in which they are embedded within social and political realities. Standards structure practices, affect the material composition and parameters of our surrounding man-made environment, but they are also informed by social and political practices, communities, and rationales. This means standards do not just appear out of nowhere; rather they have their own histories of negotiation, modes of control and regulation that precede them and possibly co-exist with them.

The choice of a research methodology in studying infrastructures is also motivated by the focus of my project upon power relations, practices of control, and the way they are enacted in the work of teleradiologists. In particular, the methodological approach to analysing DICOM, PACS, and HL7 is motivated by the adopted focus on labour management and subjectivity in my research. This means that I am interested in a particular political context in which DICOM, PACS and HL7 function not simply as sociotechnical objects used by humans, but as infrastructures with a political genealogy in the organisation and management of professional medical labour.

The two standards that I am focusing on (DICOM and HL7) have a similarly complex and evolving history. They are currently almost ubiquitous, especially DICOM whose use is tightly linked to the production of medical imaging machinery and thus precludes the possibility of digital non-DICOM radiology images. The wide-spread use of DICOM and HL7 makes their presence in teleradiology invisibilised and hidden precisely because they are so fundamental to the mundane aspects of the practice such as opening an image, sending it through, filing it under a patient's name, and submitting the report. So in many ways, my method of research and analysis draws on what Geoffrey Bowker refers to as "infrastructural inversion", which is to say making visible the technical systems that are otherwise hidden in the background and bringing their role in modulating social relations to the fore. In doing this, I have adopted three strategies of analysis that allow me to understand how these standards function in teleradiology practice, to situate them historically within a tradition of labour management, and to distinguish how their mode of control differs from other methods of labour regulation and the role of the medium in foregrounding this difference. This means that I approach the analysis of digital standards and systems in teleradiology from three different angles simultaneously and through three different research methodologies. I combine ethnographic fieldwork in teleradiology companies and interviews with radiologists with media analysis of the digital standards. In addition I adopt an approach inspired by media archaeology, through which I trace the political and technological practices that lie at the core of the digital standards and software systems we see today in teleradiology. This allows me to construct a political history of the modes of labour management that these standards, software systems, and rules of professional membership enabled, by situating their role within a lineage that elicits how control is exercised across different media.

The ethnographic research for my project is focused on understanding how standards and digital systems affect the work practice of teleradiology. This involves workplace ethnographic observation and ethnographic interviews with radiologists and other staff working in teleradiology companies. During the period between May 2016 and February 2017, I interviewed radiologists working in Sydney, Australia and Bangalore, India who were employed by companies providing radiology diagnosis for hospitals located in other countries. This ethnographic work informs the analysis of how radiologists use PACS, the extent to which their practice is dependent on software systems, the ways in which they read and diagnose the images, and also the relations and hierarchies between workers that arise through the use of these systems. There is a particular tradition in researching the human-machine interactions as a way to understand technology dating back to Lucy Suchmann's research on workers using Xerox machines (1987) which has been foregrounded in much of the STS research that draws on ethnographic methods. Some of this work has also focused on the use of digital technology in medicine; Catherine Pope, Susan Halford, Joanne Turnbull, and Jane Prichard (2014) for example discuss the use of digital decision support systems for emergency operators in the UK and approach this research through the notion of interfaces between humans and machines. In this study, they use Donna Haraway's (1985) notion of the cyborg to discuss the intersections between humans and digital technology, the ways in which these interactions lead to changes in work practice including the adoption of modes of collaboration between humans and machines, and how this make nurses adjust their work to an automated system. These two studies (Pope, Halford, Turnbull et al. 2014; Suchmann 1987) are representative of the ethnomethodological approach to the research on humans and machines at work, which sometimes tends to essentialise workplace ethnography as the primary method for gaining knowledge about digital infrastructures and the labour practices they enable. While I draw on workplace ethnography for my research on teleradiology, it does not retain the same central place that it has in STS informed ethnomethodology. Instead, in my research approach, workplace practices are situated historically and in dialogue with global processes of standardisation in digital healthcare data.

The role of workplace ethnography in my project points to both the limitations of ethnography as a method and also to its importance. The practice of teleradiology that is the unifying focus of this study problematises the notion of "the site" as one of the cornerstones of ethnographical research (Goelman 2005a). Displacement and dispersing are experiences that are becoming ever more common in social research on transborder and global practices (Marcus 2014); they also characterise my experience as a researcher hopping from one company to another between two countries, as well as the experiences of the radiologists I am studying. Whether they are sitting in their own country and diagnosing patients abroad or they have moved to a new state or continent to read images from back home, there is always a sense of interruption and incompleteness of the field. In many ways this incompleteness is real. The site of the teleradiology workplace is only one part of a chain of places, organisations, and actors that make this practice possible. Aside from posing challenges of access to professional workplaces (see McDowell 1998 and Nader 1972), workplace ethnography does not always warrant the kind of insight into the workings of complex transborder practices like teleradiology that one hopes for. In most of the instances when I was finally allowed to visit a workplace, my observations and interviews were highly curated by radiologists and other supporting staff sitting at their desks under the gaze of the management, while reluctantly answering my questions. From the dozens of contacts during my fieldwork, only a few responded and just four teleradiology companies allowed me to visit their sites, observe the work of radiologists, and to talk to them. I heard a lot of polished marketing presentations from different companies in response to my requests for meetings and interviews. I only managed to gather some insight (albeit limited) into the workflows and workplace relations in one company, Worldwide Teleradiology in Bangalore, by shamelessly overstaying my welcome and haplessly turning up and hanging around for days.

While ethnography, thought of as a localised and highly focused methodology, does not provide the whole picture of how teleradiology infrastructures are transforming labour, it has nevertheless been indispensable in understanding how a global practice and universalised technological standards produce different effects in different contexts. As the examples of teleradiology labour in Sydney and Bangalore show, these experiences can be very different in different places and for different radiologists. While infrastructures disappear into the background of the practices they enable, the standardisation that underpins them also tends to obscure and render invisible the multiplicity of experiences, subjectivities, and relations that arise in different contexts. The insights into the lifestyles of radiologists with different licensing at different locations, the hierarchies among them and the arrangement of the work process in these companies all provide an important part of my analysis, which shows how drives towards universalisation and standardisation intersect and clash with local realities.

Chapter outline

The dissertation chapters are structured around four infrastructures that I identify as key for the organisation of teleradiology practice and the specific infrastructural control exercised over teleradiology labour. These are: the professional licensing requirements for radiologists, the organisation of workflow management, the standard for digital imaging in medicine (DICOM), the digital systems used for transferring, viewing, and diagnosing radiology images (PACS), and the interoperability standard for healthcare (HL7). In each chapter, I offer an analysis focused on three aspects of the way these infrastructures function in teleradiology. First, I show how they are employed in everyday teleradiology practice and in the management of digital healthcare. Secondly, I offer a historical perspective that traces the genealogy of the infrastructure as a mode of professional labour control in healthcare. Thirdly, I analyse the political significance of the medium in the standards and the digital systems. Though this approach I situate historically and politically the infrastructures I am analysing, illustrate the development of the standards, licensing, and digital systems as technologies for labour management, and examine their relationship to the type of regulation and subjectivation exercised through earlier pre-digital technologies of control shaped by nation states and scientific standardisation.

In the first chapter, I analyse the way teleradiology labour is subject to a specific set of restrictions and rules exercised through the institutions of professional organisations and the requirements for radiology licensing. Aimed at regulating medical practice and affirming professional expertise, radiology licensing acquires a central role in governing the mobilities and hierarchies of labour in teleradiology. Through my analysis of the requirements, institutions, and actors involved in the licensing of radiologists in different states, I show how this practice reveals a complex notion of expertise. Rather than seeing radiology expertise as a stable category I argue that this is continuously reconstructed and reaffirmed in relation to changing national and international markets, biopolitical regulations of nation states, and modes of self-regulation and guarding of professional autonomy. These different factors and participants construing and conditioning the notion of radiology expertise create what I see as infrastructures of expertise, that is to say, socio-technical structures within which expertise is modulated and operationalised as means of regulating markets and labour. These infrastructures make the multiple borders that teleradiology labour has to navigate and the hierarchies between workers developed in the process. Such hierarchies and distinctions between workers become incorporated in the workflow management functions of PACS used in teleradiology and they thus become part of the processes of digitalisation and digital control in the industry.

I focus more closely on the development of workflow management in teleradiology in the second chapter, where I investigate the development of the workflow as a specific type of labour organisation and optimisation that has become central to digital infrastructures and diagnostic procedures in teleradiology. I argue that tracing the genealogy of the practice of workflow organisation leads us back to the early days of scientific management. This suggests a lineage of labour control and intensification that differs from the classical distinction between conception and implementation that is moulded through the narrative of Taylorism. I draw this alternative genealogy of workflow management from the research of Frank and Lillian Gilbreth who incorporate a focus on processuality, visualisation, collaboration, and the distribution of energy in their studies on workplace efficiency. Their experiments, which are also the first ones to attempt the optimisation of workflows in hospitals, weave in aspects of the dependencies and hierarchies conditioned by expertise, that play prominent roles in the organisation of teleradiology workflows. I show how this notion of workflow management grounded in the conservation and distribution of labour power evolves into a highly visual representation of business process management and becomes incorporated into enterprise resource planning software and workflow management systems, which in turn constitute an important element of teleradiology software systems and data standards.

The link between visualisation and control constitutes a key aspect of the specific way in which radiology and teleradiology exercise technological and scientific power; this relationship is captured in the digital radiology image that I discuss in chapter 3. The medical image epitomises the particular optics of control that characterises the association of scientific knowledge and biopower in disciplinary society (Foucault 1976, 2012). Rather than being a representation of the body, however, the radiology image is a complex technology of mediation and visualisation that selectively produces transparency and opacity. This is an aspect that becomes ever more prominent with digital imaging, where the relationship between the corporeal and its depiction undergoes an operation of datafication and subsequent visualisation. I analyse how these processes are further developed with the standardisation of digital medical imaging through the DICOM standard. I show how this standard leads to the constitution of the radiology image as a new technological object that integrates biopolitical functions of healthcare management with the focus on processuality and workflow organisation. This combined purpose of the DICOM image allows for bringing together population healthcare governance, labour management, and the integration of human work within PACS.

In the fourth chapter I develop the role of PACS for the organisation of teleradiology labour further. PACS emerge and evolve in conjunction with the establishment of DICOM and incorporate software and hardware components for the viewing, storage, and transfer of DICOM images. I trace the development of two key elements of these systems, namely the archive and the network architecture. These elements integrate two core features of teleradiology management which are the organisation, safeguarding, and use of medical data on one hand, and on the other hand the coordination and channelling of flows of information in ways that create new topologies of connectivity and dependency. These two lines of image data and network management inform the early academic and military research in PACS prototypes; I argue that the contexts of these developments bear consequences for the way the systems function and the types of relations and inclusion and exclusion they enable. Furthermore, the image archive acquires new faculties and possibilities for extracting value from the accumulating repertoire of diagnosed radiology studies. The PACS archive becomes not just a technology for organisation and storage but also a valuable asset in a big data economy of developing automated tools for radiology diagnostics. This leads to teleradiology companies investing in the development of PACS and RIS and to them making the software products and services part of their revenue model.

The role of data and digital systems that a new model of data economy brings into being puts teleradiology in a more complex context where the role of digitalisation does not exhaust itself with new forms of control and labour intensification. In the last chapter of my dissertation I explore the ways in which the digitalisation and standardisation of teleradiology expand into issues relating to organisation and the integration of teleradiology within larger healthcare economies. I analyse the development of HL7 – which is a core healthcare set of data standards underpinning interoperability in the production of HIS and RIS – and what this development reveals about the processes of translation and codification that are part of the way in which institutional practices become data ontologies. The ways in which data definitions, formats, and relations are structured in different version of HL7 is indicative of the changing context of the entanglement of state institutions, private company interests, and the politics of data standards and software development that increasingly dominate the field of telemedicine and teleradiology. I trace the evolution of HL7 from a standard exclusively concerned with messaging to its attempt to construct an all-encompassing digital healthcare ontology, to its most recent focus on modularity and platformisation. This development underlines the growing complexity of the digital healthcare market within which teleradiology is situated, and also the possibilities for re-assembling of actors and power relations.

By focusing on these infrastructures and infrastructural technologies, I trace how data and the management of data become incorporated within the structures for the organisation and intensification of professional radiology labour productivity. In my work, I construct a genealogical lineage of the data infrastructures that enable the transfer of medical images and the control over the digital labour of teleradiologists and other workers involved in the process of outsourcing while also providing a close analysis of the technological characteristics of DICOM, PACS, and HL7. This approach allows me to examine how data infrastructures operate by situating them in the context of material practices of labour management and forms of recording and organising knowledge specific for healthcare and radiology. Thus, I analyse the emergence and development of data infrastructures as part of the political economy of radiology and teleradiology outsourcing while also interrogating how data structures, the relations between data objects, and the organisation of network connectivity produce new political realities and transform existing ones. In my discussion I move from infrastructures specific to teleradiology toward the HL7 data standard for healthcare information exchange and thus open the possibility to think of the implications of data infrastructures as situated political technologies beyond the concrete case study of teleradiology outsourcing.

Chapter 1: Infrastructures of expertise

Carving spaces

Based in the Central Business District (CBD) of Sydney, the office of Omniscan Teleradiology is positioned in the heart of an urban architecture of power built on steel, glass, and concrete. It is located in one of the high-rise office buildings, with a trendy cafe on the right side of the entrance and a restaurant in a low sandstone building with stained glass windows on the left. It is a curious colonial decoration in the midst of modern architecture. Omniscan Teleradiology was established in 2003 with headquarters in Spain but with the intention to cater for the Swedish market. After securing contracts with Swedish hospitals, Omniscan Teleradiology's rapid reach into the rest of the Scandinavian market was eased by the mutual recognition of the qualifications of the medical professionals across the countries in this region. The company is now providing teleradiology services to hospitals in Spain, Sweden, Denmark, Norway, Germany, and the UK. It has adopted a particular strategy about where to place their offices however, which tries to optimise factors such as lower costs of living, pleasant climate, and time zone differences that allow radiologists to provide nighttime diagnosis while working regular business hours. Spain for example, provides a cheap base for operations and its lower tax rates make it attractive not only for the company but also for Scandinavian and UK radiologists who can, in addition to paying lower taxes, choose to work from Barcelona to enjoy the milder weather and cheaper living expenses.

The search for a pleasant climate and suitable time difference led Omniscan Teleradiology to open an office in Australia. The company is a little Scandinavian island in the Sydney CBD; all of the administrative staffers speak Swedish and while I'm there they talk to each other and on the phone in Nordic languages. This little Scandinavian bubble on Australian land is even more complex than it first appears, with the movement of workforce across continents regulated through the negotiation of time zones, professional requirements, national healthcare sovereignties, cultural differences, and corporate power.

Giacomo, who is Italian, had worked in Sweden for some time before joining the teleradiology company in 2013, when he was originally tasked with managing the planned office in Hawaii. The project got stalled because of resistance from the USA health authorities however, who had insisted that if Omniscan Teleradiology is to provide medical diagnostics on USA soil then it would have to undergo the process of medical certification and monitoring that is common for all USA registered healthcare entities. This proved to be a huge setback for the planned new office. Omniscan Teleradiology attempted to contest the ruling and to take the case to court, arguing that none of the radiologists will actually be providing diagnosis for USA patients or for USA hospitals. In the end it proved too time consuming and capital consuming to negotiate the issue of healthcare sovereignty and corporate regulation with the United States power apparatus. So, the company moved on. It decided to invest in settling in Sydney and Giacomo, by then already having been in Sydney for six months while awaiting the resolution of the Hawaiian conundrum, was invited to head the office.

The challenges in establishing offices abroad, however, did not end with the Hawaiian misadventure. Once settled in Sydney, the company was once again scrutinised by local health authorities. The local Royal Australian and New Zealand College of Radiology (RANZCR) requested that all their radiologists should be licensed to work in the Australian healthcare system. This time Omniscan Teleradiology filed a case, hired a lawyer, and managed to successfully argue for being allowed to practice on Australian territory without going through the medical licensing process, provided they do not work with Australian patients. They have to go through an annual financial audit process but do have no interaction with RANZCR since they do not operate in the local market and their radiologists are not certified in Australia. Instead the company and the radiologists who work for it maintain membership of the professional radiology organisations situated in the countries of the hospitals for which they diagnose cases, namely UK, Norway, Sweden, and Denmark. Radiologists with German or Spanish credentials are not sought for the Sydney office because of the high costs of living and allocation that the company covers, which are not sufficiently well reimbursed through the healthcare fees received for cases from Germany and Spain.

The strategy of Omniscan Teleradiology, which advertises the teleradiology positions as a type of working holiday option, compelled it to search for new destinations that can combine pleasant location with a strategic timezone positioning. The profile of the workforce is specific. Most of the teleradiologists, as Giacomo tells me, rarely stay in Sydney for as long as a year; usually it is just a few months. They come to Sydney (often with their families) so they can visit Australia, travel, surf, and expose their children to an English-speaking environment. The company's recruitment strategy is based on an image of leisure and exoticism that attracts European radiologists. The company's recruitment videos promise an active and exciting lifestyle by the ocean. Similarly to his colleagues, Giacomo has also settled into this lifestyle of leisure and outdoor activities. When I first see him in the office he is sitting behind his desk in shorts and flipflops, his running shoes lie in one of the corner of the room. Since the start of the COVID-19 related lockdowns and travel restrictions, the company has moved to home-based work arrangements, which is relatively easy to implement in the field of teleradiology if the doctors have access to DICOM (Digital Imaging and Communications in Medicine) viewers which are an essential part of the Picture Archiving and Communication Systems (PACS).

This strategy led Omniscan Teleradiology to enter negotiations with the small island state of Aruba in the Caribbean in the early months of 2016. It was concluded that the island is perfectly located to offer a similar vacationing and working lifestyle, while being less expensive than Sydney. It also has the advantage of being located far enough from Europe to offer some leveraging of time zones and work hours. The company has hired a three-room apartment at the beach and radiologists take turns working from there for three-to-four months. It is a position advertised as a family-friendly working holiday in a "Caribbean paradise" that promises a nice climate in an exotic tourist destination. The work hours are from 4pm to 10pm, five days a week; the company calculates that this is 75% of the working hours in Sydney and it covers most of the cases as there are more cases earlier in the day than there are later. The pay for the job in Aruba is the same as in Sydney, which Giacomo thinks should change with time because the cost of living is much cheaper there. It is also far more convenient to get people on short-term contracts in Aruba because of lower costs; the ticket, visa, and accommodation in Sydney are all much more expensive and Omniscan Teleradiology provides all of this in order to attract the radiologists.

In 2017 when I visited the Sydney office, Omniscan Teleradiology was setting up the Internet connection and the workstations in Aruba. The company had had issues with the government there because of requirements to obtain a license for radiology practice and for the radiologists to be registered with Aruba's professional body. However, "because it is a small country", as Giacomo pointed out, the CEO was able to meet with the Minister of healthcare and other government representatives to discuss the case, and explain that they are not going to work for the Aruba market and neither would they work with local hospitals or patients. The CEO got an oral agreement that Omniscan Teleradiology could get radiologists on tourist visas while the government looked for a more permanent solution. The company wants to eventually open a branch, register an entity and get more people to work from there because it is an attractive and cheap destination. Meanwhile, its CEO had accidentally met with the Director of a local hospital that desperately needs pathology services and had managed to make an agreement to provide telepathology to it; the company hopes this will open the market to other islands and potentially expand the relationship between Omniscan Teleradiology and the local healthcare system.

The example of Omniscan Teleradiology and the arrangements that it makes as part of its expansion and recruitment of radiologists, shows the important role of professional organisations for managing the mobility of teleradiology labour. Professional organisations have traditionally exercised a regulatory role in the organisation of radiology labour and expertise within the borders of individual countries by maintaining collectively agreed upon criteria for radiology practice. Since the early 2000 however, when commercial international teleradiology practice began, the regulations imposed through professional membership organisations had to be reformulated in order to extend their scope of action and to issue guidelines about the rules under which teleradiology can take place. This development creates a unique situation in teleradiology whereby professional expert organisations have acquired a role in labour mobility management. In the example of Omniscan Teleradiology, the regulations of different national professional organisations allow it to offer remote diagnosis for the Scandinavian countries and the UK, and also to open offices in Australia but not in the US. The USA requirements to have all radiologists licensed by the American Board of Radiology (ABR) posed a significant obstacle to the company. Being registered with the ABR means undergoing a lengthy process of verifying the candidate's education, undergoing a four-year residency programme and undertaking exams in order to be eligible to practice in the country (American Board of Radiology 2020). These conditions, which only partially satisfy the certification requirements for practicing radiology within the United States, position professional membership as a key technology for managing the cross-border mobility of radiologists and teleradiology companies.

Professional radiology organisations have a complex role in the management of labour in the industry, stemming from the specific notions and practices of membership, inclusion, and self-regulation that have shaped historically the institution of professional expertise. This role is becoming even more prominent in the context of teleradiology, which does not require the physical migration of radiologists in order for them to be included in national professional labour markets and healthcare systems. The new context of remote work mediated by digital infrastructures is diminishing the significance of other mechanisms for enforcing labour mobility regulations, such as visa regimes for instance, while making the role of professional membership and recognition of expertise increasingly significant. What I show in this chapter however, is that teleradiology reveals how expertise is construed through the interactions between multiple institutions, regimes of regulation, and actors. While radiologists are undoubtedly experts in their field having completed medical education and professional practice, the recognition of their expertise in a globally organised industry is increasingly conditional. The conditions of this recognition are negotiated through the interactions between traditional ways of guarding the production of medical knowledge and the management of professional labour markets, and newly emerging practices of bordering that draw on data provenance, the regulation of finance flows, and neoliberal practices of continuous examination and self-improvement. As I will show in the course of this chapter, these different mechanisms are used to determine when and where somebody is recognised as an expert radiologist, who can diagnose patients, and also to establish hierarchies within labour that are further reflected in the design of software systems.

In the course of this chapter, I describe the complex ways in which medical expertise is constructed and maintained in teleradiology and argue that it is contingent on political, technological, and economic factors that frame and constrict the validity of expertise in teleradiology outsourcing. This approach, as I explain in the section 'Infrastructural approach to expertise', advances an infrastructural understanding of expertise that highlights the involvement of different sociotechnical systems, human actors, and political realities in the construction and operation of expertise. In the section 'Borders of expertise', I show that the validity of expertise is determined and constrained through the overlaying of multiple juridical, professional, political, and market spaces. I follow this analysis with a specific focus on the dependencies between structures for the maintenance of expertise and the intensification of professional labour whereby maintaining certain level of expertise requires radiologists to seek high-volume jobs in 'Expertise and intensification of labour'. In 'Economy of expert shortages and duplicating workflows' I outline the political economy of international medical outsourcing and migration, which is conditioned by a growing demand for radiology professionals in the Global North, national protectionist policies of the professional organisations, and the logic of racial capitalism. I then close the chapter with the example of an Indian radiologist working for the Australian market and his professional history of navigating the infrastructures of expertise outlined in the previous sections.

Infrastructural approach to expertise

While the example of Omniscan Teleradiology highlights the role professional licensing can play in regulating international labour mobility, professional expert organisations invoke notions and practices of border and border-making that are not exclusively subsumed under the category of nation-state borders. Instead they work across different scales and logics of inclusion and exclusion, which has significant implications for the ways in which teleradiology labour is subjected to the regulation of its mobility and productivity. Notably, professional radiology organisations and the kind of regulatory control they exercise over their members develop historically through the complex processes of institutionalisation of healthcare. The complexity of these processes of institutionalisation comes from the way in which they combine two antagonistic dynamics in the evolutions of professional expertise – on one hand the establishment of mechanisms for self-regulation and professional autonomy (Starr 1982; Halpern 1992), and on the other hand the move towards integrating healthcare within the apparatus of the state (Foucault 1976; Rose 2007). This dichotomy in the way professional organisations function with respect to structuring social and political practices has implications for the way that teleradiologists navigate different borders and also broader implications for the way labour is organised in the industry and the hierarchies that define it.

The strategic expansion of Omniscan Teleradiology demonstrates how the regulations imposed through professional radiology organisations can make it possible or impossible for a company to open offices in different countries. In this sense, the example of this company represents just one very partial aspect of the way professional organisation requirements affect teleradiology labour. As I show in the course of this chapter, the role of professional radiology regulation does not exhaust itself in acting as a tool for the management of labour mobility across state borders. Based on rules and standards for membership and voluntary adherence to professional guidelines, it weaves itself into complex practices of regulation and control. These practices exercise a specific type of border-making, through what I call "infrastructures of expertise". The infrastructures are not grounded in the physical materiality of hard infrastructures, such as hardware, network cables, or radiology monitors, even though in teleradiology the articulation of expertise becomes tightly linked to issues of data transfer (as I also show in the course of this chapter). Rather, these infrastructures of expertise develop and function as a set of rules, institutions, and conditions for professional membership that continuously establish what radiology expertise entails. They enact how medical professionalism is defined and employed for operations of inclusion and exclusion of the radiology workers. One of the defining features of these infrastructures is that they encompass the heterogeneity of how medical expertise is constructed across different political and economic territories, which leads to a heterogeneity of practices of bordering and relates them to the way that teleradiology labour is organised and managed.

The mechanisms of constituting expertise bear upon the different logics of the social and political role of expertise in relation to wider frameworks of governance; this includes state biopolitics (Foucault 1976; Rose 2007), professional labour markets (Connell and Walton-Roberts 2016; Iredale 2001; Starr 1982) and risk management (Beck 1992; Rose 2007). The relationship between medical professional regulations and the biopolitics of the state rests on the close entanglement of expertise and professionalism with the governance structures and technologies of the modern state (Kivelä and Moisio 2017; Mitchell 2002). This dependence preconditions the actors, institutions, and the stakes involved in nation state regulation of healthcare expertise. However, the close relationship of medical expertise with the institutions of the nation state and with the notion of national sovereignty is complicated by the way states are included in supranational alliances and, themselves, include other subnational economic and political institutions.

Furthermore, the practice of boundary making through which the radiology profession distinguishes itself from other medical specialties and secures the boundaries of its market and knowledge space charts yet another political, economic, and cultural context, within which radiology expertise is construed. And an additional concern to this is that the technologies of self-regulation that organise the dynamics within the professional field and are generative of modes of intensification of labour and its internal hierarchies. These dynamics of border making are not mutually exclusive and become entangled in teleradiology practice. But before I discuss their entanglement, I want to first outline the specific ways in which these different aspects of how professional regulation functions produce different notions and practices of inclusion and exclusion, and hence frame teleradiologists through different political notions of subjectivity.

These different dynamics and logics of regulation in professional licensing involve various actors. Rather than seeing professional licensing as a monolithic technology of governance exercised by professional bodies consisting of radiology experts, I uncover the multiple layers that constitute the mechanisms and logics of this type of regulation. Expertise in the case of teleradiology is a dynamic concept that has historically developed through various practices. Its boundaries are negotiated through national institutions, professional market regulations, supranational alliances, and the changing relations between these different forces that shape how expertise is governed. These different layers of what constitutes professional expertise and the mechanisms of its governance acquire new functions in the context of teleradiology, where they become incorporated within structures for the control of mobility and productivity of labour. As I show in more detail below, professional expertise becomes an important part of regulating transborder practice in teleradiology.

The regulations of medical expertise and the mobility of medical labour are not homogeneous, even within a single country. Rules of membership in professional organisations, educational requirements, state regulations of practice, hospital conditions for physician accreditation, and international codes of conduct and mobility, all play a role in defining, reaffirming, and constricting what radiology expertise is and where it is valid. These different regulatory protocols, developed under different historical circumstances and following distinct logics of classification and governance, form what I name as infrastructures of expertise. The notion of infrastructures of expertise denotes a number of characteristics of the way that structures for regulating professional expertise in radiology and teleradiology function. It refers to the ways in which different modes of regulation combine in order to exercise control over expert knowledge and practice, creating a complex configuration of modes of governance. These different modes of governance pertain to different spheres within which expertise is operationalised in different respects, including: as part of the biopolitical apparatus of the state; within the construction of professional markets and also through notions of risk and risk management. The different elements of how radiology expertise is constituted combine in the regulation of international labour mobility and in the regulation of cross-border teleradiology. Federico Pérez (2016) makes a similar argument about the infrastructural character of legal regulations for urban development in Bogota, Colombia. Pérez demonstrates how these legal infrastructures are not homogeneous and how they require interpretation and develop historically by layering one law over the other.

The historical aspect of the development of infrastructures of expertise in teleradiology leaves traces of the different roles the medical profession has acquired throughout the course of its establishment as a core political, economic, and scientific institution in matters of illness and health. As I show in this chapter, these layers can sometimes embody conflicting logics of the entanglement of medical knowledge, political power, and economic rationale. This contradiction carries on within the complex ways in which teleradiology professional labour is subjected to a combination of privileging and exploitation. It further complicates the relationship between medical expertise and the health and productivity of populations, as teleradiology labour traverses state borders and charts various remote work arrangements. The mediation of digital technology is another important aspect of the infrastructures of expertise in teleradiology. Apart from creating new conditions of relations between labour and political territories, the digital infrastructures enabling outsourcing become enmeshed with professional regulations in numerous ways. They become an essential part of the materiality of the infrastructures of expertise that encode rules and exceptions in the software systems used by teleradiology companies. Using different options to modulate the individual access of radiologists to patient cases and channel studies to them according to their professional expertise and license, these digital systems are not only transferring data and labour but also enacting the regulation of medical expertise. Moreover, the importance of professional expertise and professional organisations in the above regard grows even more significantly in the context of remote outsourced practice, which does not require the physical mobility of workers.

Borders of expertise

The labour of radiologists, their options for remote work and labour migration, as well as the status they have within the outsourcing chain, are heavily dependent on the infrastructures of expertise and the way professional qualifications are regulated. A key instrument of this regulation is the institution of medical licensing and certification that allows doctors to practice. In order to be recognised as radiology experts and to be allowed to practice, radiologists must undergo a process of licensing by the local medical authorities. This means that the process of becoming a professional involves not just the academic education and subsequent clinical placement training (Bleakley 2011) but also examination and licensing by the medical boards and professional colleges (associations) that give the right to practice. While Western allopathic knowledge has gradually established itself as a dominant paradigm and practice around the world through a long history of exclusions of Indigenous and alternative forms of healthcare, the recognition of medical expertise (through the process of licensing) charts a complex and fragmented space of how and where radiology expertise is recognised and constituted. The logic of medical professional expertise charts lines of inclusion that draw complicated borders through the institutions of medical licensing and through the scope of recognition of qualifications within states, between states, and also within supranational entities. The institutionalisation of medical expertise through the practice of professional licensing meanwhile, charts a complex interrelation between the domain of state biopolitics and the distinct logic of self-regulation that is exercised through autonomous professional associations (see Starr 1982). In this process, professional autonomy and state sanction are sometimes at odds while at other times they tend to work together. What this means for the study of teleradiology, is that a purely statist framework of analysis (such as the one proposed by Venco 2012) does not adequately capture the ways in which the regulation of expertise operates as a mechanism for bordering, control, and intensification of labour.

On its own, radiology licensing is entangled in the complex relationship between states and professional autonomy. While the regulation of professional standards and licensing in teleradiology is performed through the radiological colleges or associations in each country, the registration of medical practitioners and the regulation of labour mobility is enacted through the authority of state and its institutions. In order to be allowed to diagnose patients in Australia for instance, a radiologist will have to undergo a process of registration conducted through RANZCR and the Medical Board of Australia (MBA). In USA, UK, and India the procedure is similar, requiring prospective radiologists to undergo licensing managed jointly by the local professional associations; the American Board of Radiology (ABR) to diagnose patients in the US, the Royal College of Radiology (RCR), and the Indian College of Radiology and Imaging (ICRI) for India along with the state medical boards in each case. The principle of regulation of radiology labour exercised through these organisations follows a similar pattern in all of these countries. It involves a combination of requirements for the membership in the professional organisation and legal rules for professional medical practice mandated through state institutions. These professional organisations of radiologists are independent of the state but are also involved in the evaluation of expertise and the implementation of measures to regulate it, for instance through initiatives for continuous professional development (that I discuss further later in this chapter). This leads to a complex system for constituting and managing professional expertise through both state institutions and professional organisations. These two actors that are involved in defining medical expertise have historically endowed it with different role and meaning; in the case of nation states it has been linked to the biopolitical functions of government, while in the case of professional association it has been made an important part of the constitution of professional autonomy.

The historical development of the medical profession and its current embeddedness within state institutions, predicates a strong interconnection between the regulation of expertise and the territorial and political forms of control and bordering exercised by nation states. We can also see this in the organisation of teleradiology workflows, where the requirements for medical credentials of radiologists and the choices of who diagnoses which cases are coordinated according to state-specific rules of healthcare practice. The recruitment for the offices of teleradiology companies is guided by the qualifications and licenses for practice of the radiologists. And as the example of Worldwide Teleradiology already illustrated, these licenses are issued by and linked to national institutions and national professional organisations.

In his seminal work on the birth of modern medicine, Foucault addresses the interdependence between technologies of governance established by modern state institutions and the development of healthcare (1976). Crucially, Foucault elucidates the role of medicine in establishing the various functions of what he refers to as "police" – in other words, the institutions whose role is to manage and govern populations (2007). This function of healthcare links medical professionals closely to the imperative of caring for populations, their productivity and wellbeing. The role of medicine in the biopolitical apparatus of the state has an important role in shaping the regulation of expertise as part of a wider concern with good governance. In this sense, the regulation of radiology practice through licensing is to a large extent determined by the role of healthcare professionals in these systems and logics of governance. It is managed by institutions which are either part of the state apparatus or which are supported by the state.

At the same time, medical licensing is a key instrument for labour market regulation which allows radiologists to safeguard their position, wages, and power by restricting the possibility of employing non-radiologists or foreign radiologists for imaging diagnosis. In his social history of modern medicine in the US, Paul Starr (1982) describes how the development of professional healthcare and the educational and professional institutions that support it evolves through complex interactions between different actors and interests. A major factor driving these complex interactions is the attempt of members of the newly established medical profession to establish sovereignty over the labour market for healthcare treatment. The movement for medical professional sovereignty from the 18th century onward drives a number of initiatives in the Western world and in colonised lands that aim to heavily discredit or ban the practices of traditional and Indigenous healers (Arnold 1993; Martyr 2002). This movement, which is part of the establishment of modern allopathic medicine, should be simultaneously seen as a movement for asserting the power of scientific biopolitical technologies and as an attempt to carve out a protected market for the newly institutionalised profession. The process of establishing medical science and practice as one of the central pillars of an expert knowledge and power to act upon populations is not homogenous or lead by a single power. Rather the practice of medical licensing, as we see it now in the field of teleradiology, is the product of long processes of establishing the internal and external borders that define the zones of expertise and sovereignty in the profession; this is what science and technology studies (STS) scholars refer to as "boundary making" (Burri 2008; Star 2010). These boundary making practices have been important in establishing the scope of expertise of radiologists which is defined through a combination of disciplinary, institutional, and national borders.

As Paul Starr (1982) shows, a number of developments in the organisation of healthcare in the USA are the direct consequence of practices of gatekeeping. The establishment of medical education for instance entails complex negotiations and disagreements about the constitution of the curriculum and the requirements for entry and graduation of students. While educational institutions are competing for a larger number of fee-paying students, already practicing doctors are worried about the competition from a large medical community that will overpopulate the market, leading to decreased fees and clientele. These concerns put the institutions of the state, medical academies, and professional bodies at odds. They also show that the regulation of medical expertise through licensing involves complex interactions between different actors and institutions, each of which has a role in determining and regulating what being a healthcare professional entails and what the political and economic position of an expert is.

The process of establishing medicine as an institutionalised, standardised practice is one that involves the formation of new groups of experts. These are experts with a vested interest in the market of health and illness and also in the parallel establishment of state and private institutions – that is, colleges, state regulatory bodies, and professional associations – that reproduce and regulate healthcare labour (Starr 1982; Brown 1980). All these different actors have played a role in establishing the practice of professional licensing through both cooperation and adversity. The driver behind these movements is not the logic of the free market but rather an economic rationale of market regulation, that is exercised through extraeconomic mechanisms combined under the umbrella of licensing requirements. Radiology licensing can be seen in the historical context of this process of emergence of the medical profession, at the intersections of state power and professional authority, guild and capitalist corporatism. While this process of regulation seems straight-forward and involves the established institutions that act as gatekeepers in the healthcare market (namely medical schools and professional associations), it is the result of a long history of establishing boundaries of expertise. The 18th and 19th century are marked by movements for professionalisation and regulation of the practice of medicine in different parts of the world that established the grounds for a complicated relationship between medical professional expertise and state power. Eliot Freidson (2001) refers to this position of professionalism as a "third logic" that sits between the logic of the market and the power of bureaucracy. In this respect, the regulation of medical expertise shares both market rationales and biopolitical considerations, and this has implications for teleradiology labour which is managed today through a hybrid logic that governs practice through both nation state institutions and independent professional organisations.

The practice of teleradiology, as the example of Omniscan Teleradiology shows, involves radiologists from different countries, providing diagnosis to patients in hospital in different countries, and these radiologists can themselves be dispersed around the world. The vignette in the previous section shows that there is a multiplicity of territories that are evoked and operationalised in the way Omniscan Teleradiology navigates the mobility of its workforce. Giacomo and the management of Omniscan Teleradiology operationalise the notion and scope of expertise in a way that starkly connects it to the political and economic space of Scandinavia and the UK. The company explicitly assumes that its activities and the labour regimes under which its workforce should be governed constitute a continuation of the regulations in the countries where its radiologists are registered and to which they send their diagnoses.

At Omniscan Teleradiology, the conditions imposed through licensing requirements, which demand that radiologists have Scandinavian or UK credentials in order to diagnose cases from hospitals in Scandinavia and the UK, have also been appropriated by the company as a condition for exceptions in its mobilities. The scope of validity of expertise and how it is defined become part of extrastate and suprastate policies and alliances that make it possible to negotiate and provide relaxed conditions of exception between certain countries and groups of countries. One such condition with a growing importance for teleradiology is the role of trade unions and free trade agreements (FTA) that supersede local requirements for licensing that pose obstacles to foreign trained radiologists. In the USA, the prospect of large-scale FTAs has been an issue of concern in the radiology profession. In the early 2000s a report of the American College of Radiology (ACR) Task Force on International Teleradiology included an evaluation of the possible effect of NAFTA on the local radiology labour market and its implications for the current and future regulation of teleradiology across borders (van Moore, Allen, Campbell et al. 2005). The College expressed uncertainty whether the agreement "could pre-empt U.S. legal standards, such as state licensure requirements, that otherwise would apply to international teleradiology" (van

Moore, Allen, Campbell et al. 2005). Most significantly, the evaluation assumed the possibility of trade tribunals overriding the sovereign authority of nation states to impose regulations of healthcare practice.

Other authors from Canada and the USA express similar concerns about the effects of free trade agreements on healthcare in their countries (Arnold and Reeves 2006; Grieshaber-Otto and Sinclair 2004). While NAFTA was never agreed upon and was subsequently replaced with the United States-Mexico-Canada Agreement (USMCA), the potential effects of a transnational trade agreement coming into place and intervening with the existing legislation and practices of radiology licensing are still an issue on the table. Marylin Higdon (2018) notes that under the current GTA (global trade agreements) under the World Trade Organisation (WTO) framework, which USA is part to, there is no danger of undermining the national regulation authority but that this is only the case because of the agreed conditions of the GTA which can change in the future, and probably will change under the pressure for further liberalisation (see also Spears 2013). These changes concern the conditions for licensing regulation which poses barriers to the free movement of workers and capital. Meanwhile, this practice of mandating mutual recognition of qualifications and licensing for medical practice is already put in force within the European Economic Area (EEA) conditions for free labour and capital mobility in the service economy in general.

Looking at the work arrangements of the international radiologists at Omniscan Teleradiology and how licensing affects them, it is easy to fathom the reason why the American College of Radiologists anticipates significant changes. The shared economic space of EEA and the agreements and directive issued by the European Union institutions in relation to labour and capital mobility in the union imposes rules for the free transborder movement of workers between member-states and also for the mutual recognition of education and professional qualifications. The 1993 EEA agreement (European Economic Area 1993) that establishes the conditions of economic integration between the participating countries in Part 3, Chapter 1, article 30, includes the foregrounding condition of mutual recognition of qualifications as a precondition to the free movement of people in the European Economic Area. These regulations are further reinforced by the Directive of the European Parliament and of the European Council on the recognition of professional qualifications from 2005 (European Parliament 2005); this Directive demands that member states automatically recognise the qualifications of workers from the European Economic Area. These transnational regulations of expertise affect how radiologists from EEA states can travel and work abroad and also affect who has the authority to decide how expertise is evaluated and recognised. The conditions of the Directive change the configuration of institutions and how they function at the national level. One such recent example is the case of Norway, Sweden, and Denmark, where the automatic mutual recognition of medical qualifications and licenses for doctors from the three countries was annulled in February 2020 and replaced with the conditions of the EEA directive, meaning that Scandinavian doctors no longer have a privileged position when applying for jobs in other Scandinavian countries (Helsedirektoratet 2020). The implications of the Directive aiming for the alignment of local legislation are not simply a matter of multilateral agreements; rather there is a strong urge to actually constitute new, supranational structures of sovereignty in the Union that enable the free movement of labour and translation of qualifications. It also leads to the establishment of new institutions that play a role in regulating radiology expertise, such as the new optional qualification of the European Diploma in Radiology from the European Society of Radiology (2014) which offers the possibility of transferrable and official union-wide qualification. While the qualification is only meant to duplicate national qualifications presently, the ESR explicitly sees it as a pathway towards strengthening the integration and interoperability of qualifications in radiology across the Union.

These tendencies linking the establishment of free trade zones, economic unions, and free trade agreements to conditions of recognising expert qualifications across borders, show two important things. First, the borders of expertise are not stable and can shift with changes in wider geopolitical and geoeconomic conditions. While earlier accounts of healthcare professionals' roles place them within the configuration of nation state institutions and national labour markets (see Freidson 2001; Starr 1982; Weber 2019), the context of supranational economic agreements and unions changes the borders within which medical expertise is contained and regulated. This context also introduces new actors, such as the European Parliament, European Council, European Commission, and international trade tribunals, that all take part in shaping the infrastructures of expertise through the imposition of new rules and by changing the conditions of labour mobility and the validity of expertise. One consequence of the introduction of supranational actors and regulations is the change in the role of national professional associations and state healthcare institutions in maintaining the process of inclusion and exclusion of foreign radiologists. In the cases where foreign qualifications are recognised by virtue of the conditions of international agreements, the role of professional associations shifts from controlling entry into the labour market to exercising continuous control over their members through the mechanisms of continuing professional development programmes; I will discuss this in more detail in the following section. Here, it is most pertinent to note that programmes are not substitutes for the licensing requirements for foreign radiologists, however the changing scopes of internal markets, whose borders are reconstituted through economic and free trade agreements, mean that for more and more radiologists the rules of inclusion and exclusion have changed. Instead of undergoing the entry examination in order to practice in a foreign country, radiologists are increasingly subjected to conditional inclusion through the mechanisms of continuing professional development.

Another important observation to stem from the free market and free mobility conditions of the European Economic Area is that the constitution of borderless economic space does not erase the political presence of the border as a mechanism for categorisation and the imposition of hierarchies. The European space is marked by deep inequalities between the East and the West and the South and the North, with each of these axes of economic disparity carrying different historical and political significance. Furthermore these disparities intersect with and shape the conditions of labour migration within the Union. I will not delve into the complexities of internal European migration, which I have done elsewhere (see Apostolova and Hristova forthcoming; Apostolova 2018), but it is worth noting that instead of erasing the issue of borders and inequality, free labour mobility simply reshapes the tensions between nation states and national labour. The migration of healthcare professionals is an especially acute case in point. The migration of medical experts follows the patterns from the South-East to the North-West of the Union and a large number of academic analyses and reports (Connell 2010; Ifanti, Argyriou, Kalofonou et al. 2014; Żuk, Żuk, and Lisiewicz-Jakubaszko 2019) point to the scale of this "physicians exodus", leading to brain drain in the South and the East of the Union and significant understaffing of local hospitals. Recent months in 2020 have witnessed the unmasking of the profound inequalities encoded in the principle of free movement in the European Union, in the light of the healthcare crisis caused by the COVID-19 pandemic. As hospitals in the East and the South were experiencing serious deficits of medical staff as well as the reintroduction of border controls between members states, the European Union passed recommendations to safeguard the continuing free mobility of essential workers, including healthcare workers, at the insistence of member states from the West (European Commission 2020). This example shows the complex webs of inequalities and hierarchies underlying the infrastructures for regulation of expertise.

While the case of European Economic Area regulations is specific to the radiologists and teleradiologists working with European hospitals, teleradiology practice in India provides another example of the way that infrastructures of expertise are imbued with hierarchisation and inequalities among radiology workers. In the Indian company Worldwide Teleradiology, which provides services for the USA market, the role of USA licensing leads to a 2-tier workflow where medical images are first read by Indian-certified radiologists and they then undergo a second read by radiologists licensed with the American Board of Radiologists (ABRs). There is no difference in the work that these two categories of radiologists do – they both examine the image, consult the patient record and any patient history and past radiological exams if available, form a diagnosis and then dictate a report to their transcribers. Some of the ABR registered are even Indians who have received their education and worked in the USA. Even so, the ABRs are paid significantly more than their Indian-certified colleagues and their labour is the one that remains visible in the final report. They are the ones who sign the diagnosis sent back to the USA hospital while the expert labour put into the first reading and reporting of the study remains invisibilised.

The mechanism of licensing thus plays a role in the practice of teleradiology, by enacting a specific racialisation of labour which not only limits the validity of expertise and the access to labour markets for some radiologists, but also allows for the hierarchisation of labour along racial lines. This racialisation of labour works through the complex entanglements of race and class inherent to the development of capitalism and which operate with a notion of race and racialisation that is not limited to skin and blackness. Rather, race functions as a principle of economic and political categorisation and stratification, which naturalises and rationalises the subjugated position of certain groups. Etienne Balibar and Immanuel Wallerstein in their seminal work *Race, Nation, Class* (1991) argue that race, nationalism, and economic exploitation are intertwined; they further argue that race and racism function beyond the classical framework of biological racism and can be expressed instead through cultural and ethnic difference. There is abundant scholarship exploring how the colonial domination of Asia and Africa was used to model technologies for punishment and exploitation in the metropolis, although Cedric Robinson (2000) convincingly argues that racism exists before and beyond capitalism, as a hallmark of Western culture where it has been used to develop, sustain, and rationalise social and economic hierarchies and stratification by binding together economic position with cultural and ethnic difference. The racialisation of labour does not only emphasise and utilise distinctions between different groups but also actively produces categories of differentiation and differential inclusion (Mezzadra and Neilson 2013). Migration regimes are one such example of racialisation of labour through bureaucratic and legal mechanisms that produce and apply different categories on migrants, thus building hierarchies of rights, abjection, and exploitation between and within ethnic groups (see Robertson 2019; De Genova and Ramos-Zayas 2003; and Balibar 2004 who employs the concept of recolonisation).

The role of licensing in imposing and sustaining these hierarchies of racialised labour shows how technocratic and technological solutions can absorb past political and economic forms of stratification. In a manner similar to the way migration categories function, licensing becomes a bureaucratic mechanism for imposing difference and political and economic hierarchies. In this way it mimics past technologies for the rationalisation and naturalisation of difference that resorted to biological and ethnic markers to justify the inferior position of certain groups. In the USA the regulations for radiology licensing are not nation-wide but rather operate at the level of individual states; this means that each teleradiologist working for the USA clients of Worldwide Teleradiology needs to undergo a process of licensing that allows them to diagnose patients in the state where the client is being treated. Thus the radiologists working for Worldwide Teleradiology have to secure licenses for each state of each hospital to which they are providing diagnosis. This practice specific for the USA shows the multiple embedded technologies of regulation that a radiologist has to navigate, and which can have particular configurations in each country. The institutions, actors, and rationales of bordering act on radiologists in different ways, depending on their nationality and professional license, forming almost modular infrastructures of regulation of expertise. As I show above, licensing, even if it is originally meant to safeguard national labour markets, can be incorporated and operationalised within logics of bordering that work on supranational level and, as I discuss below, on the level of individual hospitals. The alliances and agreements for mutual recognition of qualifications work distinctly along racial and colonial lines in the case of Indian radiologists. Even within the former Commonwealth encompassing former UK colonies, Indian qualifications are regarded as insufficient for applying for an UK radiology license, unlike the qualifications from Australia, Canada, and South Africa (General Medical Council 2017). This means that Indian radiologists must undergo a significantly more complicated process of recognition of their qualifications and right to practice. These mechanisms of racialisation are part of the way licensing functions as a bordering technology that determines the inclusion and exclusion (Mezzadra and Neilson 2013) of radiologists in national labour markets and imposes limits on the conditions under which radiology expertise is recognised.

However, racialisation and national markets are not the only underlying logics of bordering behind the way licensing operates as part of the infrastructures of expertise. The infrastructures and the regulation of expertise also include corporate actors and rationales that play a role in determining the conditions on which radiology expertise is recognised. Two such examples are hospital credentialing which is a dominant practice in the US, and the use of non-compete clauses in contracts that ban doctors from working in other healthcare institutions. Hospital credentialing (or hospital privilege) is a practice that makes the professional practice of a radiologist conditional on their recognition by a hospital institution. A physician cannot work in a healthcare institution in the USA, unless they undergo a process of credentialing which involves the medical board of the hospital verifying their qualification, experience, and expertise and recognising them by giving them the privileges to practice a particular medical subspecialty (Youssef and McCoubrie 2016). This evaluation is performed by the medical board of the hospital that decides whether a doctor is sufficiently qualified and has shown good quality of practice (American College of Radiology 2019). The board voting on hospital privileges for physicians should all be members of the eligible professional organisations that regulate clinical practice.

The logic behind hospital credentialing is partially motivated by risk mitigation, which is addressed through the process of checking qualifications and credentialing through medical boards. The rationale behind this requirement is that through it, the hospital officially recognises the qualification of the radiologist and also accepts certain responsibility and liability for their actions and practice (Youssef and McCoubrie 2016; Patel and Sharma 2019). The process of credentialing also serves to establish the particular sub-specialty expertise of a medical practitioner however, and can thus narrow and specify their expertise not just down to a state and a medical institution but also to a particular sub-domain and sub-specialty of medical knowledge and practice. This leads to the embeddedness of teleradiologists within multiple logics of bordering and regulation exercised by different institutions. This model of organisation and regulation of healthcare and the medical profession plays an important role in determining the scope of radiology expertise. Each radiologist is licensed in certain states and credentialed in certain hospitals. This creates a very modular and differentiated model of expertise which acts differently on individual radiologists and the practice of radiology in general.

Further, hospital privileges can also include noncompete clauses, which are more common in the USA than in other parts of the world. These noncompete clauses impose the condition on radiologists that they cannot work for a competing practice within a certain geographical region during their employment and also for a certain period after their employment with the hospital is over. Timothy Boden (2015) explains that historically the practice of noncompete clauses developed in the 1990s in the USA when most of the radiology practices were small practitioner owned enterprises and when some of the financial relations into which they enter, bank loans for example, depended heavily on the viability of the business practice. The noncompete clause comes as a binding agreement that insures practitioner-owners against the danger of one of their colleagues leaving the company and starting their own business that steals some of the current clients. The implications for teleradiology practices is that they have to navigate the conditions of these clauses when assigning cases. For example, some radiologists cannot provide diagnosis for the hospital where they used to work in-house. There is a double movement at play within the logic inherent to this complex constitution of expertise. It is a logic that simultaneously moves towards increased standardisation of medical expertise which makes the transmission of medical knowledge and practice easier, while moving to develop mechanisms within the institutions of expertise that restrict and condition its validity and the possibility of exercising expertise.

Expertise and intensification of labour

Apart from offering imaging diagnosis, Omniscan Teleradiology also provides single radiology sessions to radiologists working at the hospitals with which the company has a contract. Giacomo, the head of the Sydney office, leads one of them; the details he gives of how the session is organised reveals the multiple purposes that it serves for the company and for the radiologists involved. Giacomo had agreed to let me observe the lecture and asked me to be at the office at least 15 minutes before 7pm when the session starts - long after the rest of the company workers are gone. When I arrive in front of the company building, the CBD is already in off-business hours mood. The sandstone restaurant by the side of the building is full of people having dinner and the little piazza echoes with their chatter. Giacomo comes in his shorts, t-shirt and flip-flops, telling me about his busy day. We reach the floor of Omniscan Teleradiology; the office is empty and dark, he goes to his room, tells me to pick a chair and when I switch on the light, he says it works better with the lights off. We are now in the room lit up by the three screens of his PC, the light from the open office space where the administration staff usually sits, and the lights of the surrounding skyscrapers coming through the large windows of Giacomo's office. He waits for an administrative assistant in Barcelona named Sylvie to log him and all of the radiologists that will attend his lecture. They are all sitting in Sweden and all work at one of the client hospitals. He talks to Sylvie over Skype, arranges how and when they will start, checks out how many people have logged in and discusses how to proceed. Giacomo gives an hour-long presentation about intestinal obstruction, showing cases from his practice and the practice of his colleagues, explaining the images, pointing out tips on how to recognise the presentation in CT scans and x-rays, and how to report on them. For each of them this lecture brings in points from the Continuing Professional Development (CPD) system of their respective professional organisations - for Giacomo as a lecturing and mentoring experience and for his audience as a subspecialty learning activity. These points are important for radiologists because they guarantee the continuation of their membership in the professional colleges, and thus constitute an ongoing re-affirmation of expertise.

In recent years, the tendency for the conditionality of professional licensing in radiology has accelerated with the introduction of continuous learning programmes and new requirements imposed by radiology boards in different countries. In 2004 the American College of Radiology implemented a new practice of certification under the name Maintenance of Certification (MOC) (Madewell et al. 2005). The MOC replaces the existing life-long validity of the radiology license with a system whereby the validity of certification is conditional on meeting specific requirements of practice every year. These requirements include uninterrupted work practice (with exceptions for maternity leave and sick leave), participation of self-assessment online exercises, assessment of the cognitive abilities, and finally assessment of their performance in practice. This last aspect of MOC includes the workflow performance of radiologists in which their turnaround time for reports, ratio of erroneous readings, and auditing of professional practice are directly linked to efforts to improve the labour efficiency and productivity of the radiologists. The imperative of increased efficiency is in turn tightly linked to conditional membership within the professional community. The American College of Radiologists is not the only radiologist professional body to implement formal procedures for continuous education and professional development. RANZCR is also implementing a Continuing Professional Development (CPD) programme with similar components, as is the Royal College of Radiologists (RCR) in the UK.

The implication of these programmes for continuous learning and professional development is that they create a form of labour intensification that is linked to the conditions of membership in the radiology profession. There is pressure for radiologists to take on high volume jobs that allow them to read many cases and thus maintain and improve their professional experience. The high volume of reads is not formally a part of requirements for the continuing professional development programmes, but it is implied by the system of continuous assessment and auditing that is instituted through them. As radiologists are required to prove their expertise every year, they feel the need to practice more, which means to work more. In my interviews with radiologists in both Sydney and Bangalore, a good radiology position was consistently defined as one that provides them with a large number and a good variety of cases, which enables them to maintain and develop further their expertise. This interdependence is not simply a personal feeling of individual radiologists, but also an instituted measure of good practice.

Phillip Foster, a university professor and the leader of a research centre on radiologist assessment in the subfield of mammography, shared with me in July 2016 that the quality of reading depends on the number of images that a subspecialist in mammography reads per year. This interdependence is also cited in research published in prestigious journals, that compares USA and Australian radiologists specialising in mammography and draws conclusions that the higher number of cases Australian radiologists read is one indicator of their better expertise and of better medical outcomes (Suleiman et al. 2014). The correlation between a high volume of mammogram readings and high level of accuracy demonstrated in the practice of the radiologists has also been the object of other studies with a focus on the mammography subfield where the images are especially challenging to read because they are higher resolution than other radiology images, contain more details because of the different types of tissue in the breast, and are also more prone to false negative and false positive interpretation (Rawashdeh et al. 2013). The scientific nature of these studies gives them strong credibility in the field of medicine where evidence-based standards of practice have been the norm since the late 1980s (Timmermans and Berg 2003: 13). It also shows that there are two complementary logics of labour intensification in radiology and teleradiology; one logic driven by the capitalist rationale for profit postulates that more read images means more profit for the hospital or the company, and another logic of labour intensification is driven by logic that is intrinsic to the development of mechanisms of self-regulation within the medical community. This specific drive for labour intensification helps to explain the relative lack of resistance against high-volume jobs, like the ones in Worldwide Teleradiology where radiologists can read up to 200 cases per day (as I described in the introduction). While Abhishek, a radiologist at a big oncology hospital in Bangalore, tells me that he quit his position at Worldwide Teleradiology because of the intensity of the work, the rest of the radiologists from my fieldwork did not view the intensity of work in a negative light. On the contrary, they considered this as a positive work setting that allows them to improve their expertise and advance in their professional development. This complex drive for productivity has wider implications that affect the organisation of labour and the inclusion of non-radiology workers in the workflow, as I show in the next chapter. Loaders, workflow support, and transcriptionists all take on tasks that help maintain the intensified productivity of the radiologists.

The logic of self-regulation shapes a specific pattern of productivity. As I argue above healthcare, as part of the biopolitical apparatus of the state, is concerned with the productivity of populations. The development of the infrastructures of expertise in radiology however, links the regulation of professional boundaries with new modes of intensification of labour and the productivity of medical specialists. The push for increased productivity comes not only from hospitals and teleradiology companies, but also through the requirements of continuous education that are becoming part of the conditions for licensing and membership in radiology professional organisations. This complex pattern points to what Foucault (2008) sees as an "economy of power" in his study on state power and its evolution in modern liberalism. Foucault asserts that one of the defining features of modern liberal government is its attempt to limit the reach of its own power and to constantly examine its right to govern. The authority to rule in this liberal model of governance comes from the mechanisms that the model itself creates to limit its power and examine it. The continuous re-examination and re-affirmation of expertise through the Continuing Professional Development programmes can be seen as following a similar logic, where the power of medical expertise becomes contingent on its ongoing assessment. This brings in another aspect of the role of the Continuing Professional Development, which is that these ongoing assessments also impose the terms of conditional inclusion as a specific type of bordering, as I noted in the previous section of this chapter. This dual purpose of the CPD programmes is possible because of the complex political position of radiology labour, and healthcare labour in general, as part of biopolitical apparatuses and holders of the power of expertise on one hand, and on the other hand as workers whose mobility, productivity, and status are determined regulated by a variety of institutional and economic actors.

As part of their continuous professional development programmes radiologists have to also perform a number of unpaid work tasks including attending conferences, performing audits for colleagues and being audited themselves, reading and watching educational materials, publishing articles, and participating in discussions of interesting cases (American Board of Radiology 2019; Madewell et al. 2005; Medical Board of Australia 2016a; Royal College of Radiologists 2016). These activities, which are now part of the conditions for maintaining professional status, become integrated within the work routines of teleradiology companies and lead to an entanglement of professional development, educational functions, prestige, and strategies for recruitment. Through these professional development exercises the intensification of labour is interlinked with the maintenance of expert status. Teleradiology companies become important actors in sustaining an economy of professional knowledge and scientific expertise. As part of the work package they offer the possibility for radiologists to take part in a number of educational and research activities such as building educational materials from their practice, involving their own employees in the delivery of radiology presentations, the writing of academic papers, and the process of auditing required by professional radiology bodies. At Omniscan Teleradiology Giacomo for example regularly gives video presentations to radiologists in Europe, who sign up for his sub-specialty talks. But apart from that, the company itself is also benefiting from the lecture in at least three ways. First, the lectures are a paid educational service provided by Omniscan Teleradiology. Secondly, through the use of medical images from the company's practice, the lecture allows the company to use the resources of both radiologists and patients to showcase the expertise of their doctors and increase the prestige of the business. And, thirdly the lecture itself is also used as a strategy of recruitment.

There is a carefully arranged aesthetics to the setting of the lecture. Giacomo's silhouette against the background of Sydney skyscraper cityscape gives a sense of cosmopolitan worldliness and, at the end of his talk, he clicks on the last couple of slides: a scenic picture of the Opera House in Sydney and a picture of himself in the bush smiling while squatting next to a kangaroo. Breaking his usual stern professional manner of speaking, Giacomo jokingly warns his audience not to try to step on the tails of kangaroos, as he is shown to do in the picture. He ends the talk by advertising Omniscan Teleradiology as a working environment and encouraging his audience to apply for a position at the company. Another picture of Sydney harbor, the Opera House, and the CBD shows the location of the company office circled in.

The company has developed and is selling three educational products. It was realised at some point that the expertise of their radiologists (180 radiologist in different countries) is something that they can utilise to get into a new market. So, they started selling not only diagnostic but also educational services. Omniscan Teleradiology offers three-day courses with lectures in Barcelona, which are also uploaded online and can be accessed later. These courses are also good for the company's marketing strategy because they showcase the range of specialists available through it. It also offers fellowships, paid by the hospitals employing radiologists who want to sub-specialise. The fellowships are currently offered at the office in Barcelona, where fellows can work alongside a subspecialist and "shadow" them by observing their practice. The fellowships are linked to a separate type of labour mobility for the radiologists employed by the company, whereby the doctors working at other offices are sometimes asked to work from the Barcelona office for a couple of weeks or a month so that they can train the fellows.

Apart from in the online lectures and fellowships, the company is also incorporating educational elements in its software. Omniscan Teleradiology develops its own Radiology Information System (RIS) after initially having used one produced by Siemens. RIS is a database-centred software system for the storage and writing of textual data from radiology exams, that is to say, the radiology reports, study orders, and patient record information. It works in coordination with PACS that handle the imaging data. RIS is also integrated with HIS that manages and stores all textual clinical, administrative, and financial data in a healthcare institution. While PACS conforms to the DICOM standard, RIS and HIS use HL7 standards for the management and communication of healthcare information (Nance Jr, Meenan and Nagy 2013; Oosterwijk 2007). There are some overlaps in the functionalities of RIS and PACS as well different initiatives and solutions for their integration, from harmonisation between DICOM and HL7 to the use of special software brokers that interface between the two systems and enabling the translation and exchange of imaging and textual data. I will discuss these systems and standards in details later in the dissertation. For now, it suffices to note that the home brand RIS developed by Omniscan Teleradiology serves to distribute cases among radiologists, enable auditing and second readings, and in this particular case, it has important educational and training functions. The move to its own proprietary software has allowed the company to save money but also to adjust the software to its own needs and to develop it as one of the products it is offering to clients. The company RIS also has the option to incorporate an educational module. This module includes the option for a second opinion. Some cases are arbitrarily assigned for a second reading by a more experienced radiologist in Omniscan Teleradiology. The differences between the first and the second readings are marked according to significance - minor, major, etc. The first radiologist can agree to them or dispute them and ask for a third opinion. The feature is advertised as a quality control and education option and it shows how the requirements of professional licensing become incorporated into the business models of companies, turning the imperative for increased productivity imposed through the institutions of professional societies into productivity that can be commodified and converted into profit.

Worldwide Teleradiology in Bangalore, India, has also adopted strategies for profiting from the educational activities and quality control required through the continuing professional development programmes of professional organisations. The company has a separate department that is organising the educational and research output of the company's radiologists, as well as their own continuing professional development. This department manages the weekly online meetings where radiologists discuss cases from their practice, supports the preparation and publishing of scientific articles, and manages the company's educational portal. Like Omniscan Teleradiology, Worldwide Teleradiology has also turned the continuing education requirements into a service offered to radiologists around the world through their educational website. This website however offers free educational resources and live lectures. The radiologists working for the company and the images of patients, de-identified for the lectures, are put into use in an economy of prestige and recognition for the company.

The work of the education department at Worldwide Teleradiology is exclusively concerned with the production and distribution of knowledge, which involves different company employees. Transcriptionists are tasked with identifying interesting cases during their work and marking them for the educational department. The marked cases are then evaluated by the person responsible for preparing scientific publications, who contacts the radiologists that have read the case to ask if they would be interested in authoring an article with her help and with the participation of the owner of the company, Arjun. In addition, interesting cases are assembled for the in-company training provided to both the Indian radiologists and ABRs. These trainings take place four times a week: three times during the lunch break at the company and once a week, on Wednesdays after work hours in the evening. Even though they are not part of the requirements for continuing education imposed by the professional associations, radiologists must attend.

The training also includes a quality assurance (QA) module where cases are reviewed by the special QA team formed at the company which consists of trained transcriptionists and is led by Prabath. The transcriptionists are not trained medical doctors and do not have a specialised education in radiology, so their use in the quality assurance process is surprising from the standpoint of expert evaluation. It is consistent with a model of distributing work tasks to less qualified and lower paid employees as part of the business strategy of the company. They are responsible for coordinating the peer-review process, whereby the radiologists employed by Worldwide Teleradiology read already diagnosed cases by their colleagues at the company and give them feedback. The QA team also coordinates the feedback they receive from USA hospitals and make sure to respond to the comments when a diagnosis is contested by the USA radiologists. When a hospital receives an emergency study from Worldwide Teleradiology, it is considered a preliminary report and the local radiologist looks at it at the morning. If they find inaccuracies or something missing, they send email or fax to Worldwide Teleradiology, or upload a report via RIS/PACS.

Prabath's work is mostly coordination and what he calls "detective work", this is, reading through previous communication and reports in order to find out who has made a mistake and whether there was missing, or inaccurate information sent from the hospitals. Prabath sends the comment on the report to the ABR certified radiologist and the Indian certified radiologist who have read the cases and asks them to take another look. Sometimes they have to respond within 2-3 days, sometimes if it is not urgent, it can take them a month. After they read the comments the Worldwide Teleradiology radiologists respond saying whether they agree with the feedback or not. If they do not agree, the report will be sent to one or more other radiologists for evaluation. Prabath is responsible for coordinating and collecting this feedback. After all the radiologists consulted have agreed about the diagnosis, Prabath writes a reply with the help of Abilaj who is the most experienced Indian certified radiologist. Prabath is in a peculiar position. He has to convey expert opinions and evaluation without being an expert himself. This means that he has to perform his work in a specific way, employing elaborate linguistic skills in order to navigate between his position of non-expert and his task of contesting and questioning expert evaluations. As Prabath explains to me, when their radiologists disagree with the opinion of those radiologists in the USA hospitals, he and Abilaj must put a lot of thought into phrasing the reply. Prabath says: "When they don't accept the comment, we reply sarcastically, we don't say *no*." There is a similar level of consideration and attentiveness when approaching the ABRs in the company. This is partly the reason why Prabath has to do such extensive "detective work" as part of his job; he has to make sure he has tracked down where the mistake has occurred so that he does not contact the ABRs needlessly. This arrangement at Worldwide Teleradology has incorporated Prabath into the infrastructures of expertise built to validate and regulate the performance of professional skills and knowledge in a way that makes him crucial for the continuous assessment and reaffirmation that is sustained through the Continuous Professional Development programmes.

Aside from coordinating the feedback from USA hospitals, Prabath is also involved in the internal peer-review process which serves a dual purpose: firstly, to ensure the quality and accuracy of the service that the company offers; and secondly, to satisfy the requirements of the Continuous Professional Development programmes that are now intrinsic to the maintenance of professional expertise. Discrepancies between the Worldwide Teleradiology report and the peer review are marked with scores between 1 (no error) and 5 (major error), with an assigned *a* for an error that has significance for the clinical treatment of the patient or a *b* for an error that has no significance for the clinical treatment. If radiologists accumulate too many bad reviews, the QA team prepares individual learning objectives for them. Prabath and Abilaj prepare together cases for the training of the radiologists that include a PowerPoint with images, a summary of cases and errors, and a learning point, which is then reviewed by the owner of Worldwide Teleradiology and included in the final version of the lectures.

These examples highlight the fact that the role of medical licensing is not defined only by practices of boundary-making but that it also functions as a logic driving the intensification of labour. This specific intensification of productivity is motivated by the attempts of the profession to self-regulate, which leads to conditional inclusion instituted through the programmes for Continuing Professional Development. The requirements of these programmes pose demands for increased professional activities in the form of conferences, audits, peer reviews, trainings, online lectures, as well as a number of cases diagnosed throughout the year. The incentive to perform more work tasks is easily incorporated within the business model of teleradiology companies, as this section has demonstrated. However, the requirements of medical licensing for continuing professional development function as a logic of intensification of labour that develops alongside the capitalist logic of increased productivity driven by profit. Although the two logics develop separately and although the intensification of labour through the technologies of Continuing Professional Development is grounded in the liberal mechanisms of economising and self-regulating of power, they still coalesce in a way that makes labour in teleradiology a very particular kind of political subject. This peculiarity rests in the ambiguous connotations of labour intensification, combining capitalist profiteering and the maintenance of expert power. This ambiguity constitutes the teleradiologists as subjects that are simultaneously privileged and exploited and marks the hierarchical dependencies between them and the other workers in teleradiology outsourcing.

Economy of expert shortages and duplicating workflows

The technologies of bordering and intensification of labour produce a specific economy of expert shortages and ways to compensate for this deficit. Professional expertise charts very distinct patterns of mobility for medical workers. In comparison to other labour migrants, the migration of health professionals is conceptualised at state and international levels through specific notions of "brain drain", health inequalities, and deficits of medical workers (Connell 2010; Connell and Walton-Roberts 2016). Their labour and the possibility of leaving the boundaries of one state and working in another one entail considerations of the importance of doctors not just for the national economy, but for also for the health of the nation. The dominant trajectory of medical labour mobility from less to more developed countries has led to fears of "brain drain" - a notion with strong connotations of extractivism. As Robyn Iredale (2001) points out, traditional nation state policies for protecting the national medical labour market have raised obstacles to the entry of foreign professionals and have led to deficits of health professionals in many places (also see Starr 1982). In this general context of medical labour deficit, wealthy countries can attract doctors from poor ones, thus extracting not just productive labour but also valuable medical expertise from poor parts of the world. It is notable that in the case of medical professionals, experts function not simply as high-skilled labour but they constitute a key part of the national healthcare system and their deficit, distribution, and skill level are evaluated as functions of the system. This is exemplified in the World Health Organisation (WHO) Global Code of Practice on the International Recruitment of Health Personnel (2010) where the principles for the management of the international labour mobility of healthcare professionals are linked to its impact on national healthcare systems. The premise of the document, which serves as a voluntary adherence code for countries that have accepted it, is based on two core principles for understanding the role of health personnel and their mobility: firstly that there is a "global shortage of health personnel"; and secondly that an "adequate and accessible health workforce is fundamental to an integrated and effective health system" (ibid. 2).

The notion of deficit is a central one in the development of teleradiology in multiple ways. More than other types of outsourcing, the rationale behind the outsourcing of teleradiology is grounded in concerns around the deficit of radiology labour in the context of a growing demand for medical imaging services. The topic of the chronic shortage of diagnostic radiologists has been a matter of concern and discussion in professional publications and scholarly analyses. The reasons for the shortage are interpreted in terms of demographic dynamics and an increase in the use of medical imaging diagnostics (Corbett 2017). In his piece for the USA radiology portal Aunt Minnie, Daniel Corbett discusses the shortage of radiologists in the USA job market by analysing data from the recruitment service Radiology Business Solutions. According to the figures from the job postings and applications over a two year period between 2015 and 2017, there is a significant drop in ratio between advertised positions and applicants for them; Corbett sees this tendency as the result of generational changes, with baby boomers entering retirement age and the shifting proportion of patients in demand of radiology services in relation to the volume of practicing professionals that can provide them. A similar train of thought is present in the analysis of Australian radiology workforce from 2001 (AMWAC 2001) and the projections of healthcare workforce for 2025 (Health Workforce Australia 2012). The projections of Health Workforce Australia point out the expected deficit of radiologists which will deepen in the future and vary between minus 287 and minus 540, according to different prediction scenarios (ibid. 286). The large bulk of such publications and analyses appears in the early 2000s, which is a period coinciding with the beginnings of commercial international teleradiology practices. What is significant about these analyses is the way in which they construct the notion of deficit as the result of an interdependent relationship between productivity and the consumerism of health services in the overall population. The shortage of radiologists is a function of the lower number of graduates and practicing doctors, many of them on their way to retirement, and simultaneously, the function of a changing demography and changing healthcare needs of the overall population. This relationship also shows that the problem of deficit of radiologists is not a concern contained within the profession itself. Instead, it is articulated through an overall rethinking of the economy of population and its properties within a particular territory.

Foucault, in his lectures on territory, links the problem of scarcity in his historical analysis of the issue of grain deficit in 17th and 18th century France on one hand to the ways in which population as a political category of a modern form of governance is related to the duty of providing and abundance, and on the other hand, to the ways that the problem of scarcity leads to opening up of the territory and redefining its character, scope, and economy (Foucault 2007: 30ff.). In the case Foucault is analysing, the grain deficit leads to a reorientation of the political space from the model of the urban polis to a model that encompasses the economy and space of productive land around it. In the case of teleradiology, we can see a similar opening up of the healthcare labour market, traditionally contained within the confines of the state. The deficit of radiologists leads to the labour migration of foreign specialists who are recruited to diagnose patients and also to the establishing of companies that offer cross-border services. The notion of deficit exacerbates the necessity to satisfy the need, cater for the population and maintain the health and productivity of the political and populated territory; and teleradiology is one of the ways to meet this necessity. Foreign radiologists become the resource needed to bring back the productive balance, to satisfy the population, to reaffirm that the territory is governed well and thriving. The ability of wealthy countries to attract foreign radiologists inevitably aggravates shortages in the countries where they come from (Akhter 2019; Yu and Levi 2007). This deficit that brings about the need for outsourcing is not thought about just in quantitative terms but also in terms of the qualities of populations and radiology experts. It triggers processes of compensating the local deficit that draw on and exacerbate hierarchies of labour that operate across national, technological, and geopolitical scales.

Part of the consequences of this drive towards compensating local deficits of radiology labour is the production of uneven and differentiated labour regimes for different radiologists involved in cross-border practice, as I noted in previous sections. On one hand there are radiologists like Giacomo and his colleagues in Sydney who travel to exotic and attractive destinations being recruited by companies that provide support for every aspect of their relocation. On the other hand, there are radiologists like Abilaj, who are incorporated within these global networks for transferring patient data and expert labour but remain immobilised by visa and professional licensing regimes and whose work remains invisiblised. Even so, radiologists, including radiologists in India, are a privileged group of workers nonetheless (Seethalakshmi 2013) and the rise in teleradiology, especially nighthawk teleradiology, which covers the night shifts by offshoring the jobs to places in different time zones, is a sign of this privilege. Night shifts are especially undesirable for radiologists. In the US, which is the largest market for radiology, the need for night-time emergency radiology arose with the growing significance of medical imaging for mitigating liability in case of misdiagnosis, and it introduced the practice of 24/7 radiology service which up until then was a daytime position (Levy and Goelman 2005). In the early 2000s the digitalisation of medical imaging and the development of PACS made it possible to start outsourcing and offshoring the night-time radiology (ibid.; Goelman 2005a) and this move was embraced by hospitals in order to make the in-house positions more desirable for radiologists. By that time, the use of medical imaging for diagnosis had increased the demand for radiologists and led to a market where radiology doctors were in deficit and had the upper hand in bargaining for their work conditions and remuneration.

The outsourcing of radiology diagnostics, however, brings forth concerns about the dangers it could potentially pose to the position of local radiologists, as well as concerns with the structures of accountability and liability that safeguard patients. The management of risk is a key consideration in the organisation of teleradiology outsourcing and consequences of remote diagnosis that determines to a large extent both the scrutiny that teleradiology outsourcing is subjected to and the mechanisms of its regulation. In both media and academic publications, teleradiology outsourcing is presented as wrought with risks, abuse, and possible fraud. Levin and Rao (2011) criticise teleradiology practice by emphasising the dangers to professional autonomy that this business model can pose for example. They argue that outsourcing endangers the professional practice firstly by introducing cheaper labour and competition in the market along with corporatisation, and also by opening up the possibility for other medical specialists to lay claim to radiology expertise. Further, Levin and Rao frame teleradiology as representative of two tendencies endangering the autonomy and prestige of the medical profession, these are commoditisation (commodification) and the potential exploitation of radiologists by corporations which leads to lower wages. These worries, which have persisted in literature on medical sociology (Galloway 2008; Pellegrino 1999; Starr 1982), point to the inherent contradiction in radiology; it is an economic practice that does not want to recognise itself as being subsumed under the rules of the free market, defining itself as simultaneously in and out of the market. This ambiguous positioning has implications for the ways in which teleradiology is regulated and considered in the radiology community. The question of commodification of medical care is a complex one. Radiologists provide services and establish their own practices and companies to do that. The rise of anxiety about the market logic of healthcare comes with the possibility of non-medical entities taking on the provision of medical care or employing doctors. The American College of Radiologists express a similar concern in their White Paper on Teleradiology Practice, where the College warns: "…some teleradiology companies focus exclusively on report delivery. Besides devaluing our specialty and undermining the role of the radiologist as an independent expert in diagnostic imaging and a fully engaged member of the consulting team, this practice further commoditizes the product of our efforts" (Silva III, Breslau, Barr et al. 2013: 576).

This scepticism toward teleradiology, however, is yet another direction framing foreign radiologists and, especially radiologists in the Global South, as inherently risky. For example, in a reportage for Radio

Canada, Thomas Gerbet (2017) discusses the possibility of Canadian radiology images being outsourced to India. Describing the office of a Bangalorean company that he visited, Gerbet emphasises the image of darkened spaces and the uncertainty of liability in cases of erroneous readings; it is an emphasis that plays with the racialisation of labour and which allows for outsourcing to India to be presented as exoticised and risky. Gerbet's article is not the only one presenting teleradiology outsourcing as a risky and murky enterprise. Another article from North America by Katherine Eban (2011) describes the case of misdiagnosis of an outsourced image reading, in which the ensuing inquiry opened a Pandora box of falsified doctors signatures and underqualified staff writing radiology reports. As Eban explains, the images are first read by the radiologists in the outsourcing company contracted to conduct after hours readings, and although they need to be later read and signed by USA doctors in the morning, this process of quality assurance did not work stringently enough. What transpires in such discussions is a process whereby a notion of risk is construed that interlinks professional boundaries defined by professional organisations with racialised borders that presents the Global South and workers from the Global South as inherently dangerous and risky. Nishigandha Burute and Bhavin Jankharia (2009) in their article examining the development of teleradiology in India, write that one of the major obstacles to the industry is the perception of India as a "Third World" country which affects the way that local radiologists and their expertise are regarded. As they point out: "[d]espite the growth of medical facilities in India and the reasonably high levels of quality, people in the West are still wary of having Indian radiologists in India interpret studies." (ibid.: 17).

The result of this racialised construction of Indian radiologists as insufficiently qualified and the process of outsourcing as wrought with risks leads to the specific duplication in the workflow that I described earlier in this chapter. At Worldwide Teleradiology, the patient images are read and diagnosed first by an Indian certified radiologist before undergoing a second read by an ABR certified radiologist. These images are then read a third time by USA radiologists in the USA hospital who check the diagnosis from the company radiologists. The imperative of risk management associated with outsourcing and foreign experts thus means that an outsourced radiology study is read by more radiologists than one that is diagnosed on site in the hospital, and that the teleradiology company pays for the services of two radiologists per study. This duplication of labour that is necessitated by risk associated with outsourcing to India, is compensated by intensifying and increasing the productivity of the radiologists that are employed by the company. To a large extent this task of labour intensification is achieved through the specific collaborative workflow in Worldwide Teleradiology which I will analyse in more detail in the next chapter.

The economy of duplication that risk management in teleradiology necessitates thus leads to the development of specific infrastructural solutions and specific subjects in order to accommodate the strategy of duplication as risk management. The organisation of the duplicated workflow is one of these infrastructural solutions, which is also reflected in the design of software and hardware functionalities of PACS and RIS. As I pointed out earlier, these systems allow for the incorporation of second reading, peer reviews and training options. The hierarchisation and duplication of the workflow is codified in automated workflow management functions of PACS, where the option of two-tier diagnostic process is embedded by merging workflows and incorporating audit trail into the process (Benjamin, Aradi, and Shreiber 2010). The home brand RIS of Omniscan Teleradiology similarly incorporates the function of a second read and an audit trail. An interesting parallel of this duplication in the workflow is the fact that Worldwide Teleradiology has also adopted a strategy of duplication in its network connectivity infrastructure. A stable and strong Internet connection is crucial so radiologists can smoothly do their remote work. This is a critical issue in Bangalore where the power network and the Internet are down a few times each day and leave homes and industry without electricity or internet connection. As a workaround solution to this constant threat of infrastructure failure, the company has doubled its infrastructure in order to always have a back-up. Apart from the generators that ensure power supply, Worldwide Teleradiology has contracts with two separate Internet service providers to minimises the risk of complete network failure. If one of the networks is down, they switch to the other. This is critical for the work of radiologists because of the urgency of some cases and also because of the size of radiological images. Some of the more complex modalities, such as PET and MRI, produce image files that can be up to 1GB or more. They consist essentially of hundreds of images of slices of the body that are afterward arranged in the right order by an algorithm and an unstable Internet connection risks losing some or all of these images during transfer.

This duplication in the workflow and the need to compensate for it by increasing the productivity of radiologists leads to the emergence of new subjects that serve the drive toward labour intensification, by taking over some of the tasks in the diagnostic process but performing them in a lower paid position. The Indian-certified radiologists conducting the first read at Worldwide Teleradiology are one such example, but there are numerous other subjects that I discuss in more detail in the next chapter. Their roles in transcribing, managing the workflow and assisting the US-certified radiologists, enable intensified productivity at the company while rendering their own labour invisible. This politics of visibility and invisibilisation reverberate with the description of the murky dark spaces of the teleradiology office from the account of the Canadian journalist Thomas Gerbet (2017) whom I reference above, evoking ambiguity and risk. One of the invisibilised and elusive figures in teleradiology is the ghost. Ghost reading or ghost reporting is an especially notorious phenomenon, where a licensed radiologist signs reports from a radiologist who is not licensed to provide diagnosis for these particular patient cases. Thus the reports are done by one radiologist (the "ghost") but signed off by another one for the purposes of reimbursement and liability. The practice is illegal and very damaging for the reputation of companies. What the ghost does, however, is in practice not different from the first preliminary reading provided by Indian-certified radiologists, who are similarly invisibilised in the process. This similarity is noted by radiologists themselves. In a dialogue on the pages of the *Indian Journal of Radiology and Imaging* from 2009, Arjun Kalyanpur (2009), a radiologist with his own teleradiology company, contests an earlier article by Burute and Jankharia (2009) who, he argues, conflate the role of Indian radiologists performing a preliminary first reading with ghost reporting. Kalyanpur contends that one is legal and used for quality assurance and risk management, while the other is illegal and distinguished by the facts that the second read is fictitious, and that the US-certified radiologist signs the report without consulting the images. This easy conflation of the two practices shows the inherent ambiguity of these invisibilised subjects and how, as Ulrich Beck (1992) notes, the management of risk produces its own new risks.

Navigating deficits, crossing borders

While I started this chapter with the example of Giacomo and his Scandinavian radiologists based in Sydney, I want to close it with the very different story of Sandeep, an Indian radiologist, whose career has lead him to multiple countries and through multiple statuses and recognitions of expertise. His story exemplifies how the administrative, professional, and political infrastructures determine the conditions of inclusion and exclusion of radiologists and affect and shape individual life and work trajectories. Political and economic rationales of labour deficit and migration regimes, and the stratifications and racialised hierarchies sustained through labour deficit and migration regimes, have rendered Sandeep's career path highly complex and ridden with continual instances of exclusion and conditional inclusion.

Sandeep is in his fifties and comes from a small village in Karnataka but now he lives in one of the oldest colonial neighbourhoods in Bangalore, Jayanagar, where we met in front of a white stone Hindu temple. Sandeep is one of the few exceptional cases of foreign radiologists providing teleradiology diagnosis for Australian hospitals from abroad. It took a long a meandering journey for him to get to his current position. He studied medicine in India and after graduating he worked for a few years teaching at one of the Bangalore medical universities. Sandeep, like many of his Indian colleagues, wanted to work in the USA or the UK but the complex procedure for obtaining the appropriate license as an Indian proved an obstacle.

In 2002 another opportunity came his way and he left for Oman to work in one of the big tertiary hospitals there. At that time Oman was experiencing a deficit of radiologists and started accepting foreign professionals after instigating a more relaxed process of credentialing which allowed Sandeep to apply with his Indian qualifications. The country accepted Indian radiology qualifications although the applicants had to undergo an interview and a written exam to get the job. The work in Oman was tempting because of the high quality of the hospitals there and the high volume of cases which allowed Sandeep to improve on his professional development and become a more competitive candidate for positions abroad. He spent 8 years working there during which time the country managed to increase the number of local radiologists by investing in the training of Omani radiology students. The improved supply of local radiologists led to a dramatic change in policies and attitude toward foreign radiologists like Sandeep. Towards the end of his stay, the atmosphere and opportunities for foreign radiologists was beginning to deteriorate; now that the country had its own locally trained radiologists, it was slowly starting to replace migrant workers with domestic ones by reducing foreigners' opportunities for promotions and career development. Seeing the changes, Sandeep started to consider moving to another country. He first intended to move to UK. He studied and took the FRCR (Fellow of the Royal College of Radiologists) exam that is a required certification for UK radiologists. However, in order to be allowed to practice in the UK he had to also spend a year training at a local hospital, which proved to be an impediment.

Fortunately, Sandeep found out that his FRCR qualification could help him find a job in Australia through a special condition in the Australian skilled migration visa stream called "special area of need" (Medical Board of Australia 2016b). This allows foreign medical professionals (among other types of professionals) to migrate to Australia and practice there, but only in designated areas in the country that have been framed as having a deficit of specialists in their field. The process of migration under the "area of need" exception is easier; it is beneficial for professionals like Sandeep who come from the Global South and whose educational credentials are not that easily recognised in the country. Migrants working under "area of need" conditions are allowed to work in their specialty, initially under supervision for a period of one year. Sandeep was sent to work in a small town on the Pacific Highway, somewhere between Sydney and Newcastle. While the job was good, the lack of entertainment and the cultural difference between their old home in Bangalore and their new, predominantly white and Anglo home, were taking a toll on the family. Sandeep's wife was unhappy, and the little town was not what they were hoping for in their new life in Australia. After 2 years working in the town on the Pacific Highway, Sandeep passed the RANZCR exam and became a fellow of the College. He was hoping that this would allow him to practice as a fully qualified radiologist without the restrictions of the "area of need" conditions.

Becoming a fellow of the College made him fully qualified to work in Australia as he was also registered with the Australian Health Practitioner Regulation Agency (AHPRA). However, when he moved to Australia under the "area of need" working visa conditions, he was required to sign a memorandum agreeing to work in areas of need for 10 years.

Sandeep was caught in the bureaucratic cage of the Australian visa regime. Neither he, nor his wife were happy about being bound to the small town on the Pacific Highway. Disillusioned, they started planning their return back to India. It was only then that he found out that the "area of need" condition is not only a spatial but also a temporal concept. This meant that he was allowed to work in towns and regions that experience a deficit of radiologists or during specific times, such as weekends or during the night, when there is also insufficient staffing of radiologists. Shortly before leaving the country, he started working at a teleradiology company in Sydney, Imaginex Teleradiology, once or twice a month during weekends. The pay was good, he would make up to a thousand Australian dollars per weekend, but he says the job was more a way for him to escape the boredom of his little town prison, meet friends, have some social life, and go out for drinks. This is how he started working with Imaginex Teleradiology, the company that is currently employing him from Bangalore. Imaginex Teleradiology provides teleradiology services for Australian and UK hospitals making use of the easy convergence and mutual recognition of credentials between these two countries from the Commonwealth. When Sandeep was leaving to go back to India, Imaginex Teleradiology offered him work with them when he returned. He already had all the credentials needed and had experience working for Australian hospitals as well as for the company itself, and Imaginex Teleradiology wanted to keep him as a teleradiologist working from India. Sandeep has now been working with the company for a bit more than two years, working from his office in Jayanagar and reading images from hospitals in Australia where he was not allowed to practice.

Sandeep's case shows a different aspect of the conditional inclusion of radiologists in teleradiology workflows, but it shares a lot of similarities with ghost reading and the duplication of roles in the workflow. Even though one of them is an illicit practice and the other is an institutional condition for migration management, both ghost readings and "area of need" rules for medical migration create the structural conditions for invisibilising and marginalising radiologists while including them in the systems for intensifying work productivity and the management of deficits of healthcare labour. Both ghost reading and the "area of need" condition for practicing radiology in Australia show the ways in which differential inclusion (Mezzadra and Neilson 2013) is enacted. But these examples also show the role of deficit and excess in managing the political processes of these instances of differential inclusion, the role of which I discussed in the previous sections. Sandeep's experience in Oman shows how the management of radiologists deficit creates the conditions for temporary and conditional inclusion, where foreign professionals are simultaneously fulfilling the need for doctors and are always already framed as redundant. His story of moving from one country to the next also demonstrates how radiologists have to navigate the complexities of how expertise is constructed across borders and through different mechanisms of categorising what constitutes expertise and where it is valid. The effects of these complicated infrastructures of expertise reverberate beyond labour mobility and inform the organisation of teleradiology workflows, as will be discussed in the next chapter.

Conclusion

In this chapter, I examined one of the key paradoxes of teleradiology - the uneven relationship between deficit and excess in the way the practice is organised. I argued that this relationship between deficit and excess that we can see in the organisation of teleradiology outsourcing stems from the logic of governing the different territories determined through licensing, national borders, and risk management. These different logics of governance all lead to duplicities and excesses of labour in the teleradiology workflow but they do so in different ways.

I showed that the complex ways, in which the practice of teleradiology and the various mobilities of labour, data, and money are regulated have impact on how labour and productivity are managed. I offered an analysis of the ways, in which remote labour and the transfer of diagnosis are regulated by arguing that the different logics of restriction and inclusion can be seen as distinct political and economic territories, within which the practice is governed. Territory functions not just as 'political technology', as Elden asserts (2013), but also as a specific technology of intensification of labour. This function of the territory is a core mechanism for driving forth the outsourcing of teleradiology and the ways, in which it creates and exploits unequal terrains of radiology practice. The strategies for enacting policies of inclusion and exclusion in teleradiology through licensing, hospital credentials, migration restrictions, and data and finance regulations are driven by logics of territoriality that are at times complementary and at time contradicting each other. This multiplicity of logics of territoriality is part of the complex history and entanglements of healthcare institutions, which traverse regimes of market regulation, professional expertise, the role of medicine in state biopolitics, as well as more recent regimes of data governance. The regulation of teleradiology practice becomes dependent on these entanglements that can pull the scope of territoriality in opposing directions. For example, as I show in this chapter, the market logic behind licensing in the USA simultaneously narrows the validity of radiologist credentials down to individual hospital institutions but also, in a parallel tendency, through the contractual rules of multinational trade agreements like NAFTA, opens up the possibility for less regulated cross-border teleradiology. The contradictory regimes for either limiting or enabling teleradiology practice lead to a variety of options for inclusion of radiologists - some of them conditional and restricted, such as in the case of Indian certified radiologists included within the US-bound workflow or the “area of need” conditions for radiology practice in Australia. Further, some of the possibilities of including radiologists within the teleradiology workflow are linked to the complete erasure and invisibilising of their role - as in the example of ghost reading.

Chapter 2: Workflow management, automation, and affect

Managing data, managing labour

During one of my fieldwork interviews in Bangalore, Santosh, a young man who develops Picture Archiving and Communication Systems (PACS) for radiology and manages his own teleradiology platform, jokingly remarked that radiologists think they are the most technologically savvy doctors. And in many ways, there is good reason why they would think so. The very beginning of radiology as a profession is conditioned by the emergence of the technology of the x-ray which creates the need for expert labour to handle the x-ray machines and interpret the images it produces (Pasveer 1989). Alan Bleakley and John Bligh (2009: 380) go as far as to argue that x-ray technology has disrupted medicine beyond the introduction of new professions; it has destabilised the practice of medicine and lead to the "dispersal of the clinical gaze". This strong entanglement of radiology labour and technology acquires additional weight in teleradiology; in this instance, technology is incorporated not just into the production of images, but also in the process of transmission of imaging and textual patient data as well as in the organisation and control of different work tasks involved in the diagnostic process. What is even more important is that the digital infrastructures used in teleradiology combine these two aspects (the transmission of information and the organisation and control over the labour process) within one single technology of labour and data management, namely "the workflow".

The organisation of workflows in teleradiology links a series of processes: the administrative manipulation of patient admission, appointment, and scheduling of exams; the production, transfer, and storage of the radiology image; the process of reading and diagnosing and the subsequent filing of the report in the hospital information system (HIS). These different stages involve different roles and workers. In the case of outsourcing, these roles and workers can be situated in different countries and subject to different labour conditions. The interconnectedness of these outsourcing processes is organised through the use of different specialised digital infrastructures. The first one of note is PACS which consist of the imaging modalities (the machines that take the images); secure network for their transmission, digital storage and archive; and a viewing station where the radiologist reads the images. PACS is linked to HIS most often through the Radiology Information System (RIS), where patient data about appointments and referrals is uploaded and transferred. It receives the data about scheduled radiology exams and the associated patient data from RIS, pulls in the necessary information and incorporates it into DICOM (Digital Imaging and Communication in Medicine) images that the imaging modality produces. DICOM is the universally accepted format for radiology images (which I discuss more in Chapter 3). The ready DICOM images are then sent to radiologists through the RIS worklist function. The worklist lines up the studies that are ready to be diagnosed and assigns them to a radiologist based on precoded criteria in the system. These criteria can be modified by a hospital or a teleradiology company, giving different radiologists access to the relevant radiology studies based on their sub-specialty and license. The whole process of transferring patient data and images, matching the imaging studies with the relevant clinical and administrative data and then assigning the study for diagnosis, is automated through the worklist and workflow functionalities of the different digital systems. The workflow functionalities prescribe the sequences of events and transfers between hardware and software systems, as well as between different clinical entities and roles. These functionalities are also codified in DICOM and HL7, which are the two data standards used in teleradiology to standardise the textual medical data.

Thus, the workflow is the main technique for the management of technological transfers of files and for the management of sequences of tasks performed by different workers in diagnosing the images. The teleradiology digital systems, and the notion of workflow as a whole, are not only used to organise a sequence of actions; they are concerned with a specific question of labour and the value it creates which is: *how to maximise productivity and intensify labour?* This question in teleradiology has a particular inflection that relates the organisation and management of labour to the organisation and management of data; this is a relationship that generates insight into the ways in which labour and data are interconnected in digitally organised workflows. This relationship also partly drives the processes of digitalisation in radiology that transform diagnostic workflows through the transformation of the medium of clinical information from film and paper to digital data. In one article Eliot Siegel and Bruce Reiner (2003) describe the significant changes that took place in the Baltimore Veteran Affairs Medical Center after the introduction of filmless (that is, digital) imaging and the reorganisation of workflows this enabled:

> Physicians currently use the electronic medical record to request imaging studies from workstations located throughout the medical center. These orders automatically generate electronic folders in the PACS database and trigger automatic retrieval of old comparison studies (those performed more than 3 months previously) from the longterm archive into a short-term archive (studies done up to 3 months previously) for rapid retrieval by the workstations. A function known as a modality work list makes it possible for these orders in the electronic medical record or hospital information system (HIS) to be pushed or pulled (depending on the imaging modality) automatically to or from the various imaging modalities where they can be accessed

> by the technologist. The list of studies to be interpreted becomes available to the radiologists at their PACS workstations. Each radiologist can determine the types of studies (according to modality or anatomic area or a combination of these) to be displayed on his or her work list. This capability eliminates the need to type in or barcode patient information from a piece of paper. The study is then dictated into a digital dictation system and is then transcribed directly into the hospital electronic medical record. The department has begun to use voice recognition, which will eliminate additional overall work flow steps but at the cost of additional steps for the radiologists. (Siegel and Reiner 2003: 165).

The new functionalities of automatic information retrieval, exchange and assignment radically transform the organisation of work that was previously in place at the medical centre. They change the roles and tasks of administrative and clinical staff and even eliminate the need for certain roles, by stripping down the diagnostic process to the interactions between healthcare experts (such as referring doctors, radiologists, and radiographers (technicians)) while all other functions and tasks are automated and performed by the digital systems. Two workflow diagrams from Siegel and Reiner's (2003) article (see Figure 1 and Figure 2) starkly illustrate the significant difference in the workflow before the introduction of digital modalities and after it.

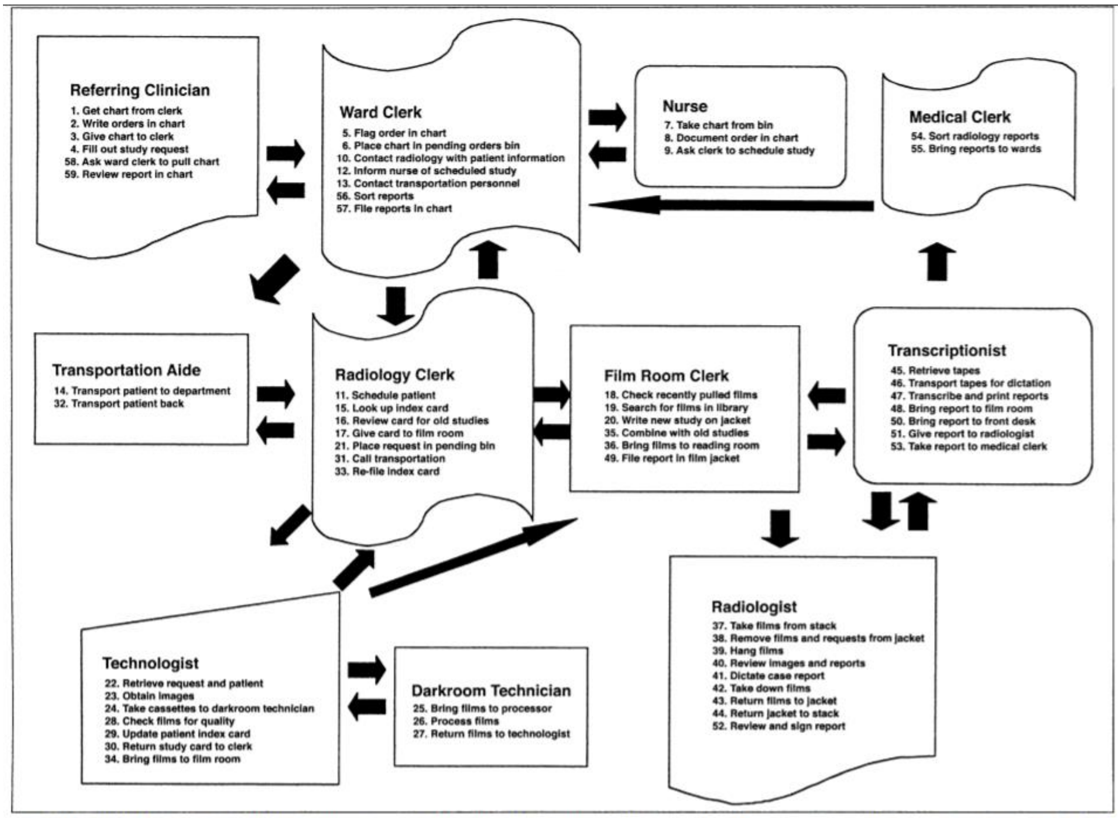

Fig 1. Flow chart for ordering, acquisition, reporting, and review of inpatient chest radiograph using conventional film-based radiography system shows 59 steps involving 11 hospital staff members.

Figure 1 Flow chart describing the workflow before the introduction of digital systems. Reprinted from Siegel and Reiner (2003): 166.

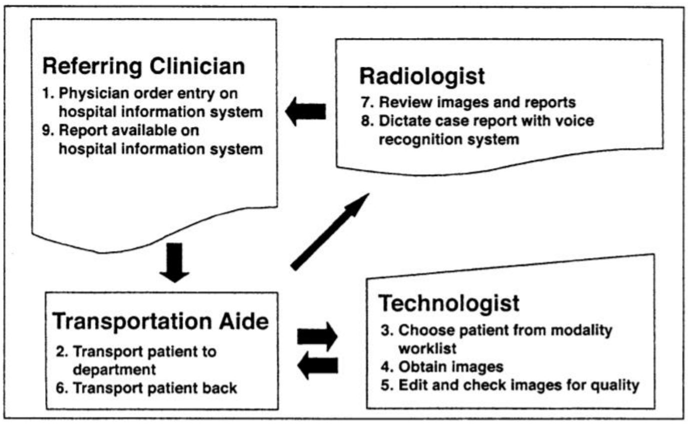

Fig 2. Redesigned flow chart for ordering, acquisition, reporting, and review of inpatient chest radiograph using picture archiving and communication system (PACS) shows 50 fewer steps by seven fewer staff members when compared with conventional film-based radiography system.

Figure 2 Flow chart describing the workflow after the introduction of digital systems. Reprinted from Siegel and Reiner (2003): 167.

The second optimised digital workflow does not only represent the reorganisation of the labour process in the clinical centre. It also points to one of the core fantasies of digitalisation and automation, that is to say, tedious tasks are taken over by machines, as lags caused by human workers walking from room to room and carrying the healthcare records and images become replaced with the almost instantaneous transfer of files over digital networks. As I will show in this chapter, the reality of automation can be very different from the ideal of a streamlined workflow that Siegel and Reiner visualise, and part of the difficulty in achieving the austere and simple diagram of automated workflows in the everyday work of teleradiology companies is the complexity of labour involved in teleradiology outsourcing. One important part of this complexity, as mentioned in Chapter 1, is the stratification and hierarchisation of expert labour through the mechanisms of professional licensing and credentials. The hierarchisation of medical credentials leads to duplication of the workflow in the case of Worldwide Teleradiology, where Indian-certified radiologists perform the first reading of USA images and the US-certified radiologists (ABRs) perform the second reading that is signed and sent to the hospital. But beyond this specific characteristic of teleradiology labour, examining the workflow at Worldwide Teleradiology and revisiting the history of workflow organisation shows how complexity and the inability to fully contain labour within schemata of optimised processes is an inherent feature of the workflow. This is pointed out by consideration of two aspects of the development of workflow management and automation. Firstly, in the history of labour management and especially in healthcare work organisation, there is a strong affinity to thinking about labour control through the possibility of organising and channelling elements and media. This affinity which emerges out of thinking labour through energy (Daggett 2019), air (Nightingale 1863), paper (Timmermans and Berg 2003), and data (in the case of digital radiology), shows how the easy convergence between data management and labour management develops, but it also reveals the limitations of this convergence. Secondly, looking at both the history of workflow management through the experiments of Frank and Lillian Gilbreth (1914, 1919, 2007), and at its present practices at Worldwide Teleradiology, I demonstrate the inability to completely contain the labour process within this vision of optimisation and intensification, and the tendencies for spillovers, waste, and excesses.

In the following section, 'Affective economies of the workflow', I describe the organisation of the outsourcing of teleradiology workflow at one of the companies from my fieldwork, Worldwide Teleradiology. I interpret the tightly integrated combination of digital systems and fine-grained division of labour in the company as building on a history of labour management that assigns different categories of productivity and efficiency to tasks and movements and offloads the less productive ones to lower-paid workers. Following this analysis, in 'Workflow, automation, visualisation' I offer a historical examination of the practice of workflow management from the days of early scientific management to the development of digital Workflow Management Systems. I demonstrate the continuities in standardisation, quantification, and visualisation as core techniques for managing both labour and data flows. In the section 'Energy, waste, and metabolism as principles of workflow management', the method of organisation of labour through collaborative labour is traced back to the early 20th century work of Frank and Lillian Gilbreth, whose experiments and publications combine affective and ergonomic concerns in the organisation and optimisation of human work performance.

Affective economies of the workflow

In the early weeks of 2017, I visited the office of Worldwide Teleradiology in Bangalore as part of my fieldwork. Worldwide Teleradiology is one of the first Indian companies offering teleradiology services to the USA and founded by two US-trained and certified radiologists. The two founders have had significant role in developing the industry of teleradiology outsourcing while also being engaged in local healthcare initiatives in India, thus leveraging the social, cultural, and financial capital they have acquired through their mobility. The company has also managed to attract other Indian radiologists with USA qualifications who, although living abroad, retain strong links with their families, Indian communities, and Indian politics, a phenomenon discussed in length by Thomas Birtchnell (2013).

On that day, I was lucky to catch a rare moment in the work process – one of the American Board of Radiologists certified doctors (ABRs) was in the city. Usually they only have an online presence in the room, appearing on the real-time stats dashboard, in chats with transcriptionists and the workflow management team, and on the phone with the call centre team. The ABRs are spread across the world; one in Israel, a couple in Europe, a few in the USA and a few in different Indian cities. But on that day Lakshmi, who lives in and usually works from Chicago, was in the office. She had come to stay with her ageing parents for a couple of months; it is a moral imperative in Indian culture to return the care work provided by the parents which drives many migrants to return home or to come up with arrangements to support their mothers and fathers. Lakshmi had fulfilled her parental duties; her son and daughter back in the USA were now adults and each had gone their separate ways. So she could re-channel her familial obligations and divide her time between her parents in India and her adult children and husband in the USA. Lakshmi is a calm and gentle woman in her late 50s, dressed in an expensive kurta, with perfectly coiffed hair and a pretty, smooth face. She left home as a young girl in the 1990s to study in America and had since worked as a radiologist in USA public hospitals. Five years ago, she retired from her job that was tiring her with bureaucracy and too much administrative paperwork and signed a contract with Worldwide Teleradiology. This had allowed her to have a different lifestyle that better suited her needs. She did not have the two-hour each way commute to the hospital day anymore. Instead, she usually worked from home and had more time for her family and herself.

Lakshmi's time is extremely valuable. Her ABR certification ensures ongoing contracts with USA hospitals for Worldwide Teleradiology. I am told by the HR team that she and the other ABRs are "the most valuable assets of the company". Spread around the world, the ABRs are connected to the teams on site through PACS and RIS. The company's own brand PACS is used to store and transfer the images that they have to diagnose. It is a cloud-based system, so employees in Bangalore and around the world can access the same images at the same time and input reports in the system. Lakshmi's cases are assigned to her through the workflow option of these systems and are then double-checked by the workflow management team whose job is to make sure that the workload is appropriately distributed and that each of the ABRs gets the cases that they usually prefer reading. On a regular day Lakshmi would be sitting in her house in Chicago with her computer with two special radiology monitors that has a DICOM viewer software and a virtual machine installed on it. The virtual machine allows the radiologists to use two systems simultaneously. It simulates a second computer with a separate processor and memory. Some ABRs are actually using two computers. This arrangement of hardware and software components is part of a specific economy of time and productivity that has been developed at Worldwide Teleradiology with the ABRs at the centre.

The virtual machine saves Lakshmi and the company precious seconds. Every time she opens a new study to read on the computer, it takes up to 10 seconds for each image from the study to load; this is 10 seconds too many to waste from the valuable time of ABRs. Each ABR reads between 75 and 200 cases per day, which leaves 6 minutes or less per study. Suraj, the workflow management team leader, tells me that: "We want to make sure that ABRs are 100% reading at all times." Everything else is a waste. This is why there is a special job at the company for "the loaders" who are dedicated to opening studies and loading the images. The loader would be sitting in the office in Bangalore while Lakshmi is at her house in Chicago. She or he will log into Lakshimi's system with her credentials; while Lakshimi is reading on one of the systems, the loader would use the virtual machine to load up to 10 new studies for her. When Lakshimi has finished with the cases she is reading, she will switch to the virtual machine and start reading the ones that the loader has prepared for her. In the meantime, the loader would switch to her other system and start to load new images there. It works like a well-oiled machine; smooth, quick, and efficient.

But on the day I visit, the machine was put on pause. As I walked to her desk and sat next to her, Lakshmi was intently staring at the screen, switching between open windows. She was reading a case and discussing it with a colleague, another ABR working with Worldwide Teleradiology sitting in Israel. He was arguing that her report had missed some details and was sending her images via the company chat to support his point. The company has different mechanisms for auditing the reports and one of them involves peer-reviewing reports of other colleagues. Both Lakshmi and her colleague in Israel were sending one another very short messages, his asking about findings that were missed and hers reaffirming her findings. He sent a series of question marks in reply. I felt the tension rising. While she was chatting with him, she frantically opened images from the study, zooming in, then opened another image while looking at the ones he sent over the chat and also reading about the finding he suggested on medical websites and in scholarly articles. She turned to me and said with a sweet and calm smile: “It’s a baby, we don’t get them very often, so it’s difficult, we are not used to them.” She then went back to the terse chat and her feverish research online.

While she was doing this, her loader, Venu, and the transcriptionist, Shiva, sat idle. Venu had found a sales deal for a new Huawei smartphone on Flipkart, which is an online shop founded in Bangalore by two former Amazon employees; Venu was dreamily reading about its technical specifications. Shiva stood up and walked around in the room. The two red sofas that were brought in the previous week (to the amusement of the whole office) had disappeared and the possibility of stretching down on them to relax had therefore vanished too. Nonetheless, having a bit of a walk is an opportunity that should not be missed. Sitting in front of the screens in the dim room for six to eight hours per day is straining in so many ways; in particular, it drains out bodily energy and strains the eyes. Lakshmi told me that sometimes by the end of the day her eyeballs hurt. Service staff from the company cafeteria come every couple of hours and bring coffee to the employees in the office; it is coffee with so much milk and sugar, that it has the effect upon the mind and body of a hot cup of milk before bed.

The moment Lakshmi finished discussing the contested report with her colleague, Venu and Shiva were ready to promptly return to their tasks. They sat at either side of her and adjusted themselves to her rhythm. Venu loaded the images. Shiva waited for Lakshmi to start dictating the new report and then attentively sat next to her typing as she spoke seemingly to her herself, in a manner as if voicing her thoughts and doubts while looking at the study. This was all that Shiva needed; he had lengthy experience as a transcriptionist and sufficient knowledge of medical terminology, and he has mastered the genre of the radiological report. By the end of what sounds like tentative thoughts voiced by Lakshmi, she turned to him and asked him what he wrote, then corrected a few points and the report was uploaded on the company PACS and sent to the hospital. All three of them got up and performed a curious choreography, swapping their seats. Lakshmi went to Venu’s computer where the new studies he had loaded were waiting for her, the first one already opened by Venu so that she did not have to waste time. Shiva moved next to her and opened a new document for typing a report, and Venu moved to where Shiva was sitting just a second ago. This little choreographed dance took place every hour or so. At certain times one of them moved to the standing desk located in the row of cubicles, which was introduced in the company as a way to reduce the harms of sedentary work. And at all times, at the centre of this choreography is Lakshmi, like Royalty at the centre of an elaborate court ceremony. I laughed, telling her she is absolutely pampered by the guys. She beamed back and said: "Yes, they really are doing anything to make it easier for me."

Lakshmi's candid and light-hearted admission shows subtle awareness of the hierarchies and dependencies between workers embedded in the teleradiology workflow at the company. These hierarchies are built around the imperatives of increased productivity and efficiency of the labour of teleradiology diagnosis, as the example of Lakshmi, Venu, and Shiva shows. What this also shows is that these notions of productivity and efficiency function not only at the level of the individual worker and the management of their performance; these notions are also distributed throughout the organisation, linking different types of labour in a relationship of dependency and mutual regulation as part of the efforts to increase labour productivity. The remark that the company is striving for a 100% productive use of the working time of ABRs made by Suraj, the workflow management team leader, and often expressed by the HR team, reveals a rift within the organisation of labour throughout the company that emerges from distinguishing between different types of activities: productive and not productive, valuable and less valuable. Everyone in the company has internalised this distinction and acts upon it. Through this pressure for productivity on the ABRs, the capitalist imperative for profit making is combined with the specific logic of labour intensification in the profession, which is laid down through the conditions of professional membership and the Continuing Professional Development programmes that are instituted by radiology colleges (discussed here in Chapter 1).

In Marxist scholarship, the distinction between productive and non-productive labour is based on the value produced directly for capital. That is to say, manual labour producing commodities as well as service labour employed in a capitalist enterprise are productive, whereas domestic labour, state employees, and workers whose labour does not directly contribute to the accumulation of capital are unproductive (see Gough 1972; Huws 2019; Marx 1969, 1976). In this sense all of the employees at Worldwide Teleradiology are productive labour. However, the organisation of the workflow imposes specific dependencies between the employees in different roles that destabilise the category of productive labour as homogeneous and constructed solely in relation to capital accumulation. The hierarchies within Worldwide Teleradiology revolve around the question of what constitutes productive labour which is reflected in the way different types of tasks are organised along a scale of productivity and value for the company. Within this understanding of productivity, the diagnosis of the ABRs is more valuable and productive than the time spent on opening pages or typing the report and the organisation of the workflow aims to distribute these tasks among the other workers. It is also seen as more productive and value-generating than the work of Indian-certified radiologists, which is not central to the business model of teleradiology outsourcing from USA hospitals to India (see Yu and Levy 2007). While within the Marxist understanding of the binary between productive and non-productive work all of these activities are productive for capitalism, there is nonetheless a difference between them, both in the way they are regarded in the context of the company and in the relations between workers that they sustain.

How can these differences and the relationship between workers be defined? In the case of Lakshmi, Venu, and Shiva, the distribution of tasks offloads the actions that do not require professional radiology qualification to workers who can perform them for less remuneration. While this example of division of labour is driven by an economic rationale, the dependencies generated between the workers are complex and show that the notions of productivity and labour management are subject to negotiations that have developed historically. As I will discuss further in this chapter, these developments underpin the understanding of how value is produced for capital by subsuming the vital economies of energy, flow and affect, and by attempting to organise and control their direction and intensity. One aspect of this negotiation evident in the arrangement of the workflow at Worldwide Teleradiology, is the dynamics between different types of labour in sustaining the productivity of ABRs. The roles of the transcriptionist and the loader do not merely assume some of the work tasks that Lakshmi should be performing in return for a lower wage. Rather, they also function as a crucial part of the process of workflow optimisation and automation because they are strategically deployed at points of lag and friction in order to smoothen the process. Venu, who loads the images for Lakshmi, essentially duplicates the already automated process of image retrieval through the PACS. His task of opening the images so they load while Lakshmi is diagnosing the previous ones is meant to save time, but in the process he also has to adjust to her rhythm of work and make sure that (having prepared her screen) he is ready to switch places whenever she is. Shiva, whose job is to type Lakshmi's report, is similarly a figure whose role duplicates an already automated process. There are already advanced technologies for automated reporting widely used in teleradiology such as Dragon, which is an automated voice recognition software used for medical transcription, as well as the use of structured report templates that radiologists can use to save time. However, Shiva's role saves additional effort and smooths potential disruptions in the process. He is better at understanding non-native English accents (especially the Indian accent of Lakshmi) than Dragon, which is heavily biased towards native English accents and does not accurately transcribe non-native speech. Secondly he also saves Lakshmi the time and effort of choosing the right format. In fact, as I captured earlier in this chapter, he almost intuitively picks up the details of her diagnosis as she is thinking aloud while looking at the images. He phrases her thoughts in the shape of a medical report and formats it for her.

As Lilly Irani (2015a, 2015b) demonstrates in her research on microwork in Amazon Mechanical Turk, the reasons why human workers substitute for automated tasks or augment automated processes can be economic. Automating certain tasks, such as labelling emotions, can be more expensive than delegating them to low-paid workers. However, I will develop the argument that there is another economic rationale to the duplication of tasks and the hierarchical organisation of the teleradiology workflow; this is a rationale grounded in a specific economy of affect, that arises in the process of labour optimisation and automation. Sarah Ahmed (2004) uses the concept of affective economies to discuss how affects and emotions (she does not distinguish between the two) accumulate in social settings and acquire social force and value through the process of their circulation. While Ahmed thinks of affective economies through an analogy with the accumulation of capital, what I describe in this chapter constitutes a different type of affective economy; this is to say, a metabolising economy of affect where affects circulate and are absorbed as by-products of processes of labour intensification. As I will discuss further in this chapter, this metabolising economy of affect can be traced back to the early days of scientific management and to various scientific and economic theories that conceptualise labour power through physical and biological analogies. Early scientific management sees the optimisation of labour as a way to efficiently channel the energy of the worker and their labour power into the task they perform (Daggett 2019; Foster and Burkett 2008). This idea of reining in the energy of the worker and channelling it into productive activities, or eliminating movements that are unnecessary for the work process and activities that are deemed non-productive, dominates the early 20th century writings of Frederick Taylor and Frank and Lillian Gilbreth (1914, 1919, 2007) and it has informed much of the practice of labour management ever since. The organisation of teleradiology workflow at Worldwide Teleradiology is similarly founded on the distinction between productive and non-productive activities and the desire to maximise the productivity of radiologists by reducing the time that they spend on non-productive tasks. This process of reorganisation of labour, which Karl Marx calls "real subsumption", reduces the subjectivity of the worker and their affect (in the sense of potential to act (Massumi 2002)) to what is valuable for capital. As the example from Worldwide Teleradiology reveals however, this reduction is always incomplete. The tasks that are considered less valuable do not disappear but are instead distributed to other workers. At the same time, the intensity of the labour process for radiologists inevitably leads to the accumulation of negative affects that need to be offloaded to the other workers in the company. This dynamic of "affective metabolism" is evident in the way all employees of Worldwide Teleradiology are concerned with keeping the US-certified radiologists, who have to be the most productive, calm and satisfied.

Shiloh Whitney (2018) suggests that all affective labour can be seen through the notion of metabolism, or the absorption of what she names "affective byproducts". Here, Whitney is referring to affective surpluses that are neither productive or reproductive and cannot be absorbed in the economy of capitalisation of labour. While Whitney discusses this notion of metabolism in relation to affective labour, I show that there is an aspect of a metabolising economy of affect in teleradiology labour. I also show that the early scientific management studies of Frank and Lillian Gilbreth suggest a strong link between labour optimisation and the metabolising of undesired affective surpluses not just in the sense of emotional affects but also in the sense of distributing energy waste and depletion.

Another example from the organisation of the workflow in Worldwide Teleradiology that makes this interdependence between labour optimisation, automation, and the metabolising of affects even more evident, is the organisation of the workflow management team. This team of six people sits behind a glass door, right next to the spacious office where the radiologists and transcriptionists are working. As I described in the previous section, all of the digital infrastructures used in teleradiology include workflow and worklist functionalities that are used to automate the transfer of images, patient records, and the assignment of cases to radiologists. In Worldwide Teleradiology, which works with multiple hospitals in several countries, the arriving cases are automatically assigned to radiologists based on their credentials through the local PACS and each case has a deadline for completion depending on what kind of study it is and where it comes from. These automated assignments are pre-programmed in the system and radiologists only see the cases sent to them. They can also see when a case has arrived and how long they have until it has to be sent back to the hospital. There is a three-colour coding scheme that shows new cases as green, older cases as yellow, and ones beyond the deadline as red. Some of the reports are configured for a 30-minute turnover, while others are configured for a 24-hour turnover.

The task of the workflow management team is to monitor the incoming cases and the progress on reporting them. Most of the people in the room are assigners whose role is to check how cases are assigned and re-assign them if needed. Another part of the team checks if everything is included in the order, prepares the order for the hospitals, searches for patient history and previous studies, ensures that the patient records are complete and ensures that the radiologists have everything they need for diagnosing before they even take a case. The rest of the team are coordinators who also assign cases but must additionally constantly watch how many cases are currently in the system, how many cases are assigned to each ABR, and swap cases between ABRs if needed. Suraj, the head coordinator of the team, tells me that "[w]e have to make sure that the ABRs are always 100% reading", essentially emphasising that ABRs must not be wasting their time loading or writing reports or searching for patient history and previous studies. The whole system is geared towards the productivity of the ABRs, whose signature on the cases is crucial for the contracts and profits of the company. Suraj explains: "They are our main revenue generator; we have to keep them happy." This imperative spreads across the different departments and roles in Worldwide Teleradiology: the workers at the Human Resources department must always word their feedback on work improvements for ABRs in a way that will not anger them and make them feel criticised; the loaders and transcriptionists have to silently and non-intrusively support the ABRs' readings and adjust their work and almost intuitively anticipate the ABRs' needs; the workflow team management workers must readjust the automatic assignment of cases according to the individual ABR's preferences, which they figure out with time. These specific affective relations and dependencies grow on the basis of the highly automated and structured teleradiology workflow, that is coordinated through the interconnected digital systems used for transferring the images and managing the sequences of tasks to be performed as part of the diagnostic process. Thus in summary, maintaining the productivity of the ABRs involves affective adjustments and compensatory mechanisms to be carried out by the rest of the staff at the company.

This labour of keeping ABRs happy becomes entangled with the technologies for labour management and intensification. The hyper-intensity of work at Worldwide Teleradiology (much higher than in other companies) yields a count of between 75 and 200 cases per ABR per day. All the time while Suraj monitored the real-time dashboard and checked that all cases are assigned and not critically late he kept a number of open chats, each with a separate radiologist. These chats popped up every now and then as he constantly chatted with the ABRs, discussing their speed of reporting, outstanding cases, breaks from work, and individual cases. While he was telling me about his job, one of the chats lit up and Jonathan, the ABR sat in Israel, wrote complaining that his cases have got "too much body". This is a professional jargon for images of the torso, which radiologists find too complex and tiring to read because there are too many organs to look at. They take longer to diagnose, bringing down the count of read images and therefore the pay. There is a hierarchy of value attached to different images; head Computer Tomography (CT) and Magnetic Resonance images (MRI) pay the most both because they are faster to read, and referrals for these modalities are reimbursed at a higher price. X-rays pay the least; these are also the only images that the company receives from the Indian hospitals it works with and are therefore read by retired Indian radiologists or even the teleradiographers (technicians) trained at the company. Suraj responds promptly by reassigning Jonathan's cases for a pre-read by an Indian radiologist in order that Jonathan can do a quicker second read. Immediately after Suraj's intervention, the chat lit up again. Jonathan does not like having his cases pre-read and he is not happy. Suraj is exasperated, but eager to please.

As Suraj tells me about his work, I grew more and more aware of how a big part of his job it is to appease the ABRs. He knew each one not just by name, but through an intimate knowledge of their everyday routine and character. He knew if they'd had a baby recently and needed breaks to breastfeed, or if a plumber was coming to their house during working hours and they needed to attend to it. Suraj pointed to a name on the dashboard and explained that this radiologist needed a ten-minute break every 2.5 hours. Another ABR had asked to have his work hours reduced to six hours per day, saying that he was more productive when working shorter hours; this was true, he was reading 75 cases sharp no matter whether he worked six or eight hours. When Suraj remarked that one of the new ABRs made too many mistakes, with every case having some error, he looked at the clock showing the three USA time zones they work with, saying that the radiologist must be very tired because it was 5am where the ABR is, and it was really hard to work at that hour.

While we were talking, Suraj compulsively refreshed the workflow dashboard, discussing with his colleagues directly and also via chat who gets which case, while checking between systems. The cases lit up in green, yellow, and red indicating the time that had passed since they were received. All of the cases received in the company are controlled through this dashboard. Amid the constant updating of the screen to track any changes in the status of individual reports, Suraj kept telling me about the ABRs. He told me how they laugh and make fun of him when he misspells a medical term. Suraj does not have medical qualifications, he had worked administrative office jobs before. But he has been at Worldwide Teleradiology for eight years now and said it felt like a family. He gets messages from the boss on his personal phone via Whatsapp all the time, weekday and weekend, day and night, depending on where his boss is in the world. Suraj has to navigate and cushion the demands of the company for faster diagnoses via chat with the ABRs. He said with an emotional voice that they are much nicer in person and that it is sometimes really hard to talk to them online because they can be sharp, and they write things that hurt him. Two years after starting work with Worldwide Teleradiology, he had a breakdown and had to quit. The emotional toll and the stress of his work proved too much, and he spent three months at home with his mother, in bed and unable to work. Then the company called to ask him to come back and he returned.

The history of dependencies between affect and the intensification and automation of medical labour goes beyond Worldwide Teleradiology. It touches on the ways in which the notion of professionalism in healthcare generally is construed through a hierarchy of affective involvement. In his work on professionalism Talcott Parsons (1991) introduces the idea of "affective neutrality" as being essential to the proper conduct and disposition of the medical professional. This understanding of professionalism leaves a significant mark on the development of healthcare; it leads to a phenomenon in medical practice that conditions doctors to manage their affective responses in accordance with the notion of professional work efficiency, which in recent years has been an object of intense criticism (Crowe and Brugha 2018).

Through the notion of affective neutrality, a specific understanding of work efficiency can be charted that juxtaposes expertise and knowledge to affect and being affected.

This understanding of efficiency and professionalism in the medical sphere has implications for the way teleradiology labour is organised and plays a role in justifying teleradiology practice in contrast to in-house radiology placements. As Giacomo, the Italian radiologist heading the Sydney office of the Swedish teleradiology company Omniscan Teleradiology puts it, work as a teleradiologist spares you from the depressing environment of the hospital. You don't have to see sick people and people in pain, you don't hear their cries and wails. You only read the images and send back a diagnosis. This affective distance from the patients gives a spatial dimension to Parsons' notion of affective neutrality that is enabled through the development of systems for the transfer and archiving of digital imaging. The idea that a radiologist can work better undisturbed and away from the site of affective disturbances of the hospital in particular, is linked to the way that the notion of affective neutrality develops as a core principle in both the management of labour and the management of the self among doctors and medical students (Crowe and Brugha 2018; Dornan et al. 2015; Smith III and Kleinman 1989). These principles involve the careful management of affect by doctors in such a way that nurtures the objectivity of discretion and suppresses what can be seen as an excessive emotional involvement in the suffering of the patients. These principles also impact on the embeddedness of specific hierarchies of labour in healthcare; these are hierarchies that draw justification from the notion of professionalism as devoid of affective involvement, and which set gendered lines between the objective professionalism of medical doctors and the care work provided by nurses and other healthcare staff.

The entanglement of workflow management and affect that characterises the work of Suraj so profoundly, seeps into every other conversation at the company. Keeping ABRs productive equates to keeping them happy; this draws together an unexpected dependency between the digital systems for labour management and the management of data flows and the circulation, regulation, and distribution of affect within the workflow chain. In this dependency, the imperative to keep ABRs happy is not an abstract idea of wellbeing, but rather part of a historically developed understanding of what productivity is, how it increases and what makes labour less productive. Part of this development is visible in technologies of measuring productivity, such as the real-time dashboard and KPIs. Some of the other aspects of this underlying theory of productivity are less explicit however, and point to role of energy, flows, affect, and the medium for conceptualising and managing labour power and productivity. I next turn to this underlying theory of labour productivity in tracing the history of workflow management that has influenced the organisation of teleradiology labour, as it now exists in companies like Worldwide Teleradiology.

Workflow, automation, visualisation

The notion of workflow and workflow management constitutes an important part of all the digital data standards and the functionalities of digital systems used in teleradiology. This notion is used to describe and to control the sequence of events and actions that form the diagnostic process from the admission of a patient, the scheduling of a radiology exam, the processing of the image, sending it for diagnosis, to the return of the ready report. The practice of teleradiology is organised around the ordering and management of these clinical and administrative acts. Workflow management encompasses the sequence of tasks performed in the course of a predetermined series of events and it involves the coordination of actions by doctors and other healthcare staff, the transfer of information, and the interoperability of digital systems. In many ways, the management of teleradiology and teleradiology labour *is* the management of workflows. This is why all of the standards and systems that I am analysing here include references to workflow organisation and management; the standard for DICOM, PACS, and the standards developed by HL7 all operate by standardising, harmonising, and automating clinical and administrative workflows in teleradiology.

These techniques of standardising, harmonising, and automating are intertwined with a particular tradition in workplace organisation most often related to Frederick Taylor's (1911) attempts to reorganise the labour process that initiated a long tradition in labour management and automation. Taylor, with his famous theory and practice of scientific management, makes an important contribution to the standardisation and regulation of labour in the industrial age; a contribution that entered the popular imagination with the vision of dehumanised and tediously monotonous work, profoundly explicated in Charlie Chaplin's film *Modern Times*. The particular organisation of the workflow at Worldwide Teleradiology, as an example of the teleradiology workflow in general, shows a more complex and ambiguous picture of labour automation. Here intensification does not only translate to monotonous menial tasks but also shows also a high degree of interdependence between the workers and a higher degree of cognitive and affective labour involved in the management and performance of their work.

In the work of Frederick Taylor the optimisation and intensification of the work process is already embedded within a series of concerns, whereby mechanisation acquires complex political implications. In the foreword to his seminal study on labour management, Taylor shares a vision and concern with productivity that places a lot more importance on it than the mere increase in profit for the sake of capital; he links the increased productivity of the workers to the concept of prosperity, which has national and geopolitical significance. In essence, more productive workers lead to a more prosperous nation with industries that can compete with the foreign ones in the global market (ibid. 5-8). At the same time this wider geopolitical focus on the intensification of labour translates to a very intimate focus on the individual bodies and minds of the workers. On one hand this focus involves the scientific quantification of time, energy, and motions - an approach synonymous with scientific management. On the other hand, however, the studies of Frederick Taylor (1911) and Frank and Lilian Gilbreth (1914, 1919, 2007) (which I analyse in more detail shortly) pose questions that transcend quantification and are concerned with less tangible aspects of the work process such as energy, waste, collaboration, and hierarchy. The continuing importance of these less tangible aspects of labour automation and labour management, can be seen in the example of the workflow organisation at Worldwide Teleradiology where close cooperation between workers together with the economy of time, energy, and affect, have all become essential for navigating an increasingly intense workload.

As a type of organisation of labour the workflow combines two central features; firstly a highly visual abstraction of the labour process and secondly a heightened focus on the sequence of actions and the relations between participants that are enacted through it. The workflow on its own has not been analysed as a specific form of labour management and automation, setting aside research in business management and software engineering that recommends or develops workflow management solutions. The workflow is important for understanding automation in industrial context as a logic of organisation of the work process however, and it also has important use an alternative and highly visual mode of algorithmic automation and management.

The workflow chart has been integrated into visual programming languages and standards (for example those standardised by the Object Management Group (OMG) and Unified Modelling Language (UML)). OMG standardised the workflow and business process notation in the mid-1990s. It lies behind initiatives for the standardisation and mapping of these notation languages into executable languages used for software programming in industries. This versatility of the workflow chart as an abstraction and executable model makes it important for understanding the ways in which control and automation are enacted in teleradiology. It also points to the ways in which the organisation of tasks in the workplace is linked to the algorithmisation of the labour process.

The history of the workflow diagram, as a method of organisation of labour processes, can be dated back to the time of Frederick Taylor. At this time another researcher in scientific management, Frank Gilbreth, took a slightly different approach. Working in partnership with his wife Lilian, who later put their studies in use in developing a method for scientific management in the household, Frank Gilbreth was inspired by Taylor. Instead of the utilising time studies that Frederick Taylor adopted to time how long it takes a worker to perform a task however, the Gilbreths used motion and micromotion studies.

This method of micromotion studies made use of the new media of cinema and film and captured the movement of workers on camera to analyse their efficiency. Seated in front of a black board with white chequered lines forming a grid behind their back, with a stopwatch in the background, workers would perform their tasks and be filmed. This new technology of motion capture was advertised by the Gilbreth family as a novel and more scientific way to analyse and improve the efficiency of labour and they proclaimed it to be superior to the time studies performed by Taylor (Price 1989). In some of their later studies, the Gilbreths attached diodes to the fingertips and hands of workers so that they could also trace the trajectories of movements.

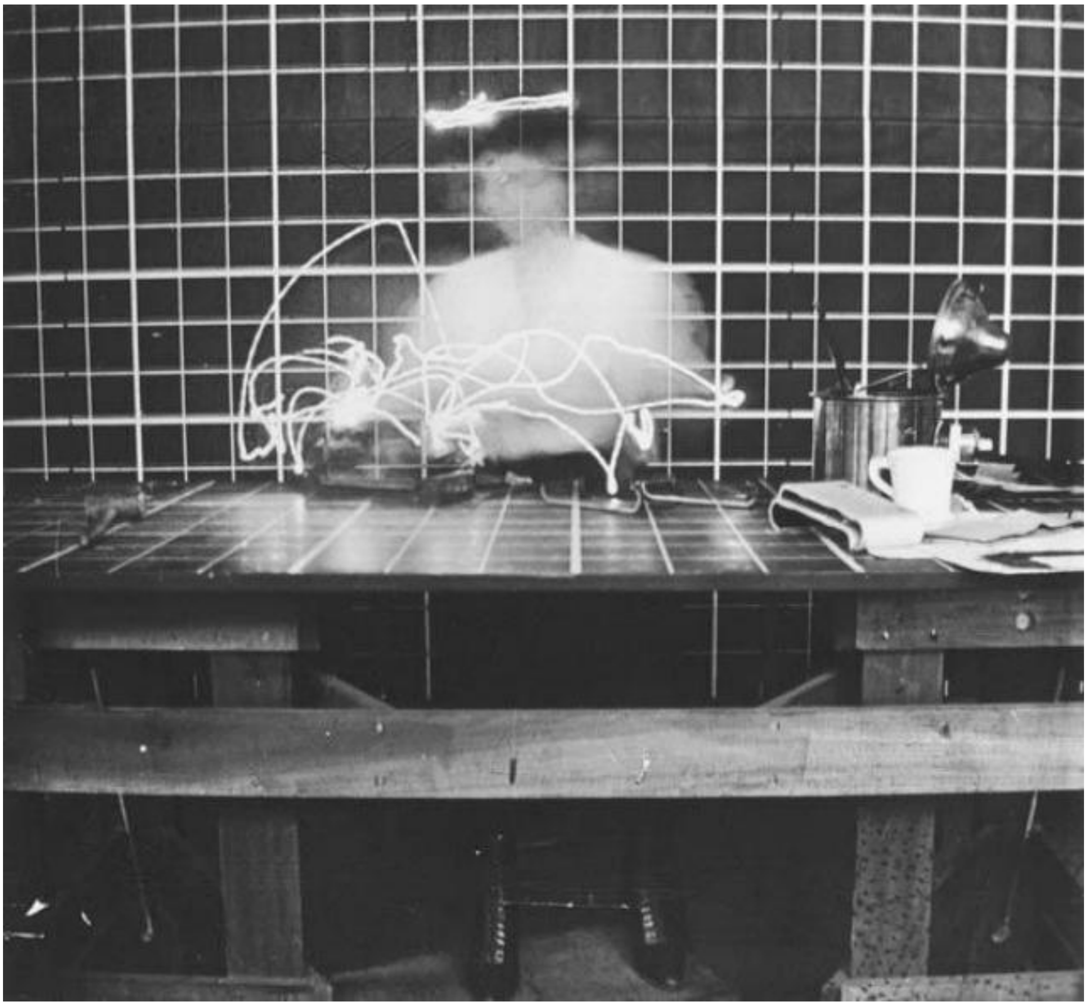

Figure 3 Micromotion study of a female typist. Screen capture from the original movies of Frank and Lillian Gilbreth (2007).

This new use of cinematic technology and the increased interest in capturing the movements of the working body combined earlier experimentations in photographic capture of movements where science and aesthetics intertwined (such as in the work of Eadweard Muybridge), with a new desire to record, analyse, and control the movement that emerges in the works of scientific management. Films recorded by Frank and Lilian Gilbreth were used not just as a tool to capture the movement of working bodies, but also as a teaching tool to help workers improve the efficiency of their movements by observing, mimicking, and correcting their gestures (Mees 2013, Price 1989). Thus, these films served as a visual algorithm of sorts, that provided a diagram and a model for performing work tasks. They not only have the documentary purpose of recording, but they show the role of technological images in organising the materiality of movement and production. This materiality receives a notably literal interpretation in Frank Gilbreth's work, which later included making three-dimensional models that replicate the trajectories of movement of the workers' body which are made visible by the attached diodes. These visualised 3D modelled trajectories were set against a 3D grid that helped to quantify them. It is not an overstatement to say that Gilbreth was probably the first person to create 3D visualisation models from the data of his studies. The visualisation techniques he used were essential in analysing the mechanics of work and optimising them; this is a feature that, as I will soon show, becomes even more prominent through the introduction of digital workflow management solutions.

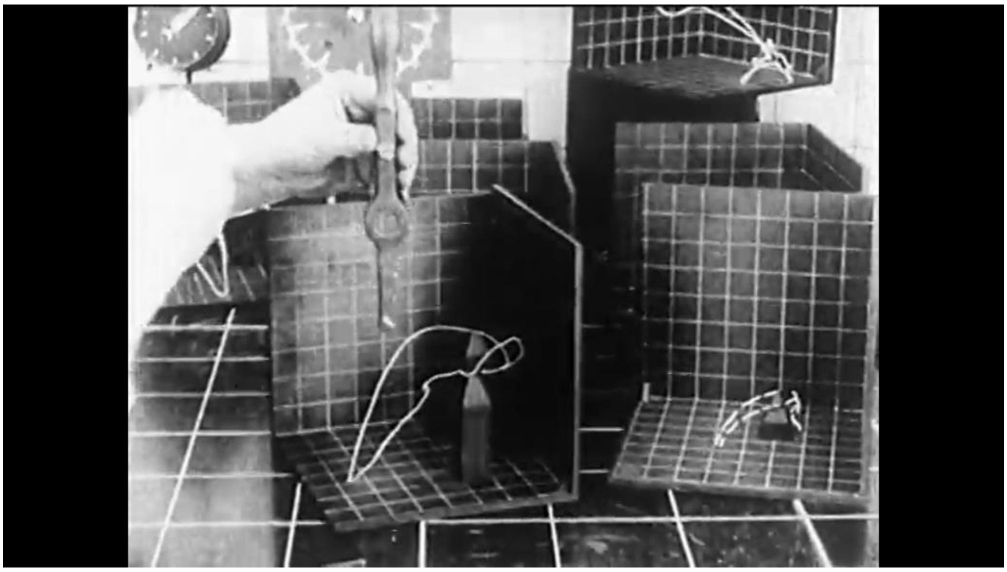

Figure 4 3D models of work motion trajectories. Screen capture from the original movies of Frank and Lillian Gilbreth (2007).

The Gilbreths did not only film workers as a way to train their movements and organise the workflow. Another important innovation that Frank Gilbreth introduced is the process chart. This is a detailed visual diagram of how a work task has to be performed and the actions it involves. They developed a special notation system for this purpose called "therbligs" (an anagram of their family name). These process charts are the predecessors of contemporary workflow diagrams widely used in business planning and robotic process automation. In the diagram below, a process chart for loading rifle grenades from Frank Gilbreth's works prescribes the steps that have to be taken in the process of assembling, checking, and packing rifle grenades in a factory, with different types of operations marked with different symbols. Here, the visualisation of the labour process is more abstract than in the film materials and the body of the worker does not feature that prominently; instead the focus is placed purely on the processuality and sequence of the workflow.

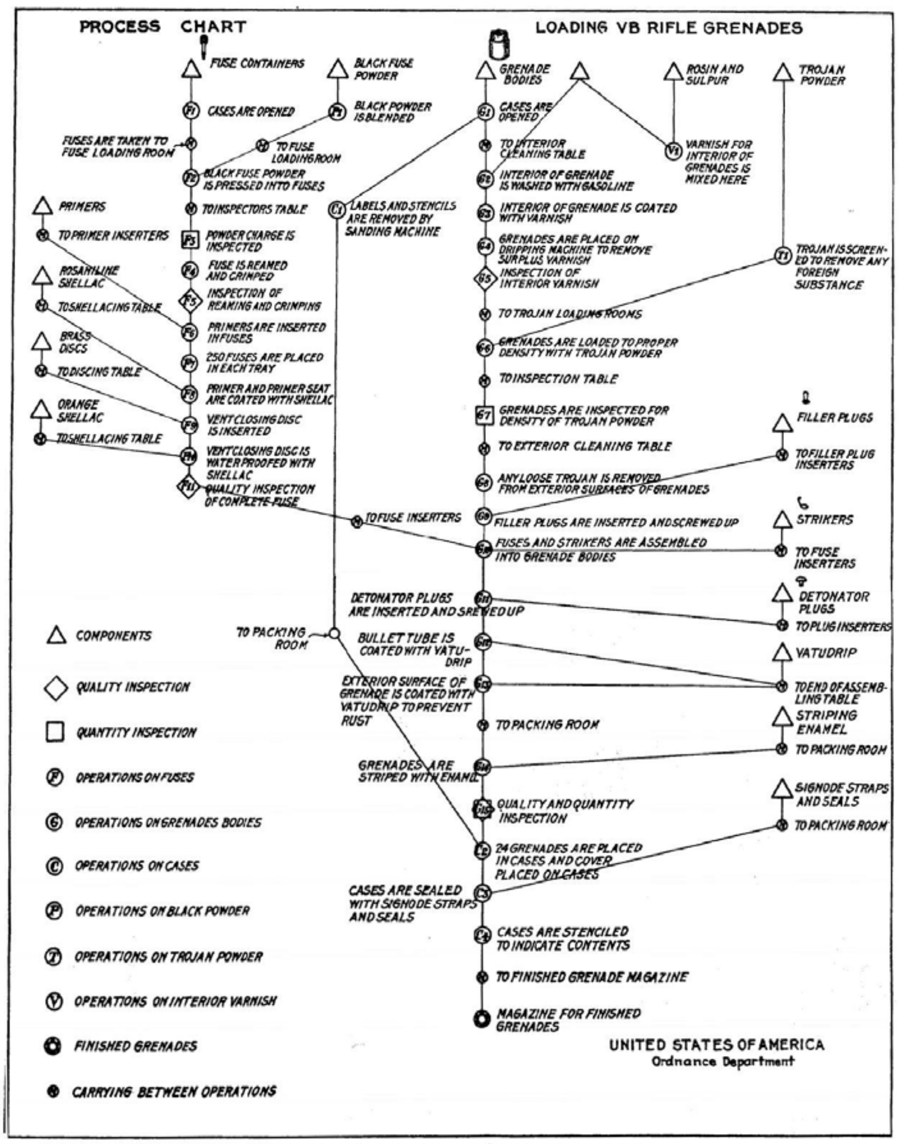

FIG. 5 PROCESS CHART FOR LOADING RIFLE GRENADES

Figure 5 Process chart for loading rifle grenades. (Gilbreth and Gilbreth 1921: 12).

This type of graphical representation of the workflow functions as a visual algorithm that has to be followed and replicated. It is one of the core technologies for the visual organisation and abstraction of business processes that remains in use in different industries, where the symbolic representation of different functions and actions in the workflow today is also still similar to the notation used by Frank Gilbreth. This notation is also used to depict workflows and business processes on different scale. In the 1980s and 1990s the workflow organisation and notation started to become part of the development of software systems for managing the functions of organisations. This includes Workflow Management Systems which are one of the two big classes of software solutions for organising the enterprise, together with the more prominent Enterprise Resource Planning Systems (Cardoso, Bostrom, and Sheth 2004). The graphical notation of workflow processes remains an important part of the functional development of workflow management. In the 1990s it was an object of standardisation by the Workflow Management Coalition (WMC) and the Object Management Group (OMG), in the course of their work to develop standards for visual representing different parts of the workflow process and formats for its interchange between organisations and across different digital systems.

The graphic notations standardised by these two organisations capture workflow processes on multiple levels, from the level of organisational processes to the level of individual tasks. They also importantly capture workflow processes as both descriptive and executable models. There are different layers to what the workflow in the radiology company is, and what effects the workflow has on the control over labour in teleradiology outsourcing. At a very large-scale level, the workflow diagram provides an overview of the outsourcing relations between the healthcare institutions that produce the medical images and the companies that hire radiologists who interpret and write reports. This is a very commonly referred to diagram on teleradiology companies' websites that stresses the technological possibilities of interconnectedness and transfer (figure below). These workflow diagrams (that have a marketing purpose) show schematic representations of the outsourcing process with the main actors involved and the networks and hardware used to connect the site of the hospital to the teleradiology company.

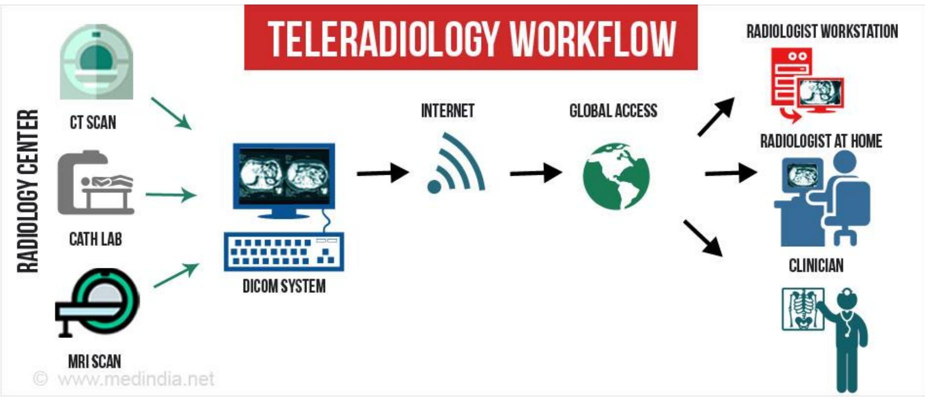

Figure 6 Teleradiology workflow diagram representation for marketing purposes from the website medindia.net.

This first layer of the workflow above shows little of how this type of organisation of labour operates. It presents a rather flat image of the types of relations that form around the infrastructures that enable teleradiology. As we zoom in and peel off layer after layer of the workflow however, we can see significant complexity that involves different modes of mediation and control. Ursula Huws (2014) for instance focuses on issues of international division of labour and the inequalities and precarity generated through the outsourcing chains that move production and services from regions with stronger union traditions and workers' rights to regions with lower wages and weaker labour protection (see Huws 2014; Venco 2012). Key in the analysis is the focus on the importance of the compartmentalisation of business processes into business functions, each performed by a different set of workers (Huws 2014: 28). Diagrams like the one above, sketchy as they are at first glance, already indicate the presence of an analytical process where discretion as to what constitutes separate functions and how they can relate to each other is being exercised. It allows teleradiology companies like Worldwide Teleradiology or Omniscan Teleradiology for example, to take over one part of the diagnostic process that is focused exclusively on the reading of the medical images, while the hospitals retain control over the treatment of the patient, taking of the images, and the financial and legal relations they have with the patient. This exercise of discretion makes it possible to separate the function of radiology analysis and then outsource it, thus making it the subject of a distinct form of control, measurement, and intensity.

Huws (2014) and Venco (2012) analyse these instances of business process outsourcing in the context of an emerging new global division of labour. Huws (2014) points out the relationship between automation, standardisation of the labour process, and the possibility of outsourcing, which is accelerated by the growing use of digital technology in industries. Drawing a link between Braverman's (1974) critique of automation in the industrial factory, Huws (ibid.) argues that the standardisation of work tasks is instrumental in shifting the control over the labour process from the workers to the management and for establishing mechanisms for the quantification and measurement of work efficiency. Huws also goes further than this however, by pointing to the ways in which digital technology and communication enabled the deterritorialisation of the factory beyond the national level, thus creating an even more complex chain of control and exploitation.

The analysis of Huws (2014) draws out two important conclusions about the development of workflow management in digitally mediated environments that are pertinent for understanding how workflow automation affects teleradiology. Firstly, Huws draws attention to the importance of scale in workflow management and the different effects it has for the exercise of power and control within the workflow. While Braverman (1974) discusses labour automation on the level of individual work tasks and how the autonomy of the worker is diminished through standardisation and automation, Huws brings questions about uneven geographies of labour, hierarchy, and racialisation into her analysis of business process standardisation. Secondly, revisiting Braverman's critique of scientific management and labour automation, leads to the question of possibilities of control in cognitive labour automation in professional and highly specialised jobs such as radiology. At the core of Braverman's critique, which is built on analysis of manual factory labour, is the argument that scientific management delves a rift between the cognitive and manual labour involved in performing work tasks.

Going one level deeper, the workflow organisation reveals how the outsourcing chain operates at the teleradiology company itself. Here, apart from the trio of the radiologist, transcriber, and loader, there are a number of other roles making the transfer of images and diagnoses possible. There is a whole team dedicated to overseeing the workflow, redistributing cases, managing availability, and prompting radiologists to finish the reports that are pending. This teams sits in a separate room in front of monitors displaying real-time dashboards that indicate how many cases are currently handled or pending; this is a real-time surveillance system that, as discussed in the previous chapter, is enabled through the DICOM standard. The discussion that I pursue here however, is role of this team in conjunction with the monitoring system.

The conceptualisation and visualisation of the workflow operates on a granular level; gestures as minute as the clicking of a button or filling of a form are notated for instance. The scalability of the workflow as a technology for labour process abstraction, management, and automation has important implications because of the possibilities it allows for an exercise of control which cuts across different levels and scales. This makes it possible to link the impacts of automation on the subjectivity of individual workers to the ways in which more systemic and geopolitics effects of automation take place. The workflow diagram for a general-purpose worklist from the DICOM documentation, shown below, provides one such example of a very granularly defined and visualised process. This diagram represents the actors, steps and modalities involved in the scheduling and performing of a radiology exam. The diagram below from the documentation of Integrating the Healthcare Enterprise which is an initiative aimed at developing interoperability scenarios for healthcare settings shows an even higher granularity of the tasks, that is focused on distinct tasks performed by digital systems designed for the exchange of documents between different enterprises.

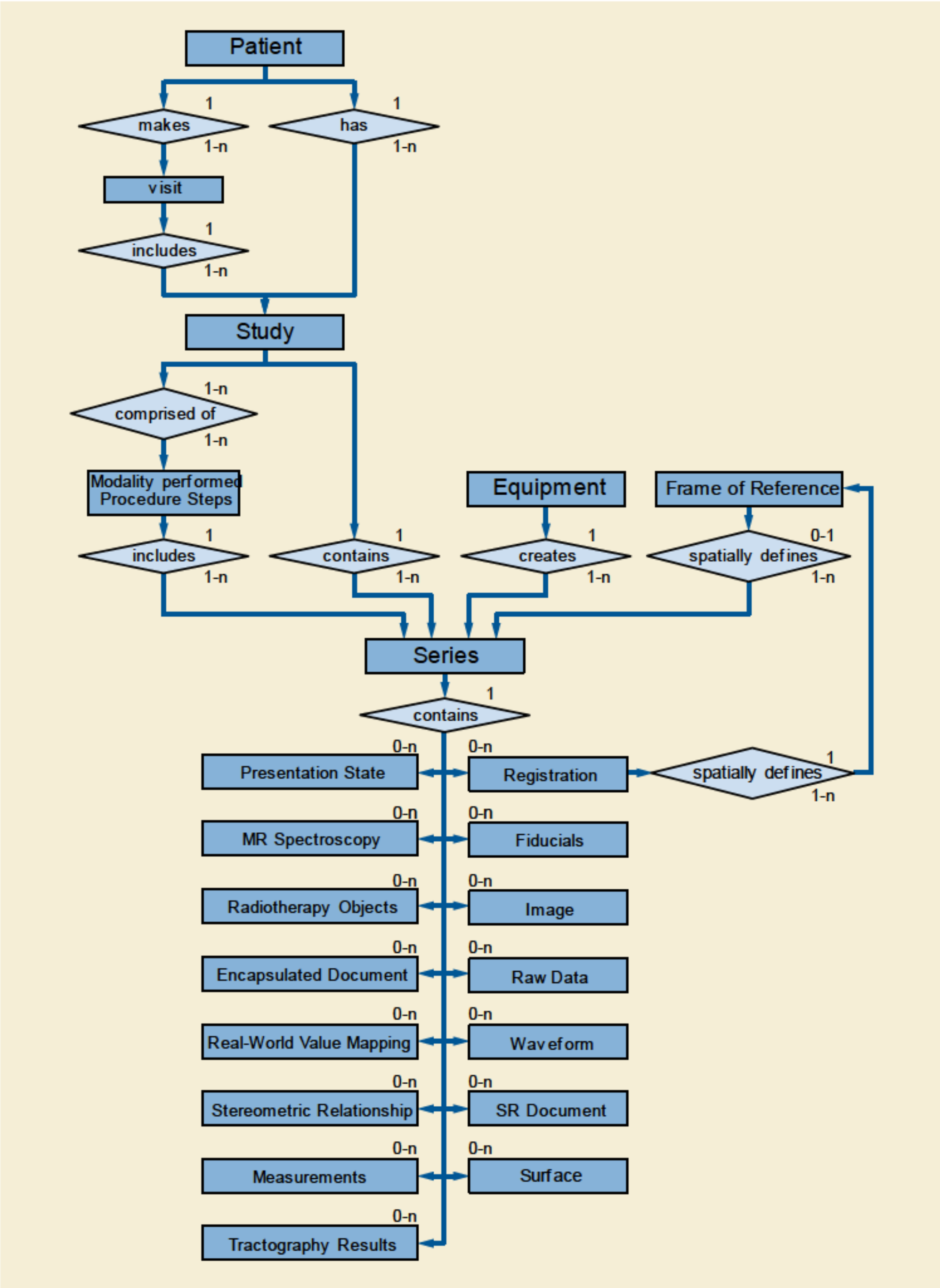

Figure 7 Workflow diagram representing the DICOM model of the real world – the subjects and objects involved in a radiology study and the relationship between them. DICOM PS 3.3 2016b. Fig. 7-1a.

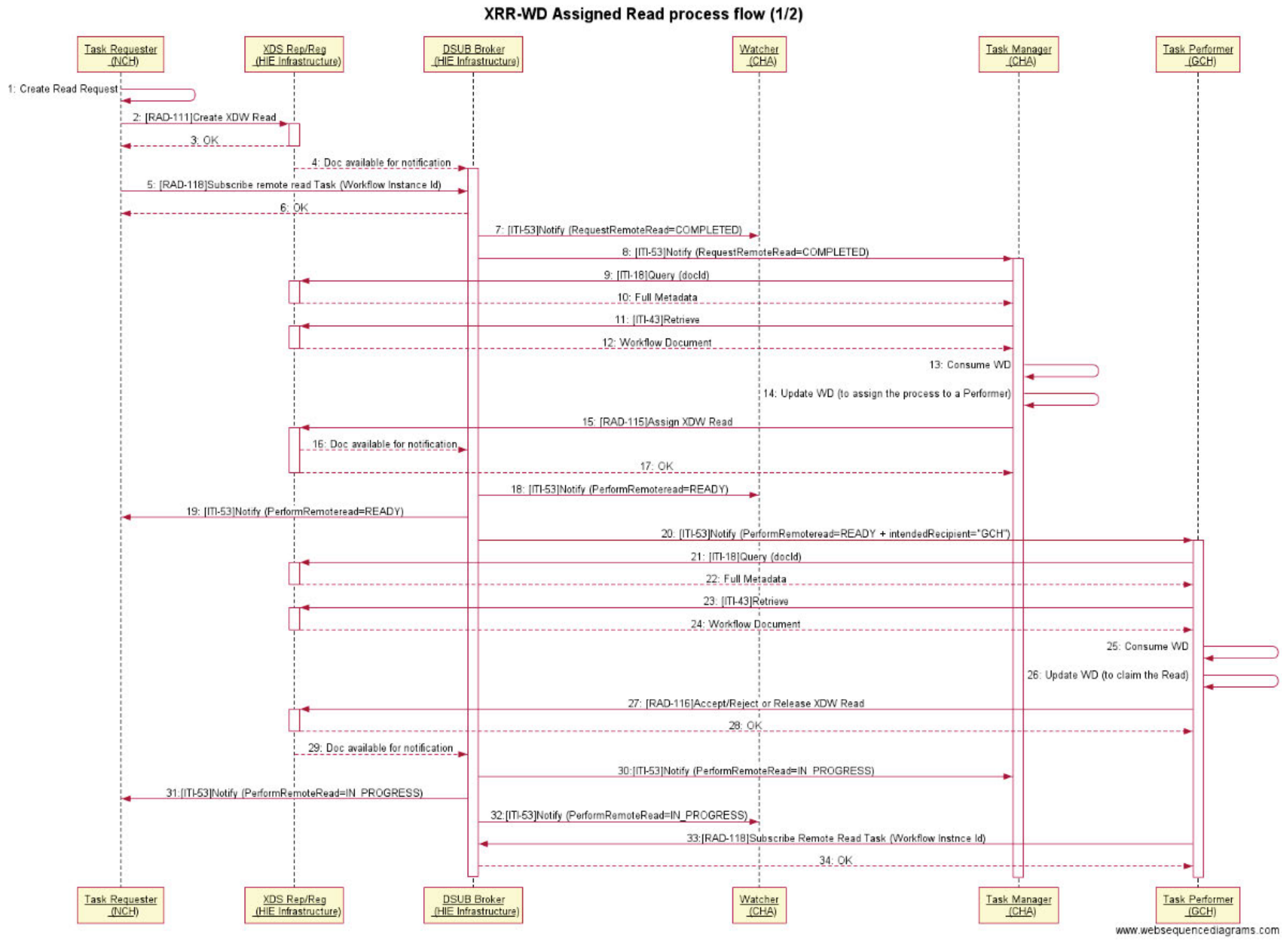

Figure 8 Workflow diagram for assigned remote radiology diagnosis in cross-enterprise diagnostic process, that is, in the case of outsourcing. Reprinted from Integrating the Healthcare Enterprise (2017: 35).

The workflow operates simultaneously as a mental diagram and as a visualisation of an abstracted labour process. It also operates through the actual tasks performed according to these abstracted representations of the process. Understanding the workflow's political implications involves understanding how each of these different avatars of the workflow function and map onto each other. This organisation involves a type of control that is exercised through the materiality of software systems, however the abstraction of the workflow and its visualisation play an important role in developing fantasies of labour optimisation which represent the work process as a streamlined flow, stripped of unnecessary digressions. What is important to note is that these diagrams are not schematic descriptions; rather, they are schematic prescriptions of how the work process in teleradiology settings should take place. From Gilbreth's process charts to the workflow charts used for standardising workflows and data exchange scenarios, the development of the workflow and its highly visual mode of representing labour processes is a part of important technologies of labour management that not only impose control over labour but also reimagine what the labour process entails. This streamlined process frames certain movements, impulses, and affects as unnecessary and redundant while creating the necessary conditions for the parallel affective economy within the teleradiology workflow that metabolises these redundancies.

Energy, waste, and metabolism as principles of workflow management

The body of the worker receives special attention in the theory and practice of scientific management. In different ways, the interest in bodily movement and ergonomics informs many of the developments in thinking about industrial labour and industrial production. One of the major points of interest is the way a body operates, spends, and conserves energy. This speaks of a markedly mechanistic understanding of the body which came into prominence during the 19th century at the peak of industrialisation, when the worker became regarded through an increasingly technological lens. The photographs and films made by Eadweard Muybridge are one example of this interest in the body as a working and moving mechanism that points towards this technological prism of understanding the body; an understanding on one hand through the technological medium of photography and film, and on the other hand through an interest in the mechanics and physics of movement. During the 19th century the study of the human body was heavily influenced by the interest in industrial machinery and production; these two objects of interest conflate not simply because working bodies are employed in factories, but also because they stem from common scientific frameworks for thinking about productivity, movement, and energy. John Bellamy Foster and Paul Burkett (2008) argue that as well as informing developments in the mechanisation of industrial capitalism, scientific research in physics and thermodynamics also shaped a central concept in the work of Karl Marx and Engels, namely labour power and the principles of labour value and reproduction. The influence of contemporaneous scientific theories on the development of the Marxian notion of labour power impacts on the understanding of labour as a commodity that is generated both through the complex interaction of processes of production and reproduction in the political economy and also through the interaction of chemical processes and physical laws of energy conservation in the body (Burkett and Foster 2006).

The issue of energy and productivity is central to the work of scientific management where special attention is paid to the optimal, most efficient movements of the working body that consume the least amount of energy. This concern with conserving the energy of the worker is important to note because it links the issue of productivity and efficiency to the question of reproduction of labour power. Labour power as a central concept in understanding these interactions and relations in the works of Marx and Engels is understood as the potentiality that enables the process of energy expenditure of labour. These notions of potentiality, expenditure, and conservation form the core principle of scientific management as well, especially in the work of Gilbreth, and they are central to understanding how the affective economy of labour forms the core of scientific management and the concept of the workflow.

Both Taylor and the Gilbreths incorporate concern with the conservation of energy of the working body into their principles of scientific management. Taylor times the periods of rest and labour, mandating Schmidt (the factory worker he chooses as the subject of his experiments in scientific management) to take breaks at regular times as part of regulating the expenditure of his energy. Frank Gilbreth, similarly, was increasingly concerned with the issue of fatigue. As part of his attempts to distinguish himself from Taylor and to increase the acceptance of his own methods of scientific management, Gilbreth frames his studies as "fatigue evaluation studies" which diagnose the faults in workplaces that make workers less efficient and therefore lead to "fatigue" which he sees as the biggest threat to productivity (Gilbreth and Gilbreth 1919; Price 1989). Gilbreth focuses on different aspects of the motions of the worker and their environment - light, air, temperature, workplace comfort. All these variables influence the efficiency, expenditure, and conservation of labour power and Gilbreth's work shows an approach to labour and an understanding of labour power that is highly relational, dynamic, and embedded in the environment of work. Labour power, understood as the potentiality of energy to be spent on work, is subject to influence by a multiplicity of factors. Meanwhile, the efficiency of the worker is the product of carefully managing the environment as well as the condition and ergonomics of their body. This approach to labour power, which bears similarity to the Marxian metabolic-energetic theory of labour (Burkett and Foster 2006), has important affective consequences that come to the surface within the successes and failures of the Gilbreths to organise labour efficiency in the workflow.

While concern with energy and the reproduction of energy in the body informs the early work in scientific management, this approach is far from purely mechanistic. Starting from Frederick Taylor's studies, the scientific method of analysis of the workers, their potential for efficiency and the appropriate ways to perform work (or as Gilbreth calls it, the "one right way to do a job") go far beyond the analysis of physical movement. They also inquire into the social environment of the worker, that is to say, their lifestyle, character, upbringing, and ambitions. The acute and careful interest in the life of Schmidt constitutes a central part of Taylor's study that has so heavily informed scientific management; it involves understanding not only how a worker moves, but also what moves them, or how can their body and mind is guided in the desired direction, pushed towards the desired pace, discipline and complicity. The inquiry into Schmidt's intimate mind and social life is hidden behind the narrative of regimented and controlled, machinic bodily movements. But nonetheless, the detailed research into Schmidt's life and disposition also points to a complex understanding of the way that labour power accumulates and exhausts itself under the influence of the physical and social environment in addition to being exhausted through the internal processes of the worker's body and mind. Mark Andrejevic (2007) sees in these particular interests, a predecessor of the 21-century use of big data analysis for surveillance and targeted marketing which seemingly extracts value from the human body in a different way to the exploitation of physical energy, by instead exploiting subjectivity and affect. But the work of Taylor and Frank and Lilian Gilbreth does suggest there might be commonalities between these two modes of (physical and affective) value extraction and that the notion of energy and affect each have important roles in shaping both what Marx calls labour power and what practitioners of scientific management strive to control and channel though standardised and quantified measure of efficiency.

It is through this understanding of labour power as potential and vital energy, that we can see how the notion of affect – understood as pre-individual and relational potentiality and virtuality (Massumi 2002) – helps us to understand practices and concepts of scientific management that inform workflow organisation and which have their continuities in teleradiology workflow. In Gilbreth's work, the attempts to streamline the workflow and optimise the labour process are combined with an interest in the possibility of generating, reducing, and distributing the emotional and energetic aspects of the work process. The idea behind filming workers as a way to induce pride in their work and their desire to perform better is one such example from the experiments that they conducted over the years aimed at manipulating affect in order to increase productivity. The interconnectedness between labour optimisation and the management and distribution of affects transpires even more in fatigue studies, and especially in the experiments in surgery rooms where the possibility of distributing tasks makes the introduction of labour management methods possible.

The link between efficiency, the metabolic-energetic theory of labour and an affective theory of labour transpire most evidently in Frank Gilbreth's work on workflows that involve more than one worker and thus require collaboration in the performance of work tasks. One of the most significant fields where he performed his micromotion studies was the surgery room. There, Gilbreth had the ambition to improve the efficiency of the surgeons by suggesting a combination of his methods through standardisation of the motions of the surgeons and their assisting team, standardisation of the surgical room environment and the composition of the medical team, and micromotion studies to analyse and correct the motions of the doctors (Baumgart and Neuhauser 2009; Gilbreth 1914). The latter suggestion was met with snide remarks about his lack of medical expertise by medical professionals commenting in the same issue of *Modern Hospital* in which Gilbreth's work was published (Boyce 1914: 119), however the suggestions to improve the surgeon's efficiency by improving the efficiency of the surgeon's assistants was welcomed. At the core of this principle of labour management improvement stood a notion of the social character of labour; this complemented the idea of the physico-chemical efficiency of the labouring body and an individualistic, albeit environmentally situated, dependency between production and reproduction. In the discussion of the principles for scientific management in the hospital, Gilbreth writes: “In the hospital, as in all other centers of activity, there is one best way for doing each thing that is done, but the complete best way is seldom in the consecutive acts of any one person.” (Gilbreth 1914: 322). Thus, the concern with energy conservation and the management of energy wastage (or *fatigue*) received a pronouncedly social interpretation through the focus on complex workflows. The notion that the efficiency of work can be achieved by regulating the energy expended by the worker is now conceived as a socio-energetic, or indeed socio-affective, interdependency between different workers with different tasks, or between what Gilbreth calls “functions” (ibid.)

Figure 9 Micromotion study in the surgery room performed by Frank Gilbreth. Screen capture from the original movies. Gilbreth (2007).

The focus on the team in the surgery room means that a different and more complex method for metabolic, energetic, and affective regulation and conservation needs to be invented; one that inevitably involves regulating the relations between different workers in the team. Frank Gilbreth approaches the surgical team as a system where *functions* can be assigned to different people according to their skills. He marks different participants in the team with different symbols (1, 2, 3, etc for doctors and A, B, C, etc for nurses) and films their work using his technique of recording their movements against a background with a painted grid. The analysis of the surgery room as a system of different actors performing different functions allowed Gilbreth to distribute these functions in a way that will increase efficiency. In his theory, this meant that he would assign functions to those most skilled for them (Gilbreth 1914). The strong opposition against a non-medical expert directing the movements and gestures of surgeons however, meant that there was much more acceptance of the idea of motion studies and management pertaining to the nurses than the doctors (Boyce 1914). Nonetheless, the scientific management focus on the surgical room brings a new angle to the concern with fatigue, energy, and efficiency. It shows that efficiency and productivity can be approached in a way that does not treat all workers as being equally subject to the regulation of motion and speed of work, but rather that efficiency and productivity of the unit can be achieved by offloading the task of achieving efficiency to certain workers. Indeed, one criticism of Gilbreth's work, is that the high performance and efficiency successfully achieved in his examples, is accomplished by delegating more tedious and time-consuming tasks to other workers (Price 1989: 4).

However, rather than an accidental flaw in Gilbreth's workflow management method I would argue that the possibility to distribute the conservation and expenditure of energy and affect at work is a core feature of workflow automation and control. This possibility exhibits itself in the workflow organisation at Worldwide Teleradiology where the roles created to offload work tasks from the ABRs, and the other radiologists, are part of this logic of automation. In this instance, the increased productivity and efficiency of labour can be unevenly distributed and metabolised among the workers, leaving some to take on a bigger part of labour power expenditure than others. While Gilbreth's experiments were most concerned with the physicality of labour, this positioning of his work should be seen in the context of the predominant mode of production in the industrial age that placed increased importance on the physical mechanics of movement (Callen 2016; Wolkowitz 2006). The focus in teleradiology workflow management is determined by the increased importance of information transfer for the generation of value and this new context of workflow management aligns with the processes of standardisation of medical practice. These new practices of standardisation, related to organising information and archiving in healthcare, play an important role in new forms of management and efficiency that become central to the development of digital healthcare systems and play an important role in the ways that control and hierarchy are enacted in teleradiology.

Conclusion

The genealogical analysis of the workflow presented in this chapter, which draws on theories of thermodynamics and organic metaphors of metabolism, has highlighted a specific focus on labour management that constructs the physical, economic, and political dimensions of the working body by imbuing practices of labour control and intensification with notions of energy expenditure, conservation, and metabolism from the natural sciences. These categories constitute a materialist approach to labour that also demonstrates the complex relationship between the abstract diagrams used as tools for labour optimisation and automation, and the labour processes that they represent. While workflow charts and diagrams are meant to describe and prescribe the sequences of actions and the participants in the work process, there are however affective surpluses that they fail to capture.

The teleradiology workflow, which is a representation of how data is transferred between systems and how labour participates in the processes of handling clinical information, analysing images, and sending reports, constitutes an important part of the technologies of standardisation and automation in the industry. Part of its importance and usefulness is the way it links the transfer of data and the management of labour into a single process. This relationship between data management and labour management has its limits however and the case of Worldwide Teleradiology shows what some of these limits are. The heterogeneity of labour involved in the process of teleradiology including ABRs, Indian-certified radiologists, transcriptionists, loaders, and workflow managers, undermines the possibility of a complete overlap between the management of digital data transfers and the management of labour. On one hand, some of these roles emerge as a way to compensate lags and imperfections in the automated workflow. On the other hand, they work to constantly subvert and override already automated processes, by swapping the already assigned cases and using the radiologists' logins to open the images for them. Lastly as I showed, the interdependence and hierarchies between different workers in the teleradiology workflow is also established and sustained through an economy of metabolising the affective surpluses that arise as byproducts of the processes of labour intensification and automation. In the following three chapter I examine how these principles of workflow management are incorporated within data infrastructures in teleradiology. As I will show, the focus on data management builds on some of the underlying concerns with the regulation of flows that are evident in scientific management studies but the new medium of digital data introduces new concerns, new modes of control, and new interdependencies.

Chapter 3: DICOM and the politics of image capture

A new body politic

I was sitting in Bangalore, in the office of Worldwide Teleradiology, next to one of the Indian certified radiologists who performs the first reading of images coming from the USA hospitals, before they are read and signed by the American Board of Radiologists (ABR) certified doctors working with the company. The company only receives CT-scans and MRI images from USA hospitals because they are the most costly cases to diagnose. Each study comes with an x-ray image however, that radiologists use as a map to orient themselves while browsing through the CT-scan image. CT-scans take hundreds of images of slices of the body that are then arranged together through the image reconstruction algorithms installed into each CT scan machine, finally creating a 3D model of the body through which radiologists browse to examine certain areas and organs. As I was peeking at his screen, it was lit up with the x-ray image of a body pierced with dozens of bullet pellets spread across the left part of its chest and abdomen. The dots were distinctly visible across the semi-opaque organs with ECG wires and electrodes gently transpiring among bones, flesh, and pellets. The image came from a hospital somewhere in the USA, from an emergency department, possibly a life-and-death situation at the other end of the world. The image's serene composition on the screen contrasted with the scenes of violence and pain that it evokes. It also contrasted with the quiet chatter and buzz of the spacious office of the company where I was sitting. To think that somewhere, in a street, a house, or a club a man was shot, maybe in the midst of a fight, maybe unexpectedly and without warning, and is now struggling with pain and grasping for life, while the images of his wounded body are travelling to different corners of the world to get diagnosed by radiologists is uncanny. But it is not just the distance between the screen and the patient that evokes this feeling of unease and oddity. It is also the image itself, torn between the concreteness of a specific body linked to a specific place, hospital and bed, and the abstraction of the x-ray that renders the body anonymously scientific. Radiology itself is an apparatus that determines and modifies the way a body is seen by the institutions of healthcare, while the digitalisation of medical imaging has brought about significant changes in the ways the optics of these institutions have changes. As I looked at the black and white picture on the screen, I asked the radiologist a question I had been asking again and again: "Does it make a difference whether you are reading an image from the USA or from India?" And I receive the answer I had been getting time and time again: "People are people, it makes no difference".

The radiologist's answer points to the specific cultural imaginaries that are linked to the technologies of medical imaging (Stephens 2012). Jose van Dijck (2005) argues that one of these cultural imaginaries is the ideal of transparency of the body, which is achieved through scientific innovations in medical imaging. Radiology gives rise to the conviction that these images represent an objective insight into the human body and its workings. Moreover, the ideal of the transparent body feeds into imaginaries of the common and universal humanity of the body. One such example of the use and interpretation of medical images as generalised representations of the human body is the Virtual Human Project launched in 1994. As part of this project, two cadavers, one male and one female, were scanned in CT and MRI machines in their entirety, then frozen in gelatin and carefully sliced in cross-sections of between 0.3 and 1 mm. Each cross-section was digitally photographed and irreversibly destroyed in the process, flesh crumbling into ashes after each slice. The digitalised images, however, serve as an interactive anatomical atlas, preserved for eternity in the form of universalised representations of human anatomy. Catherine Waldby (2000a; 2000b) in her work on this project, argues that the Visible Human brings together the materiality of human flesh and the materiality of digital code to produce a new type of imagery and reading of the body, in which the visuality of real human flesh is combined with the mutability and recombination properties of digital data.

However, the understanding of the medical image as a neutral and universalist depiction of human anatomy is illusory. Behind the universalising image of human anatomy that medical science projects and that the radiologists are quick to evoke, the visualisations of patients' bodies are subjected to technological and political control exercised both through standardisation and through the digital infrastructures for transfer and storage of medical images. The digital image on the screen is a special file format, namely DICOM (Digital Imaging and Communication in Medicine) format, that is now standardly used in radiology. DICOM files contain the image data as well as metadata with patient information, details about the procedure and modality used, the referring physician, and the healthcare institution. All this information is incorporated within the DICOM file as part of the process of taking the digital image at the imaging centre. The administrative and clinical information is automatically pulled from the Hospital Information System (HIS) which is used to schedule the exam, and the relevant fields in the DICOM file are populated with this information. Thus even if the image on the screen in Bangalore looks sufficiently anonymous and evokes universalised imagery of human anatomy, it in fact contains data that not only describes who the man on the screen is and why he was referred for a CT-scan but also provides details about the hospital where the scan was taken; this is information that, in the context of teleradiology outsourcing, also determines who can diagnose the image.

A complex relationship between the body and the political economy of outsourcing teleradiology is therefore established through the functionalities and data structures used in these interconnected digital systems and standards. When a patient is admitted into a hospital in the USA and needs to undergo a radiology exam, the hospital schedules an exam through its HIS. This scheduled exam includes patient information, as well as a prompt for the exam to be scheduled in the Radiology Information System (RIS) which puts it on the worklist of the facility performing the imaging procedure. These two systems communicate with each other by using the same HL7 data standard for exchanging information. The patient information collected in the USA hospital through HIS and formatted according to HL7 standard, is then received at the imaging facility where the RIS interfaces with PACS. PACS consists of the imaging modality that produces the radiology image (a CT scan, MRI, or digital x-ray machine); a secure network for the transfer of the images, storage and archive; and a DICOM viewing station. When RIS connects to the PACS, it sends the request for an image and PACS extracts the textual data in HL7 format that is needed to compile the radiology study, adds it to the DICOM image, and then returns it to the RIS where it is sent for examination to the radiologists. After the radiologists diagnose the image, it is sent back to HIS via RIS. There are multiple variations of this process depending on the exact combination of software and hardware systems at each hospital. The main components of the workflow remain the same however and the exchange of information and its capture in the DICOM image are a central part of this procedure. Images are channelled into this complex infrastructure in ways that are highly pre-determined by the structure of a teleradiology workflow, which in turn depends on the case, image modality, jurisdiction and hospital where an image comes from. They are then redirected to the appropriate radiologist working with the company. All this information that determines the path of an image is already inscribed on it in ways that simultaneously complicate the notion of the image and draw upon existing dependencies between embodiment and political subjectivity.

This infrastructure infers the relationship between bodies, embodied subjects and the political and economic community of the nation state. At the same time, it operates within distinct technological zones of expertise (Barry 2006) and according to the technological possibility for transfer and interpretation. My focus here is on how these two dimensions of the socio-political infrastructure of teleradiology intersect in relation to the radiology image and what they can tell us not just about the political terrains that intersect within the radiology image but also about the possibilities for new terrains and subjectivities that are opened through this intersection. The tension between universality and particularity in the radiology images plays an important role in generating the possibility to construct a specific economy of medical visualisation. This economy is enacted by producing and extracting value from the radiology image through navigation of its different levels of representation as a scientific anatomical image and as a commodity participating in the establishment of hierarchies of labour and processes of valorisation. The different value and valency of radiological images find their ultimate multiplication in the digital age when the medical image, a specific and standardised format of visualisation and representation, acquires the potential to yield predictions, depict population health patterns, and participate in the development of new forms of automation.

The medical image in radiology brings forth the complex relations between the political economy of visibility, digitalisation and the political and economic status of the body, through the process of making the body visible and reading it. The physical properties of the body, its permeability and vulnerability to outside influences and agents, its opacity and ability to absorb and react with magnetic fields and radioactivity, become part of the biopolitical calculations of how bodies can be made readable, cared for, and governed (Foucault 1976; 2008; Lemke T. 2011; Rose 2007). The medical image is part of the apparatuses of inscription, diagnosis and control of the body that have all been established within healthcare systems such as the anatomical atlas and the medical record; the image thus participates in a changing political ontology of the body both as a physical entity and as a political subject.

In his work on medieval political theology Ernst Kantorowicz (1957) analyses the link between political power, territory and embodiment, pointing to the important symbolic role of the body of the ruler as a vessel of power and sovereign of the realm. The importance of embodiment and the body in articulating a connection between the land, the king and his subjects, lies in uncovering the significance of the duality of the royal body as a man and as a vessel of power that is divinely invested for the consolidation of legalistic and theological notions of political territory and the economy of sovereign power over it. While Kantorowicz's work is specific to the medieval context of Western Europe (with a focus on medieval England) the duality of the royal body that he discusses reveals the paradox of embodiment and political subjectivity. This paradox is that the body simultaneously acts as a container and signifier of its anonymous, universal, both powerful and vulnerable biological vitality and also through its political and social interpellations. The radiological image introduces a new aspect to this duality; it makes it possible to separate the biological body from the social and political signification of the body, by manipulating the data and metadata attached to an image. While the imaging data produces a visualisation of the body, the metadata in the DICOM file contains demographic information and information about the hardware and the labour process to produce the image, as well as institutional information. I will return to the significance of metadata in the last part of this chapter. But before that, I want to first address some of the later developments in the political meaning of the body that link it to issues of territory and political subjectivity.

The strong link between statehood and healthcare underpins conceptions of the health of the national body such as those in 1920s and 1930s Germany, that Thomas Lemke (2011) describes as part of his analysis of biopolitics. This link was also predominant in numerous other countries during the era preceding World War II. Conceptions gradually shifted over time, from anatomical metaphors for seeing the state as one body, with the king being the head, towards a biopolitical interpretation of the population as a "multiple body" (Massey 2009: 194). The link between body, health, and political territory in modern biopolitics deploys a different correlation between the body and the concept of sovereign territory. It stresses the possibility of acting upon the body in order to make it healthier and more productive (Lemke 2011; Rose 2007). Emily Martin (1994), in her work on the evolution of the notion of immunity in modern medicine, makes a different albeit related argument about the link between medical theories of the body and theories of the nation state and economic organisation. Martin argues that the symbolic relation between the body and political power draws also on interpretations of the economy of labour, energy and value, which lead to parallels between dominant economic theories of organisation and control and the medical notions of how the body regulates itself and interacts with its environment. She discusses how changing theories of productivity and control over labour, such as systems theory and the flexibilisation of the economy, are put into dialogue with medical theories of how the immune system functions and how its operation should be supported. These changing theories suggest not only a mimicry in the organisation of complex systems but also a mimicry that reflects notions of sovereignty and the porosity of national borders onto the model of the medicalised body and its interactions with the world. Martin's study thus suggests a connection between health and political organisation, linking the body and state through metaphors of borders, sovereignty and economies of production and reproduction.

I argue that the radiology image intervenes in these economies, but its relationship to them is not straightforward. The way in which the political meaning and symbolism of the body is transposed onto the medical image becomes complicated through the mediation of digital data standards and systems for the transfer of information. The political meaning of the body as simultaneously an individual body and a body politic is grounded in a specific relation between political subjects, sovereignty, and territory; these are notions that become much more complex when we discuss digital media and software systems. Especially, this begs the question what would their meaning be in the context of digital infrastructures in healthcare?

Drawing on analysis of the practices of image diagnostics in teleradiology companies and analysis of the documentation of the international DICOM standard, I argue that the digital medical image represents a new and important technology for visualisation, control, and extraction. This new technology of control expands on past technologies of seeing as instruments for ordering (Scott 1998) and governance through knowledge (Foucault 1976). Importantly, it also introduces new forms of control and extraction that arise from the technological properties of the medium along with the materiality of its sequences, processes, and connections. The DICOM file format introduces new temporal dimensions in the image that allow the integration of workflow management and real-time health statistics and also allow surveillance that further complicates what STS authors refer to as an ontological multiplicity of the image.

I will be offering an analysis of the entanglement of critical material facets of the digital medical image: that is to say, the political and technological regimes of visibility that are enabled through it; the notions of seriality and temporality embedded within it; and the way in which both of these facets are put to use in enabling different modes of control, subjectivation, and value extraction in the context of teleradiology outsourcing. I start by analysing the links between political subjectivation, visualisation and the body in political theory, and the history of biopolitics and how all of these linked elements are influenced by digitalisation. In sections ahead, I discuss the materiality of the digital medical image and the multiplicity of nonhomogeneous political ontologies that it evokes.

In the course of this chapter, I examine what the digital radiology image is and how its dependencies to labour subjectivity and labour management are formed. In the section 'Multiplicity of the digital image', I analyse how medical images develop a complex relationship to the representation and visualisation of human bodies, which changes across the different media of imaging diagnostics. Next, in the section 'Networked images', I focus on DICOM, the special image standard used in digital radiology, and its role in construing what a post-visual image file is, and how it renders technological and political relations in the process of radiology diagnostics. In 'Seriality and temporality in the image', my analysis zeroes in on the data and metadata categories in DICOM files and reveals how technological affordances map onto political categories and relations. I conclude the chapter with the example of the operationalisation of DICOM images as a technology of control in the rolling out of a public-private partnership between a teleradiology company and the Government of Tripura and show how the different data categories and technological affordances acquire an acutely political role.

Multiplicity of the digital image

The digital images almost universally used today have changed significantly from the times of the first x-rays transmitted on plaques and whose main mutable quality was the degree of transparency that allowed doctors to see the body; however, even the early days of x-ray images introduced what authors see as a scattering of the medical gaze (Bleakley and Bligh 2009) and contributed to a process of multiplication of the body (Mol 2002). This process of scattering and multiplication of medical knowledge and the notion of the body that Mol and Bleakly and Bligh all refer to, leads to reconfiguration of relations between institutions and actors within the healthcare system. Bleakly and Bligh (2009) see the changes in the relations triggered by the development of new technology as changes that reduce doctors' power and authority, at the expense of an increasing importance of technology.

I want to press this metaphor of multiplication further. Annemarie Mol (2002) proposes an ontology of the body as being constructed through multiple methods of scientific observation and manipulation and the ways in which these methods rearrange and refocus the reality of the body. However, visualisations of the body participate in political constructions and propagations as much as they participate in scientific structures. There is a specific way of learning about the body, and its anatomy and pathology in medical science and visuality is an integral part of this process. Visuality and visualisation do not simply reveal but they also structure and impose types of power relations, politics of knowing and economies of production and reproduction of what is made visible (Armstrong 1993; Foucault 1976; Halpern 2014; Latour 1986).

The image of the body in radiology is not singular, it contains multiple levels of visualusation and inscription that need unpacking in the process of radiology reporting, as well as in the analysis that I am offering here. One of the things that struck me during my fieldwork was the multiplicity of images that take part in the education and practice of radiologists and in the way a radiology image multiplies and unfolds in the process of its reading. As radiologists reads each image, they scroll and browse through the body looking at its various visualisations in different colours (visualised through flows, activity of glucose absorption, density of tissue), cross sections and whole body, all side by side. This proliferation of images in the process of radiology diagnostics speaks of the multiple functionalities and properties of the body that can be captured and visualised in radiology and through which the body of a patient can be abstracted and visualised, in the process literally separating (or abstracting) different types of tissues and processes taking place within the organism. There are, however, different levels of abstraction in the field of radiology, which become evident in educational materials and presentations. At a presentation on the effect of toxic poisoning on the brain at the annual conference of RANZCR in 2016, the presenter for instance presented an array of images of the same condition. She showed x-rays, screenshots of MRI, stylised visualisations from anatomical atlases and photos of dissected brains. These were all different visualisations of the same condition and how it affects the body, but they referred to different planes of observation and manipulation. While the pictures of dissected brains offer a relatively straightforward representation of a concrete body, MRI, x-rays and illustrations from anatomical atlases, all offer a technological visualisation of the corporeal albeit in different ways. The pictures in anatomical atlases are what Villem Flusser (2000; 2011) calls "technical images", that is, images that are not representations of reality but instead act as further abstractions of scientific narratives, in this case the description of the symptoms and appearance of a disease. These "technical images" provide a schemata or a visual diagram and structure of scientific knowledge, rather than a depiction of unabstracted reality.

Digital x-rays, MRI images, and all digital radiology images for that matter, present a different type of visualisation that does not refer to a scientific narrative. Instead they adhere to the performative language of code and data. Anne Beaulieu (2002) argues that medical images and medical professionals working with them co-exist in the context of a paradoxical iconoclasm as physicians and researchers try to reframe the role of imagery from representation of the body to visualisation of medically significant data. She views this reframing as part of a controversial attitude towards images in the field of neurology and, in the instance of her specific research, brain imaging. The paradox of iconoclastic imagery underlying the field of radiology as a whole – that is, a medical field that is equally concerned with anatomy as it is with the physics of visualisation – points to the mutability of images and the multiple relations and dependencies imprinted on them.

As the neurologists in Beaulieu's study insist, medical images are first and foremost data (information about processes, patterns, and relations); this tells us a lot about the process not just of reading them and who makes claim over the knowledge of medical images but also much about the process of their production. This is especially true for complex radiology images like CT, PET, and MRI that are produced through computer visualisation of the data obtained by making different elements in the body react with intricate machinery. These images do not visualise the body per se, but rather, data from the body. The importance of this distinction lies in understanding what can be read in a body image and what can be inscribed in it. The physics of medical imaging reveal part of the complexity of this inscription (Bushberg and Boone 2012). The body is seen not as a singular entity but as a receptor and container of data that can be read into it, extracted from it and imprinted on it. In this process, the body is read through its inclination to allow certain interferences and to enter into certain relations. Its opacity and ability to absorb or resist x-rays produces x-ray images, CT scans and mammographies. In MRI scans certain properties of elements of the body, such as the reactivity of protons in hydrogen molecules in it, produce data that is extracted through reading the possible relations that a body can enter. As Joyce (2008) points out, early conceptualisation of MRI technology saw it as a tool for "mapping quantities in the body". This is an interpretation of medical imagery that helps to expand the notion of ontological multiplicity of the body by signifying its production through multiple relations and quantifications.

The understanding of the medical image as a visualisation of different relations and properties encoded on the body outlined above, reveals the complexity of a political economy of medical imaging. This political economy is not just pressed onto the body through the power - epistemological, institutional, and monetary - exercised via imaging modalities (Burri 2008; Burri and Dumit 2008; Joyce 2008); it is also exercised through the relations and properties that are imprinted on the body image as part of the process of abstraction and digitalisation in the production of radiological images. Radiology images do not only carry medical data. They contain demographic signifiers and data related to institutional and financial transactions within the healthcare system. This is an important clarification to make since analyses of medical visualisation and the interpretation of the body predominantly read the epistemological and ontological tensions produced through these practices as stemming from the relations of authority and power that are imposed through scientific knowledge alone, therefore ignoring questions about political economy. Nevertheless, these questions are part of the production and circulation of medical images. They are not only related to external factors that contextualise the image but also constitute a part of it; this is a relationship that is solidified in the process of the image's digitalisation.

Annemarie Mol (2002) discusses the notion of multiplicity of the body by proposing that the different ways in which the body is observed, diagnosed, and treated in medicine produce different ontological notions of what a body is and also, in turn, lead to different practices of interacting with this body. In DICOM, the multiplicity of the digital image as a specific visualisation of the body refers to the multiple statuses and properties inscribed onto it. Similarly, Marc Berg and Geoffrey Bowker (1997) link the multiplicity of the medical record to practices of inscription, categorisation, and quantification that constitute a particular mode of seeing and acting upon the body. They argue (like Mol) that the multiplicity in ontology of the body constituted through medical practices of inscription and manipulation, concerns an ontological non-singularity that is not only present in the sphere of discourse but also traverses the borders between discursive inscription and political practice. How the body is seen determines how it is manipulated; how the body is measured and categorised, determines the actions prescribed to it for recovery and treatment. This movement between inscription and practice, between the artefact of medical records or digital medical images and the practices they describe and prescribe, is of central importance for analysing the ontology of the image in order to understand the political economy it generates.

Going back to the vignette of the body pierced by pellets, then, it is clear on the basis of questions about standardisation, multiplication, visualisation, and political economy, that the image on the screen hides the complex digital infrastructures enabling the transfer of medical imaging data across continents. These are infrastructures that, in their technical properties and parameters, encode and black-box new regimes of visibility made possible through the digital medium.

Networked images

The question of how subjectivity is constituted and transformed through the process of digitalisation and outsourcing of medical images, is to a large extent situated within the process of production, circulation, and governance of these digitised images. Since the mid-1980s digital images in medicine have been the object of standardisation through the DICOM format which is now used almost universally by the manufacturers of medical imaging technology and systems for the display and transfer of medical images. DICOM codifies a format of the medical image that includes different aspects that are important for the medical image's inclusion in a network of connected devices that can take, exchange and display it. This means that the standard necessarily refers to different aspects of image production and diagnosis of the image. The DICOM file contains metadata about the physical properties of the digital image including size, grayscale conversion and compression; it also refers to events and roles in the healthcare system including the name and ID of the patient, the referring institution and physician, the radiologist reading the study and (if applicable) information about the patients participation in a clinical trial. The DICOM standard however, comprises thousands of pages of specifications describing not only how the data should be structured in files, but also all aspects of the process of the digital medical image's production, exchange and storage relating to both healthcare scenarios and network and communication scenarios. These different properties point to the ontological multiplicity of the images which, in the description of the DICOM standard, imply the connection between the "real world" model of DICOM and the machine readability of the images.

The DICOM standard, first published in 1985 as a result of the collaboration between the American College of Radiologists (ACR) and the National Electrical Manufacturers Association (NEMA), defines parameters for the image files used in healthcare. It also defines the structure of the data contained in the DICOM file and the terms of conformance that allow for the transfer of medical images across medical imaging equipment and health information systems. The process of developing this standard was triggered by a few developments in the field of medical technology. The Computer Tomography (CT) modality developed in 1970s had changed the landscape of medical imaging and analysis in multiple ways. CT together with other complex imaging modalities such as MRI that were developed in the following years increased the costs of imaging but also raised the stakes among actors that participate in the production and analysis of medical images. CT and MRI changed the possibilities of inscribing and reading the outputs of the imaging machines. While x-rays are purely pictorial representations, the new modalities also produce data outputs that are illegible for radiologists. As the DICOM website states: "it was very difficult for anyone other than manufacturers of computed tomography (CT) or magnetic resonance imaging (MRI) devices to decode the images that the machines generated, or to print them"

(National Electric Manufacturers Association 2017). This development which changes the notion of what is inscribed in an image and how it can be read, challenges the disciplinary boundaries of expertise over the interpretation of medical images; it thus poses a serious ontological issue for radiology. Kelly Joyce (2008) traces back the contestations around these questions that traverse professional boundaries, technological expertise, and issues of institutional power. Her work on MRI images and technology focuses on neuroscientists, a professional group which is in competition with radiologists for the recognised expertise to read medical images. This competition is not simply concerned with claims over medical knowledge. Rather, it involves very concrete stakes pertaining to the institutional and financial power of medical departments and professions, as Regula Burri (2008) describes in her analysis of the conflicts over CT and MRI technology in hospitals. The market for medical technology continues to be one of the most expensive and fastest-growing fields on the healthcare market, and the expertise in working with the machines and reading the images that they produce translates into vast investments of finance and other resources into clinical departments and a much higher workload for radiologists.

In this changing and competitive environment of claims over the expertise and production of medical images, DICOM has become instrumental in enabling different hardware and software to exchange images without loss or distortion of information. The initial partnership between ACR and NEMA that put the foundations of the DICOM standard into place (back in 1985 it was still called ACR-NEMA standard), established the parameters of specific relations that are enacted in DICOM. While NEMA, as a representative of the manufacturers of medical devices, is concerned network connectivity, file format, and interoperability, the needs of ACR demand that the DICOM standard reflects the clinical scenarios and administrative situations from their practice. This leads to the extreme level of complexity and detail in the standard which has to simultaneously describe and prescribe how data is exchanged and how this exchange reflects and in turn affects the clinical and administrative scenarios. In the earlier vignette where a patient image from a USA hospital is sent to Worldwide Teleradiology for instance, the DICOM image reflects aspects of the clinical and administrative context: patient ID; referring institution and physician; body part scanned; potential diagnosis as well as an indication of whether the case is critical. These components of the DICOM file trigger certain responses; the fact the image comes from an USA hospital means it must undergo the two-tier diagnostic process, the level of urgency instigates the deadline for diagnosis and drives the case up in the worklist, while the indication what body part is scanned determines the sub-specialty radiologist who will examine the image. Since 1983, when representatives of NEMA and ACR met to discuss the standard for the first time, the context of the clinical setting has stretched out to include numerous digital infrastructure systems; among them, the most important one for the development of teleradiology was PACS.

This development links medical imaging as a practice and process of knowledge production to a concept of "agnosticism" that has developed within the field of data standards. "Vendor-agnostic" or "vendor-neutral" systems is one of the hallmarks of digital data standards; it establishes the principles of neutrality, agnosticism and universality as the conditions for the growth of the market of medical devices and the development of medical imaging informatics in general. These principles, as some of the scholars writing on standards argue, reinforce a liberal model of technocratic and market-oriented governmentality (Barry 2006; Gibbon and Henriksen 2011; Ponte, Gibbon and Vestegaard 2011). The standard is meant to presumably remove obstacles to small vendors entering the industry market by ensuring interoperability between different brands of hardware. Keller Easterling (2014) notes for instance that the principles of non-hierarchical organisation and connectivity projected by standardisation initiatives contribute to the establishment of "smooth" spaces of expansionism and extractivism.

This smoothness in the case of DICOM is grounded within operations to develop the parameters of the standard; these parameters are in turn defined in accordance with hardware capabilities, quantification, and process diagrams such as those included in the previous chapter. In the first draft of the ACR-NEMA standard, the process of ensuring interoperability in the standard was already set in motion through quantifying the number of bytes and blocks of information contained in a DICOM file, and through describing the types of hardware interfaces and commands that can be used in the process of communication between imagining machines (Horii 2005). Later versions, as DICOM became more comprehensive and detailed, are often described by users as an almost insurmountable hurdle (Pianykh 2008); the paradox of the standard is that the more detail which goes into its development, the less accessible it becomes.

Seriality and temporality in the image

This DICOM format, which has become almost universal in healthcare systems around the world, presents a complex insight into how medical images are constituted in a digital environment. As Kelly Joyce (2008) contends, digital medical images are visualised data about patient bodies. However, the DICOM standard means that these images also contain data about the process of their production and the circulation of the files within digital infrastructures and healthcare systems. These data and the importance of readability of the image play a central role in establishing the standard. Rather than just one type of data where quantities and relations are visualised as patterns and gradients, DICOM files are complex assemblages of data referring to different properties and the contextual situating of the image. The DICOM header, which contains the metadata describing the image, includes technical specifications as well as demographic and healthcare information; it thus ties the technological properties of the file to signifiers related to the biopolitics of medical examination. But how exactly does the political get imprinted on the technological? This is the main question into which analysing DICOM gives an insight. It says a lot about the meaning of multiplicity of the medical image with respect to the notion of political subjectivity and the way in which a specific conversion between technological and political regimes of visibility takes place in the process.

As I pointed out earlier, the image itself is an assemblage of data that articulates a multiplicity of properties and relations. The logic of structuring these multiplicities into binary codes and a limited number of categories follows the logic of a "bound seriality" that constructs a body politic and a notion of political territory through the operation of categorising and inscribing. In his book *The Spectre of Comparisons*, Benedict Anderson (1998) argues that the imagined community of the nation state is produced through two types of operations of seriality – "bound" and "unbound". They both serve to construct an image of interconnectedness and belonging, but they do so in very different ways. While the unbound seriality works through narratives and representations, for instance in novels, newspapers and reports from the country that construct certain shared images and stories, bound seriality works through abstraction and by separating groups of people into categories along ethnic, racial, cultural and class lines for instance. Anderson sees the work of bound seriality in the technologies of the census, which defines political subjects through a finite number of categories with assigned values; this is a project of the nation state that is grounded in universalisation, totality and abstraction. We can see a similar logic of abstraction and totality in the format of DICOM data, where the files contain an inscription of the real world in a series of information object definitions (IOD). Some of these inscriptions refer directly to bound seriality categories of the nation state when identifying the patient: ID number; sex; date of birth; nationality.

To an extent then, DICOM refers to and repeats the ways in which embodied political subjectivity is inscribed within political territory through the technology of the census. It is codified through the demographic categories of the patient (National Electric Manufacturers Association 2015a), but it would be reductionist however to assume that DICOM simply transposes political categories of seriality from the nation state. Indeed, it would be hard to assume that the seriality with which DICOM operates participates in any notion of community similar to what Anderson (1998) sees as the framework produced by bound and unbound seriality. Instead what DICOM operates with, is the notion of interconnectivity and interoperability. It uses a technology of bound seriality to the extent that it works through the predetermined values of a finite number of categories that describe the actors, the actions they perform, and the technological context of their interactions. These tools of categorisation operate however, on a different technological and political plane. While the imagined community of the nation state uses the technologies of seriality and abstraction to construct parameters of belonging, the technological utility of DICOM seriality uses them to instigate protocols for connectivity.

DICOM adheres to an object-oriented ontological model of the world, which is used to define scenarios and objects that participate in them. It organises and defines data by placing them in different interrelated categories such as Service-Object Pair (SOP), Information Object Definition (IOD), and Information Entity (IE). A Service-Object Pair is a particular scenario for manipulating or generating data. The workflow diagram below for instance, depicts the SOP General worklist scenario; that is, the most general case of a patient being referred for a radiology study. The diagram includes different information objects (rectangles) and relationships between them (rhomboids). Each information object has an IOD which defines what IEs it includes, and what values they can take. The patient IOD, for instance, consists of the IEs name, sex, Patient ID, date of birth, ethnicity, as well as method of deidentification if the DICOM image is to be deidentified.

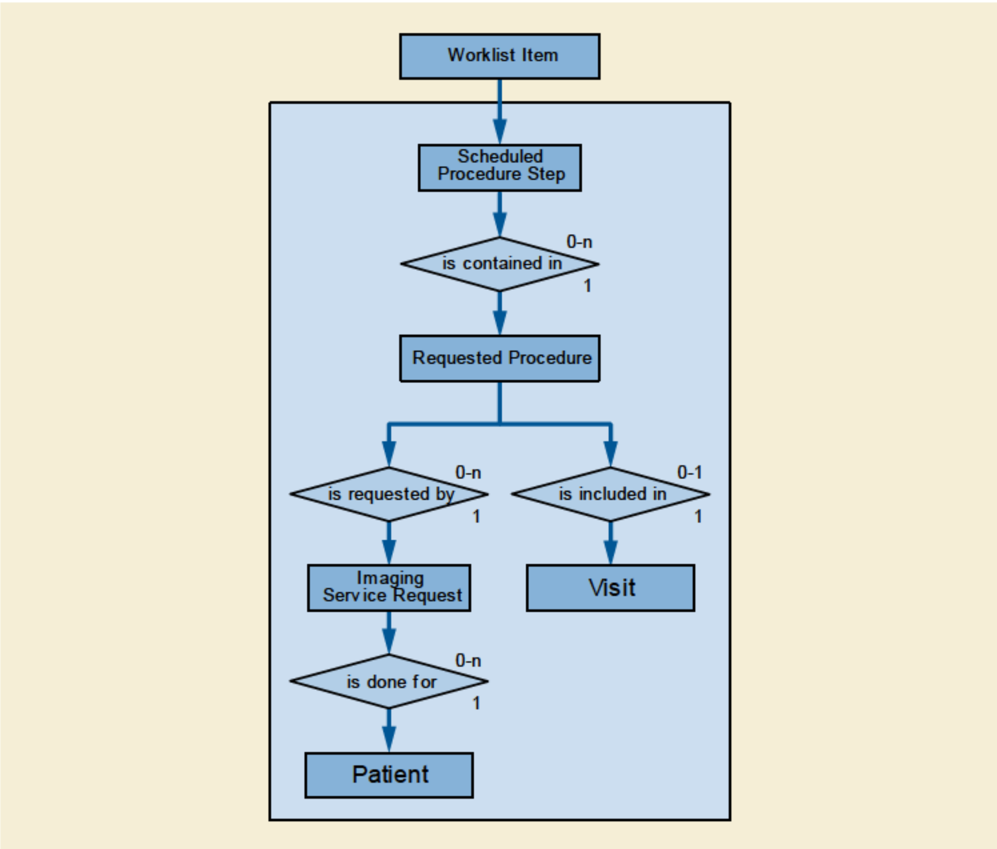

Figure 10 Modality Worklist Information Model E/R Diagram showing different information objects (IOD) and the relationships between them. Reprinted from National Electric Manufacturers Association 2020: fig K 6-1.

Table A.2-1. CR Image IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	CR Series	C.8.1.1	M
	Clinical Trial Series	C.7.3.2	U
Equipment	General Equipment	C.7.5.1	M
Image	General Image	C.7.6.1	M
	Image Pixel	C.7.6.3	M
	Contrast/Bolus	C.7.6.4	C - Required if contrast media was used in this image
	Display Shutter	C.7.6.11	U
	Device	C.7.6.12	U
	Specimen	C.7.6.22	U
	CR Image	C.8.1.2	M
	Overlay Plane	C.9.2	U
	Modality LUT	C.11.1	U
	VOILUT	C.11.2	U
	SOP Common	C.12.1	M
	Common Instance Reference	C.12.2	U

Figure 11 Computed Radiography image object definitions. Reprinted from National Electric Manufacturers Association 2020, Part 3, Section A.2.1

The Information Object Definitions (IODs) describe abstractions of attributes that refer to a specific class of Real-World Objects. They can refer to patients, studies, images and modalities, all of which are defined through a list of attributes, services and relations that can be acted upon. But these attributes and values do not refer to notions of community, unlike in the cases of bound and unbound seriality that Anderson (1998) evokes. Rather, the DICOM categories refer to the technical characteristics of data and how it can be exchanged, and to the processes of production and exchange of radiology images and diagnoses. This means that DICOM categories, in contrast to the categories used in the construction of political communities, do not describe commonality and hierarchy. Instead they describe the mutual embeddedness of information objects; that is, what information objects are made of and the sequences of events in information exchange.

In the documentation of the DICOM standard, this seriality is enacted through the combination of temporality and pluggability of IODs and SOPs, in a way that defines them relationally and which enables a combination of dependency between the embedded elements on one hand and flexibility on the other. The DICOM format anchors the demographic and contextual information to the image so that they cannot be separated by mistake during storage and transfer. This means a DICOM file is simultaneously an image as well as compendium of demographic data of the patient, data about the study and its institutional context, and data indicating what equipment took the image and the technological conditions of its production, readability, and transfer.

The file header also contains data that refers to concrete temporally arranged sequences of events, which take place from the time a patient makes an appointment. This reconstructs and simultaneously prescribes a standard for the sequence of hardware, movements and actions that become part of the complex inscription mechanisms of the DICOM image. Before discussing the importance of temporality in constructing the DICOM file and its specific version of seriality however, it needs to be pointed out that one of the key functions of this standard is to ensure a smooth transfer of data across different hardware and software systems in the healthcare environment. This means that the concept of demographic data co-exists with a different kind of population of accountable participants: that is, the equipment; the modality; and the image with its pixel, waveform, and signal attributes. This begs the question then: what kind of seriality can bind together these different planes? And, in a way, also: is the kind of abstraction and seriality to which populations are subjected through the census compatible to, or intersecting in any way with, the kind of abstraction that enables two digital machines to exchange data between each other?

The importance of temporality in the inscriptions in the DICOM file is key to understanding the differences between the type of seriality through which different populations are construed and the seriality that codifies the standard for medical images. There are two types of temporality here. Firstly, there is conformity to a common framework of time measurement that foregrounds the technologies of the clock and the calendar, which Benedict Anderson (1991) and Walter Benjamin (1968) both see as crucial for imposing the "homogenous empty time" of capitalism; secondly, there is temporality of patient management, which I turn to shortly.

The "homogeneous empty time" that Anderson (1991) and Benjamin (1968) conceptualise, constructs the conditions for opening up the subjective experience and connecting it to coinciding events and experiences. With the time/date stamps that accompany each file, the image is locked onto a canvas of standardised temporality that can be measured and understood across different contexts. The values of "time", "datetime", and "date" in the standard are universal formats that allow a radiologist in India to understand when an image was taken no matter where it was taken. They create the conditions of a shared notion of time and what Anderson and Benjamin call "synchronicity", that is, an awareness that things take place in a shared temporality which becomes the canvas for interconnectedness and comparability. In this sense, the DICOM file contains the abstraction of the standardised time of modernity, measured in dates, hours, minutes, and seconds. This abstraction points to the interdependency of standards that is intentionally sought after in DICOM files, in order to increase their scope of application and to ensure an economy of portability and interoperability across different domains; this is something that Susan Leigh Star and Geoffrey Bowker (2000) also note in their work on the mutual embeddedness of standards.

More significantly, the DICOM format captures another type of temporality that is concerned not just with synchronicity but also with sequences and chronological order. In the process of translation between the real world and the DICOM format, the documentation of the standard describes and prescribes the sequence of events that take place in the production of the image. This involves much more than the encounter of the patient with the imaging modality, as the standard relies on an abstracted model of what events are significant for the documentation of a medical image. It starts with the patient appointment through image acquisition and then includes the process throughout the diagnostic stage, the storage of the data, and the subsequent actions that can be performed on the file including queries, computer aided diagnostics (CAD), and audits. The moment when the image of the male body pierced with bullet pellets arrives on the screen of the radiologist in Bangalore from the USA for instance, marks only one stage of the sequence of events that are continuously captured in the DICOM file throughout the process of its production. The temporality captured by DICOM spans a period that starts with the visit of the patient and continues beyond the ready report to include the management of the radiology study which can include storage, auditing of the report, and future references. This temporality defines the sequence of events that should take place during a medical exam that involves a radiology study with different events also capturing the use of different digital systems. The HIS for example will record the patient visit and serve as a holder for the rest of the information to be collected by the imaging modality during the image acquisition and by PACS as part of the storage, transfer and analysis of the image. The temporality of patient management in summary, is a combination of workflow management and a sequence of hardware operations that are inscribed on the image, as the diagram below from the documentation of DICOM (Section 17) shows.

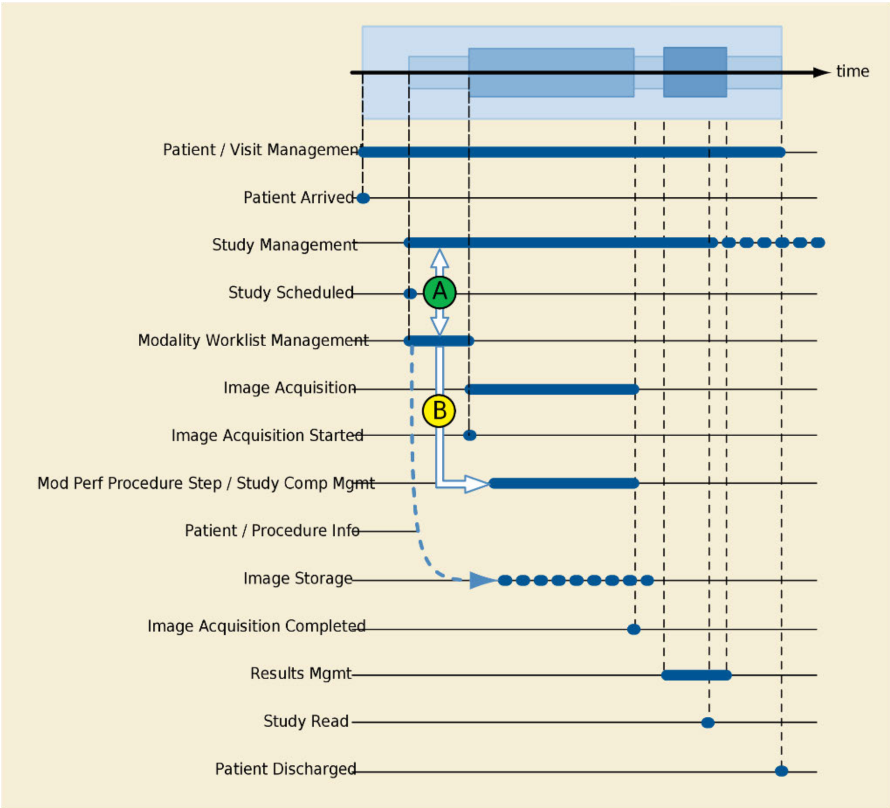

Figure 12 Functional View - Modality Worklist and Modality Performed Procedure Step Management in the Context of DICOM Service Classes. Reprinted from National Electric Manufacturers Association 2013, fig. B-1.

In this diagram we can see the way DICOM incorporates a specific temporality and a notion of sequence in its inscription of images. This temporality is defined through the DICOM service classes that refer to sequenced operations and relations between IODs that include: image acquisition, storage, and retrieval; patient appointment, scheduling and discharge; and image analysis and audit. This is a temporal sequence determined by the layering of a different timelines including administrative processes, the labour process of image production and analysis, and the temporal sequence of inputs and outputs between machines involved in the process. The importance of temporality and sequences in DICOM is not simply that they give a description of a sequence of events that an image goes through; rather they are also normative and prescriptive as they indicate the sphere of possible connections and transfers of data.

This normative and prescriptive aspect can be seen for example, in a DICOM conformance statement for Philips "iCT family" "Brilliance Big Bore "and "Ingenuity CT family" scanners running on the iPatient (4.x) platform (Philips Conformance Statement 2016). The conformance statement is a document that should accompany medical imaging hardware, in order to indicate what functions are supported by them and how they can transfer and receive images from other pieces of hardware. In this statement the temporality of connections is of crucial importance for establishing the input-output relationship between the technology in clinical settings. The sequencing described within it sets the "potential constraints" for how "real world" events can follow from each other (ibid.: 16) and appreciating the importance of these constraints is crucial for understanding the type of seriality that is at play in DICOM.

An important feature of this algorithmic affinity of DICOM is the codification of sequences and steps to be performed, which, in the words of the Philips Conformance Statement, puts "material constrains on what can be done when". This algorithmic governance technology (Aneesh 2009) embedded in the DICOM standard defines the scope and limitation of possible actions not only for the hardware that processes the images but also, through the hardware, for the work process and the labour involved in it. This has important consequences for the ontological and political meaning of the DICOM file. Ontologically, it appears that the multiplicity of the image is far more complex than just the different ways of seeing and visualising the body. Moreover, DICOM also introduces an ontological dissonance in the notion of medical image, through the role of temporal seriality and the sequence. In his work on Laocoon and the difference between visual arts and literary arts, the German Enlightenment scholar Gotthold Ephraim Lessing (1853) poses the treatment of time as a major point of difference between the two. Lessing argues that the genres of art deal with either temporality or spatiality. The image (in this case the painting) can only capture one single moment of an event, so its effect depends on the strategy of choosing the right moment. On the other hand, literature is a temporal art as words roll out and can depict a sequence of events. The DICOM image standard disrupts this genre distinction and the implications of this disruption go beyond a simple matter of genre identification. The disruption is crucial in the case of DICOM, because it problematises the notion of what the medical image is and how it can be analysed. It points to the specific economy of abstraction and representation that underpins digitalisation in the outsourcing of medical images and labour (Waldby 2000a, 2000b; Cooper and Waldby 2014; Flusser 2000). The radiology image presents an operation of abstraction that is enabled through what Flusser (2000) terms 'apparatuses' of the production of the technical image, which distinguish it from visual arts. This difference in the case of the DICOM image, is especially evident in the way it always contains and describes the process of its production and circulation. Thus the DICOM image cannot be analysed outside of its context of production, exchange, and manipulation, which constitute an integral part of the metadata elements that make this image.

The seriality in DICOM is linked to sequences of events and processes and the way in which meaning and identity are produced through them. Giles Deleuze (1998), in his short note on Boulez, Proust and time, sees the link between temporality, sequence, and seriality as a link leading to two important consequences: firstly the combinatorial nature of meaning in seriality, which implies that sequences in seriality produce certain meaning; and secondly the unstable nature of identity in this context of recombination. In DICOM, we see the significance of the sequence as an algorithm and seriality that produces meanings and implies control. All subjects whose identity is captured in the file metadata, acquire their roles and value (or attributes) in relation to the workflow processes in which they are included. Each information entity incorporated in the DICOM image format has its place there as a result of actions (that is, a study, being the patient of a study, diagnosing or performing a study) performed in the digital healthcare environment. Moreover, as I showed in Chapter 2, the workflow is far from a neutral sequence of such actions. Beyond their abstracted diagram representations, teleradiology workflows are ridden with hierarchies and negotiations of the status of different subjects. These negotiations of status and hierarchies affect the radiologists who can be placed in a different position of expertise according to the diagnostic workflow in which they participate, and they also affect the auxiliary workers, such as loaders, transcriptionists and workflow managers, whose roles are inseparable from the process of production and circulation of the radiological image.

The sequences of events captured in DICOM depict a flow of data between software, a flow of point-to-point connections between hardware, and the workflow that involves the labour of medical workers. This format is meant to be used primarily by engineers and developers of software for the image transfers between computers and between institutions. It provides two types of references for this connectivity: the data format of the image that standardises the way images and accompanying data are represented; and the network connectivity protocol that defines how nodes in the network will establish connection and confirm they "speak the same language" that will allow them to exchange DICOM files. DICOM provides guidelines and structures for how data should be formatted and communicated, but these guidelines are actualised in the instance of each separate point-to-point connection again and again. DICOM compliant machines need to verify and establish their adherence to a common protocol every time a connection is established for the first time. This highly technical operation, which in professional jargon is called the "DICOM handshake", ensures that the two machines that establish connection can both support the same functionalities and formats (Pianykh 2008). In the process the two machines identify each other and their respective properties, and they establish the potential for forming a pair connection between a service class user (SCU) and a service class provider (SCP). This specific process of identification is important for understanding the technopolitical field established through DICOM. The standard provides an exhaustive description of IODs, SOPs, values and attributes, and also prescribes chronological sequences of events; however, this is also a field that makes communication, identity, and validity possible through a point-to-point connection. As Alexander Galloway (2004) points out, this operation of mutual intelligibility between digital entities is crucial for the way that distributed network control works; in the case of DICOM, this control is exercised by excluding non-conforming technology and data formats from the connection. What does not conform cannot participate in the processes of production, exchange, and diagnosing of radiology images.

This property of the distributed network, where any relation of dependency is negotiated between each two of the nodes without the interference of a centralised hierarchical structure that facilitates and manages this connection, has important political implications. Florian Sprenger (2019) for example, discusses the political implications of distributed networks in mobile phone communication and location capture, in a way that draws productive parallels between technological and political concepts. He argues that the method of location capture in mobile communication, which triangulates the sending and receiving of signals to the nearest three cell towers, presents the solution for simultaneously capturing location and behaviour, which has been a long-standing problem for cybernetics. This problem is not only technological but also political, because it entails possibilities and limitations of control exercised across space and time over different entities that are autonomous of each other and which exhibit autonomous behaviour. What Sprenger points out, is that the technology of distributed mobile phone networks presents a unique solution to this problem by posing an equivalence between nodes and medium; this is that each node (i.e. mobile phone) continuously locates itself by registering itself on the network in a way that means to function is to be captured. This ontology of "addressability", as Sprenger calls it, is in turn part of what can be termed an ontology of "capture" that makes the act of identifying, through capturing and being captured in each instance of point-to-point communication, a precondition of existence.

This ontological condition of the network has crucial political implications because there is an important incongruity between the technological and political regimes of visualisation and capture. Sprenger, for example, argues that the mobile phone network operates within a logic and a field of power that is dissimilar to the notion of territory as geographical concept. In the case of DICOM, for which interoperability is a condition for existence, the network brings forth relations of connectivity and control that construct a specific topology of power and subjectivation that defines subjects through their participation in the production and circulation of radiology images. DICOM intervenes into existing demographic and institutional relations by placing them in the context of the process of production and reproduction of the radiology image. The sequence of actions codified by the standard, the different Information Object Definitions (IODs), the relations between these IODs and the attributes they can take, are all records and prescriptions of how the files are produced and exchanged. This constant actuality of the process of production and exchange show the extent to which the digital medical image cannot be separated from the relations of production it embodies. As I will show in the following section, the consequences of this dependency also mean that political categories and subjects can be affected and reconstituted through the production process of DICOM images.

Producing digital optics

DICOM allows for a different kind of optics that, as I discuss in the previous sections, disrupts the notion of the image as a representation in two ways. First, the process of visualisation introduces digital data as yet another level of mediation between the body and the final image and second, the data structure of the DICOM image captures the processes of its production and circulation and makes visible the political and economic relations behind it. This distinction between an image as representation and a political act is important for understanding how the digital image differs from an analogue image; it creates a distinction in the medium that entails more than a difference between continuity and discrete quantification (see Gerard 1951; Pias 2005).

The question of what exactly distinguished the digital from the analogue was one of the questions that preoccupied early cyberneticians. In the years after World War II the scholarship of cybernetics developed in the USA through the collaborations of different scientists and scholars. One of the arenas where this new scholarship was discussed were the Macy Conferences held in New York at the Josiah Macy Jr Foundation between 1941 and 1960. They gathered scholars from the sciences and humanities who would present papers and participate in interdisciplinary discussions. During the Macy Conference in 1951, after a talk on the nature and behaviour of synapses given by Ralph Gerard, von Neumann, Wiener, Bateson and others engaged in a heated discussion about the distinction between analogue and digital in biological and other systems. This discussion reflects on the distinction between analogue and digital as abstract and generalisable qualities of systems and patterns of behaviour; it suggests that this distinction is not only seen to be produced through a particular level of technologization but is also perceived to be produced through different patterns of behaviour and relations that (in the case of the digital) are more easily prone to quantification. In fact it is exactly this ease of quantification and what the early cyberneticians see as discrete quantitative difference between states in digital systems, that makes them ideal for encoding information.

Some of the points raised in this interesting debate can help us understand the complexities of the optics afforded by DICOM because they pay close attention to the mechanisms for quantification and measurement in the digital and also to the possibility for coding and transmitting information. The groups at this conference discussed what makes a process digital or analogue. Two points from the recorded conversation are worth noting. Firstly, the distinction between analogue and digital lies in the level of discretion as analogue processes are continuous whereas the digital introduces concrete units of measurement and quantification. Secondly, the digital is seen as an operation on the analogue, meaning that an analogue process can be made digital if we divide its continuum into discrete units. As Claus Pias (2005) explains, the distinction between analogue and digital that was debated in the early years of cybernetics entailed not just a discussion of different modes of organisation and transfer of information but also other discussions that were focused on the possibilities opened through a transition between analogue and digital, and the potential for control allowed through each of these media of organisation. The political significance of the digital medical image is partly rooted in this distinction and the possibilities opened by the new ontology of visibility that comes with digitalisation. The optics of data and digitalisation that underpin the DICOM image standard introduces a different scale and precision of observation; more importantly though, the difference it brings is in the ability to make visible new aspects and relations and through this act of doing so, it also creates the ability to bring these aspects and relations into the sphere of control. Orit Halpern (2014: 22) points out that one of the differences that digital data brings as a way of seeing and knowing, is precisely the potential of actionability that it contains. Similarly, Louise Amoore argues that the politics of visibility and making visible through capture, aggregation, recombination and analysis, are integral to the economy of digital data (Amoore 2006; 2018; Amoore and Raley 2017).

Temporality constitutes an important aspect of this different optics in DICOM; it allows the capture of relations and behaviour as they change and thus expands the territory of political action beyond spatiality and towards a political economy of processes, sequences, and time. The way this expansion operates across technological and political terrains is part of the mechanisms through which DICOM constitutes a new apparatus for subjectivation and control. Furthermore, the question of the possibilities of transition between analogue and digital that the early cyberneticians raise, is key to understanding how these different layers of control and subjectivation intersect. Here I focus on one example of conversion and transition between analogue and digital, that reveals the political meaning and implications of constructing a DICOM file as a technology of control that can operate on multiple levels precisely through the kind of optics that the digital allows.

In the beginning of 2017 when I visited Worldwide Teleradiology which works with hospitals in the US, Singapore, and Africa, the management excitedly told me about the new government tender they had won just a few months ago. The tender is for providing teleradiology diagnostics to remote rural communities in the state of Tripura, a small north-eastern state in India with a largely tribal population and a mostly mountainous and challenging terrain. Under the framework of the federal programme called

National Health Mission, the state government of Tripura is introducing telemedicine as a way of addressing poor healthcare services in some of the disadvantaged communities. The National Health Mission is a government programme that in 2013 succeeded the original National Rural Health Mission and the later established National Urban Health Mission; these were two initiatives founded as part of successive governments' commitments to secure health equity and build infrastructure that would reach some of the most marginalised populations, where illness and mortality rates are much higher than in more affluent urban communities (Balarajan, Selvaraj, and Subramanian 2011; Mudur 2005; National Health Mission 2016). In recent years the use of telemedicine solutions has become one of the key priority areas for achieving the ambitions of universal healthcare across India (Reddy et al. 2011). This is a development that (as I will show) has important implications for the transformations of governance and the operations of subjectivation enacted upon different populations.

This particular initiative, which lead to the first government contract for Worldwide Teleradiology, had to solve one of the common problems in rural areas; that is, the lack of trained professionals (particularly specialists) and to provide radiology diagnostics for 20 hospitals situated in rural regions of Tripira. Apart from the issue of insufficient medical staff (Teleradiology Solution cites data showing that 45% of the state healthcare centres in the districts are understaffed), the medical facilities have the necessary equipment for x-ray modality imaging, albeit analogue. Under the tender arrangements, Worldwide Teleradiology provides remote diagnostics for hospitals through a contract signed with the public company Webel Electronic Systems Ltd, which is a subsidiary of West Bengal Electronics or "Webel" (Jayadeepa 2019). Webel is also actively involved in projects for the digitalisation of people's identity and election participation which aligns surprisingly well with the digitalisation of medical images and the automatisation of the diagnostic workflow (as I will show). While the rates for the services provided to the hospitals in Tripura are much lower than those Worldwide Teleradiology gets from foreign clients – the contract between the government of Tripura and Webel quotes a rate of 73 rupee per image (National Health Mission 2016) – the arrangement makes up for the lower pricing through higher scale. This is a five-year contract and the management at Worldwide Teleradiology informed me and the number of cases is significant enough for the company to consider. The most interesting part of the arrangement, however, is the challenge of providing teleradiology diagnostics based on analogue images. This challenge has led to an important solution that also provides an insight into the meaning and consequences of the transition from analogue to digital that were discussed by the early cyberneticians.

The film images from the analogue machines are captured on mobile phones via the phone camera at the local hospitals and uploaded to the Worldwide Teleradiology home brand cloud PACS called "RADSpa". The medical or technical staff in Tripura also manually enter the metadata for compiling a DICOM digital image when uploading it in RADSpa. This metadata includes the patient's identity, sex, age and location, as well as the location of the medical facility where the images is taken. The new DICOM image then enters the PACS system of Worldwide Teleradiology where it is not only diagnosed but also subjected to a specific organising of information transfer and the labour performed in the transmission and reading of the x-rays. This conversion to DICOM is an important step that also allows for a new instantiation of the relationship between embodiment, visualisation, and political territory. While the CEO of the company referred to previous methods of low-cost digitalisation of x-ray images in his presentation (Kalyanpur 2018), the step taken to convert these images to a DICOM format is a unique solution for this partnership that does not replicate the previous studies that he was citing. Instead it goes one step beyond these methods by converting the analogue file to a format that can be incorporated in the company PACS that manages the workflow.

This conversion from an analogue film to a DICOM image has important consequences. One of the functionalities of all PACS is to enable the management of the workflow. When an image is uploaded on the PACS, its metadata is read by the system. It can then be allocated to the radiologist who is supposed to diagnose this particular case, depending on the medical issue and the location where it comes from. The PACS system, by using the DICOM data, enables the allocation of cases which in most software products is supported through a real-time workflow dashboard. The dashboard allows data aggregated from the incoming DICOM images to be processed and visualised for the workers managing the workflow. The visualisation via the dashboard shows when and from where a DICOM file has arrived, what the modality is, and the case of the study. It can also track the deadline for completing a reading and the available radiologists who can take the case.

I will focus in detail on the workflow management and the PACS system in Chapter 4. However, what is relevant to the issue of visualisation and digitalisation in the DICOM standard is that the notion of temporality discussed in the previous section is not only implicit in the documentation and conception of the standard, but also becomes operationalised in its uses. In the context of teleradiology outsourcing, the visualisation of the data through the dashboard integrated in the PACS system builds on a long history of labour management and workforce monitoring that has become more automated and managed by algorithms. This development of algorithmic management through software spreads in multiple industries such as logistics (Neilson 2018; Rossiter 2016), outsourcing (Aneesh 2009; Huws 2014), and platform work (Niebler, Altenried, Macannuco 2020; Wood, Graham, Lehdonvirta et al. 2019). The PACS dashboards fed with DICOM metadata play a comparable role of real-time surveillance and control over the labour process. They track the efficiency of radiologists' work in real time and monitor key performance indicators (KPI). The home brand PACS used by Worldwide Teleradiology (RADSpa) allows monitoring of the turnaround time of reports with an indication system that marks cases in different colours and shows whether a report is getting delayed. The time for returning studies to the hospitals in Tripura indicated in the contract agreement is 6 hours (National Health Mission 2016) which is much longer than the USA workflow, but nevertheless the workflow KPIs are monitored through PACS and referenced in the communication of the company, in order to show how the project has improved healthcare provision in the rural communities in question (Jayadeepa 2019).

The way in which indicators and data from the DICOM images are operationalised not just in the context of the workflow, but also in the context of governance instruments and federal state commitments to the health of the population, make Tripura teleradiology an interesting project. Ever since Narendra Modi came to power as Prime Minister of India 2014, the focus of governance in the country has shifted significantly towards digitalisation, especially the development of digital infrastructures and inclusion of different communities in these infrastructures and the services provided through them. A major role in this new vision for governance is played by the Digital India programme that Modi inaugurated: it promotes technologies of digital governance founded on digital identity of the population; the establishment of standards for data exchange in different areas; and the development and support for infrastructure for digital services and payments (Ministry of Electronics and Information Technology, Government of India 2015). Modi's vision consolidates and centralises the drive to digitalisation in India, although a lot of initiatives and infrastructures (including projects for telemedicine in Tripura) precede him (National Health Mission 2013).

The Tripura NHM telemedecine website describes the projects under its framework as "*a journey towards e-governance*" (National Health Mission 2013). This orientation towards a more comprehensive and encompassing project of digital governance has been integrated into the latest policy documents for a National Health Policy (Ministry of Health and Family Welfare 2017) where digitalisation and the adoption of digital infrastructure and services is one of the state's key recommendations and commitments (ibid.; Wadhwa 2019). Key policy recommendations include: the adoption of e-health services; the adoption of digital data standards in the field of medical data transfer; and the use of Aadhaar (the unique ID introduced in 2009) as an identifier in the healthcare systems. This context for the Tripura project reveals how some of the new ways to operationalise DICOM metadata are a tool for monitoring and governance. The use of the unique ID has been integrated into the contract agreement and the implementation of the project also includes the development of a web-based and publicly accessible dashboard that monitors status of the project in real.

As noted by scholars researching smart technologies and population data collection, technologies of data aggregation and visualisation are often deployed as a measure of securitisation and surveillance (Amoore 2014; Antenucci 2019). In the scheme of the Digital North East initiative which is part of Digital India, there is a clear imperative to capture identity and to use the database for different purposes of differentiation, valorisation, and control. Digital North East includes a variety of initiatives aimed at developing business process operations (BPO) capacity in the cities in the region, the infrastructure, and technological parks together with establishing digital services for personal identification, allocating government subsidies and cashless payment. The patient data (which is part of the DICOM metadata) is meant to include the now standard unique identifier called Aadhaar, which has been central to the formation of a new digital politics of identity within the country. This new identifier has arguably introduced a different relation and dependency between the state, its subjects and private capital, allowing for identity capture and valorisation by both private and public entities; this dynamic is seen by some as a new "transactional identity" (Jacobsen 2015; Chauduri and Koning 2017). In the North East regions which has been ridden with conflicts for decades however, identity and visibility is much more contentious. With insurgencies led by the Indigenous Naga people, and lately migration from neighbouring countries and Indian states, ethnic and religious identity has been at the centre of contestations and attempts of assimilation. Since 2016 these controversies were further reignited when a proposed amendment to the Citizenship Act threatened to declare a large number of people of Muslim and indigenous faiths in the North Eastern states illegal, if they could not produce proof of Indian citizenship from before 1971 (Kamei and Rahman 2019). This new initiative of the government is part of a larger process of introducing digital identity, which is often accomplished through making the access to social services conditional on the use of Aadhaar (see Cohen 2016).

This dashboard that is hosted on the Worldwide Teleradiology company domain provides statistics for two types of data; firstly the efficiency of the workflow of the company, and secondly the number of cases received, diagnosed and in process of diagnosis. This type of data is visible in the upper part of the home page of the dashboard and also in the TAT (turnaround time) statistics that indicate the percentage of studies that have been reported within the agreed upon TAT (see Fig. 13). This dashboard thus affords a new aspect of visibility through the digital formatting of the DICOM images; but much more pertinently, it also links the notion and practice of visibility that the image affords back to practices of governmentality, control and care for the population.

Figure 13 Tripura Teleradiology Dashboard. Home screen. Screen capture from the website. https://tripuradashboard.telradsol.com/#/dashboard/home

The rest of the visualised data in the dashboard shows real-time information about the health status of patients in different districts, displaying the number and type of cases received over a certain period (which ranges from statistics for the current day to statistics for the whole duration of the project), as well as the number of critical cases. This type of visualisation, which differs from the visualisation that generates the radiology image itself, relies on the extraction of information from the metadata in the DICOM file. This information does not produce a medical image, but instead generates a new kind of optics concerned with control and transparency that links the demographic metadata of patients to metadata pertinent to the temporality of the diagnostic process. This is an important consequence of the transition to DICOM files that operate on different levels, producing different optics and visibilities through its different components. While the file data generates the visualisations of medical images for instance, the metadata can produce a different type of visualisation. These two different types of optics are very different. In principle, there is no difference in substance between the type of information that can be included in data structures and the type that makes metadata. The distinction is a matter of relation however; metadata describes data, it provides contextual information about the information carried by a digital object, but this relational difference opens the possibility for very different types of afforded visibilities through the optics of either data or metadata. While the data in the DICOM file produces an individualised object, that is, the image of a single patient, metadata, as Matteo Pasquinelli (2015: 14) argues, refers to "the collective and 'political' nature that is intrinsic to all information". Recently, other scholars have further argued that new big data analytics technology destabilises the distinction between individual and collective (Cohen 2019; Amoore 2014; Mittelstadt 2017). Pasqinelli's argument can certainly be extended to data as well. However, in the case of the use and circulation of digital medical images in Worldwide Teleradiology, we can see that the aggregation, analysis, and visualisation of metadata does indeed open up the possibility for a different type of optics that diagnoses collective subjects - labour at the company and patients in Tripura. The dashboard displays an integrated real-time visualisation that tracks both the cases of patients at different centres, their age, sex, and health complaints, as well as the performance of the teleradiology team of doctors in Bangalore.

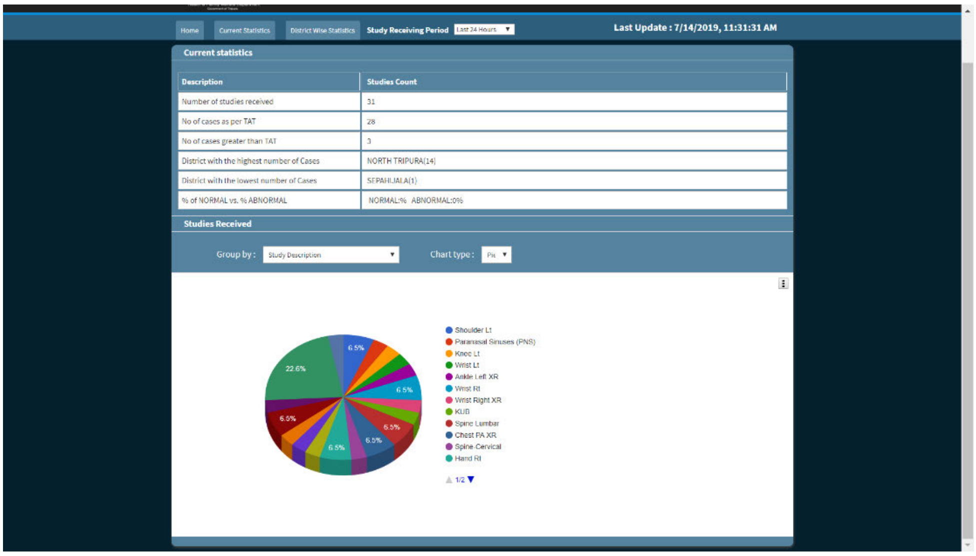

Figure 14 Tripura Teleradiology Dashboard. Current statistics screen. Screen capture from the website: https://tripuradashboard.telradsol.com/#/dashboard/current

While the Tripura Teleradiology dashboard presents an aesthetics of real-time observation of the inner workings of the project, it is worth asking: what exactly is made visible here, and to whom is it made visible? Shannon Mattern (2015) writes about the history of the dashboard, noting that as a technology and as an interface, the dashboard, in addition to giving an insight into the inner mechanisms of a system, can often serve to control what is made visible and how it is presented to the user (for similar arguments see Kitchin, Lauriault, and McArdle 2015; Tkacz 2015). In the Tripura Teleradiology dashboard there is a clear attempt to visualise an account of the epidemiology of the population, while simultaneously presenting the dashboard as an interface for transparency; this constructs it as a tool for public and open control and insight into the public-private partnership (PPP). This visualisation allows certain narratives to be made visible and seen while hiding other arrangements and power relations. The narrative of universal health care and the commitment of the Indian state to the health of the population, is one of the core narratives that are put on exhibit through the dashboard. As I already pointed out, the National Health Mission, the institution commissioning the project, is instrumental in articulating and implementing these commitments of the state. Within these commitments towards universal healthcare that are especially targeted towards marginalised populations, there has been a strong push towards the development of digital healthcare systems such as HIS. The digitalisation of healthcare is one of the strategic goals laid out in the National Health Policy (Ministry of Health and Family Welfare 2017), along with the adoption of data standards in the field of medical informatics. This includes the adoption of DICOM along with other international standards for electronic health records (EHR) and transfer of data within healthcare systems (HL7).

DICOM and the rest of the digital infrastructures put in place and envisioned through these policies, become incorporated within the optics of the state and its technologies of "seeing", following James C. Scott (1998) who describes the optics of governance through the concept of "seeing like a state". In this regard, Scott is talking about the organisation, quantification and standardisation that are put in place by state institutions in order to impose a particular and totalising model of modernity and progress (ibid.). In this sense DICOM enables a technology of visibility that renders subjects, statistics, and relations visible in ways that an analogue image and analogue medium would not permit. Each patient in Tripura who becomes part of the project by seeking radiology diagnosis is instantaneously made visible on the dashboard and logged in the project database. The real-time dashboard immediately exhibits the number of patients and the types of ailments they are seeking help with, providing an optics of governance of the population that is particularly poignant in the context of a heightened focus on the north-eastern states.

The politics of the teleradiology dashboard enabled through the DICOM file standard are complex and not exclusively concerned with securitisation. They combine the focus on transparency and accountability set out in the contract agreement (National Health Mission 2016) where a real-time dashboard is required to publicly monitor the performance of the contractor, with the developmental commitments of the Indian state. This combination shows that the process of digitalisation does not merely make it possible to transfer images from the hospitals in Tripura to the office of Worldwide Teleradiology in Bangalore, but instead that it also enables new possibilities for identity capture and control. These new possibilities are articulated through the transparency and real-time temporality afforded through the DICOM-powered dashboard. Orit Halpern (2014) notes that the notions of smartness and control that developed in the history of cybernetics and which continue their existence in smart technologies for monitoring and visualisation, transcend idea of being rendered visible by building on a notion of temporality of real-time feedback that attempts to shorten the loop between being captured and being made visible. In this context the focus on temporality made possible through the DICOM metadata expands the significance of temporality, visualisation, and seriality that was discussed in the previous section, through the technological materiality of sequences and connectivity.

While the Tripura teleradiology dashboard makes the accountability of health institutions and private contractors visible, it invisibilises both the contentious issue of identity in the North East region, and a newly emergent operationalisation of identity in the context of digital images. This new use of digital patient data is located in the same office building where the Tripura images are read by the Worldwide Teleradiology doctors, taking place two stories above in the office of daughter company TeleRadTech which is developing the in-house PACS called RADSpa. In recent years the company also started developing AI tools for automated image diagnostics, which will speed up the diagnostic process. The images from Tripura have an important role in the development of these new tools for automation; they provide the high volume of imaging data available for training the algorithms. As the founders of Worldwide Teleradiology explain in a feature article on science and digital technology in India, "[w]orking in the area of public health brings with it the advantage of gaining deep insights based on the large volumes of radiology data available" (Holla 2019: 34). The large sets of DICOM images from the Tripura project and from other philanthropic projects through which Worldwide Teleradiology provides diagnostics to marginalised communities, enable the AI algorithms to be trained to recognise patterns, therefore assisting with diagnostics that are later incorporated in the software products of the company and used in its own workflow. Such use is restricted in the case of images outsourced from other countries for which (unlike in the case of Tripura) there are restrictions on where they can be stored and (for privacy) what they can be used for. These new relations, generated through the possibility of AI and big data analytics, are however also articulated through the notions of public health and population epidemiology which rather than being just a discursive gesture, point to the ways that technological configurations reverberate onto political categories. This also complicates the actors involved in processes of capture and subjectivation; that is in this instance, that the "seeing" agents are not just the state, but also the company and an imagined collective subject of public monitoring and control.

This new operationalisation of data, identity capture and visualisation complicates the boundaries between political and technological regimes of visualisation. The technological affordances of DICOM data and metadata allow for interventions in political regimes of seeing and moulding subjects. The mutual articulation of technological and political modes of control and organisation makes it possible for the state of Tripura to articulate the political control over its subjects through the DICOM-powered real-time dashboard, while also enabling Worldwide Teleradiology to redefine its business model for new AI tools through the politics of public healthcare. Importantly, the optics of control afforded through the structure of the DICOM file also enable a type of dual optics that brings different subjects (patients as well as radiologists) together into visualised and instantaneous technologies for management, value capture, and automation.

Conclusion

In conclusion, and in order to sum up the arguments of this chapter, the example of the real-time teleradiology dashboard in Tripura provides a vivid illustration of the ways in which new modes of control are enacted and old ones redefined, through the medium of the digital medical image. The possibilities that the materiality of the digital medium affords allow for the imposition of new and more penetrating modes of control. Identity capture and real-time statistics construct an optics of governance that complicates the notion of visualisation as control, because they open up new possibilities for valorisation of identity but also enable the construction of interfaces such as the dashboard that can serve to both reveal and obscure relations of power and enable narratives of transparency and accountability.

Furthermore, the digital medium of the image which is subjected to standardisation through DICOM allows for intersections between political, technological, and economic power to be exercised through a digital optics of control. It structures and organises data, connectivity and workflow, which are three central points of control that instigate the conditions of governance in a society increasingly mediated through digital networks. As I showed in this chapter, the significance of this mediation lies in the core role of digital media in organising the material conditions of the production and circulation of information, value, and means of governance. As DICOM standardised images increasingly underlie and precondition the organisation of radiology diagnostics and healthcare systems, they become essential for articulating how labour and populations are managed and cared for. The DICOM images also allow for new transpositions of power; the state of Tripura exercises its governance of populations through rendering the management of labour workflows visible at Worldwide Teleradiology for instance, while the company itself develops new models for value extraction through its temporary custodianship over public health data. Such a travesty of relation is made possible because of the ways in which digital infrastructures – networks, data structures, and standards – generate new political categories and transform existing ones.

Of these new categories, as I show in the chapter, the newly emergent notion of seriality is of central importance. It introduces a new temporal aspect to the ways in which a field of techno-political power is constituted and the ways in which its actors and subjects are accounted for. It makes the sequences of processes and the necessity of connectivity within the network a condition for both being visible and being controlled in a digitalised field of healthcare. Temporal seriality, capture, and the network, constitute a new context of political subjectivation. This is a context where subjectivation and visualisation do not refer to a body politic corresponding to a single and monolithic political territory, but rather to a territory that spreads across different layers of technological and political spaces. These layered territories include the network itself, the digital infrastructures of DICOM standard, and the systems used for transfer and storage of the images. They also include however, the specific territories of control of the Indian state and the teleradiology company, which can and do intersect on the field of digital visualisation. The important consequence of these intersections is that they condition the ways subjects participate in different ecologies of power and recombine within different constellations of power, subjectivity, and valorisation.

Chapter 4: PACS and topology of archives

The economy of PACS

As I indicated in the previous chapter, the development of the Digital Imaging and Communications in Medicine (DICOM) standard for radiology images is closely linked to the development of Picture Archiving and Communication Systems (PACS), which are discussed in more detail throughout this chapter. PACS is a generic name for the configuration of hardware and software components that are designed for the transfer, viewing, and storage of medical images. It consists of the imaging modality (the machine that produces the image); the network through which the images are transferred; the DICOM viewer software and the special radiology display; the archive where the images are stored and the software system that enables the exchange of data among these components. The development of PACS dates from the 1980s, although the work on the development of digital systems for the transfer of radiology images first started to emerge in Germany in the late 1970s (Lemke 1979). This development is marked by a central concern with the possibility of transfer and storage of radiology images. PACS came to replace the pre-digital transfer and storage of radiology films; the latter was organised around a different medium requiring physicians to move around the clinic in order to see the images and it also involved a different, tactile way of seeing and diagnosing the images by holding them to the light and turning them around. The new digital systems proposed and developed throughout the 1980s responded to the conditions and possibilities opened by the new digital medium that allowed for remote transfer and a different kind of manipulation, storage, and optics of control.

The development of DICOM and PACS are interlinked in a very specific way - DICOM defines the "language" through which different components of PACS communicate with each other and exchange data. The standard for communication of medical images also aims to enable PACS elements used by different brands to connect to each other and exchange information using DICOM. Similarly to other standards, PACS acts as type of infrastructural space that Easterling (2014) calls "extrastatecraft", where technologies of governance are tightly linked to the materiality of the production and circulation of goods, information, and services. PACS exercises power over manufacturers and users not through legal regulations and state power but through voluntary conformance; in this instance it is pushed as a necessity for participating in the market of medical devices and provides the universality in semantics and materiality that enables the expansion of this market.

The market for PACS is dominated by big players like Fuji Film, Agfa, Phillips, Siemens and GE Healthcare who also manufacture hardware for imaging modalities (such as digital x-ray, CT scan, MRI, and PET scan machines) as well as the viewing stations (monitors) for radiologists. All these modalities come with their own software component consisting of algorithms through which the images are generated, and data is pushed and pulled to and from the network. Before DICOM, interoperability between the different PACS components meant that all the hardware elements had to be produced by the same vendor. The wider interoperability that DICOM affords has made the market for PACS more diverse. While PACS historically assisted development of medical imaging informatics in reference to the whole configuration of software, hardware, and networking elements (Huang 2003; 2011), today PACS refers more often to the software system that links the different hardware that radiology departments use. This decoupling of software and hardware has allowed new players who are not manufacturers of imaging modalities to offer PACS as a software product, including teleradiology companies themselves.

Two of the teleradiology companies I visited have developed their own PACS. One reason why companies develop their own PACS is that in a large enterprise it ultimately pays off to use their own product. More importantly than that however, PACS also becomes a vehicle for these companies to peruse various new business activities. Omniscan Teleradiology is selling its PACS with the added benefit of second opinion consultations from its own pool of radiologists, thus incorporating the labour of its employees into the functionalities of the digital product. The other company, Worldwide Teleradiology, has a sister firm that is exclusively working on the development of PACS not just for the radiology department but also for cardiology, veterinary clinics and clinical trials, as well as an interface for patients to access their radiology images. The software company arm of Worldwide Teleradiology also actively works on computer aided diagnosis (CAD) and AI features of the products they sell, making use of the vast archive of images at the company's disposal. These archived images contain valuable information including data about the appearance of different pathologies that can serve as the basis of machine learning programmes and include the added value of the expert labour of the radiologists working for the company. Their diagnoses are incorporated in the metadata structure of the files and they contribute to the development of automated diagnostic tools that use a combination of image pattern recognition and the expert classification of images that have already been performed by the radiologists.

This new context of CAD and AI incorporated within PACS, creates the conditions for an emergent economy that capitalises on the cognitive labour of radiologists twice, once through the service they provide to hospitals, and secondly by using this labour as a resource for the development of machine learning algorithms for automating pattern recognition in radiology images. This model of valorising cognitive labour as a resource is conceptualised by authors like Carlo Vercellone (2008) and Kean Birch

(2020) as accumulation based on rent profit, or as Birch calls it "technoscientific rent", that extracts value from the interactions of users with technology. As I demonstrated in Chapter 3 through the example of the Tripura teleradiology project, this economy of technoscientific rent is increasingly becoming part of how digital infrastructures in teleradiology are used to accumulate value; this is done by turning both patient data and the labour of radiologists into a resource for the development of machine learning and big data analytics solutions that can in turn become marketed as new commodities. The archive as a core components of PACS (which is discussed in detail in the next section of this chapter) plays a key role in enabling the development of these new economies of accumulation.

Radiologists can also be involved in PACS development through the feedback that they give to manufacturers. One such example from my fieldwork is the collaboration between the radiologists from a well-known oncology hospital in Bangalore called Healthcare Global Enterprises (HCG) and Siemens. The radiology department at HSG diagnoses both patients of the hospital and patients from other healthcare institutions in India and abroad. It is not a big department; there are just four workstations for viewing and reporting images. However, apart from providing diagnoses for the patients it also serves as an important part of the Centre for Excellence established in partnership with Siemens (HCG and Siemens to collaborate 2011). Under the conditions of this partnership, Siemens exclusive provider of technology for radiation oncology for the hospital. In turn, HCG receives access to the newest products of the company, continuous maintenance, and its radiologists participate in the research and development phases of the software. The partnership extends beyond the radiology department with systems for real-time analytics and treatment customisation. The research and development (R&D) collaboration between HCG and Siemens tests and provides feedback on the functionalities of a whole system that consists of: the imaging PET-CT scan machine manufactured by Siemens (which comes with Siemens developed software); the desktops produced by the same company; and a PACS system developed by Siemens. At the radiology unit however, the collaboration focuses on the functionalities of PACS and specifically those of the DICOM viewer.

During my visit to HCG in December 2016, one of the engineers from Siemens was sitting and observing the work of the radiologists, diligently taking notes. He was a part of the team developing this software upgrade for the Siemens viewing station and imaging equipment and was accordingly recording feedback and any difficulties that the doctors might have with the new upgrade. The engineer was called in that day because the doctors could not find some of the images in the cardiology function of PACS. This breakdown in the functioning of PACS within the department not only makes the digital infrastructure temporarily visible but it also sheds light on the multiple actors in producing and analysing the images. The development team of Siemens has now been entirely moved to Bangalore, although some of the functionalities, like neurology, were previously developed in the United Kingdom. The current team had undergone four months training in Oxford so they could take over the work done there. The scientific research team is based in the USA and the feedback that is provided by the doctors at HCG is combined with the feedback received from all around the world, then the science research teams and the product managers make a decision which changes and suggestions to be incorporated in the update or upgrade. This transnational production chain for the digital infrastructure also incorporates the HCG radiologists, who provide unpaid research input by sharing their feedback on the use of Siemens PACS.

The visit of the Siemens researcher also provided him with a rare occasion to get a glimpse of the functionalities of GE (General Electric), which are considered by the radiologists to be better than Siemens in many aspects. Some of the feedback Siemens had received previously from HCG was based on their radiologists' experiences with GE, who suggested that Siemens should add coloured option for some of the images, similarly to the GE DICOM viewer for example, which highlights different metabolic processes in the PET-CT image by using different colours. This feedback mechanism introduces a specific workflow in the production of the hardware and software used in the industry that incorporates the invisibilised labour of radiologists' feedback and the negotiations between engineers and doctors in defining what the images should look like and how the digital systems should be used.

This global process of developing and customising PACS is partly motivated by the lower costs of labour in India, where engineers do the same jobs as their colleagues in the United Kingdom but for significantly lower wages. The partnership also gives Siemens the opportunity to collate data from user from different regions across the world and develop a product that is not too locally biased. The issue of transborder use and development of PACS is much more complex than the problem of customisation however, because this also provides insight into the ways in which considerations about digital infrastructures, data provenance, and network connectivity are inescapably situated within concrete topographies and topologies.

While the other two infrastructures I am analysing in this dissertation – DICOM and HL7 – develop in coordination and under the centralised governance of a standard-setting organisation, the development of PACS is very local and to an extent parochial. The early days of PACS development were marked by distinct projects in different countries, where medical institutions and specialists in digital communication technologies started initiatives to build infrastructures through which digital images could be exchanged, stored and viewed. These initiatives dating from the early 1980s developed separately in Europe (Lemke H. 2011), USA (Huang 2011) and Asia (Inamura and Kim 2011). In Europe PACS was developed in collaboration between academic institutions and private companies with a prominent role performed by

Siemens in Germany, Austria and France (H.U. Lemke 2011). In Japan and South Korea, the research on PACS was similarly dominated by academic institutions (Inamura and Kim 2011), while in the USA it was undertaken in partnership between medical institutions and the Department of Defence (Huang 2011). These significant differences handed a major advantage to the USA where the resources made available through the Department of Defence were far exceeded those available for PACS development in Europe or Asia. As I discuss further in this chapter, the role of the military in the development of early PACS in the USA also provides an insight into the role of PACS network architecture, which serves to establish very particular type of connection, linking separate sites to the exclusion of their surroundings. In the case of early USA military developments, the network architectures for the transmission of images were established against the backdrop of foreign and hostile environments in war zones and remote army bases; this is a model that I will proceed to argue points to the continuing legacy and relevance of the secure network in PACS, as a technique of selective connectivity.

The issue of the image archive and the question of data provenance in teleradiology are similarly contentious subjects that underline the role that political topologies and geopolitics play in the transfer of medical information. The question of how data is organised, and where it is located is one of the foregrounding problems that have driven the development of PACS from the early days. As I will show, the archiving and storing of the radiology images traverses complex issues of knowledge organisation and the management of labour through digital infrastructures.

In the following sections, I investigate how PACS develop and function by historicising and situating politically their different components. In 'Circuits of liability and the management of risk', my analysis focuses on the entanglements between the management of data, risk, and finance and the mutual translatability and dependencies between them. This section is followed by an examination of the archive as a core functionality of PACS in 'Flow and archive', which links together its organisational use in standardising medical work to the technological role of storage and archiving in network connectivity and processing of information. I conclude the chapter with a historical analysis of the early military development of PACS in 'Topology, logistics, data', which shows how the technological affordances of the archive and the network intervene into and mould global political terrains.

Circuits of liability and the management of risk

In Chapter 1 of this dissertation, I initiated the discussion of teleradiology through a focus on the way radiology labour and its mobility are organised and managed through infrastructures of expertise. As I showed, these infrastructures create specific conditions for inclusion and exclusion of radiologists within national regimes of expert labour. In this chapter, PACS offers an opportunity to explore how the data that radiologists handle as part of their work circulate and are managed within the digital systems for transfer of patient images and diagnoses. Transferring medical data across borders inevitably carries risks and thus constitutes a central element of how the provenance of radiological images and patient information are regulated. In his seminal work on the risk society Ulrich Beck (1992: 19) writes that the management of scarcity and the management of risk follow categorically similar logics of establishing what good governance is. The management of risk is closely related to the production and regulation of expertise in society and the way that experts acquire a key role in the operations of classification, categorisation and quantification that determine notions of risk and how it can be controlled and prevented (Mitchell 2002). Risk functions as a "market device" (Muniesa, Millo and Callon 2007) that helps establish, contest and renegotiate the limits of what the radiology market constitutes; it does this by framing certain practices as risky and attempting to exclude them from the scope of legitimate and trustworthy practice. Risk works through the categorisation of territories and labour, deeming some territories, subjects and relations more unsafe than others. In this categorisation finance and data remain closely linked to a rigid political geography defined by the borders of nation-states.

As I will show in this section, the practices of risk management link digital radiology data to concrete concepts and embodiments of locality. The notion of locality is problematic however, especially when it concerns the question of storing and transferring digital data in the practice of teleradiology. Where medical data is located, how it is transmitted to the radiologists and how this process of transmission can be managed and safeguarded, all inform the development of the two key components of PACS, namely the archive and the secure network that I will discuss further. Before I do so however, I want to first focus on the question of how the location of digital data is determined in the process of teleradiology outsourcing, and how the importance of location is conceptualised and linked to practices of risk management and data sovereignty.

The complex configuration of different definitions and practices of risk and risk management is linked to the multiple actors taking part in negotiating the rules of practice. Apart from the professional associations like the American College of Radiologists (ACR) and the Royal Australian and New Zealand College of Radiologists (RANZCR), practices and risk management are regulated through medical insurance bodies who are thus another important group of actors. In the USA state mandated health insurance schemes like Medicare do not cover international teleradiology (Centers for Medicare and Medicaid Services 2014). Medicare billing also requires imaging diagnostics providers to be registered at the location where they physically work in order to organise the reimbursement of treatment (Kalyanpur et al. 2008). This means that international teleradiology cannot be reimbursed by Medicare and there are a number of cases where images cannot be sent overseas for diagnosis due to these restrictions being imposed through specific financial flows. The European Economic Area (EEA) has more flexible and relaxed rules of reimbursement; however, it generally applies the principle of a common economic space and allows parties in a teleradiology service provision contract to choose the country legislation that is going to apply (European Commission 2008; European Society of Radiology 2014; Raposo 2016). What transpires in these different cases nonetheless though, is the complex role that financial flows play in determining the scopes of territories within which the transfer of teleradiology data and diagnosis can take place.

The role of financial liability in limiting the scope of permitted data mobilities is especially pronounced in the 1996 USA Health Insurance Portability and Accountability Act (HIPAA) which is one of the major legislations used to regulate the outsourcing of teleradiology from this country. HIPAA mandates numerous regulations for the provision of healthcare and the transferability of health information, for the purposes of continuing the insurance coverage of workers who switch to new insurance providers. In 2005 and 2006 HIPAA was amended to include provisions for the security and privacy of electronic medical data, making it the main regulation reference point for organising the privacy and safety of data storage and its transfer in teleradiology services for the US. In this respect, HIPAA also demonstrates the dependencies between data, financial relations within the framework of healthcare insurance and transactions, and the way that data and financial relations are both put into use for the purposes of risk management and practices of bordering.

When I visited Worldwide Teleradiology, a note on the door leading to the shopfloor indicated that the space was HIPAA compliant and prohibited the entry of non-authorised persons, thus exhibiting the significance of the data privacy jurisdiction for enacting practices of bordering. In this case, the shop floor of the company was explicitly marked as adhering to the USA regulations, circumventing national borders and instead being subject to what Saskia Sassen (2013) sees as emergent territorial formations defined by the force of financial and trade jurisdictions. The company has to comply with the HIPAA regulations and it undergoes regular audits of compliance in the three aspects of data protection – physical, organisational and technical – that HIPAA regulates (HIPAA Journal 2016). These rules require Worldwide Teleradiology to ensure that: physical access to the office is controlled; patient data is protected with passwords and levels of access; and that the company enters into contractual relationships with the US hospital that make it subject to the authority of HIPAA.

All international subcontractors must sign contracts making them business associates of the USA hospitals they work with; this is a status that gives HIPAA the jurisdiction to monitor their adherence to the Act. Data, finance, and risk are interlinked in the HIPAA provisions in a way that does not only affect the contractual relations of companies. It also poses standards and requirements for: the type of network connection; the position of computer screens which should not be visible to unauthorised people (Edemekong, Annamaraju, and Haydel 2020); and for documenting the configuration of all network components (HIPAA Journal 2016). Maintaining HIPAA compliance is crucial for Worldwide Teleradiology because this secures its continuing contracts with the USA hospitals. While these measures on their own are not exceptional - protecting data with passwords, controlled access and network security is not limited to HIPAA recommendations, the fact that Worldwide Teleradiology must undergo regular audits from HIPAA officers demonstrates the way that the Act functions as a mode of regulation defining a specific technological zone (Barry 2006) that determines practices and roles, and which extends outside of the territory of the USA. As Saskia Sassen (2013) illustrates, the nation state and its institutions can be operationalised in processes of bordering and reterritorialisation that are not synonymous with the notion of state sovereignty; thus, the state itself takes part in construing new political and economic territories that do not coincide with its borders. In the case of HIPAA these complex dependencies between state sovereignty and other forms of bordering are evident in the fundamental primacy of the conditions of financial reimbursement in determining the rules of data provenance. Rather than working through notions of political membership and belonging, the regulation of data privacy instead serves to construct relations of financial liability and risk.

The example of insurance reimbursements in the USA and the way they determine the possibilities of bordering and inclusion shows that financial flows move differently and this difference has interesting implications for the transfer of data in outsourcing. While Medicare requirements anchor the liquidity of cash to the fixity of national space and do not allow cross-border teleradiology diagnosis, HIPAA instead imposes USA rules outside of the country by prescribing parameters of network connectivity, practices of data security and physical security, and also organisational arrangements. Writing about the regulation of finance in the USA, David Bieri (2018) argues that the regulatory differences between and origins of different financial flows have implications for the spatial geography of money in terms of where it concentrates, how it moves, and what risk is associated with it. The role of nation state institutions in establishing rules and regulating contract agreements has the ability to bring forth new geographies of financial flows. In these flows transnational and global movement of money is tightly linked to the power of individual states to impose the parameters of such movement, as Shaina Potts (2020) argues in her study of the institutional and regulatory dynamics around the handling of the national debt of Argentina. There is a similar interdependence in the case of healthcare insurance finance, where the difference between private and state mandated insurance leads to what Bieri (2018) calls a "hierarchy of finance" and to different geographies of reimbursement payments that link Medicare payments more tightly to the spatiality of the nation state. These hierarchies of finance lead to differentiation between different patients data depending on the type of health insurance they have; while some data are subject to strict regulations of its provenance and handling, other are not.

The case of Worldwide Teleradiology makes the complex configuration of different technologies of bordering and regulations of data provenance evident. Since the company provides diagnoses for multiple countries, this results not only in different configurations of the teleradiology workflow, as pointed out in Chapter 2, but also in differential regulations of the health data that is received by the company and diagnosed by its radiologists. Similarly to financial transfers, data gives the illusion of easy transfer between national borders because of the digital networks and universally accepted protocols for its transmission (Galloway 2004). However, like money, data is the subject of regulations and it is not homogeneous. Personal and healthcare data move differently, and this has implications for how teleradiologists receive patient cases and diagnose them. Countries impose various restrictions and requirements for the transfer of patient data; this points not only to risks being defined in relation to digital data, but also raises issues around data sovereignty including how it is protected, who has rights of ownership and use, and what data is protected. While HIPAA imposes requirements for the secure transfer of data and its protection at the site of the teleradiology company for example, other countries deal with the data issue in more restrictive ways.

Controlling the provenance of data leads to various strategies that demonstrate the complicated relationship between nation state territories and the digital infrastructures of data centres, cloud servers and networks. While USA cases led to modifications in the workflow and the instalment of specific measures for risk management, cases coming from Singapore are subject to separate regulation that attempts to insulate patient data from the rest of the data flows in the company and also, crucially, attempts to solidify the link between the national territory of the country and the radiology data sent to India. The arrangement of teleradiology service between Singapore hospitals and Worldwide Teleradiology in Bangalore required a special technological and regulatory solution that keeps all the patient data on Singapore's territory. The data is stored on a server located in Singapore and is accessed in the company through a designated computer that is only used for diagnosing images from this country; thus the Singapore workflow is infrastructurally insulated from the rest of the workflows within Worldwide Teleradiology's premises. The rest of the servers used by the company that are predominantly deployed for USA cases, are located in the USA with the main data centre in Delaware. While the IT infrastructure team explains that this arrangement is mainly for the sake of speed of transferring data, the question of where data is geographically stored is underpinned by geopolitical and economic considerations. Anupam Chander and Uyen Lê (2015) see these "data localisation" measures as an example of "data nationalism"; that is, they signify attempts to restrict the movement of data within nation state borders and to establish oversight over them. Although the Singapore Personal Data Protection Act (2012) allows for transferring personal data outside the country's borders with the appropriate security and protection, the special arrangement keeping data on Singapore soil, or rather in Singapore data centres, was one of the conditions for securing the teleradiology contract between Singapore hospitals and Worldwide Teleradiology. Aside from all of these issues pertaining to data sovereignty and security, other spatially situated power issues also arise; the restrictions on data centre locations are also situated within emerging "cloud geographies" of economic and political power drawn through the location of data centres around the world (Amoore 2018) and Singapore in this regard has established itself as one of the leaders in data warehousing (Neilson and Notley 2019).

Another aspect of data that the management of data flows in teleradiology highlights, is that data is not homogeneous and different types of data *move* differently. Cases sent from the UK to Omniscan Teleradiology in Sydney are anonymised for instance; all personally identifiable information of the patients, such as name, age, address and social security number is removed, and then replaced with numbers that help to distinguish cases from one another in the system without revealing personal data. This technique of pseudonymisation is recommended by the National Health Service (NHS) (Chan et al. 2016), even if the Royal College of Radiologists (2012) is content with advising higher security measures when handling personal data overseas. The solution used at Omniscan Teleradiology accentuates the specific properties of digital data that allow data flows to be categorised and fragmented into separate classes that can be treated differently; this is something Brent Mittelstadt (2017) also discusses in relation to privacy and personal data. The way in which data affords the ordering of bits of information into classes and subclasses, leads to the possibility of separating and instituting various degrees of authority over radiology information. Some parts of this information carrying what is considered personal information can thus be subjected to stricter control and be more tightly linked to a spatially fixed notion of national territory. As some authors have pointed out, the technological affordances for anonymisation disrupt the possibilities of political subjectivation and action (Amoore 2014; Cohen 2019; Floridi 2014; Mittelstadt 2017; Munn, Hristova, and Magee 2019). They do so by removing traditional markers of subjecthood, such as name and other identifying information, therefore bypassing existing legal and political frameworks. So while anonymised data can still be exposed to technological, economic and political manipulation, such as the outsourcing arrangements in teleradiology or the use of anonymised DICOM files for machine learning algorithms, it precludes the possibilities for political claims around them.

These different notions of risk brought to light through the practice of teleradiology present a complex configuration of how risk is defined. It transpires that there are multiple objects of attention in risk management including: the health of a patient's body; the autonomy of professional expertise; and also healthcare finance and data. These different objects warrant a number of risk mitigation and management measures that are focused on the way mobility exacerbates risk, and which are thus enacted to try to control either the mobility of data or its visibility. This concern with the transparency and obfuscation of data presents an interesting parallel to the practices of invisibilisation of labour and the way they are also linked to risk management and notions of risk. Returning to the examples of news stories detailing the dangers of teleradiology, it is worth noting that limited visibility is a source of both anxiety and security. While the possibility of non-transparency in the teleradiology company is a source of anxiety mixed with racialised metaphors of dark and obscure labour, non-transparency or limited transparency of patient data is an instrument of risk management in the case of pseudonymisation of UK patient records. Thus transparency creates an asymmetrical relation in the management of risk; that is, the work of teleradiologists has to be open to visibility and inspection, whereas the patient data they need to diagnose can and must be conditionally accessible and visible.

Flow and archive

The issue of where data can be stored is linked not only to questions of liability and data sovereignty but also to the development of the archive in PACS, which is one of its key socio-technical elements. The archive in PACS brings together two technological and epistemological functions of archiving, on one hand the organisation of knowledge and on the other hand the role of data storage in enabling computing and information processing. These two functions are interwoven in the organisational history of the archive in healthcare, which have important implications for the structuring and hierarchisation of roles in the workflow. In Chapter 2 the organisation of the workflow was discussed with a focus on the historical development of practices of labour intensification and scientific management. PACS archives offer another important perspective to the organisation of labour in healthcare institutions, which can be traced by examining developments in the management of patient information and in particular the establishment of the patient record as a key instrument in diagnostic and therapeutic practices.

The parallel I draw here between the patient record and the archive as a technology of organising and categorising information builds on the work of scholars like Michel Foucault (2002), Ann Laura Stoler (2002; 2009) and Mike Featherstone (2006), who analyse the archive as a technology of the biopolitical apparatus of the state for collecting information about populations. These authors see the role of archives as being central to policies of enacting categorisation, enforcing surveillance, and constructing and imposing dominant narratives and epistemologies. The patient record in healthcare serves a similar function; it codifies what knowledge gets counted as medically significant, how health conditions are classified, and how patients are treated. Marc Berg and Geoffrey Bowker (1997) argue that the medical record also acts as an ontological tool which constructs the specific ontology of the body of the patient, through the collection of information about vital functions and parameters. As demonstrated in Chapter 3 where the specifics of digital medical images were discussed, the radiology image has a similar role in constructing particular ontologies of the body and informing medical practice.

However, my focus on the history and use of the archive in radiology allows me to suggest another perspective to the function of the archive. I highlight the role of materiality in determining the complex influences of the radiology archive on the organisation of labour and institutional processes. Collecting and storing information entails cultivating material practices and spaces for depositing and accessing the stored data. The need to develop these practices and spaces is one of the key drivers behind the invention and design of PACS. As their name suggests, the key functions of PACS are related to the storage and transfer of digital imaging data. However the archiving, systematising, retrieving and exchange of medical information as pertinent concerns influencing the organisation of healthcare labour, predates digital data.

Marc Berg and Stefan Timmersmans (2003) in their book *The Gold Standard*, link the standardisation of recording and archiving practices in the early 20th century to the reorganisation of work processes and architecture in the hospital. The introduction of the medical record was part of a wave of standardisation of medical care that (through the medium of the paper record) prescribed what parameters and vital signs should be monitored in patients, and (through the act of inscription) made the role of doctors standardised. In the early 20th century, the medical record became a highly uniform archive of patient data that informed medical diagnosis. It contained personal information, complaints and symptoms, patient history and history of the progress of the patient's condition – all captured in a standardised manner, following prescribed rules of what has to be recorded and how. One of the main purposes of this new uniform record was to standardise medical practice, which was until then highly dependent on doctors' individual habits, preferences and experiences pertaining to what is and is not significant for diagnosis. Moreover, private patients often did not even have records, or their records were only kept and accessible by their personal doctors. This meant there was a strong interpersonal dependence between doctors and patients where their relations and the organisation of the labour of diagnosing and treatment, were to a high degree in the hands of the doctors themselves. The introduction of the medical record shifted these relations and placed the record at the centre of the organisation and management of tasks; now any doctor, with or without prior knowledge of the patient, could step in and perform the work of diagnostics and treatment. These changes were part of a movement to optimise work at the hospital through the standardisation of procedures and by introducing an evidence-based, scientific method of professional medical labour; in these processes, the role of the archive as a technology for organising knowledge is central (Foucault 2002).

This intertwining of the archive as a material logic of organising information and the archive as a technology of power crystallises in the organisational setting of the hospital, where the archive acquires the important function of organising professional knowledge and establishing uniform practices of healthcare. The archive, in its concrete representation of the medical record, has an important link to the processes of standardisation of medicine and the growing professionalisation of the field. The movement to establish what a medical record should contain marks a process of discrimination in terms of what constitutes scientific medical knowledge and how it should be inscribed and catalogued. This aspect of the medical archive underscores the link between the institutionalisation of knowledge, and the role of record-keeping in establishing and maintaining practices of governmentality and the specific arrangements of power and control. The organisation of the hospital archives has profound effects on the organisation and division of labour enacted in the clinic and in this regard the switch to a digital medium of archiving introduces new points of intensification, displacement and impasse, which in turn lead to new changes.

This drive for optimisation has lasting consequential implications however, particularly for the development of professional medical labour and for the ways in which labour intensification is enacted in teleradiology companies. The health record establishes the central role of data, measurement and reading in the practice of medical diagnosis. This shift towards a data economy of healthcare imposes new ways of seeing and acting upon the body (Berg and Bowker 1997). The patient record means that the inscribed record of observed symptoms becomes the primary point of reference for making decisions about treatment (Hess and Ledebur 2011); this signifies an important rift in the development of healthcare that helps to solidify the central position of objectivity and evidence-based knowledge in terms of defining medical professionalism. This goes to show how the establishment of standardised records and hospital archives participates in the complex development of the organisation and standardisation of knowledge production in the clinic.

The role of the medical archive goes beyond its epistemological implications. It enables important transformations in healthcare labour and its organisation; it makes diagnosis possible from a distance; and it is instrumental in facilitating a highly logistical organisation of labour in healthcare that is focused on the management of data flows and storage. The standardised practices of record keeping in hospitals have introduced the new institutional role of the record room and the record room clerks as a key component in hospital architecture (Berg and Timmermans 2003: 46). Berg and Timmermans note that the standardisation of the medical record and the increased importance of record keeping in healthcare institutions, lead to significant changes in the architecture of hospitals where the record room takes centre place. Since records become key for treatment and diagnosis, they have to be easily accessible from every part of the building. The role of the record room is further incorporated within practices of labour organisation in hospital institutions, which has been viewed as an example of the introduction of Fordist management techniques into the clinic through innovations in their architecture (Ahuja (2012). These new techniques are linked simultaneously to the archive as a storage around which practices of healthcare labour are organised and also to the role of the record in the complex and dynamic flows managed in hospitals that include the flows of patients, supplies, communications, personnel, specimens, and waste (Bonnet 1966).

At the time when PACS emerged as an idea and began to be developed by academic and military institutions, the departments of radiology were already faced with the introduction of digital imaging. They were therefore already being presented with the question of how does the digital change the practice and the organisation of archiving, storage, and diagnosis. Until PACS were introduced the digital modalities recorded images on film so that radiologists could view and store them in the medical records (Duerinckx and Pisa 1982). This created an uneasy symbiosis of analogue and digital whereby digital imaging modalities developed but the substandard quality of the digital display technologies meant that radiologists still preferred the analogue film image. Today the displays in radiology means that departments have the capabilities to display the large images in detail and with high clarity and the DICOM standard covers the requirements for display of radiology images. But in 1980s the display was one of the factors influencing the developments in radiology image archiving. The continued prevalence of film images means that today the departments continue past practices of storage and archiving that require big storage spaces for the films, and if a doctor needs to consult a past study they must physically retrieve it from the storage. These movements of doctors between departments are seen as inefficient and unproductive; the development of the digital imaging systems is thus imbued with the imperatives for increased productivity and decreased waste of time and energy of the radiologists (Duerinckx and Pisa 1982.; Lemke, ter Haar Romeny, Osteaux et al. 2000).

The archive has a special place in these fantasies of efficiency and organisation that points to the increased importance of the movement and management of information workflows in the healthcare industry. It brings an aspect different from the conceptualisations of workflow management in the factory that the Gilbreths draws upon. While Taylor (1911) and the Gilbreths (1914, 1919) think of efficiency and productivity primarily through the movements of the individual working body, the development of medical archives and records points to a science of productivity management that is concerned with the logistical organisation of movement and transfers. This focus places greater importance on the management of systems and the organisational role of the medium of transmission. The development of healthcare archives (which underpins the history of radiology archiving and communication systems) combines the issue of the mobility and organisation of flows with the increased drive for professionalisation and standardisation in the field of medicine.

The archive constitutes a central part of the core digital infrastructure used in teleradiology; that is, PACS and its role had multiple implications for the practice of medical imaging outsourcing. In the vignette I presented here, we can notice one of the important effects of the archive on the organisation of workflows, which is that the time needed for image retrieval from the cloud server (measured in units of non-productive time for ABRs) necessitates the role of the loader within Worldwide Teleradiology. This example shows the temporal dimensions of the digital archive that stem from navigating between different temporalities and modes of operation in digital infrastructures. Wolfgang Ernst (1999, 2013, 2015), Adrian Mackenzie (1997), and Robert Gehl (2011) argue that the archive is one of the constituent modes of operation of the worldwide web, which together with the processor, creates a dynamic of intervals of immediacy and delay that defines the temporality of digital transfers of data. The archive (the systems used for storing information) plays an important logistical role in regulating the speed and setting the parameters of temporality in the transfer of information because it acts as a break, or a point of delay and interval, that makes it possible to have oversight and control over the flow of data. This argument importantly shows that the archive affects the organisation of work and power over labour through its materiality. The archive of medical imaging accentuates multiple issues of organisation and control that stem from its materiality including: the possibility to access archived diagnosed cases for auditing – as the ABR in Israel does with cases read by Lakshmi; issues related to storage and national legislation that lead to the use of differently located servers for different clients of the company; and also the importance of standard formats for the files.

The introduction of medical records in the hospital marks a shift in the organisation and institutionalisation of medical care. The processes of automation and workflow management in teleradiology are tightly linked to the concern with data transfer, storage and proper organisation. This central place of digital data in the organisation of work and workflows marks a point of difference to the historical practices and theories of workflow organisations of Gilbreth and Taylor that focus on the body of the worker. While theories of scientific management focusing on the body of the worker operate through notions of energy and efficiency, the archive as a mode of organisation poses the spatiotemporal configuration as a central point of concern. The switch to digital imaging is supposed to solve the spatial problem of the radiology archive: the film archive takes room, requires special conditions of safe storage, and also means that doctors have to walk up and down to the physical storage whenever they want to consult a past study. It does, however, introduce a new and very specific interdependence between workflow, temporality, and space. Here the role of the loader at Worldwide Teleradiology who saves precious seconds by preloading images, is one example. The company also uses its network of servers around the world strategically in order to save time. This is why the USA cases are on the company's server in Delaware, as the leader of the IT infrastructure team explains to me during my visits.

Filmless radiology solved this spatial problem but posed new issues of temporality and location. Good image quality requires digital storage space, which was initially an obstacle for the development of PACS at a time when several terabytes of data storage required expensive and bulky solutions (Bick and Lenzen 1999). Another problem is the time it takes to retrieve an image which leads to an economy of duplication and hierarchisation of archives. The logic behind this duplication and hierarchisation is to have different solutions for short-term storage for easy retrieval, and long-term storage for the already diagnosed imaging studies. In the early 1990s this had already emerged as one of the issue that needed to be resolved through the PACS architecture (Mun, Freedman, and Kapur 1993), leading to the establishment of a hierarchy of storage solutions to be deployed in coordination as part of the operation of PACS. In this hierarchy, images are archived and stored across different media, according to a temporal scale of both immediacy to the moment of study and relation to the clinical workflow.

The challenge for digital radiology is to maintain several types of storage for different purposes: some studies need to be accessible for reading and are loaded on the worklist server; other studies are of potential relevance for ongoing conditions and for tracking progress so they do not have to be lined up for immediate consulting but need to nevertheless be easily accessible; and then there are also disaster backup archives, medico-legal archives, and long-term storage archives for keeping copies of the radiology images as part of patient records and institutional records (Huang 2019; Heckman and Schultz 2006). As part of the organisation of PACS architecture institutions adopt Hierarchical Storage Management (HSM) or Life Cycle Management (LCM) tools which automatically move images to the appropriate archive after a certain period. In the process of doing this, these tools delete the file from the server used for storing and retrieving recent studies and leave only the metadata in the server database (Heckman and Schults 2006). These different categories of archives move across different media. Those that need to diagnosed, are stored on fast and expensive Direct Attached Storage (DAS). Those that are not immediately in the line of diagnostic workflow are stored on inexpensive and slow Storage Area Network (SAN) or Network Attached Storage (NAS). Historically, these different types of storage solutions have used hard disks, redundant arrays of inexpensive disks (RAID), tapes, and now increasingly cloud storage. These different archival media create an intertwined logic of duplication and flow management, which aims to simultaneously address issues of risk associated with the loss of records, the speed of processing, and the diagnostic labour process that is intrinsically linked to the way data moves, is stored and can be retrieved.

Wolfgant Ernst (2013), Adrian Mackenzie (1997) and Robert W. Gehl (2011) all argue that the archive constitutes an important part of how large digital infrastructures such as the Internet function. They build on von Neumann's concept of the interdependence between the processor and the archive as two technologies of handling, categorising and manipulating data, which work in coordination and create a specific temporality of memory and control in the digital environment. While they focus on the Internet and its dependence on a combination of archive and real-time processing of requests, Gehl (2011) also points out the ways in which these two elements of digital infrastructures affect labour and the possibilities of exercising control. This connection plays out through the way in which human labour is incorporated within the fast time of processing and subsequently included into the digital archives of data that feed new big data economies of automation and prediction. PACS integrates these two temporal aspects of fast processing and diagnosis versus the long-term storage of patient records. In this way, the archive in teleradiology remains in a constant relationship with an economy of regulating flows pertaining not only to the flows of data that circulate between different storage hardware systems but also to the workflow management in the companies. The archive is thus twice bound to issues of temporality. This is firstly through the seconds and minutes it takes to load an image, which constitutes a temporal lag that is immediately registered in the workflow and which triggers different strategies to remedy the lag, either through pre-loading and saving copies of the images on a local server or (as in the case of Worldwide Teleradiology) by employing workers whose sole task is to preload and prepare the studies for reading. Secondly, the archive itself is regulated through its specific notions of temporality and classification, whereby images move across different archival storage media according to the time that they were first taken and their relevance to the present moment of patient diagnostics.

The move towards digital data in radiology complicates the previously discussed inherited genealogies of workflow management. This move to more complex modes of control and management is not grounded just in increased volume and better possibilities for quantification; rather, as I argue below, this is linked to the materiality of infrastructures that enables the scaling up of workflow management and which crucially enables the construction of new temporalities and topologies within teleradiology logistics. This move is also supplemented with an acute focus on the properties of the medium of transfer and the possibilities to deploy them in the process of constructing highly mobile, networked and yet insulated topologies of transfer and organisation.

Topology, logistics, data

The early history of the development of PACS is marked by the strong involvement of the USA Department of Defence (DOD). This involvement predicates a specific focus on the role of digital radiology as DOD conducted several projects for the development of predecessors to PACS, namely Digital Imaging Network Systems (DINS) and Medical Diagnostic Imaging Support systems (MDIS). In the mid-1980s, DOD initiated a series of projects in collaboration with academic medical departments in Georgetown Hospital at the University of Washington in Seattle and also in collaboration with MITRE Corporation (Cerva, Kerlin, and Pocinki 1990; Mun, Freedman, and Kapur 1993), with the intention of testing and developing digital systems for the transfer of radiology images for both peacetime and battlefield healthcare. These projects played an important role in channelling funds towards this particular strain of research and also in establishing DICOM as a core standard and requirement for the development of digital systems for radiology image transfer (Cerva, Kerlin, and Pocinki 1990). The link between military institutions and the adoption and promotion of standards is, as Deborah Cowen (2014) and Keller Esterling (2014) argue, part of the logic of increased importance of circulation and distribution for the functioning of the economy and for the production of value that starts to exceed the spatial constrains of the industrial factory. Cowen (2014) sees this increased importance of circulation as part of a logistical turn in capitalism, where the military (which is the original logistical organisation) becomes a path-setter (ibid.).

These early attempts to construct infrastructures for the transfer, storage, and viewing of radiology images responded to very specific conditions of medical practice. DOD wanted to establish infrastructures for the remote diagnosis of military personnel deployed in active war zones and army bases in foreign countries. The main concern of the DOD project for developing DINS (digital imaging network systems) was logistical; that is, how to successfully and quickly transfer images and data between different locations in a hostile environment. They needed secure and stable network connection that could transfer the large radiology image files between the military bases and continental USA (or CONUS in military jargon), while being insulated from the technical problems on the ground and from potential interference.

In a rather striking way the concern of DOD remains at the core of international teleradiology today. Some of the examples from the practice of Worldwide Teleradiology and Omniscan Teleradiology described in the preceding chapters exhibit similar attempts to insulate the infrastructures and workflow of teleradiology from the surrounding environment and the healthcare systems of the countries where these companies are respectively located. The endeavours of Omniscan Teleradiology to avoid having to conform to the certification requirements in Aruba, Australia and the USA is one such example, as also are the imposition of a HIPAA regulated space and the special secure network for Singapore hospitals at Worldwide Teleradiology. Manuel DeLanda (2005) contends that the military provides a specific organisational model for this logistical reorientation, firstly as a model for the disciplining of the body in military operations and industrial workflows, and secondly as a principle and strategy for expanding and exercising control on a large scale (2005). The involvement of DOD in the development of PACS reiterates the role of the military in the research and deployment of digital technologies and infrastructure, which defines the beginnings of different contemporary technologies such as cloud computing, artificial intelligence, and internet networks (Hu 2015; Roland with Shiman 2002).

In the case of teleradiology and the development of PACS, documents outlining the projects initiated by DOD show that the development of DINS addresses a specific set of concerns related to the management of flows and circulation that do not directly relate to the energy flows and metabolism in the working body but impact on the subjectivity of labour nevertheless. This set of concerns is focused on the logistics of traffic and storage of data, but it is also tightly related to a focus on the medium and its role in enabling or impeding circulation. At its core, the preoccupation with the medium draws attention to the properties of media of transfer and their interaction with the environment and, in the context of military operations, to the role of digitalisation and digital networks in enacting the possibilities for insulation and exclusion.

The DOD projects documented in numerous military publications give even better insight into the operations of simile that DeLanda (2005) suggests and they shed light on the reconceptualisation of the medium in this context, that is, the expansion of the logistical logic of organisation within military healthcare (ibid.). The idea of using digital imaging technology in the battlefield at that time had already been tested once by the Israeli army during the Lebanon war in 1982. Israel used CT scans to quickly determine the seriousness of injuries to soldiers on the ground and to avoid the unnecessary transfers of wounded soldiers to the larger hospitals that are equipped for complex surgeries. One of the problems faced by the military, is its own success at developing new weapons that damage bodies in new ways and require new and more precise methods of diagnosing injuries (Dolev 1987). In the context of the war in the Lebanon, the use of CT scans on the battlefield was part of important logistical calculations about the movement of wounded bodies through an active war zone which is an operation involving significant resources and risks. The CT scan allows for triaging the injuries by assigning categories of gravity to patient cases and making decisions about their transfer based on these categories. While we can see here that already there is an anticipation of the particular qualities that make digital imaging especially suited to the needs of a large-scale logistical organisation – that is, discretion, precision, and channelled mobility, it is in the DOD projects however, that these qualities can be seen to have fully taken centre place within the development of teleradiology networks.

The above projects assembled research teams to develop digital imaging network systems (DINS) which was a predecessor of PACS. DINS allowed for the transfer of digital images between the different hardware used to capture and transfer radiology images, as well as between CONUS and the countries where USA troops are deployed. What was identified by DOD as a main problem with film radiology at that time was congruent with the logistical concerns leading to the use of CT by the Israeli army, although the DOD projects exhibited a more acute concern with the properties of the medium. There was for instance an understanding of the ephemerality of film images and their susceptibility to corruption in tropical and hot climates, seeing as films are not simply a heavy load to transfer across military divisions and battlefield hospitals but they also get damaged and lose their accuracy and usefulness (Kerlin, Cerva, and Glenn 1987: 3-1). It was this property of the digital identified by DOD, giving primacy to its relative ease of transfer while also being insulated from the surrounding environment and its effects of decay and waste, which was one of the central drivers behind the adoption of digital systems for radiology in the military. The digital image allowed for the logistics of data flows and wounded bodies to be reorganised, according to new possibilities for transfer, storage, and categorisation.

As digital images reduced the resources and space needed for equipping and maintaining a battlefield medical facility with a radiology functionality, they also prompted changes in the organisation of mobilities and dependencies between medical units. Part of these reorganisations involved the development of a series of centralised networks on the battlefield, under the "hub-and-spoke" model of arranging connections between medical facilities. In this model, the healthcare centres are connected in a hierarchical network of communication and responsibility that determine the mobilities of wounded soldiers and medical images. Radiology images are sent from the small field hospitals (spokes) to larger centres with more professional staff (hubs), where the urgency of each case can be determined and soldiers are accordingly transferred between different categories of medical facilities based on the category of gravity of their case. The two diagrams below show the network topology of one of the DOD projects and the ways it is used to organise the flow of data, patients, and labour. DINS, which is shown in its hardware configuration in the first diagram, is located at echelon 3 hospital, some 150km away from the battlefield. The CT scan available at echelon 3 is used to scan injuries of wounded soldiers and then send the images to CONUS for evaluation. Based on the radiology report soldiers are then either treated at their current location or sent back to the USA for more expert care. This produces specific topologies of efficiency and mobility that are conditioned by the digitalisation of medical images and which function alongside the network topologies developed to prescribe the connectivity between hardware systems in DINS.

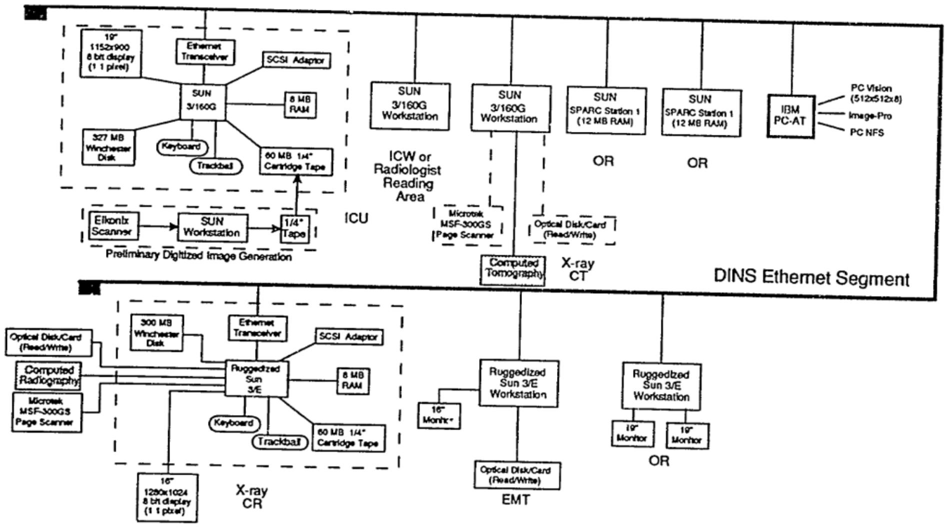

Figure 4-1
Hardware Configuration of the Battlefield DINS Prototype

Figure 15 Diagram of battlefield DINS network topology. Reprinted from Cerva, Kerlin, and Pocinki 1990: 4-4.

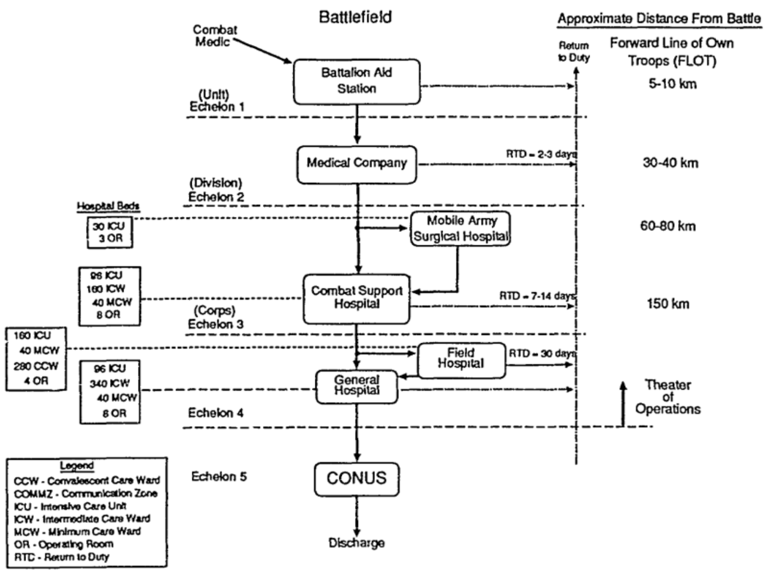

Figure 4-2
Casualty Flow through the Five Echelons of Combat Care

Figure 16 Diagram of casualty flow topology designed for the purposes of introducing battlefield DINS. Reprinted from Cerva, Kerlin, and Pocinki 1990: 4-10.

These network topologies that describe the connections between PC monitors, keyboards, CT scans, and storage disks are used by IT engineers to prescribe and configure the way different nodes in the network are connected to each other and how they can exchange information. One key feature of the information transfer in digital networks, and hence their topologies, is the dependency between temporality, processuality, and topology. The configuration of connectivity between machines in the context of DINS and later PACS, draws as much attention to the participating machines as it does to the process and the workflow of information exchange, which (as demonstrated in Chapter 3) is linked to the role of a specific notion of temporality and seriality. The temporality and seriality that define network topologies have a distinct connection to the question of organisation in terms of the processual aspect of organisation of data flows as well as in terms of the institutional aspect of organised structures of power and practices of action. That is to say, a network topology does not only provide a spatial organisation for a digital network but it also determines the paths of information exchange and therefore the relations and dependencies between different nodes.

This link between network topology, workflows and organisation underpins the dependencies between the development of PACS and the practice of teleradiology as we can observe it currently in offshore outsourcing, at Worldwide Teleradiology in Bangalore for instance. What is important to note when understanding this connection, is that this link elicits the complex developments and drivers behind the practice and the effects it has on the subjects involved and affected by it. Contrary to analyses that read outsourcing and teleradiology in particular as reiterations of generalised economic relations of centre and periphery (Venco 2012), the history of DINS and PACS points to the importance of understanding the materiality of large technical systems (Mayer and Accuto 2015), digital data, and the different topologies and relations that they enable. These topologies do not necessarily produce the binary political landscape of centre and periphery but, instead, manage to etch particular organisational structures into existing political and economic landscapes, that then produce and replicate their own relations. The DOD project very starkly exemplifies the possibilities afforded by digital systems to construct networks, flows, and topologies that enable only certain connections and proximities while excluding others. The concept of battlefield DINS, rests upon the idea of enabling only certain flows and only within the DOD logistical network. The network topologies and the hub-and-spoke network of military healthcare centres depict a specific model of logistical biopolitics, whereby the network and the flows enabled within it constitute an exclusive space where vital flows of data, labour, and value are circulated. In the DOD research, battlefield DINS were also linked to CONUS via military satellite technology in order to enable the direct transfer of images to USA hospitals and to allow for prompt diagnosis and consultation. The network of hospitals and healthcare centres linked through this chain of military logistics and mediated through DINS exhibits a topology of flows connecting strategic locations between CONUS, battlefields where DOD is engaged in military operations, and military hospitals in neighbouring ally countries where USA soldiers can be sent to undergo more extensive treatment. Bélanger and Arroyo (2012) refer to this specific topology of nodes that are isolated from their adverse surroundings and linked together through a digital network, as "supply chain archipelagos". What defines this arrangement that emerges in the field of post-fordist military logistics, is the combination of "islandisation" (or insulation from the surrounding territory taken to the extreme) and flexible and hyperconnected networks.

In the first development of DINS for battlefield teleradiology, network topologies were overlayed with the topologies of military healthcare logistics and the geopolitics of military healthcare and technology in the context of late 20th century and early 21st century USA interventions. But the combination of insulation and hyperconnectivity remains an underlying logic of teleradiology logistics in the practice of outsourcing today. The development of PACS, building on the DOD projects, retains this important aspect of digital networks that was utilised in the DINS battlefield projects, that is, the ability of these networks to transfer information while insulating it from the conditions of the local healthcare system. These possibilities for infrastructural compartmentalisation and insulation are evident in the way that the different workflows in Worldwide Teleradiology are separated and subject to different regulations. Most remarkable of all is the contrast between that way that the USA cases are handled with urgency and with safeguards to protect the privacy of patients, and the way cases from Tripura are handled with a diagnosis expected within 24 hours while they are also subject to the surveillance optics of a publicly accessible dashboard.

Conclusion

The overview of the history of PACS and the early analogue and digital practices that influence the development of this key infrastructure for teleradiology demonstrate the role of the materiality of digital data and infrastructures for the evolution of specific technologies of organisation. As I showed in this chapter, the management of workflows and labour have a concrete and material dimension that links the performance of medical work together with the media of record keeping and archiving on one hand and the network configurations on the other. The discussion of past practices of archiving and the establishment of network connectivity suggests that the configuration of PACS (consisting of the archive, secure network and the viewing station) is informed by and also influences the ways in which healthcare management has been linked to the organisation of hospital space, temporalities of archiving, and retrieving information. As I show in this chapter, the design of PACS and the past practices of archiving reveal the entanglement between knowledge organisation, labour management, and the materiality of the record. These interrelations reveal the very material dimension of the organisation of expert labour and the relations between radiologists and other auxiliary staff and patients. The data produced, collected, and exchanged as part of teleradiology practice is not static and inert but, on the contrary, plays crucial role in affecting labour practices and mobilities.

The historical approach to the analysis of PACS helps expand and complicate the understanding of how digital infrastructures exercise control over labour. As I demonstrate in this chapter, the possibilities of modulating workflows and regulating who is part of the diagnostic process and at what time, are not generated through quantification and algorithmic control exclusively. Rather, the control exercised through PACS is informed by the legacy of practices of manipulating different media in medical settings – that is from paper records to hospital architecture and then digital storage, as well as networks for data transfer.

At the same time, the development of PACS also elucidates the significance of the specific challenges posed by cross-border practice. The need to secure the transfer of information and how to provide expert diagnosis at a distance underlie the development of network architectures and solutions for connectivity across border that, although not exclusive to teleradiology, highlight the potential of data infrastructures to intervene in different territories and create new enclaves of exclusionary protected zones and flows.

Chapter 5: HL7 and the organisation as a medium

Organisation and data

At the start of July 2016 I attended a convention organised by HL7 (Health Level 7) Australia, which is the Australia affiliate of HL7 International – a non-profit standard setting organisation that develops and manages standards for interoperability in the exchange of medical data. HL7 is the name of a series of standards for the organisation and exchange of medical data that were first developed in the mid-1980s, as well as being the name of the non-profit organisation responsible for the development of these standards. The series of standards include HL7 Version 2 (HL7 v2), HL7 Version 3 (HL7 v3) and Fast Healthcare Interoperability Resources (FHIR) which, as will be discussed further in this chapter, build on one another but represent different visions of the relationship between digital data and healthcare institutions. They also all serve an important and similar function in the healthcare environment by enabling the transfer and interoperability of medical data, which makes each of them critical for the practice of teleradiology. I will hereafter use the name HL7 to refer to the whole set of different standards. HL7 has developed and continues to develop as a way to enable the transfer and exchange of data within the whole healthcare system. This ambitious enterprise means that HL7 pertains to different types of medical, administrative and financial data. Unlike DICOM, which developed in close relationship with the hardware for digital medical imaging (imaging modalities, storage solutions and viewing stations) HL7 is not bound to any specific type of hardware infrastructures. Instead it focuses on the level of application interoperability by prescribing how data should be structured for the purposes of exchange between different software programmes and different systems.

The event in July 2016, which took place in a hotel in central Sydney, gathered members of the Australia HL7 affiliate. Aside from the members, who are in their majority government employees at two state institutions – namely eHealth NSW and the Australian Digital Health Agency, the workshop gathered software developers, public healthcare workers, private clinical staffs and representatives of digital technology companies offering health-related products. The two-day workshop included presentations by members of HL7 and industry representatives. During one of the coffee breaks at the workshop, I began chatting with two of the attendees - one of them working at the Australian Digital Health Agency and the other in the management of a private healthcare institution. The two of them, sipping coffee and eating cookies, were discussing one of the issues at the centre of most of the presentations these two days; that is, problems with the transfer and availability of patient data. The man working for the Australian Digital Health Agency said that the current problem is that there is no adequate exchange of patient data between institutions, despite the introduction of electronic health records. This means that a patient can be diagnosed with, say, a peanut allergy at one clinic, but this information might not be shared with the next institution where they go to for treatment. The second institution might update their data with an indication for no allergies, give the patient peanuts and then they die. So, what the employee of the Agency suggested, sipping from his coffee, was that everyone gets a tattoo on their arm, like a barcode, where all the crucial health information is available to read in case of an emergency. I laughed thinking this to be a joke, but his interlocutor readily embraced the idea and added: "Yes, but this barcode should be on both arms, in case one of them gets ripped off in an accident." The two of them then went on discussing which body parts are best suitable for a healthcare barcode tattoo; ones that are not easily ripped off from the body are vital, a patient cannot live without them, and they are easily accessible in an emergency situation.

The barcode is, in fact, one of the inspirations behind the development of HL7. This group of standards plays a key role in the development of digital systems and solutions in healthcare, by providing what is supposed to be a universal format for the communication and exchange of medical data. Compared to DICOM (Digital Imaging and Communications in Medicine), HL7 has a much broader applicability in healthcare and is used in settings beyond the imaging department. While DICOM and PACS have been developed specifically for the transfer and storage of medical images and reflect the economies of production and diagnosis of the digital image, HL7 in contrast encapsulates wider processes of digitalisation and it touches on the way digital infrastructures absorb and transform principles of organisation and control in healthcare systems. As I discuss further in this chapter, one important aspect of this transformative role of HL7 is its relationship to the medical archive. In contrast to the pronouncedly materialist presence of the archive in the history of development of PACS, HL7 and, more specifically HL7 Version 3, adopts a method for prescribing the structure of digital healthcare information that is strongly influenced by linguistic theories of the relationship between language, actions, and effects. It borrows the concept of the "speech act" from John Austin's (1975) theory of the pragmatics of language according to which statements and other utterances can effectuate change, prompt action, and be a form of action themselves.

This version of HL7 is now gradually replaced with the latest version of HL7 called FHIR (standing for "Fast Healthcare Interoperability Resources" and pronounced "fire"). FHIR is to some extent an Australian's brainchild. The developer of this new standard, Graham Grieve, is Australian and has been actively involved in the local affiliate and in close touch with key members. He was present at the connectathon, providing explanation and practical help when people asked about concrete scenarios for data representation and the actions they need to take with it. There are high hopes that FHIR will overcome some of the criticism mounted against the two previous version of the HL7 – namely HL7 V2 and HL7 V3 – which are both still widely in use but considered too cumbersome and rigid in the representation of healthcare events (especially in the case of HL7 V3). A few days later, Graham walked me through his vision of the standard. It is influenced by the practice of "agile software development" which attempts to cut the period between development and feedback short, incorporating an almost real-time feedback loop into the design process (Beck, Beedle, Van Bennekum et al. 2001). This process is achieved through what Graham calls "a wiki-like process of development" with an online platform where people post questions, feedback and suggestions for how to use FHIR, and get immediate responses from other members of the ad-hoc community of software developers including Graham himself. This process is very different from the standard practices of HL7 where suggestions are raised by members only or through the balloting procedures at conventions. So in many ways, FHIR represents a dramatic change in the way that HL7 operates and how it is managed by the HL7 organisation.

This new standard has better compatibility with web resources and mobile applications by using REST API ("Representational State Transfer Application Programming Interface") which is an architectural style for distributed hypermedia systems developed by Roy Fielding (2000) in his doctoral dissertation.

Fielding developed REST API in response to the need to adopt common rules for the use of HTTP pages and the way that systems can interact with them, make inquiries, extract data and so on. REST API thus exemplifies a tendency whereby standardisation, in this case of HTTP, creates the need and conditions for further standardisation and the production of services and products that support the transition to a new standard and that expand the functionalities of how it can be put to use. This underlines another aspect of healthcare standards functioning as infrastructures; they not only enable things to move and circulate within a socio-technical system but are also generative of new productive and reproductive practices and relations, material changes and commodities. In his work on network protocols Alexander Galloway (2004) shows how the agreed upon standards that constitute net protocols become the basis for development of what we know as the Internet; that is, a network infrastructure that has become the breeding grounds of a myriad of new products and services. And this characteristic of infrastructures is not valid only for digital standards; roads (Dalakoglou 2017), railways (Bear 2007; 2020) and cinema (Larkin 2008) all take their place in social contexts, taking root on existing material and symbolic modes of mediation, and gradually becoming imbued with local meanings, calculations, speculations, and practices. And in a manner similar to the way that REST API develops on the basis of HTTP, FHIR also makes use of the existing architectural logic, wide spread, and wide recognition of REST API in order to make HL7 more user-friendly for an online environment.

By defining data structures, HL7 provides the essential context that gives digital information its meaning. This means that information is not just digitalised and tagged with metadata, but (more importantly) that there are specific and explicit relationships between different data in the system. These relationships indicate how different data objects relate to each other, for example by determining that an imaging order is a sub-type of order. HL7 also defines the data elements that an imaging order has to contain; that is, patient data, referral data, insurance information, information about the software that has generated the message, data about the exam and so on. These are all components that programmes using HL7 to exchange information will be looking for in a message that is identified as an imaging order. HL7 also specifies the actions that can be performed on different digital objects. Data can be queried and exchanged and different data objects can exist in a temporal-causal relation to one another, for instance when an imaging order will require the subsequent creation of an imaging report.

The exact relationship between digital objects differs among the three versions of HL7 (HL7v2, HL7v3 and FHIR) and I discuss this in more depth in the subsequent sections. Nevertheless, the existence of all these definitions, relations, and hierarchies is at the core of what HL7 is and how it functions. In data science these relationships and hierarchies construct the ontology of data within a specific domain – that is, they provide the context of interconnectedness that gives meaning to each element in a given domain of digital information. Data ontologies reveal the heterogeneity of digital data and its limits as a language of communication that transcends boundaries. The organisation of information within domains and within structured contexts through HL7, aims to provide the frameworks through which data becomes readable across different systems. In my use of "ontology" in this chapter I refer specifically to the use of the notion in information science, while also acknowledging that the choice of "data ontology" (that is, how data and the relations between different data objects are organised) has repercussions for the kind of control that is exercised through digital infrastructures.

What makes the HL7 standard an important part of the digitalisation of teleradiology, is that it highlights a logic of digitalisation that links together the standardisation of information and information exchange to questions of organisation. It underpins the key digital systems used for the exchange and organisation of information in hospitals and hospital departments, namely the hospital information systems (HIS) and their sub-systems – radiology information systems (RIS) – that are used in radiology departments. These two types of systems are key to the exchange, management and storage of data within healthcare organisations. They were initially developed for the transfer of textual and numerical data but have since evolved to integrate images from PACS. RIS in particular represents a mediating interface system between HIS (where administrative, financial, and clinical information is exchanged) and PACS (which stores and transfers images). The interoperability between HL7 and DICOM has been essential in enabling this integration, replacing earlier models of connectivity through brokering interfaces in the form of hardware and software tools that bridge the semantic gap between the two standards (Boochever 2004). The purpose of these brokering interfaces was to translate between HL7 and DICOM and transmit data between PACS and RIS/HIS. This special role of the brokers, marking the disjunction between different standards, sheds light on the always incomplete effort of achieving interoperability that in turn creates a baroque patchwork of standards, tools, and workarounds; however, it also signifies the important role that mediation plays in the functioning of complex infrastructures.

In this final chapter, I discuss the processes that enable the embeddedness of teleradiology infrastructures within the digital systems through which data is transferred, in the larger context of healthcare practice. As I indicate previously in the course of this dissertation, all of the companies that provide teleradiology services that have been given as examples, need to be able to connect and exchange images and reports with the hospitals for which they diagnose patients. While PACS and DICOM have been specifically developed for handling and standardising digital imaging data, their function in the healthcare system is limited to the radiology department and respectively to the teleradiology companies. In order for companies and hospitals to exchange information that goes beyond imaging data, they also have to use HL7 and HIS. However, the significance of HL7 for my analysis of teleradiology infrastructures goes beyond the practicalities of how data is transmitted between medical enterprises. Analysing HL7 also illuminates important aspects of the digitalisation of healthcare and shows how data infrastructures operate on multiple levels firstly through the political work of forging alliances and negotiating the representation of local healthcare practices within the standard, and secondly through the underlying principles of the data ontologies. The development of HL7 demonstrates the extent to which the technological solutions of interoperability in healthcare are not static and permanent, but instead result from the ongoing negotiations between different actors including healthcare professionals, state and private healthcare institutions, and also software developers who have a prominent role in the decisions and solutions behind digital healthcare standards.

In this chapter I analyse the mutual mapping and friction between organisational and digital ontologies and relations through the case of HL7. In the following section, 'The politics of interoperability', I explore the notion of interoperability, which underpins practices of technogovernmentality through standardisation and quantification. I show how the development of an international standard for medical data is tightly linked to the establishment of alliances across state, business, and professional organisations with the aim of expanding cross-border markets and as a way of control through voluntary adherence. This link between organisation and digitalisation is further advanced in the section 'HL7 and its history of development', where I examine in detail the process of the translation of organisational structures in the healthcare system into data ontologies in HL7. I show how this process involves the ambition of absolute subsumption of the healthcare institution by digitalisation through the convergence of description and executability in the logic of digital objects. However, I argue that this process is always incomplete and modified by the historical and technological context of the development of other infrastructures, tools, and platforms for the exchange of digital data.

The politics of interoperability

In the practice of teleradiology HL7 remains even more invisibilised than DICOM and PACS for a couple of reasons. Firstly, HL7 is not so intrinsically linked to the processing and transfer of images which makes it even less familiar to radiologists themselves. Secondly, it is not so closely tied to hardware infrastructure, especially in comparison to DICOM for instance, which is a standard adopted by imaging modality manufacturers. As HL7 is not linked to hardware production, it is less visible in everyday teleradiology practice. In fact, the very name of HL7 positions it as a standard that is not a determining hardware specifications per se. Level 7 refers to the Open Systems Interconnectedness Model (OSI Model) layers; this is a conceptual model for how digital systems can connect and exchange information on different levels (or layers). OSI Model layers refer to different components of a network that is transmitting information, and the uppermost layers depend on the connectivity that is enabled by the lower ones. The lowest, physical layer refers for instance to the electronic circuit link, through which signals can be transmitted; the second layer is the data layer, which contains the protocols for data transfer, such as point-to-point protocol (PPP) and Ethernet. The highest level is seven – this is the application level that defines how data is exchanged and processed by programmes. The reference to this higher OSI Model level in the denomination of HL7, indicates that the standard defines how data is described and organised in a systematic way in order that the meaning of information is not lost during transfer between different programmes.

Since 2000 HL7 and DICOM have been working on the mutual compatibility of the two sets of standards, with two working groups dedicated to the task, namely Working group 20 at DICOM and the HL7 Imaging Integration Working Group. In 2007 the two organisations signed a memorandum of agreement, which (among other things) mandates that the members of each of the working groups will automatically receive membership in the other one in order to ease the process of decision making and mutual integration (Health Level Seven International 2007b).

The reason why HL7 is important for the analysis of teleradiology labour, however, is not simply in the fact that it is integrated with DICOM. It is important for teleradiology precisely because of the reasons why this integration is necessary, that is to say, the embeddedness of teleradiology within wider systems. The need to connect PACS used in radiology departments and teleradiology to the HIS of hospitals and hospital chains, stems from the institutional and technological embeddedness of teleradiology within larger healthcare systems. This embeddedness is technological and expressed through the integration of information systems and the sharing of data. But it is also institutional and political, meaning that the teleradiology companies and their workflows are integrated within the diagnostic workflows of larger hospital systems on one hand, and with the healthcare policies of different states on the other. Thus HL7 has important technological and political role in teleradiology; this is a role that makes connections between the digital infrastructures used to manage the imaging diagnostics workflows in teleradiology companies and the issues of healthcare organisation and biopolitics that play a role in the management of medical practice and radiology labour at national and international levels. This convergence happens on multiple levels in the way HL7 functions - from the data architecture that the standards established, to the model of governance of the HL7 organisation and its initiatives of promoting its set of standards as universal models of how healthcare data should be structured in a digital environment.

Recently some authors have argued for revisiting the ways in which technological infrastructures, and in particular digital ones, are incorporated into questions of nationalism (Plantin and de Seta 2019) as well as international relations and geopolitics (Mayer and Acuto 2015). These questions about the interconnectedness of digital infrastructures inform the history of development of HL7 as well. Digital infrastructures like HL7 have an important role in mediating and enabling the transfer of information, the coordination of business and state contracts, and collaborations in the field of healthcare; indeed, this is part of the history of the development of HL7 and the attempts to establish it as an industry standard across different healthcare legislations. HL7 provides a glimpse into the way national policies, individual capitalist interests, professional standards of care and technical interoperability can all mutually articulate one another and become constitutive parts of what a digital infrastructure is and how it functions.

Importantly, HL7 as an organisation encounters some of the issues that I already discussed in Chapter 1 related to professional licensing in radiology; that is to say, HL7 navigates between expert-driven and state-driven models of governance and control. Standards and standard-setting organisations form what authors see as a (neo)liberal expert-driven technology of governance, which is grounded on principles of consensus-building, voluntary membership, and voluntary adherence (Gibbon and Henrinksen 2011; Higgins and Tamm Halström 2007; Ponte, Gibbon, and Vestergaard 2011). In their analyses of ISO which is one of the largest and most recognisable standard-setting organisations worldwide, Winton Higgins and Kristina Tamm Hallström (2007) and Keller Easterling (2014) all point out that the logic of regulation and governance exercised through such organisations departs from the principles of nation-state sovereignty by acting instead through mechanisms of conformance and networking. Easterling calls these mechanisms "extrastatecraft", distinguishing them from the modes of governance and accountability inherent to state institutions. However, as Higgins and Tamm Hallstrøm show in their research, standard setting organisations and standardisation as a specific mode of governance do not exclude the role of the state. Instead, state actors are included alongside private agents and networks in different capacities, either as participants in these networks of standardisation or as a legitimising power that can, in some circumstances, turn voluntary adherence to standards into a mandatory requirement. These processes of interlinking between state institutions and standard-setting organisations can take multiple forms, one of which is what Loconto and Busch (2010) describe as a "tripartite standards regime" in which national standard organisations play the role of intermediaries by translating different regimes of governance and ensuring that technocratic expert regimes of standardisation are mutually integrated with the interests of individual nation states.

HL7 has a similar biography to ISO, in terms of entanglement between public and private, state interests and extrastate 'governance at a distance' (Miller and Rose 1990). In its initial development HL7 began as an US project with the ambition of becoming established as the universal international standard for the interchange of medical data. One of its key founders, Clem MacDonald, first mooted the idea of introducing a standard for medical data by drawing analogies with standardisation decisions in other industries including barcodes in food retail in an article, titled "Grocers, Physicians, and Electronic Data Processing" (McDonald, Park, and Blevins 1983). Here, McDonald together with two of his colleagues argued the need for a data standard in healthcare that would make the circulation of medical information between computer systems in different departments easier while also enabling the analysis of large sets of individual or communal healthcare information in order to draw insights about trends and patterns; this equated to an insight into some of the big data analytics that are in use today. These authors thus draw comparison with two other industries where barcodes have been introduced to track the movement of goods, namely retail and logistics.

The suggestion for a data standard in healthcare eventually triggered interest leading to a meeting of the Symposium on Computer Applications in Medical Care (SCAMC), where the idea of creating a standard for describing medical data was proposed and taken over. The group working on the project restricted itself to clinical data as a focus for two reasons: firstly this was deemed necessary during the initial phase of developing standards and secondly the laboratory was the place producing the most data in the hospital (Spronk 2014). Later, SCAMC led to the establishment of HL7 however, which focused on the exchange of data across the whole healthcare organisation including medical data as well as administrative and financial information. HL7 remains a notoriously complex standard despite the latest attempts (through FHIR) to make it easier to implement. And part of its complexity is the ambition to render all events, transactions and actors in a healthcare organisation into a digital form; this process is in itself the most fascinating aspect of HL7 because it tells us what it means to digitalise a whole industry and organisation. This will be the focus in the next section.

Before discussing the different HL7 standards in themselves, I want to firstly focus on the mode of governance of the HL7 organisation. HL7's first members were people from the information technology for healthcare industry and university scientists working in the field of IT systems. In this sense, the membership and organisation of HL7 follows from the very beginning the model of non-for-profit, expert-driven enterprise; this is a model that (as mentioned earlier) has typified the characteristics of standard setting organisations. It should be noted that these attempts to cater for a universalist, non-statist and global image of HL7 however, inadvertently became entangled in the specific geopolitics of standard setting. This is apparent when looking at the early history of the internationalisation of the standard, when the US-based body encountered resistance from the European standards community, particularly in the form of CEN (The European Committee for Standardisation) for whom HL7 was deemed too tightly linked to the interests of the USA industry and state (Spronk 2014). CEN subsequently started to develop its own healthcare document data standards (Branger and Duisterhout 1994; Dolin, Alschuler., Bray et al. 1997) before eventually getting on board with HL7. This adversity between the two standard setting organisations lasted until the year 2000, when a memorandum of understanding was signed by both parties agreeing to "collaborate and seek pragmatic solutions to unifying their standards" (Health Level Seven International 2000). Their move towards collaboration was facilitated to some extent by the steps both organisations had taken to partner with another international standard setting organisation, namely the Institute of Electrical and Electronics Engineers (IEEE).

These different organisations and the constellations among them present a complex picture of dependencies and entanglements between different types of standard setting organisations with differing degrees of alliances with nation states. Loconto and Busch (2010) distinguish between two types of standard setting organisations; those (such as ISO) that represent what they see as a globalising trend and which are not linked to state institutions, and those that represent national standardisation bodies. They argue that the interplay between these two types of standardisation bodies leads to what they call a "tripartite standards regime". It is hard to so easily draw this distinction in the case of HL7 however, and probably also in the case of any standard setting organisation in reality. Rather than distinguishing between state driven organisations and organisations that represent liberal market-driven initiatives, HL7 shows how different interests are negotiated between organisations and even within them. Interests are not only linked to state institutions in this instance, but also to corporates and professional organisations. In the case of HL7, these different interests can be represented by different actors and they have distinct agendas.

It is important to note that the development and international spread of HL7 has been accompanied and facilitated by building alliances at national and international levels. During the initial years of HL7, the US-based group developing the standard for instance was already seeking alliances with the major standard-developing bodies in North America: that is to say, American National Standards Institute (ANSI) in 1994; IEEE in 2005; and ISO in 2006. The motivations behind building alliances and collaborations with other standard setting organisations are varied and they speak of the complex entanglements of expertise, state power and digitalisation. In these three instances, alliance building with ANSI, IEEE, and ISO serves to provide HL7 with legitimacy, politically expand its reach and raise its status. ISO, for example, has long been adopted both as part of industry-wide requirements and also for state regulation purposes (see Gibbon and Henriksen 2011; Health Level Seven International 2006; Tamm Hallstrøm 2004). This means that HL7 standards are officially recognised and certified in a similar way to ANSI, IEEE, and ISO. Apart from being engaged in this political mechanism of ensuring mutual recognition and adoption of standards between different standard-setting bodies, HL7 is also involved in initiatives for standard harmonisation and interoperability that entail the mutual cross-referencing of data standards in healthcare. In this regard HL7 uses: SNOMED CT (Systemised nomenclature in medicine - clinical terms); LOINC (Logical observation identifiers names and codes - started by Clem McDonald who is also behind HL7) conventions for the representation of clinical terminology; and importantly, is harmonised with the DICOM standard in the field of medical imaging.

I will now focus on the issues that stem from this entanglement of different agendas and actors in the making of standards, through the case of the local affiliate chapter of HL7 in Australia. This particular case elucidates the political dimensions of standardisation together with the interactions, dependencies, and conflicts between the different institutions involved in the process. It also opens up the discussion about the way in which the digitalisation and standardisation of data in healthcare reflects political issues that are inherent to organisational collaboration and management.

In Australia, HL7 has had local representation since 1998. The structure of HL7 is such that it has local chapters established by members and people can be members in the national chapter, in the international organisation, as well as in both. There are no constraints on who can become a member; every member has a vote in the ballots that decide on changes in the standards and every member can also suggest new changes. Crucially, it is exactly at the point where changes are being introduced, where the politics of standardisation emerge in full light. Kathleen Lark, who is the secretary of HL7 Australia, described in an interview in June 2016, that one of the differences between HL7 and other standard organisations, and ISO in particular, is that HL7 does not require members to have a mandate from their respective state and members do not have to act as national representatives. This means that people joining HL7 can be representatives of companies, state institutions, professional organisations or just individuals with an interest in health informatics. The board of the local Australian chapter is presently dominated by people working for e-Health NSW, which is the NSW government institution that deals with issues related to the digitalisation of healthcare. This represents a shift in the membership and management of the organisation from the period up to 2015, when HL7 developed under Standards Australia, which is the umbrella national standard setting organisation in Australia. The two organisations (e-Health NSW and Standards Australia) put a halt to their collaboration mainly because of the unresolved issue of Intellectual Property rights in the publication of the standards. HL7 documents from 2012 show that the issue of IP rights emerged as a critical point of debate for the Australian chapter of the organisation, prompted by revisions of the affiliate agreement that HL7 International signs with its nationally affiliated entities (Williams 2012).

In 2016 when I met with representatives of the new board of HL7 Australia, there were discussions among the members about the possibilities of rekindling the connection with Standards Australia. However, the incident above shows how standardisation works across different levels of governance, that is nation state institutions, national expert organisations, as well as international expert organisations, and also goes to show how complex their interactions and allegiances can be. Kathleen Lark explains (during interview) that the Australian HL7 organisation works to promote the interests of the local healthcare system. This means that its members develop scenarios and data types that match both the needs of the local healthcare system and the procedures in place across Australia. They then propose the resulting changes at HL7 International so that they are included in the standard while also lobbying for the changes and adopting strategies to pass the vote at the ballots. In Kathleen Lark's words, this is a unique strategy of a national affiliate: when HL7 Australia wants to pass a change in one of the working groups, members will communicate amongst themselves and make sure they are all present at the ballot of this working group so their votes support the proposal. Kathleen Lark makes a distinction between lobbying by countries and lobbying by companies, which also happens in HL7 International. She explained that the members are more inclined to understand and support this kind of organised voting behaviour when it comes from a national affiliate, than from a single company. Companies do sometimes try to mobilise a similar strategy of lobbying to move changes forward that would benefit their business. These dynamics in HL7 demonstrate the paradox of what Easterling (2014) calls "extrastatecraft": the liberal logic of governance of the standard setting organisation attempts to create the idea of a levelled field for all members by first allowing membership to anyone interested and, second, applying the same rules for making suggestions and voting changes to the whole membership body. The apparent levelled field of membership and voting has its limitations though; state and academic institutions have a maximum of 12 voting members whereas private vendors, manufacturers and insurance companies can have up to 14 (Health Level Seven International 2020).

The balance of voting power, skewed in favour of businesses, is not however the main point that I want to discuss here. Rather than simply serving to provide evidence of the power of capital in international standard organisations like HL7, the dynamics of voting and participation shows how international standardisation involves the interplay of nation state power, expertise and capital when it comes to the way that standards are designed and promoted as vehicles for technical and political interoperability. In summary, this interplay provides evidence of the way that standards can be used for different agendas. While companies attempt to pass on changes that reflect developments in their products and will place them in a more favourable market position than their competitors, states in contrast adopt independently developed standards as vehicles for market regulation and control over the production and circulation of medical information.

This complex interplay of agendas also transpires in the case of HL7 Australia. The national affiliate is dominated by representatives of the state healthcare institutions who have a quite specific agenda to use the HL7 standard as a means to regulate the field of digital healthcare in the country. The multiplicity of healthcare providers – both public and private, and the variety of software that they use, poses a challenge to the state health authorities both in NSW and elsewhere in Australia. While the healthcare provider market is open to private companies, the health of the whole population remains a national concern and healthcare data is increasingly becoming an important objects of regulation. This concern is the primary reason why NSW Health has taken the decision to participate in HL7 standards organisation, because the agency sees this standard as one of the crucial elements in creating a framework for data formatting across the whole healthcare sector that will in turn make the exchange, collection, and analysis of healthcare information in a centralised way possible. Jason Steen, an enterprise architect for e-Health NSW (at the time of my fieldwork) and member of HL7 Australia (later acting Chair of HL7 Australia) explained his vision of the role of HL7 in the regulation of healthcare data management by the government. He did so, by proposing his vision for e-Health NSW as the creator of an "interoperability platform" where health data gathered by different actors – private and public, medical institutions, health and lifestyle apps and so on – can be collated together and made available for analysis and research. The notion of an "interoperability platform" which is adopted by the Australian Digital Health Agency

(ADHA) in its Child Data Hub for instance, encompasses the functions of the state as a regulator of data and metadata formats in healthcare (Australian Digital Health Agency 2020). In this instance, the newest HL7 standard FHIR (fast healthcare interoperability resources) is a key instrument for the interoperability framework that the government is proposing.

Interoperability, which is argued to underlie the rise of logistics and the logistification of capitalism (Neilson 2012; Rossiter 2016), has become appropriated by the state for the purposes of national regulation in the field of digital healthcare (among other uses). There is an inherent contradiction in the politics of standardisation and interoperability that makes it possible for HL7 to function as a technology of governance modelled on liberalism and the market, while simultaneously being employed by different states (Australia is just one example) to regulate the digital healthcare market and enable state control over patient data. Parallels can be drawn with the way that standards in transport infrastructure and the military have been essential for both the consolidation of industries of national importance and for a centralised control of their production, maintenance and use (Gibbon and Henrisken 2011).

Interoperability as a problem of governance in relation to standardisation has also been linked historically to the perception of standards as technologies of liberal market governance. Interoperability of digital data is part of a larger dynamic in the organisation of the digital space that establishes the notion of openness and exchangeability as way to critique proprietary monopolies and enclosures (DeNardis 2009). However, this notion of openness that has been critiqued by multiple scholars (Mirowski 2018; Magee and Thom 2014; Tkacz 2014).

Data interoperability and its appropriation in state policies also signifies the way that the digitalisation of healthcare generates new objects of concern in the governance of health and links the governance of health data to the biopolitical functions of the state. In this context HL7 as a key interoperability standard in healthcare has become adopted by governments and enforced through new mechanisms of regulating national markets, especially government tenders and state initiatives for aggregating patient data. These dynamics play a prominent role in the context of teleradiology outsourcing. In India, the state-wide initiative for implementing an Electronic Health Record (EHR) through which the use of core digital standards is mandated dates from 2013, while teleradiology companies have been using HL7 and DICOM since 2002. The experience of companies like Worldwide Teleradiology becomes critical for implementation and adoption. As was demonstrated in Chapter 3 through the example of the Tripura project at the company, Teleradiology Solution managed to repurpose its infrastructure and gear it towards providing diagnostics for rural India. In this process, however, the standards for digital data used in teleradiology have become incorporated within new political uses of the digital.

HL7 and its history of development

Hl7 and its history of development of different standards exhibits a particular dependence between data and organisation that provides a unique perspective on what digitalisation means organisationally and politically. As mentioned previously, the barcode as a universally legible data format that enables the circulation and traceability of commodities informed early ideas about developing this standard for the transfer of healthcare information. Clear inspiration was initially taken from the logistical and retail industries relating to a data standard in healthcare, which in turn highlights the dominance of the idea of flow management as a core principle for the organisation of healthcare and healthcare digitalisation. As I showed in Chapter 4, the attempts to exercise control over both labour as a materially determined force of production and the circulation of information and bodies within the hospital, are informed by logistically construed ideas about the regulation of flows. HL7 is also concerned with the movement of information, possibly even more so than DICOM. HL7 is primarily designed as a data standard describing the format of data objects for exchange within a clinical environment. This difference, between simply being a record of data and being a record of medical data for exchange, was pointed out to me in my interviews with members of HL7 Australia; this is a difference that distinguishes the role of HL7 from the standards for Electronic Medical Records (EMR) that are developed separately. What this difference implies is that there is a marked distinction between the record as an archive for storage (as in the case of EMR) and the record as a dynamic organisational archive, as is the case with HL7 data structures.

The role of the archive as storage and its importance for the development of PACS was discussed previously in Chapter 4. Here however, I want to take time to point out a specific new meaning that the archive receives in the process of developing HL7. This meaning is partly constitutive of the way that HL7 develops an ontology of medical data, and it also partly reflects the ways in which healthcare is conceived as an organisational process during the course of the development of HL7. Firstly, it is crucial to stress (again) that HL7 does not represent one singular standard but rather has gone through a process of development whereby different standards are based on different sense-making related to the link between healthcare, organisation and digital media. The first mature HL7 version – namely Version 2 (HL7v2) – represents the classification of healthcare data into different segments drawing on a relatively simple idea of the data structure following the model of a message. The premise of HL7v2 is that messages are sent in response to trigger events such as patient admissions, study requests and billing (Benson and Grieve 2016; Health Level Seven International 2007a). The message structure is simple; it includes a message header and the administrative and clinical information that is being communicated, all divided into message segments using the syntax of delimiters which made HL7 v2 readable by earlier machines (delimiters have subsequently been replaced with xml syntax in Version 3). HL7v2 largely adopts an ad-hoc notion of keeping record of the event, which represents a much more descriptive than prescriptive instigation of the digital archive and its role in building digital infrastructures. Despite the fact that HL7 v2 does provide data models that are structured around the notion of segments, it remains a relatively flexible and responsive standard for healthcare notation with only 80% of the data types defined by the standard and the remaining 20% left to organisations to structure and define themselves. This flexibility is especially notable in the so-called "Z segment" which is left undefined and can be locally defined by each healthcare institution. This flexibility led to growing diversity in the implementation of the standard across countries and individual healthcare facilities which hindered interoperability between different implementations and caused what became known as different HL7 dialects. These issues were addressed in the subsequent versions of HL7 but the salient issue to note here, in consideration of the development of HL7, is that at an early point HL7 v2 was already posing some important questions about what it means to digitalise healthcare and what a standard for digital medical data does.

HL7 v2 suggests that there is a strong interconnection between communication and organisation in the development of the standard. It postulates a particular interdependence between events in the real world and the exchange of data, which has been radically changed in the subsequent Version 3. HL7 v2 is thought about primarily as a standard for messaging, and this has consequences for the logic that it follows in defining the relationships between digital objects as well as their relationship to the healthcare institution where data circulate. HL7 v2 defines data types and hierarchies and also what is referred to in the standard as "trigger events". Trigger events are situations that take place in the real world that cause the need for exchanging messages within the healthcare institution: As HL7 documents elaborate: "The Standard is written from the assumption that an event in the real world of healthcare creates the need for data to flow among systems. The real-world event is called the trigger event." (Health Level Seven International 2015). A referral to the radiologist for example, is a trigger event that leads to the creation of an imaging order. Trigger events are coded in the message; they indicate what necessitated the exchange of data. However, there is also a clear assumption that the standard does not describe all healthcare interactions and events, but instead only covers the digitalisation of messaging, thus creating a clear distinction between the domain of digital communication and the non-digital environment that this communication describes.

This premise of HL7 v2, compared to the later versions of the standard that take a different approach to the role of digital data in healthcare systems, shows the gradual evolution of the significance of digitalisation in the industry. HL7 v2 which was developed in the mid-1980s still does not preclude the existence of other, non-digital interactions in the hospital; that is, it regards the exchange of messaging as just one of the organisational flows in the clinic. Thus, it builds on the idea of the hospital as a space of the organisation of a multiplicity of flows of patients, doctors, supplies and records, as discussed in Chapter 4. The initial link between organisational events and messaging sets HL7 v2 apart from the later ontologies of healthcare information that are structured in Version 3 (HL7 v3). The premise of the organisational event as a trigger for communication or messaging, suggests an auxiliary role of communication as a recording device of decision-making. As developers point out, HL7 v2 is not as sophisticated in this regard and the move towards HL7 v3 marks a radical reorientation of how the role of the standard is seen and how it relates to the link between information and communication.

The most significant development in HL7 v3 is the introduction of Reference Information Model (RIM). This forms the core of the new standard and the standard for Clinical Document Architecture (CDA), that builds on the ontological categories defined in RIM. For HL7 v3, RIM and CDA, the developers adopt what can be seen as a pronouncedly Luhmannian approach to the new standard foregrounding the primacy of communication in the ontology of the digital representation of healthcare processes and actors (Luhmann 1992; Schoeneborn 2011). The main points of criticism mounted against HL7 RIM, as a system of categorisation and codification of different aspects of healthcare organisation, actually testify to the continuities that define this process. These continuities point to the persistent role of the medical record as a technology of organisation which binds the codification of the scientific knowledge of the body to the regulation of work tasks and hierarchies. As discussed in the previous chapter, the record, the archive, and the role of information in healthcare and teleradiology go beyond just documenting the practices of medicine because they shape future practices of knowing and treating patients, as Berg and Bowker (1997) also argue in their analysis of the medical record. The endorsement of speech act theory in RIM also builds on these past uses of the archive, signifying the growing importance of information not just for exchanging messages (which is the premise of HLv2) but also as a medium of organisation and control. This endorsement also demonstrates the interdependence built between archive and flow in the organisation of medical labour; this is brought to the fore in RIM where the record of information becomes the universal signifier for all of the activities, roles, subjects, and relations managed under healthcare institutions. To a significant extent then, RIM shows continuity with already present practices of control and organisation in the hospital; that is, the management of records and archives and the impact they have on shaping how doctors and nurses perform their work, is evident in the primary role of the record in the new data architecture framework. On the other hand however, we can see the lasting significance of the management of flows and the focus on processes and procedures that does not just make the medical archive a collection of records, but also incorporates it within the logic of workflow management.

RIM rests on two important theoretical and methodological assumptions. First, it adopts the "speech act theory" developed by John Austin (1975) as a way of structuring the architectural framework of the standard. This makes the "act" a central element for the digital representation of events, objects, and relationships that take place in the healthcare system. Developers of the standard explicitly reference Austin's speech act theory as the main inspiration and principle of construction of the ontology of data objects and the relations described in the standard. As evidenced from the following excerpt from the official HL7 documentation, this referencing of Austin's work extends beyond a mere mention but is, instead, incorporated within the foundations of the standard and constitutes an important aspect of how HL7 interprets the relationship between data and organisational roles and events:

> In this sense, an Act-instance represents a "statement" according to Rector and Nowlan (1991) [Foundations for an electronic medical record. Methods Inf Med. 30.] Rector and Nowlan have emphasized the importance of understanding the medical record not as a collection of facts, but "a faithful record of what clinicians have heard, seen, thought, and done." Rector and Nowlan go on saying that "the other requirements for a medical record, e.g., that it be attributable and permanent, follow naturally from this view." Indeed the Act class is this attributable statement, and the rules of updating acts (discussed in the state-transition model, see Act.statusCode) versus generating new Act-instances are designed according to this principle of permanent attributable statements.
>
> Rector and Nolan focus on the electronic medical record as a collection of statements, while attributed statements, these are still mostly factual statements. However, the Act class goes beyond this limitation to attributed factual statements, representing what is known as "speech-acts" in linguistics and philosophy. The notion of speech-act includes that there is pragmatic meaning in language utterances, aside from just factual statements; and that these utterances interact with the real world to change the state of affairs, even directly cause physical activities to happen. For example, an order is a speech act that (provided it is issued adequately) will cause the ordered action to be physically performed. The speech act theory has culminated in the seminal work by Austin (1962) [How to do things with words. Oxford University Press]. (Health Level Seven International 2004b)

Austin (1975) does not just see the speech act as a statements of facts, he also argues that language has the power to change and generate reality. He distinguishes between three different speech act types – namely, locutionary, illocutionary, and perlocutionary acts – according to their intention and their effect on the participants in the act of communication. Locutionary speech acts are those that convey information, illocutionary speech acts are those that through the act of saying something make it happen, such as declaratory statements like "I do" in a wedding, while perlocutionary speech acts are those acts such as requests, persuasion or demands that effectuate change after the utterance is made. HL7 v3 adopts this pragmatics of language use as its core principle, making the "act" the key data class of its ontology. This is a premise that is not only important for the internal structure of the model and how relations are represented, but also has an important consequence for the relationship between information and administrative and clinical events that are represented through RIM. The adoption of Austin's philosophy of language determines the ontology of the model, which chooses to build up the framework of representing healthcare based on the fundamental assumption that there is an equivalence between a record and a thing or event.

This internal ambivalence of RIM is related to the second, interrelated and important premise of the new HL7 v3 standard, which is borrowed from the work of Rector, Nowlan, and Kay (1991) who prescribe the foundations of the electronic medical record (EMR) (Health Level Seven International 2004b). While HL7 is not in itself an EMR standard, RIM is conceived of as an ontological architecture that captures the whole of healthcare, framed through the communicative aspect of speech acts and medical records. Organised around a few classes which are namely: Act; Entity (which includes humans, machines, and organisations); Participant; ActRelationship; Role; and finally, moodCode for the Act class that distinguishes between observations, orders, and completed actions (Health Level Seven International 2004b). The key argument that HL7 v3 borrows from their study is that there is a relationship between information communication and facts. Rector, Nowlan, and Kay (ibid.) see EMR as reflecting not simply facts about the world and the condition of the patient, but more saliently reflecting observed, communicated, and recorded facts. Writing about the faithfulness of EMR, these authors argue that "the medical record consists of what clinicians have said about what they have heard, seen, thought and done" (ibid.: 3).

This ambiguity in RIM has been widely criticised as a poor, inconsistent and illogical example of digital ontology (Smith and Ceuster 2006; Smith, Vizenor and Ceusters 2013; Grieve 2011). Smith and Ceuster in particular argue that one of the model's major shortcoming is its inability to distinguish between data records and facts captured by these records, which is not an abstract ontological shortcoming but rather leads to the confusing proliferation of information objects referring to each other (ibid.). The biggest danger, according to Smith and Ceuster (2006), is that RIM falls into "referential opacity" and essentially develops as a meta-language model, rather than an object-oriented language. They add that RIM is also a cumbersome and inflexible framework that is hard to adapt for particular healthcare needs (ibid.).

Besides the forms of criticism above emanating from developers, HL7 RIM poses more general questions about the consequences of digitalisation, and specifically questions related to the consequences of assumptions and ideas that underlie processes of digitalisation given that RIM has the ambition to provide an ontological framework for the digitalisation of healthcare. For my analysis, the logical consistency of its method of classification is not so important. What is important however, is that RIM's ontological model codifies an assumption about the primacy of information in the exercise of control and the organisation of different processes within healthcare systems. By adopting Austin's speech act theory, RIM also explicitly adopts the notion of the performative functions of language and transposes these functions into the domain of digital data.

This link between speech and action developed in the work of Austin has been the object of criticism, perhaps most notably from Judith Butler (1997) and Jacques Derrida (1988) who question the equivalence between act and speech in their work. Butler, writing about the political implications of regarding speech as a form of action, argues for the complex situatedness of language within structures of power though which words acquire the force to produce effects. This understanding complicates the relationship between speech and act that Austin describes, and specifically challenges the assumption that there is a predetermined set of conditions that make an utterance felicitous, and thus give a speech act its power to enforce a change in reality. What Butler argues is that language itself generates the conditions of its validity and meaning, thus pointing out the mutability and instability of language as a system of orientation that guides the production of meaning in social life. Derrida, on the other hand, challenges Austin's logocentrism and the implied generative relationship between meaning, speech and writing, arguing that meaning is instead produced and challenged in every instance of a linguistic act and not just by the one producing an utterance but also through its reception and dissemination.

These critiques of Austin's theory of speech acts bear relevance to the underlying theoretical assumptions behind HL7 RIM and the effects of these assumptions on the way that this digital data standard functions in healthcare systems. The premise of an equivalence between what is recorded and what is done rests on the condition of rationality, truth, and comprehensiveness of the record. As Smith and Ceuster (2006) argue from the standpoint of digital ontologies, and as Derrida (1998) argues from the position of a critique of language and meaning, this initial presumption is too often erroneous. It also presupposed a particular type of subject of healthcare; that is, the responsible actor performing and recording acts. RIM assumes certain qualities of the actors involved in the speech acts; these are documented in the standard stating that acts are "intentional actions, performed and recorded by responsible actors" (Health Level Seven International 2004b) and that this condition is valid for all professions and businesses. RIM thus assumes equivalence between recording and agency, therefore excluding the agency of patients and workers who are involved in performing healthcare acts but not in recording them. This equivalence between recording, agency, and responsibility assumed in RIM creates hierarchies and techniques of invisibilisation in digital healthcare practices. In the context of teleradiology outsourcing, where hospitals and teleradiology companies use HL7 alongside DICOM to exchange data, the equivalence between recording and agency leaves some of the auxiliary workers in the workflow process, such as the loaders, unaccounted for. As I demonstrated in this dissertation, the subjects involved in teleradiology practices where HL7 is used are already enmeshed in complex hierarchies and processes of conditional inclusion and invisibilisation. This is a context that obscures the possibilities for the interdependence between intention, responsibilisation and equivalence between the labour process and the record of actions that RIM represents.

FHIR is the latest version of HL7. It addresses some of the criticism about the bulkiness of HL7 v3 RIM, by proposing the concept of modularity and introducing resource bundles instead of using an overarching reference information model. These resource bundles offer pre-packaged descriptions of healthcare scenarios that can be modified and embedded when building HIS, RIS or using APIs in order to exchange resources between different web applications. This new flexibility of the standard offers structured resources instead of the HL7v3 CDA (clinical document architecture) and it allows programmers to choose and easily rework the resources, using them to communicate and implement actions. FHIR also departs from the speech act theory foundation of HL7 RIM by explicitly stating that there is no complete equivalence between the digital record and real-world events and relations. The new standard does not employ the overarching concept of the Act, but instead distinguishes between different types of actions within the healthcare domain. Some of them, like the Task, are related to the workflow of data exchange, while others such as Procedure or ImagingStudy involve interaction with between patients and doctors which means they are distinguished as actions that involve more than the transfer or manipulation of information. The documentation of FHIR states that there might be events and interactions in the healthcare environment that are not recorded or are only partially recorded, thus breaking from the language-centred model of RIM.

More central to FHIR however, is the focus on interfacing. FHIR introduces this once through the adoption of REST API which makes it possible to use and connect with different web applications, and twice through the very architecture of FHIR which relies on hyperlinks and RESTful interfaces for the coordinated updates and changes of the resources and bundles (Health Level Seven International 2019). Through these hyperlinks the documentation of the standard used by developers for defining data classes and relations in the software they develop can be constantly updated, which means that the problem with obsolescence of the standard will be resolved. This new vision introduced with FHIR speaks to the complexity of the intertwined development of the technologies of control and productivity in healthcare, and to the significance of the medium in this historical evolution. FHIR responds to a new context of digitalisation where healthcare data circulates not only within medical institutions but also on mobile apps used for personal health tracking, booking appointments and so on.

This new context changes how digital healthcare infrastructures function and opens them up to the need to connect and interface with other digital infrastructures such as web pages, mobile applications and different databases used by public and private entities. As I pointed out in the beginning of this chapter, this context necessitates both technological and political responses and HL7 is at the forefront of building the alliances and technologies that states and private business see as strategic tool for their success. FHIR stems from the increasing need for digital healthcare to integrate itself within larger political and technological systems including: the Internet and the new mobile app economy; the growing investments of governments into consolidating and standardising medical data; the diverse interests in big data analytics; and machine learning using healthcare data. Shannon Mattern (2014) argues that the interface points to the embeddedness of systems within systems and the interconnectedness of digital infrastructures. This aspect of interfacing is especially relevant to the growth of digital healthcare and teleradiology. While the drive for interoperability has pushed initiatives for harmonisation between different standards forwards (the joint initiative between HL7 and DICOM is a prominent example) FHIR typifies a more disjointed practice of interconnectivity and vision, where interfacing coexists alongside the efforts to harmonise DICOM and HL7. The interface has an important role in both enabling connectivity and problematising the issue of mediation at the same time. As Alexander Galloway (2012) contends, the interface enables mediation while highlighting the point of friction where communication and transfer are made possible. He sees the interface as being essential for any kind of mediation, and argues that it accentuates the importance of the medium for enabling interaction and transmission in socio-technical environments while also shedding light on the precariousness of any mediated connection that is entirely dependent on the successful operation of interfacing. The technological discourse of interoperability tends to invisibilise or obscure this instability that occurs at the points of interconnection and expansion of digital infrastructures, but it nonetheless remains part of how teleradiology practices emerge and spread into new territories both internationally and within countries, as the example of the Tripura teleradiology project shows.

Conclusion

In this chapter, I discussed the complex processes of negotiation that underpin the drive for seamless data exchange, define the different actors involved in them, and highlight the assumptions about the relationship between data and institutional and organisational processes that HL7 engenders. The case of HL7 reveals some of the key principles, processes, and failures in the endeavour to digitalise healthcare. While in the previous chapters I focused on the transformative role of digitalisation, arguing that the digitalisation of teleradiology builds on earlier modes of control through the manipulation of material environments, the case of HL7 shows the possibilities of digital data acting as a rupture, obliterating and negating earlier methods of organisation.

The history of HL7 and the heterogeneous logics behind the organisation of data that it conveys highlight the contradictory nature of the drive toward interoperability. The ambition to achieve interoperability across different digital systems and data ontologies engenders phantasies linking the seamless mobility of data to the generation of social and economic value. David Ribes (2017) remarks that interoperability is often a goal in itself. Rather than necessarily addressing current problems of data transfer, it is oriented towards an "indeterminate future" (ibid. p. 1523) for which it opens new possibilities. The ability to move data and to amass data can generate new practices of which I gave examples in earlier chapters: the machine learning department at Worldwide Teleradiology that makes use of the DICOM images diagnosed by the radiologists at the company, as well as the project for teleradiology that the same company provides to rural hospitals in Tripura. These cases show the generative role of digital data and interoperability in driving new business projects and allowing for the wider penetration of data infrastructures in healthcare practices.

At the same time, the idea that data can be exchanged seamlessly runs against the multiple borders and seams that define the materiality of data production and circulation. As I discussed earlier in this dissertation, the actors involved in generating and manipulating data – radiologists, patients, and auxiliary workers – are all subject to practices of bordering and differential inclusion (Mezzadra and Neilson 2013) that determine the conditions of where and how they can work and who can be involved in healthcare interactions. Similarly, different jurisdictions and institutional practices, such as HIPAA, restrict the mobility of data by locking personal patient information to the concrete physical locations of data centres and diagnostic facilities. The drive toward interoperability behind HL7 highlights this disjunction in the practices of control exercised over the circulation of data.

Moreover, the attempt to map healthcare institutional practices onto data objects and relations undertaken through HL7 elucidates the tensions between bureaucratic and digital modes of organisation and control. On the one hand, as I argue in this dissertation, this attempt points to the incorporation of labour management practices and institutional constraints into the design of data infrastructures. For example, the workflow functionalities embedded in DICOM and PACS and the different access and allocation of cases that they allow are representative of this overlapping between digital and jurisdictional regulations. On the other hand, the contradictory history of development of the different versions of the standard suggests the limits of this process of mapping and undermine the suggestions of equivalence between digital data and the interactions between different healthcare subjects that it represents.

Conclusion

During my fieldwork, while I was sitting next to different radiologists and watching them diagnose the images on their screens, one thing I found especially interesting was the process of reading an image. They kept scrolling up and down causing the 3D images to reveal layer after layer of the body in a seemingly scattered and chaotic manner. The visualisations of human tissue on the screen were moving rapidly as if animated by the gestures of an agitated hand and taken in by an eye that was, strictly speaking, doing anything but reading. Reading presupposes an already structured and organised meaning where the reader is guided through the conventions of syntax, morphology, and direction of writing. But bodies are not texts and the signs of a disease have to first be discovered before they are analysed. The radiologists are looking for the patterns of a disease - tumours, abnormalities in tissues and blood vessels - that can look different in each body. As I mentioned in Chapter 3, radiologists work with a wide range of images - some providing the matrix of how a pathology can look, while others showing the specific manifestations of this pathology in patients' bodies. The "reading" of the image is a continuous navigation between the particularity of one specific body and the wider phenomena of anatomies and pathologies to which this body relates.

I do not want to go too far in suggesting an analogy between the way radiologists read images and the way social scientists do research but I have always found this process of pattern searching in radiology especially illuminating. The relationship between the scientifically classified pathology and the specific body on the screen is always uneasy and the eyes of the radiologists are fervently searching for the signs that link them together. I find this process of negotiating the specific case and the frameworks through which it acquires scientifically significant meaning revealing for the challenges of situating empirical research, and especially case studies like mine, within wider theoretical discussions. Striking the right balance of recognising the specificity of the case and placing it within a field of scholarship not just as an example but also as a possibility of gaining new insights is a delicate act. And this is especially true for the practice of teleradiology, which is a sufficiently exotic object of research in social sciences and cultural studies. It is, however, a rich case that allows for insights into the complex entanglements of data infrastructures, labour, and control in ways that transcend the particular case of teleradiology. The long history of the establishment of the profession of the medical expert, the close relationship of radiology with technology, and the significant developments in digital systems and standards in this field in the last 50 years make teleradiology a case where different frameworks of regulation intersect and interact with each other. My analysis of the two teleradiology companies, Worldwide Teleradiology in Bangalore and Omniscan Teleradiology in Sydney, the standards DICOM (Digital Imaging and Communications in

Medicine) and HL7 (Health Level 7), and PACS (Picture Archiving and Communication Systems) draws on this historical situatedness of teleradiology in order to discuss how data infrastructures build on past practices of labour management and regulation of expertise while simultaneously transforming them. This approach allows me to gain insights from the case study of teleradiology that are grounded in the specific empirical material I work with but open discussions with wider relevance to the study to digital labour, digitalisation, and the social and political significance of data infrastructures.

I interrogate the role of data infrastructures in teleradiology outsourcing and the management of expert labour by analysing how DICOM, HL7, and PACS function as technologies for organising and managing data and how these functions become operationalised in the management of labour and the governance of different subjects of healthcare. I draw on work from science and technology studies, media studies, anthropology, and political economy and through this combination of theoretical and methodological perspectives I suggest that the case of teleradiology offers the possibility of rethinking some of the core ideas about the role of digital technology in the regulation of productivity and the control over labour.

Infrastructures and labour management

The analysis of teleradiology outsourcing in my dissertation suggests that a focus on data infrastructures can give new insights into how practices of control and intensification of digital labour develop through a combination of continuities and ruptures in the material praxes and techniques of regulation. As I argue in this dissertation, infrastructures include not just the technical solutions, such as data standards and information systems for the transfer of medical images and information, but they also encompass the complex sets of regulations and institutions that determine the scope of validity of healthcare expertise. The focus on the infrastructural character of these techniques for the management of expertise helps elucidate the participation of multiple actors and logics of regulation. The validity of radiology expertise is determined and negotiated through professional associations, national healthcare institutions, and supranational alliances, which demonstrates that the management of labour in teleradiology is not exclusively enacted through the institution of the nation state.

I show that the infrastructures of expertise through which the validity of professional credentials is affirmed in cross-border practice are also key for understanding the complex principles of labour intensification that underlie the management of labour in teleradiology. I argue that labour productivity in teleradiology is construed not just as an imperative driven by capital but also as a logic of self-regulation of the medical profession. This double drive behind the technologies for labour intensification in teleradiology challenges classical Marxist accounts of labour management dating from the work of Harry

Braverman (1974) that see the optimisation of the work process as a movement towards limiting the power of workers and diminishing their control over the cognitive aspect of their work. My analysis suggests a more complex understanding of the process of labour intensification which highlights the heterogeneity of labour and the different ways in which workers bear the brunt of a push towards productivity depending on their position and credentials. As I demonstrated, in teleradiology this heterogeneity leads to the hierarchisation of labour and the interdependence of radiologists and auxiliary staff.

The interdependence between different labour subjects is grounded in long-standing conceptualisations of labour through scientific metaphors of energy expenditure and metabolism (Bellamy Foster and Burkett 2008; Burkett and Bellamy Foster 2006; Daggett 2019; Gilbreth 1919), which have prompted practices of management where exertion is distributed among workers. In teleradiology the organisation of workflows follows these principles of distribution and metabolism and offloads tasks that are deemed not value-generating to auxiliary staff. These underlying assumptions about productivity also become incorporated in the principles of workflow management in healthcare institutions and in the workflow functionalities of digital systems like HIS and PACS.

Thus, the hierarchies and dependencies between workers within outsourcing chains that I describe in the dissertation reflect the intersecting of multiple regimes of expert labour regulation. These different regimes reflect national and supranational jurisdictions but also modes of governance enacted through professional organisations, as well as long-standing principles in scientific management where increased productivity is attained through hierarchisation and division of labour. Through the notion of infrastructures of expertise, I emphasise this heterogeneity of actors and logics of governance in the regulation of radiology expertise and their integration into socio-technical systems where the validity of expertise is regulated through professional membership, national and supranational jurisdictions, financial and legal liabilities, and software configurations that determine the rights of access and case allocation.

My focus on the infrastructures enabling teleradiology outsourcing points to the increasing integration and interoperability between different technological and administrative systems for the management of labour and the mobility of workers and data. A key aspect of the development of DICOM, HL7, and PACS that I discussed in the dissertation, is their interdependence. This interdependence presents itself in the way the standards DICOM and HL7 are tied to the emergence of the technical systems for the transfer of healthcare data - DICOM develops in close relation to PACS, while HL7 evolves as a standard for the exchange of data within Hospital Information Systems (HIS). This embeddedness of infrastructures within each other, which Geoffrey Bowker and Susan Leigh Star (2000) also discuss in their work on standards, importantly includes the incorporation of 'soft infrastructure' in the digital systems and standards used in teleradiology - for example, rules for the validity of expertise, standardised medical processes and roles. The integration of professional and administrative regulations is evident in the workflow functionalities of PACS and HIS which allow for cases to be assigned to the radiologist with the necessary professional credentials and also prescribe the flow of events and the interactions between different workers and digital systems. The bureaucratic organisation of the hospital, however, is also encoded in the organisation of data in the ontological model of HL7, as I demonstrate in Chapter 5.

The integration of bureaucratic and technological modes of labour management and the management of expertise in teleradiology challenges the idea of a clear-cut distinction between algorithmic governance and the political and economic technologies of control exercised through the institutions of nation states, supranational alliances, and professional organisations. While it will be a stretch to claim that these different technologies of control are articulated through each other, there are instances where the two intersect in ways that bureaucratic categories define the functions of digital infrastructures and, on the other hand, digital objects influence the ways labour and labour mobility are managed. For instance, the data classes in HL7 and DICOM are determined by the institutional and clinical roles and processes in hospitals, while, as an example of the influence of data on the management of labour, HIPAA rules for the provenance of healthcare data act as restrictions on the validity of radiology expertise in outsourcing. Benjamin Bratton (2016) argues that such convergences point to the growing role of digital technologies in shaping political practices and imagination but the detailed analysis of data standards that I offer in this dissertation suggests that there are limits to the possibility for mutual articulation. These limitations make the notion of the infrastructure ever more relevant. Infrastructures can function without being entirely homogeneous as long as there are points of interfacing and translation which can be performed either by human workers (Simone 2004) or through technological solutions (Galloway 2012, Vertesi 2014).

Data, labour, media

I show in this dissertation that the complex relationship between digital and bureaucratic modes of control can be traced to the long history of material practices of management in healthcare. These practices concern the organisation of different flows in the hospital - bodies, labour, information, and air - that have been at the centre of projects for the optimisation of healthcare work. I argue that there are continuities in the significance of regulating these flows from the early days of Western clinical care when Florence Nightingale (1863) reorganises hospital architecture, to the focus on workflow management in DICOM, PACS, and HL7. The continuous concern with the regulation of flows in the hospital provides an insight into the role of materiality in the management of expert labour. Deborah Cowen (2014) has argued that circulation and the management of flows constitutes an important aspect the exercise of control and the production of value. In teleradiology, the workflow bears the legacy of these material practices of managing flows as ways of optimising productivity through the workflow and organising knowledge through the archive. While the logistical solutions from Nightingale's study determine how bodies are situated and move in the most efficient and beneficial for their health manner, the archive records and prescribes how healthcare work must be performed in a standardised way. The uses of data in the standards DICOM, HL7 and in the healthcare digital systems for the transfer of images and information incorporate these different aspects of control - focusing on processuality and on the inscription of knowledge, however, they also highlight the significance of digital media for transforming past modes of control.

I argue that the two standards, DICOM and HL7, determine the specific properties of data in teleradiology. These digital data standards inscribe the process of production and circulation of medical images and data within the format of the digital objects. They do so by incorporating information about the actors involved in performing a study or a request, the software and hardware used, and determining the sequences of actions within which this object is embedded. As I show, this property of digital objects in teleradiology brings together practices of workflow management and practices of inscription, which has the important consequence of placing data at the centre of processes of organisation and regulation in teleradiology. My analysis makes evident that before understanding the role of algorithms in exercising control it is necessary to understand how the organisation of data into digital ontologies and relations presuppose the possibilities of certain actions and dependencies. Yuk Hui (2016) makes an important intervention in this regard in his work on the philosophy of digital objects. My dissertation contributes to this line of inquiry by analysing how specific data objects, ontologies, and relations are developed in DICOM and HL7, what is the underlying logic they assume for the digital practice of healthcare, and how they affect subjects and practices.

I discuss how the properties of digital objects in DICOM enable new forms of transparency and control that go beyond the medical gaze and allow for the real-time monitoring of labour and patients in rural parts in India. At the same time, I demonstrate the limitations of the attempts in HL7 RIM to subsume the practice of healthcare as a whole under the notion of the medical record and the exchange of information within HIS. This uneasy relation between healthcare subjects and data objects in teleradiology drives some of the process of invisibilisation in teleradiology, making the recording of events and actors a precondition for their inclusion in systems of care and surveillance. My discussion of the role of data ontologies in shaping the politics of digital infrastructures in teleradiology points to the importance of studying data and data practices not just through what is collected by also by focusing on how it is organised and how this logic of organisation can reverberate back on the subjects whose data is collected.

And last, data are not only embedded within material practices of organisation and labour management but they also impose its own conditions of materiality through the requirements of data storage and transfer. All these operations on data entail temporal and spatial arrangements that have implications not only for the labour involved directly in the storage of information but also for the labour of radiologists and other teleradiology workers. Cloud storage, the location of servers, and the time it takes for files to be transferred and loaded within global networks create new conditions for the temporality and space that labour inhabits. The lags and technological temporalities of digital systems in teleradiology become part of the contingencies that workers need to navigate and compensate for. At the same time, the specific requirements of where data is located and how it moves between state jurisdictions are part of the new technopolitical sovereignties that determine the inclusion and exclusion of labour subjects based on rights of access and the complicated politics of data nationalism.

These different subjects play an important role in the production and circulation of data and images within the infrastructures used in teleradiology. The points of interaction between HIS and PAC, on one hand, and the radiologists, auxiliary staff, and patients, on the other, become openings that create possibilities for the exercise of control, the extraction and manipulation of data. These structures of control, however, become incorporated within the ambitions of individual and group subjects and the demands they make on companies and nation state institutions. Such is the case of the regulation and intensification of radiology labour, which arises partially from the labour market protectionism practices of radiologists and their professional associations. This makes the strictly controlled workflow processes and high volume of imaging studies read by radiologists like Lakshmi and Giacomo not just coercion imposed by capital. Instead, they become part of how radiologists constitute themselves as expert subjects and negotiate the conditions of their employment allowing them to work from exotic holiday islands, to adjust their workhours and location. Similarly, the collection and manipulation of patient data through the use of teleradiology infrastructures are intrinsically entangled with practices of care exercised by the biopolitical apparatus of the state and the notion of public accountability it engenders. Extraction, control, accountability, and care become closely entangled within outsourcing practices and data infrastructures, as the teleradiology project in rural Tripura conducted in partnership between Worldwide Teleradiology and the Tripura State Government demonstrates.

Data infrastructures and the practices of control they enable also, crucially, permit the emergence and articulation of relations and dependencies between subjects involved in teleradiology outsourcing. These relations make possible the development of standards and software in which radiologists are actively involved alongside software developers and hardware manufacturers. They also underpin the workflow management in teleradiology companies where the interdependence between radiologists with different credentials, transcribers, loaders, and workflow management workers acquire pronouncedly affective aspects. These aspects make possible the expression of labour hierarchies and division through relations of care, collaboration, and affective metabolism. The subsumption of these subjects and relations under the algorithmic control of data infrastructures and the data categories of digital standards is never complete, despite the ambitions of standard developers to achieve complete mapping of roles and actions onto data objects. These points of impossibility for subsumption highlight the limits of the digital as a technology of control but also create opportunities for its expansion through the role of human mediators and interfaces.

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