Hospitals as innovators in the health-care system: A literature review and research agenda

Taran Thune

TIK Centre for Technology, Innovation and Culture, University of Oslo

(t.m.thune@tik.uio.no)

Andrea Mina

Cambridge Judge Business School, University of Cambridge

(a.mina@jbs.cam.ac.uk)

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Abstract

This paper aims to improve understanding of the role of hospitals in the generation of innovations. It presents a systematic and critical review of the interdisciplinary literature that addresses the links between the activities of hospitals and medical innovation. It identifies three major research streams: studies of the contribution of medical research and clinical staff to innovation, analyses of novel practices developed and diffused in hospitals, and evolutionary studies of technical change in the context of human health care. This is a highly heterogeneous body of literature, in which comprehensive theoretical frameworks are rare, and empirical studies have tended to focus on a narrow range of hospitals' innovation activities. The paper introduces and discusses a framework integrating different perspectives that can be used to analyze the functions performed by hospitals at the intersection with different partners in the health innovation system and at different stages of innovation trajectories. On the basis of current gaps in the literature, a research agenda is discussed for a relational and co-evolutionary approach to the study of hospitals as innovators.

Keywords: Health-care technology, health innovation system, hospitals, medical innovation, user innovator

1. Introduction

Studies of innovation related to human health have emerged in great abundance, on topics ranging from advanced biotechnology to improvements in health services. Many of these studies argue that hospitals are central actors in this innovation, yet these organizations are rarely addressed directly and explicitly in innovation studies. Instead, they are treated as contexts, partners, indirect selection mechanisms, and users in investigations of industrial development and the commercialization of science. In this paper, we focus on the role of hospitals in the generation of medical innovations through a systematic review of the relevant social science literature.

Hospitals, in particular, university or research hospitals, are part of health innovation systems, which can be theorized as distributed systems because of their extensive division of labor and complex collaborative approach to the application of useful knowledge (Coombs et al., 2003; von Hippel, 1988). Hospitals perform multiple functions in health innovation systems. They are the major providers of health-care services. They are adopters and users of new technologies (thus the demand side of externally generated innovation). They are potential developers of processes and organizational innovations. Moreover, hospitals can be an integral part of the education system in which new practitioners are trained, so they can be loci of clinical experimentation and large R&D-performing institutions in their own right. Overall, they are key sites for the adoption, reproduction, and generation of medical knowledge.

The role of individual doctors as innovators has been covered extensively in the history of medical technologies but has to be understood within a complex institutional environment and in relation to long-term epistemic and cultural change (Blume, 1992; Pickstone, 2001). The role of hospitals in the consumption and implementation of innovations—both technical and

clinical—has also been covered extensively in the health management, health economics, and health policy fields. However, despite notable exceptions (e.g., Djellal and Gallouj, 2005, 2007; Salge, 2012; Salge and Vera, 2009), the organizational capacity of hospitals to generate medical innovations has been underemphasized. In this paper, we are interested in assessing the role of hospitals as generators of medical innovation, broadly defined as "new drugs, devices and clinical practices introduced over time into the provision of health care" (Consoli and Mina, 2009). The rise of more open models of innovation (Chesbrough, 2003, 2006; Dahlander and Gann, 2010) makes it even more important to focus on the specific contribution that hospitals make or have the potential to make in upstream innovation activities as leading organizations or as partners to other organizations in the medical industrial complex. For this reason, we are especially interested in the literature that covers universities, research hospitals, and academic medical centers, and their arguably growing importance in modern health innovation systems.

Health-care systems comprise heterogeneous actors that perform distinct but related tasks (Djellal and Gallouj, 2005, 2007). Although there is a division of labor among the individual participants, many of the tasks performed by each agent cannot be completed without the contributions of other agents. Thus actor groups have multiple and mutual dependencies, which create the systemic quality of health innovation (Windrum and García-Goñi, 2008). Hospitals, particularly research or academic hospitals, become central nodes in health-care networks because they perform multiple roles at key intersections of the system (Anderson et al., 1994; Ramlogan et al., 2007). First, these organizations function as brokers among different domains and sources of knowledge, such as scientific, clinical, technical, and commercial knowledge. Second, they are bridges among different modes of learning, including learning through medical practice, through basic and applied research, through technical experimentation, and learning by adapting new technologies to local contexts

(Morlacchi and Nelson, 2011; Rosenberg, 2009). Third, hospitals connect health-care systems across stages in the innovation process as they can be involved in idea generation, testing/verification, implementation, and diffusion.

Hospitals contribute to new idea generation through experiential learning in clinical practice and research (both basic and clinical) by identifying problems and potential solutions. They often do so in collaboration with universities and firms under a variety of institutional arrangements (Rosenberg, 2009; Schlich, 2002). The outcomes of these activities are research outputs, insights for new inventions, and candidates for new products and processes (Chatterji et al., 2008). Some of these ideas may be spun out to form the basis for new companies or are licensed to existing firms (French and Miller, 2012).

Hospitals can initiate some product development activities internally, particularly development of new procedures, new services and organizational arrangements, and new tools and methods. In the product development phase, however, hospitals mostly interact with established firms to transfer knowledge about the clinical context in which the new product candidates can be used. They are then involved in testing and documenting the effectiveness, safety, and efficiency of new product candidates, thus influencing technology selection (Windrum and García-Goñi, 2008). Activities linked to learning and adaptation in the user context is a fundamental role for hospitals, along with development of a range of service innovations to support the implementation of new technology or new treatments. In addition, hospitals can shape opportunities for technological learning because experimental practice can lead to new idea generation, both as incremental improvements upon existing techniques or services, and as ideas for new products (Djellal and Gallouj, 2005; Metcalfe et al., 2005).

Insert Figure 1 around here

Figure 1 describes the multiple roles that hospitals *can* play in the generation of novelty within health care and medicine, which sets the parameters for the present study. Without implying strict linearity in these stages or dimensions, we propose that at any point in time a range of parallel and stepwise innovation activities occur in relation to the organizational context of a hospital.

The twin objective of the paper is to provide an overview of the state of the art in this interdisciplinary problem and to outline a conceptual framework that can be applied to the study of hospitals from an innovation system perspective. By highlighting the multiple roles hospitals play in distributed health innovation systems, we argue that the contribution of these institutions must be understood in relational and co-evolutionary terms: hospitals are sources of novel ideas as well as conduits for innovation generated elsewhere is the system. We argue that a more comprehensive perspective on the role of hospitals is important to better inform policy by stressing the system-level impacts hospitals have on the innovative performance of health-care service and manufacturing activities.

We use a systematic review methodology and sample widely in the heterogeneous and multidisciplinary research literature on this topic. In the next section, we present our methods and data. Three thematic strands of contributions emerge that differ in their perspectives and levels of analysis, which are articulated in more detail in section 3. In section 4, we synthesize and discuss the key findings. Having identified contributions and knowledge gaps, Section 5 concludes by highlighting emerging issues for further research.

2. Review method

The paper is based on a systematic review approach (Littell et al., 2008), which aims to make the literature selection and review process transparent and replicable. We started from the factual premise that research on hospitals and innovation spans many disciplines, empirical approaches, and publication channels. A highly heterogeneous body of knowledge presents the challenge of capturing the breadth of relevant contributions and synthesizing insights and main findings across several scientific domains. We address this challenge by using a maximum variation sampling strategy (Suri, 2014).

To select the literature for inclusion in the literature review database, multiple searches were carried out on search terms such as "medical innovation," "medical and/or health-care innovation systems," and "innovation and hospitals/academic medical centers/university hospitals/research hospitals." Identical searches were conducted in three databases with broad coverage: ISI Web of Science, Scopus, and PubMed. The first set of keyword searches was conducted in ISI Web of Science (WoS; on the title, keywords, and abstract) on the terms "innovation and hospitals," yielding 895 publications. Identical searches were conducted in Scopus and PubMed to verify that the searches generated the relevant research literature, thus validating our research strategy. Scopus and PubMed have broader coverage of publication types, including also books, book chapters, and practitioner-oriented publications. The procedure described in Table 1 was followed for each database. In Scopus and PubMed, the initial searches on innovation and hospitals yielded a larger number of hits (15,072 and 505). In these databases, we set requirements that publications should include an abstract, and searches were conducted on title/abstract/keywords, to enable a replication of the search procedures.

Insert Table 1 around here

As seen in Table 1, searching on the keywords “hospital” and “innovation” generates a large number of hits, which have to be reduced to meet review feasibility constraints. We therefore added a third term to narrow the scope of the search. After running the three queries, 307 abstracts from WoS, 638 abstracts from Scopus, and 203 abstracts from PubMed were downloaded and reviewed—a total of 1,148 abstracts. All these abstracts were read, and a decision was made as to whether the text was relevant in accordance with the inclusion and exclusion criteria in Table 1. The procedure was applied on abstracts and then on the full text of all documents that matched the criteria.

As an additional measure to ensure that we were not missing relevant publications, we also searched for publications that included the keywords “innovation” or “technology” in their title in selected journals that prior searches had identified as the four that published most frequently on this topic. This procedure provided information about 374 papers, of which 24 were added to the review database after the selection procedure was applied, and another six to the final set of papers.

To capture the literature that was relevant to our research interest, we defined two broad exclusion criteria, as described in Table 1. First, we excluded the extensive literature that addresses *only* the adoption and dissemination of innovations in the health-care context. Hospitals are large public organizations performing complex tasks through which they are

simultaneously involved in a wide range of innovation processes. They involve adoption choices and adaptive behaviors connected to the implementation of new medical technologies and managerial practices, which tend to be treated in some detail in the health-care management and mainstream health economics literatures. These include the adoption of new information and communication technology (ICT) solutions as administrative tools (e.g., electronic medical records), also covered rather extensively in the information systems literature (for an overview of ICT-mediated service innovation, see Barrett et al., 2015).

The vast literature on the implementation of medical or administrative innovation mainly describes how hospitals make technology adoption decisions or use innovations generated outside the hospital, which does not play a role in their generation. This is not to say that hospitals did not have a role in developing relevant new knowledge, but that this aspect of the innovation process is not the specific focus of the studies excluded from our database. They remain relevant for understanding implementation processes, but are less relevant if our objective is to understand how innovations are actively generated by or jointly with hospitals. Articles that link implementation to the generation of innovations have been included in the review. The same exclusion criterion was applied to literature that describes only the implementation of new treatment regimes, and to literature that addresses the efficiency and effectiveness of new innovations, without investigating how these innovations were developed or how hospitals or hospital staff contributed to the generation of these innovations.

The second exclusion criterion applied to the identification of relevant prior art concerned literature other than research papers, that is, papers that do not aim to increase scholarly knowledge about a particular question. This means that we included papers that present either new conceptual approaches or empirical studies of innovation in and by hospitals, and

exclude opinion pieces, teaching cases, letters, and other kinds of published items that are not subject to peer review. The medical domain includes many such items: they have been read as part of the research context, but have not been included in the final review database.

The search processes exposed the importance of searching broadly for research literature that addresses the role of hospitals in innovation, because numerous approaches to the topic rooted in different disciplinary settings exist, and each has dedicated journals and specialist audiences. A wide variety of fields has published on this topic, with growing intensity over the past 15 years (Figure 2).

Insert Figure 2 around here

Medical innovation and innovation in hospital/clinical settings has been addressed in economics and management, public health, health-care policy and management, innovation studies, sociology, science and technology studies, as well as in several medical and health care–related journals. The journals that have published most frequently on the topic, however, are in health-care policy and management, as well as in nursing-related journals. As Table 2 shows, there is not a great deal of overlap in top publishing journals in Scopus and ISI, except in the journals *Health Affairs* and *Social Science and Medicine.*

Insert Table 2 around here

For the final set of 46 articles that matched all the inclusion criteria, further detailed analyses were conducted. Table 3 shows how the articles represent a variety of research questions, methodologies, and data. This makes it more difficult to generate a coherent picture of the relevant knowledge base. Most of the articles describe or analyze innovation processes or innovation systems in which hospitals of different kinds play vital roles. The units of analysis are the innovation process and the network of actors that over time have contributed to the development of innovations with specific resources. The role of hospitals is addressed in relation to other actors or complementary inputs that constitute the innovation system of reference. Studies addressing the role of hospitals or particular types of hospitals directly are rarer, and in this sample few articles deal with management of innovation in hospitals.

There are many data collection approaches, but only a few large quantitative studies. They are either based on surveys of a limited number of hospitals or use bibliometric or patent data. The articles are mostly case studies of particular diseases, medical technologies, or hospitals. Fourteen articles are cross-sectional studies comparing multiple units (mainly several hospitals).

In line with the review methodology that integrates both qualitative and quantitative studies (Suri, 2014), we coded the literature on key parameters, such as study topics, methods, and data sources (Table 3). We used mainly a study-oriented synthesis approach, in which we describe briefly the key findings of the target studies, rather than aggregate findings across the articles sampled. We interpret and discuss the literature, but refrain from conducting any quantitative meta-analysis of numerical results found in the empirical evidence: this would be neither possible nor advisable because of fundamental differences in the issues addressed, data sources used, and methodological approaches employed in the literature (Suri, 2014).

Insert Table 3 around here

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3. Three strands of literature on hospitals and innovation

We have divided the innovation literature that deals with hospitals and innovation into three strands based on the main analytical units they try to describe or explain. The first group of studies has a micro-level focus in that it addresses the contribution of particular types of hospital staff to the generation of innovations. The second group addresses, either conceptually or empirically, hospitals' innovation activities, based on case studies or small sample studies of particular institutions. It typically focuses on the role of hospitals in innovation by looking at innovation activities at specific hospitals or particular units at hospitals. The third group includes studies of technological and epistemological change in medicine, in which the units of analysis are networks or systems of innovation connected to particular problems, technologies, or areas of medical practice. On rare occasions, papers with a very broad scope appear in more than one group. The first group of papers tends to take a health-care or general management perspective. The second group is relatively more heterogeneous in approach and theoretical perspective, but papers share a strong focus on organizational features and on practices that promote innovation. The third group has a more coherent theoretical perspective and highlight the problem of long-term sociotechnical changes in medical innovation.

3.1 Health-care practitioners and their contribution to innovation

Many studies focus on particular groups of individuals active at hospitals and the health-care industry more generally. These contributions dedicate special attention to medical doctors as generators of innovation in a line of research with strong links to von Hippel's (1988) foundational studies of user innovation. Medical doctors and clinical staff have played a prominent role in the development of new treatments and devices (Chatterji et al., 2008; Chatterji and Fabrizio, 2013; Kesselheim et al., 2014; Smith and Sfekas, 2013; Weigel, 2011). These studies range from quantitative analyses of patent statistics as indicators of invention by practitioners (Chatterji et al., 2008; Chatterji and Fabrizio, 2013; Smith and Sfekas, 2013) to case studies of particular medical devices (Kesselheim et al., 2014) or drugs (Xu and Kesselheim, 2014).

They generally point to two interrelated roles of medical doctors as far as innovation is concerned. First, the original ideas for new products emerge in clinical settings, when doctors find, for example, that existing devices do not solve problems or address needs satisfactorily in the clinical setting (Kesselheim et al., 2014). Several studies find that doctors are actively engaged in developing designs and early stage prototypes and experiment with different solutions. Utilizing information in US patent data on medical devices, Chatterji (2008), Chatterji et al., (2013), and Smith and Sfekas (2013) demonstrate that a substantial proportion of the product ideas had indeed emerged from the activity of clinicians. These papers assess the relevance of ideas that originated with clinicians on medical device innovation and find that these ideas have a significant impact on subsequent innovation. Chatterji and Fabrizio (2013) also show that the input from patents held by medical doctors is greater in new technological areas and in the generation of radical innovations. These studies also link the role of doctors as inventors of medical devices to their role as lead users and key partners for

medical device companies that further develop and commercialize medical devices (Smith and Sfekas, 2013), a pattern that is confirmed by the qualitative studies grouped in this research stream (Kesselheim et al., 2014; Weigel, 2011).

The paper by García-Goñi et al. (2007) relaxes the exclusive focus applied in this literature to the role of medical doctors. This insightful study looks at both managers in health-care organizations and frontline personnel. It considers their motivation for engaging in innovation processes connected to improved service provision and compares different degrees of participation and of motivation among different groups of staff. Overall, their comparative empirical analysis of different health-care professionals in six European countries finds that managers are significantly more motivated and more involved than frontline personnel (even though their preference may arguably be more sensitive to cost and efficiency concerns).

Finally, another contribution that widens the focus from medical doctors to other stakeholder groups—inside and outside health-care organizations—is the study of open innovation platforms by Bullinger et al. (2012). The role of patients in medical innovation is often highlighted as important, but rarely explicitly investigated. Bullinger et al. (2012) look into the idea generation phase of new products and services in health care that entails open communication, particularly with patients and other interested stakeholders. They find that patients and interest groups are active and important members of innovation communities, particularly in cases of rare diseases, and are both sources of adequate problem definitions as well as innovative solutions to these problems.

Insert Table 4 around here

3.2 Hospitals as innovative organizations

Approximately half the papers we analyzed address the role(s) of different kinds of hospitals in the generation of innovations (Table 5). A common theme across these contributions is the attempt to capture or conceptualize hospitals' innovativeness, on the grounds that this is undertheorized and underinvestigated (Djellal and Gallouj, 2007; Salge, 2009; Windrum and García-Goñi, 2008). This is a perspective shared with the research literature that treats hospitals as "hidden" research systems (Hicks and Katz, 1996; Lander, 2013; Lander and Atkinson-Grosjean, 2011). A common idea in this literature is that a considerable amount of R&D and innovation is underestimated because they involve activities and participants that are not adequately captured by standard indicators, such as publications, patents, and new products. The development of new knowledge and ideas for new products and services emerges from a complex interplay among scientific units, clinical units, and commercial units and often involves incremental technology and process improvements through learning by doing, which are rather difficult to observe and measure systematically.

As can be seen in Table 5, this research stream is rather heterogeneous in terms of key questions, empirical objects, and methodology/data. These papers focus on hospitals in general (Djellal and Gallouj, 2005; 2007), hospitals in particular regions or countries (e.g., French and Miller, 2012; Salge, 2012; Salge and Vera, 2009; Schutz et al., 2012; Weigel, 2011; Wu and Hsieh, 2011) or particular kinds of hospitals, that is, academic medical centers (Anderson et al., 1994; Rosenberg, 2009). Within these diverse empirical contexts, a range of issues is explored. Several papers attempt to conceptualize hospital innovativeness (Anderson et al., 1994; Djellal and Gallouj, 2005, 2007; Rosenberg, 2009) or explore empirically hospitals' innovation projects (Salge, 2012; Salge and Vera, 2009). Other papers emphasize particular innovation activities or organizational practices to support innovation, including

research and commercialization activities (French and Miller, 2012; Lander and Atkinson-Grosjean, 2011; Rosenberg, 2009). A final group of papers addresses organizational features and practices that are conducive to innovation, developing conceptualizations, such as hospitals as creative and learning organizations (Dias and Escoval, 2013, 2015; Hernandez et al., 2013; Lee and Hong, 2014; Ugurluoglu et al., 2013; Yang, 2014).

Insert Table 5 around here

These papers also differ in the types of innovations they select and consider. Many focus on the role of hospitals in the generation of new or improved products (e.g., medical devices or new treatments/drugs) (Chatterji et al., 2008; Rosenberg, 2009; Weigel, 2011). However, the majority of studies in this group focus on the generation and implementation of novelty in medical services (treatment regimes, organizational practices, and patient care) (Schultz et al., 2012; Thakur et al., 2012) or a combination of product and process innovations (Anderson et al., 1994; Djellal and Gallouj, 2005, 2007).

Djellal and Gallouj (2005), for instance, conceptualize hospitals as service providers and focus on the multiple operations run by hospitals and on their outputs. Their claim is that innovation and improvement work can occur in all aspects of hospitals' operations. They therefore propose that hospital innovation is highly diverse, encompassing administrative, organizational, and medical practices that are bundled together in services.

Another example of an inclusive conceptualization of innovation is found in the work by Salge (2012) and Salge and Vera (2009), who draw upon the distinction between science,

technology, innovation (STI) and doing, using, interacting (DUI) (Jensen et al., 2007) as modes of learning. Based on these notions, they identify two corresponding modes of hospital innovativeness: science-based and practice-based. They look at the relationship between investment in different kinds of innovation activities and performance and hypothesize that investments in both science-based and practice-based innovation are beneficial to hospital performance. More specifically, Salge (2012) investigates the organizational factors that influence sustained investment in these different kinds of innovation activities (science-based and practice-based). The results indicate temporal persistence in innovation activities, particularly in investments in science-based innovations, and that these are influenced by specialization levels, financial slack, and the strategic direction of hospitals over time. In addition, Schultz et al. (2012) find that management approaches that encourage employee involvement have a positive effect on overall innovation portfolios (i.e., the number and range of innovation projects) in German hospitals.

In line with this perspective, several papers address the question of organizational characteristics and practices that may promote innovation at hospitals. These papers attempt to map whether hospital organizations foster learning, creativity, and entrepreneurial attitudes among employees (Dias and Escoval, 2015; García-Goñi et al., 2007; Hernandez et al., 2013; Lee and Hong, 2014; Raadabadi et al., 2014) and try to identify the influence such features have on hospitals' innovative capability (Ugurluoglu et al., 2012) and innovation performance (Dias and Escoval, 2013; Yang, 2014). The results are not conclusive but, overall, seem to indicate that hospitals with a strong focus on learning display higher innovation performance, in line with general innovation theory. Notably, however, these studies are not explicit about the types of innovations hospitals promote and whether these features are beneficial for the generation of novelty or implementation of and experimentation with innovative solutions.

A surprisingly small number of papers address the commercial aspects of hospital innovation activities. French and Miller (2012) focus on the increasing commercial ethos of Canadian hospitals and attempt to outline features of the "entrepreneurial hospital," which they define as "one that explicitly seeks to constitute patient populations and case infrastructures as distinctive assets (or resources) in pursuit of entrepreneurial aims" (p. 718). According to these authors, the data they collected through interviews indicate increasing awareness of the strategic value of clinical facilities and patients as assets for research and innovation, as well as for commercial exploitation of promising results. This is interpreted as an indication of changes in value regimes oriented not only toward the improvement of human health but also toward wealth creation, which constitutes a cultural shift, with pervasive but not well-known implications.

Despite their differences, the papers that belong to this first group of studies have the distinction of combining a relational view of hospitals as outward-looking organizations with an intra-organizational perspective with a focus on the heterogeneity of innovation activities and considerable differences that characterize different units involved in the generation of novelty at hospitals. These papers conceptualize the roles of hospitals in innovation in different ways. We can distinguish between papers that focus on hospitals as large and complex service organizations and those with a sharper focus on innovative products developed in a hospital context. Among the former, a key message is that hospitals perform multiple functions but that their role is that of system integrators across functions (Anderson, 1994; Djellal and Gallouj, 2005; 2007; French and Miller, 2012; Rosenberg, 2009; Salge, 2012; Salge and Vera, 2009). Among the latter papers, the focus on product innovation is associated with an emphasis on the role that hospitals and clinical sites play in idea generation and marketing, as well as implementation and post implementation improvements of new

medical treatments and technologies (Schultz et al., 2012; Weigel, 2011; Wu and Hsieh, 2011).

3.3 Hospitals' roles in innovation processes and systems

The last group of studies identified in our database takes a systemic and longer-term view of medical innovation. They build, on the one hand, on the rich research tradition in the history of medicine and the history of technology and, on the other, on evolutionary approaches to innovation systems. They consider the characteristics and dynamic interplay of actors endowed with different (competing and complementary) bases of competence. Several papers focus on understanding innovation and technological developments in medicine from the viewpoint of a network of individuals and organizations that share the division of innovative labor. These networks, which often emerge to solve particular technical problems, co-evolve with changes in the knowledge base and underpin changes in the structure and composition of medical technology markets (Mina, 2009). Analyses of problem-driven innovation processes represent the empirical core of these studies.

The studies sampled for this review are only journal articles, as we used journal databases for literature searches. The sampled papers are closely related, however, and often based on historical and conceptual work in the 1990s on sociotechnical systems of medical technologies (Blume, 1992; Gelijns and Rosenberg, 1994; Rosenberg et al., 1995; Schlich, 2002), often published as books, book chapters, and reports. Detailed studies of the "careers" (Blume, 1992) of particular cases of medical technologies (e.g., medical imaging technologies, cochlear implants, artificial heart valves, endoscopes) led to a number of empirical observations about the generation and development of technologies in medicine, later summarized and used as the basis for renewed theoretical efforts in a series of publications included in Table 6.

Insert Table 6 around here

As Table 6 shows, several papers emphasize particular medical objects (implants, heart valves, lenses, endoscopes, medical imaging technologies) or medical practices (telemedicine, ambulatory surgery, minimally invasive therapy, electronic patient records, patient registries) whereas others look at innovation from the vantage point of different medical problems (diseases or medical conditions, such as infection with HIV, heart disease, glaucoma, deafness). Although the empirical basis is different, what is common is nonetheless the ambition to track and explore the development of knowledge, technological and medical solutions, over time, within these defined contexts or cases. The papers emphasize innovations as the development of new products but also are embedded in service delivery. Thus, they look at innovations as both products (technical solutions or artefacts such as surgical tools, drugs, or particular procedures) and services (the use of tools in treatment/care situations). An important point is that products and process innovations are linked and that product innovations entail customization and adaptation, as well as the development of innovations in organizations and service delivery throughout customization and adoption processes (Patrakaki and Klucun, 2015). Compared to the first group of papers, these studies are less heterogeneous and focus on similar research questions, explanatory models, and research strategies. In terms of the latter, the studies are descriptive, often using a combination of data sources to generate a comprehensive image of epistemological, technological, and social developments in the case context.

These studies view innovation as long-term problem-solving processes, in which collaboration between different participants and competences is a key activity (Djellal and Gallouj, 2005, 2007; Galbrun and Kijima, 2009, 2010; Geljins and Fendrick, 1993; Geljins and Rosenberg, 1994; Merito and Bonaccorsi, 2007; Metcalfe et al., 2005; Morlacchi and Nelson, 2011; Nelson et al., 2011; Rosenberg et al., 1995). A related focus is on how knowledge, technologies, markets, and institutions co-evolve over a considerable time seen ex post as particular trajectories of change. Human agency and creativity are drivers of innovation, because localized search and recombination of knowledge constitute key elements in problem-solving activities. However, technical changes in medicine do not involve only development and use of knowledge; the institutional framework, particularly regulation and demand formation, influence both creation and dissemination of new medical knowledge and medical practices (Metcalfe et al., 2005).

Furthermore, innovation processes in medicine are seen as recursive, with considerable interaction among invention, development, dissemination, and the use of new knowledge and technology. New medical innovations develop in an incremental manner and require substantial adaptation in many stages, considerable feedback from users, and considerable post-implementation development. It is hard to separate the creation of new knowledge and new technologies and the dissemination and use of these technologies in medical practices (Barbera-Tomas and Consoli, 2012; Consoli and Mina, 2009; Consoli and Ramlogan, 2008, 2011; Essen and Lindblad, 2013; Merito and Bonaccorsi, 2007; Mina et al., 2007; Petrakaki and Klecun, 2015). With this in mind, the point is made that the mainstream health-care management literature all too often separates implementation from innovation (Essen and Lindblad, 2013).

Morlacchi and Nelson (2011) claim that medical innovations or improved medical practices are the result of developments in three "co-evolving pathways": advances in biomedical scientific understanding, improvement of the ability to develop new medical technologies, and learning in (clinical) practice. These pathways correspond in part to organizations that "harbor" them (universities, firms, and hospitals), but since they are also interrelated and recursive, fluid networks and communities (of practices) that transgress each pathway are equally important. Because medical innovations draw on several sources of knowledge, "rich ecologies" of organizations—including universities, firms, hospitals, and research institutes—are involved in developing and dissemination of medical innovations (Nicolini, 2010; Ramlogan et al., 2007). At the same time, studies have also found that conflicts of interest between groups of professionals at hospitals and between hospitals and other organizations create barriers to innovation and that there is considerable resistance to developing and disseminating medical innovations (Blume, 1992; Nicolini, 2010). Increased specialization and potential intraprofessional competition, however, is also regarded as a driver for technological innovation in medicine (Gelijns and Rosenberg, 1994).

Hospitals and clinical sites are fundamental components of complex health innovation processes (Djellal and Gallouj, 2005, 2007; Geljins and Rosenberg, 1994; Metcalfe et al., 2005; Morlacchi and Nelson, 2011; Nelson et al., 2011; Rosenberg, 2009; Rosenberg et al., 1995). This reflects again the importance of medical practice for identifying problems and solutions and points to the role of hospitals as "bridging organizations," where different pathways meet and are cross-fertilized. In other words, hospitals are one of many necessary actors in health innovation, but they have a key brokering role in bringing actors together in ways that should not be taken for granted (as if all network ties were persistent over time). In the distributed system of actors that are involved in the generation and development of innovations, hospitals are often the hubs in the broader network. As seen in Table 6, most

papers describe multiple roles of hospitals or particular clinical sites at hospitals, ranging from initial idea generation to implementation and dissemination. However, in these papers, the hospital is not addressed as a unit. Rather, the focus is on clinical sites at hospitals, which have this key experimental learning and linking function intrinsically connected with innovation. Clearly, many of the innovations studied emerge out of medical practice, in which practitioners in health-care systems are involved in incremental and practice-driven improvement processes directed at improving conditions for patients (Essen and Lindblad, 2013).

As an extension of evolutionary studies of health innovation, with its focus on co-evolution across diverse sets of knowledge as a key to medical innovation, a system perspective of innovation in health and medicine is logically consistent. Among the papers included in the review are several attempts at conceptualizing health innovation systems in terms of participants and modes of interactions (Consoli and Mina, 2009; Djellal aand Gallouj, 2005, 2007; Galbrun and Kijima, 2010; Windrum and García-Goñi, 2008).

Consoli and Mina (2009) argue that health innovation systems consist of two broader domains: (1) the science and technology domain and (2) the practical domain or the health-care delivery system, with strong interactions within across domains. Hospitals are key actors in both domains, as well as brokers between them. Galbrun and Kijima (2010) use the concept "clinical innovation system" to describe the dual role of clinical sites in medical innovation. They also claim that the role of hospitals and clinical staff should not be understood merely in terms of their role in scientific investigations, testing new products, or implementing products or services. Clinical staff contribute to the generation of novelty by experimenting with technologies in treatment situations and by developing and implementing the social technologies or soft innovations (e.g., treatment protocols or advice for health-care policy on

what solutions to procure/reimburse), which are necessary for wide-scale changes. This experimental function is carried out in clinical settings and makes hospitals the key arena for connections between science-based knowledge, technology and clinical practice, and between generation, selection, and dissemination of innovations.

Windrum and García-Goñi (2008) emphasize a third domain within the system: the policy domain, which to a great extent contributes to shaping how innovation processes occur and which innovations are selected. In traditional innovation models developed for understanding private sector innovation, the market is the important selection mechanism. For medical innovations, selection is much more complex and takes place in multi-agent environments with multiple selection criteria. Selection is strongly influenced by policy and policy makers, but policy also influences idea generation and regulates how new innovation develops. But the policy domain does not operate in isolation: feedback from medical and scientific communities also shapes policy-making, as do patients and patient groups.

The systems-oriented literature expands and supplements the micro-level investigations of particular cases of medical practice. The bridging role of hospitals looms even larger, not least because the system is large and complex with a multitude of actors that are highly different from one another in incentives and competence bases. In addition, these systems differ from related theoretical constructs that emphasize sectoral or geographic boundaries or that neglect the specific nature of public sector activities and the role of context-specific policy.

4. Synthesis of findings

The most obvious finding that emerges from our inspection of the literature is that the evidence base is highly heterogeneous. Relevant research has been published in several fields of science and various journals, and little consensus has been reached about key questions and

overarching analytical frameworks. Most empirical studies published on hospitals and innovation are implementation studies, particularly implementation of new treatment regimes, ICT tools, or administrative routines in hospital settings, but investigations of the role of hospitals more broadly in the generation of novelty is a more recent area of interest (Salge and Vera, 2009). Multiple case studies have appeared on particular hospitals or specific innovations in medical technologies, treatment regimens, and drugs (see Table 6), but few attempts have been made to synthesize the evidence across this largely case-based repertoire of empirical evidence on how hospitals promote innovation.

Our literature review has identified three groups of studies, in which hospitals are seen as (1) the context of operation of innovative practitioners (a micro-level perspective), (2) the unit of analysis from an organizational viewpoint (a meso-level perspective), and (3) a central component and interface within a broader health innovation system (a more macro- or system-oriented perspective). The first two streams of papers encompass the activity of specific hospitals or groups of individuals at hospitals, whereas the third focuses on problems and the overall system through which innovations in medicine and health care emerge, develop, and spread. These approaches emphasize a multitude of roles for hospitals and hospital staff in innovation, but differ in their focus on different phases in innovation processes and also in whether they focus mainly on hospital internal roles versus roles carried out in collaboration with external actors in the wider health innovation system.

The different strands of literature largely emphasize different innovation activities and the hospitals' roles in them. Figure 3 maps the different strands of literature onto the broad perspective of hospitals' roles in innovation, as described in Figure 3.

Insert Figure 3 around here

Figure 3 distinguishes four quadrants that represent the activities associated with different phases or dimensions of innovation: generation, development, verification/selection, and dissemination/use. The figure also distinguishes between an inner and an outer layer of activities, which represent, respectively, core hospital activities in innovation and innovation-related activities that hospitals perform in support of or in collaboration with external agents (including firms and regulators).

The first strand of contributions focuses on individuals or innovative practitioners and on their role in generating innovations in medicine and health care. As we have noted, this literature dedicates special attention to the role of medical doctors and looks in some detail at the role of clinicians as inventors, their role in developing new products, and the ways in which these activities are carried out in collaboration with industry.

The literature on hospitals as innovative organizations (strand 2) is, as expected, mainly hospital-internal oriented (it covers the four inner quadrants). Some of this literature also has a particular focus on use and dissemination, particularly on the question of complementary service innovations, customization, and post-implementation improvements. This literature has a learning/organizational perspective and tends to emphasize the organizational features and management practices that promote openness and participation in innovation activities among hospital employees.

The literature on technological trajectories (strand 3) takes into account a broader range of evolutionary patterns in medical innovation processes. It adopts a theoretical perspective that is less explicitly focused on the internal organization of hospitals but, like strand 2, connects new idea generation with the development and diffusion of innovation at the system level.

One fundamental problem that has received surprisingly little attention concerns the effects of technology selection and adoption on the current and future innovative capacity of hospitals. While technology assessment and technology adoption are well-researched themes in the field of health-care policy, the links between health-care policy and innovation policy are not a well-understood understood part of the health innovation system (Windrum and García-Goñi, 2008). In particular, the relationship between resourcing of hospital activities (in terms of equipment and skills), development of clinical practice and the growth of innovation capabilities within the organization are interesting and important avenue for further research. Overall, more research is needed on a micro-level analysis of practitioners' incentives for and engagement in innovation (including nurses and administrators) (Chatterji and Fabrizio, 2013; García-Goñi et al., 2007; Kesselheim et al., 2014), on the system-level implications of health-care technology funding and selection (Windrum and García-Goñi, 2008), and arguably on the connection between the micro and the macro levels of analysis.

Looking at the literature as a body of knowledge about hospitals and their role in medical innovation systems, the perspectives, empirical strategies, data, and methodologies used in current research have limitations. First, several studies have a relatively narrow scope and are often based on a limited set of empirical cases. Very few studies are based on detailed information across multiple hospitals. Although some notable studies are exempt from this (e.g., García-Goñi et al., 2007; Salge, 2012; Salge and Vera, 2009), most published work does not utilize administrative data from hospitals to a large extent, although a large variety of data

is available on investments in innovation, innovation processes, and outcomes in many countries and health systems.

Second, because empirical studies have targeted particular empirical objects, theoretical development has also tended to focus on relatively narrow perspectives. For instance, a systems perspective is evident in some of this literature (Consoli and Mina, 2009; Galbrun and Kijma, 2010; Windrum and García-Goñi, 2008), but delineation of the boundaries of the system differs across studies. Much work remains to be done in conceptualizing and describing different participants, activities, resources, relationships, and institutional frameworks in health innovation systems.

Third, the heterogeneous literature on hospitals and innovation has drawn upon conceptual frameworks and insights developed within the field of innovation studies to a limited extent. The literature on technological trajectories in health care and medicine draws on theoretical concepts from evolutionary studies of technology (e.g., Consoli and Mina, 2009; Metcalfe et al., 2002; Morlacchi and Nelson, 2011), but they have not always integrated the useful insights that can be derived from the application of organizational and managerial perspectives on innovation. The literature on hospitals as innovative organizations addresses hospital-internal matters and has focused on drivers of innovation, including organizational and management features that stimulate creativity and learning (Dias and Escoval, 2013, 2015; García-Goñi et al., 2007; Salge, 2012; Salge and Vera, 2009). But both the innovation systems literature on health care and organizational studies of hospitals as innovators often obscure the unit of analysis and neglect, respectively, the internal or external institutional complexity of hospitals.

5. Concluding remarks and issues for further research

Thematically, there is no shortage of issues for further research on the role of hospitals as innovators. First, as seen in Figure 3, further research is needed on hospitals as selection environment for innovations and how this is related to hospitals' role in generation of innovations.

Second, the growing and pervasive emphasis on "open" innovation models calls for a careful assessment of the opportunities, and the costs, that increased engagement in innovation with external partners can bring. Interest in open innovation models in health care, particularly on patients and other stakeholders' involvement in innovation, is emerging (Bullinger et al., 2012). The governance of collaborative innovation requires experience as well as dedicated resources within the organization. It also requires a good understanding and appropriate design of incentives for researchers and clinical staff that are compatible with the delivery of health-care services (Salge et al., 2015).

Third, the capacity of hospitals to complement innovation activities carried out by external organizations (e.g., to collect evidence on experimentation with new drugs and devices), combined with the strong ties that research-intensive hospitals have with the university system, can dramatically increase incentives for companies to establish research facilities in the vicinity of hospitals in order to gain access to patients and to valuable knowledge. This may include the talent of graduates from research-intensive universities with strength in medicine and the life sciences or the intangible assets of smaller companies spun off from university departments and incubated in the local area (Mina and Probert, 2012). Therefore research hospitals can be significant factors in the location decisions of pharmaceutical and medical device companies.

Fourth, new ICT investments related to telemedicine and big data can provide new opportunities for learning if the information system of the health-care organization is designed to take full account of feedback mechanisms to guide further exploration in technology and practice.

To provide a more coherent evidence-based perspective on the role of hospitals in innovation, empirical studies with wider coverage are needed. Compared to universities and their role in innovation, which have been studied intensively over the past few years, the empirical basis on hospitals is much weaker and the conceptual and theoretical work more heterogeneous. In particular, studies are needed on innovation activities at the hospital level, which can be accomplished by collecting survey data at either the hospital or unit level and the individual level or by combining survey data with administrative data. Broader empirical studies and stronger theoretical models are also needed to underpin emerging innovation policy focusing on health and to inform stakeholders (owners, managers, practitioners, and patients) about the challenges of innovation—or lack thereof—especially in publicly funded health-care systems.

The literature review and analytical framework we present in this paper provide a starting point for further analysis of the roles of hospitals in the generation of innovation as guidelines that can be used to map actors, activities, relationships between actors and activities, their governance, and their outcomes. Because of the organizational and institutional complexity of hospitals, further empirical work should also look in some detail at departments, professional groups, and medical specialties within and across hospitals on a comparative and international basis.

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Tables and Figures

Table 1. Search terms and literature database

Steps	Search terms	Hits in WoS	Hits in Scopus	Hits in PubMed	Hits in five top journals
1	Innovation AND hospitals AND medical innovation[1]	123 (859)	147 (15,072)	8 (505)	
2	Medical innovation	99	414	93	
3	Innovation AND university hospitals (OR research hospitals OR academic medical center)	85	77	102	
	Total literature database analyzed	307	638	203	374
	Inclusion/exclusion terms (two steps)		*Only new inclusions*		
4	Abstracts: (a) Innovations, (b) hospitals, (c) not only implementation, (d) not patient effects, and (e) either conceptual or empirical studies	50	15	13	24
5	Full papers: (a) Innovations, (b) hospitals, (c) not only implementation, (d) not patient effects, and (e) either conceptual or empirical studies	29	6	6	5

WoS = World of Science. 1. Numbers in parentheses is the numbers of hits without adding the third search term "medical innovation" to the algorithm.

Table 2. Top publishing journals on innovation and hospitals in Scopus and WoS

	Top 10 journals Scopus	No. of publications	Top 10 journals WoS	No. of publications
1	Hospitals Health Networks AHA	110	Health Affairs	45
2	Health Care Management Review	61	Health Policy	29
3	Social Science and Medicine	57	Implementation Science	25
4	Academic Medicine	54	Social Science Medicine	22
5	Harvard Business Review	51	BMC Health Services Research	20
5	Healthcare Financial Management	41	Health Care Management Review	20
7	Health Affairs	34	Journal of Nursing Administration	20
8	Quality Management in Health Care	29	Journal of Advanced Nursing	15
9	International Journal for Quality in Health Care	28	Journal of Clinical Nursing	14
10	*Medical Care*	27	*Journal of Healthcare Management*	13

WoS = World of Science.

Table 3. Research questions, data, and methodology in the final sample (*N* = 46)

Key features of the articles	**Number of articles**
Main research questions addressed	
Characteristics of medical innovation processes	15
Characteristics of medical innovation systems	12
Role/s of particular participants in medical innovation (hospitals, clinical staff, medical doctors)	10
Management and organization of medical innovation in hospitals	7
Results/effects of medical innovation in hospitals	2
Methods	
Quantitative data	17
Qualitative data	13
Mixed methods	8
Conceptual	8
Empirical approach	
Medical case study (targets particular areas of medical practice)	9
Technological case study (targets particular medical technologies)	9
Hospital case study (targets one or more particular hospitals)	6
Cross-sectional (targets several units, multiple hospitals/technologies)	14
Not an empirical study	8

Table 4. Overview of papers on practitioners in health care and their role in innovation

Paper	Empirical object	Data	Key issues explored	Kinds of innovations	Role of hospital/s
Bullinger et al., 2012	User involvement in innovation through open innovation platforms	Quantitative; communication analysis	Investigates the role of user oriented, open innovation platforms in health care	Product and service innovations (ideas)	Participants in open innovation (alongside other users)
Chatterji & Fabrizio, 2013	Medical doctors in US	Quantitative	Investigates the contribution of medical doctors to innovation in medical devices	Product innovation (medical devices)	Hospital-based physicians: idea generation and marketing
Chatterji et al., 2008	Medical device firms	Quantitative	Investigates the effect of prior collaboration with medical doctors on innovation performance (new products)	Product innovation (medical devices)	Hospital-based physicians as lead users of medical devices
García-Goñi et al., 2007	Hospital managers and front line staff in six European countries	Quantitative	Investigates the perceptions and motivations of different kinds of hospital staff toward innovation in health-care services provision	Innovation in service provision	Hospital managers and front line staff, attitudes, motivation and degree of involvement in generating and implementing innovations
Kesselheim et al., 2014	Clinical doctors as "physician inventors"	Qualitative	Investigates the processes and individuals involved in coronary artery stents	Product innovation	Idea generation and early experimentation in clinical practice
Smith & Sfekas, 2013	Medical devices	Quantitative	Investigates premarket approval applications filed by medical device firms and medical doctors contribution to them	Product innovation	Idea generation and early experimentation in clinical practice
Xu & Kesselheim, 2014	Patents connected to stent technologies	Quantitative	Contribution to medical devices by medical doctors	Product innovation	Idea generation and early experimentation in clinical practice

Table 5. Overview of literature on hospitals as innovative organizations

Paper	Empirical object	Data	Key issues explored	Kinds of innovations	Role of hospital/s
Anderson et al., 1994	Academic medical centers in US	Conceptual/mixed methods	Roles of academic medical centers in innovation	Product and process innovation within medicine	Five roles for hospitals, generators of innovation, adoption, evaluative, advisory, training
Dias & Escoval, 2015	Portuguese hospitals	Mixed methods	The relationship between hospitals as learning organizations and innovation performance	Product, service and process innovations	Generation and adoption of new medical practices
Dias & Escoval, 2015	Portuguese hospitals	Mixed methods	The relationship between innovation and hospital performance	Product, service and process innovations	Generation and adoption of new medical practices
Djellal & Gallouj, 2005	Hospitals	Conceptual	Hospitals as service providers and their role in innovation	Multiple forms of innovation in hospitals, connected to different outputs and services performed	Multiple, dependent on type of innovation
Djellal & Gallouj, 2007	Hospitals	Lit. Review	Discuss different perspectives on hospitals in innovation	Hospital innovation as a broad category, includes both process, product and service innovations	Multiple, dependent on type of innovation
French & Miller, 2012	Hospitals in a Canadian region	Qualitative	Introduces the concept of the entrepreneurial hospital	Biomedical research and innovation	Entrepreneurial, capitalizing on care functions to perform in innovation
Hernandez et al., 2013	Drivers of patient-centered innovations in health-care organizations	Qualitative	The process of initiating patient-centered innovations in health care	Organizational innovations intended to make hospital services more patient friendly	Generating innovations in service delivery, entails generating organizational innovations within the hospitals
Hicks & Katz, 1996	Collaboration between R&D performing sectors	Quantitative bibliometric	Hospitals as the hidden research system	Research in biomedicine and health	Important as a venue for research
Lander, 2013	Translational medicine (immunology)	Quantitative, bibliometric	University-hospital collaboration	Research in biomedicine and health	Integration
Lander & Atkinson-Grosjean, 2011	Hospital-based laboratories	Conceptual and qualitative	Hidden role of hospitals in innovation	Biomedical innovation and translational medicine	Integration between clinical and biomedical knowledge

Lee & Hong, 2014	Hospitals in Korea	Quantitative	Determinants of knowledge sharing and innovation behavior among hospital staff	New ideas, technical tools, and methods used within hospitals	Generation of new ideas
Raadabadi et al., 2014	Hospitals in Iran	Quantitative	Cultures of entrepreneurship in hospitals	Not specific	Generation and experimentation with new solutions
Rosenberg, 2009	Academic medical centers	Conceptual/ qualitative	Institutionalization to support hybridization and linkages between medicine and natural sciences	Medical product innovations	Collaboration between hospitals and universities in biomedical and medical device innovation
Salge, 2012	English hospitals (NHS organizations)	Quantitative	Hospital investments in innovation	Science and practice-based innovation	Generation of innovations
Salge & Vera, 2009	English hospitals (National Health Service [NHS] organizations)	Quantitative	Linkage between innovation investment and clinical performance	Science-based and practice-based innovation	Generation of innovations
Schultz et al., 2012	German hospitals	Quantitative	Impact of innovation management of hospitals innovativeness	Diffusion of different kinds of innovations; focus on medical process innovations/service innovations	Really about diffusion?
Thakur et al., 2012	Hospital executives in the US	Qualitative	Definitions of innovations within health-care organizations	Adoption of best practices	Adopting and adapting new practices to local contexts
Ugurluoglu et al., 2013	Hospital managers at 250 hospitals in Turkey	Quantitative	Characteristics of hospitals as learning organizations and its influence on innovation performance	Introduction of new medical procedures	Generation and adoption of new medical practices
Weigel, 2011	Case study of one hospital in Germany	Qualitative	The contribution of the hospital to innovation in a regional medical device industry	Product innovation (medical devices)	Idea generation and leading partner in all stages of development
Wu & Hsieh, 2011	Hospitals in Taiwan	Quantitative	Impact of innovations on perceived quality of care	Medical and administrative innovations (products and services)	Adaption and development of improved services toward patients
Yang, 2014	Hospitals in Taiwan	Quantitative	Determinants of innovation capability and performance in Taiwanese hospitals	Innovative capability (ability to generate novelty)	Generation and adoption of new medical practices

Table 6. Overview of papers on innovation processes and systems in health and medicine

Paper	Empirical object/case	Data	Key issues explored	Kinds of innovations	Role of hospitals
Barbera-Tomas & Consoli, 2012	Implantable devices (artificial discs)	Mixed methods	Technological and scientific change processes focusing on developments of the knowledge base and technological tools for curing degenerative disk diseases	Product innovations	Idea generation Clinical experimentation and testing Lead users Procurement decisions and market
Consoli & Mina, 2009	Cardiology and glaucoma	Mixed methods	Evolutionary processes of medical innovation, exemplified by research on two areas of medical practice	Product and service innovations connected to treatment of particular medical conditions	Basic and translational research, problem formulation, idea generation, experimentation and testing, lead users and feedback
Consoli & Ramlogan, 2008; 2011	Glaucoma	Conceptual Mixed methods	Process of knowledge growth in an area of medicine	Scientific development and innovations in medical practices in treating glaucoma	Clinical research and collaborating with academic research units
Essen & Lindblad, 2013	Rheumatology	Qualitative	Explores a practice-driven innovation processes connected to establishment and continuous improvement of a national rheumatology registry	Product and service innovation (IT based)	Idea generation, continuous improvement, users
Galbrun & Kijima, 2009, 2010	Medical imaging technology	Qualitative	Dynamic relationships between sets of actors that over time foster innovation in medical technology	Product innovation	Experiential learning leads to innovation ideas and extends usage of technology, Lead users and testing functions,
Gelijns & Fendrick, 1993	Minimally invasive therapy	Mixed methods	Dynamics of medical innovation	Products and procedures	Idea generation, experimentation and development of supplementary service innovations; complex interplay with other agents
Gelijns & Rosenberg, 1994	Endoscopes, medical imaging technologies	Conceptual, qualitative	Development of new medical technologies, depends on close interaction between producers and users, and is influenced by changes in regulation and financing of health-care services, and patterns of medical specialization.	Product innovation (medical devices)	Adoption and adaption of technologies developed elsewhere for medical purposes Clinical experimentation and incremental improvements in practice
Merito & Bonaccorsi, 2007	HIV treatments	Mixed methods	Co-evolution of clinical knowledge and technology in development of HIV treatments	Product (drugs) and service (treatment)	Experiential knowledge, experimentation and testing Develops the complementary social technologies needed for widespread adoption

Metcalfe et al., 2005	Intra-ocular lenses	Mixed methods	Dynamics of complex and distributed innovation processes in one area of medicine	Service innovation (mode of treatment/procedure) and product innovations (implants)	Idea generation, experimentation, complementary innovations, lead users, marketing
Mina et al., 2007	Coronary artery disease	Mixed methods	Evolutionary trajectories of change; complex, co-evolutionary processes and path dependence	Service innovation (mode of treatment/procedure) and product innovations (catheters and stents)	Idea generation, research (clinical) and experimentation
Morlacchi & Nelson, 2011	Left ventricular assist device	Qualitative	Evolutionary study of innovation within one area of medical practice, that involved interplay between change in three related areas: medical practice, science and technology	Product innovation (hart implant) and service innovation (mode of treatment)	Problem formulation and idea generation, experimentation and testing, selection, develops complementary innovations
Nelson et al., 2011	Mainly conceptual, some examples	Conceptual	Innovation as an evolutionary process involving learning in three domains	Service innovations (innovation in treatment of diseases)	Clinical practice, integration of different sources of knowledge
Nicolini, 2010	Tele-cardiology	Qualitative	Development and dissemination occur through network, and cannot be meaningfully depicted in a ordered stage-like form. Highlights the political nature of health innovations	Product innovation (tele-monitoring) and service innovation (mode of care)	
Petrakaki & Klecun, 2015	Electronic patient records (EPR)	Qualitative	Customization of EPR systems in local settings; how implementation often requires local organizational and service innovations	Product and service innovations	Adopter, but creating local customization and service innovations
Ramlogan et al., 2007	Coronary artery glaucoma	Quantitative	Evolutionary processes of medical innovation, exemplified by research on two areas of medical practice	Product and service innovations connected to treatment of particular medical conditions	Basic and translational research, problem formulation, idea generation, experimentation and testing, lead users and feedback
Windrum & García-Goñi, 2008	Ambulatory surgery	Conceptual and qualitative	Systems framework for exploring health service innovation	Service innovation (mode of delivery of health services), organizational innovation and product innovation	Developing and implementing a new mode of service delivery

Figures

Figure 1. The roles of hospitals in innovation

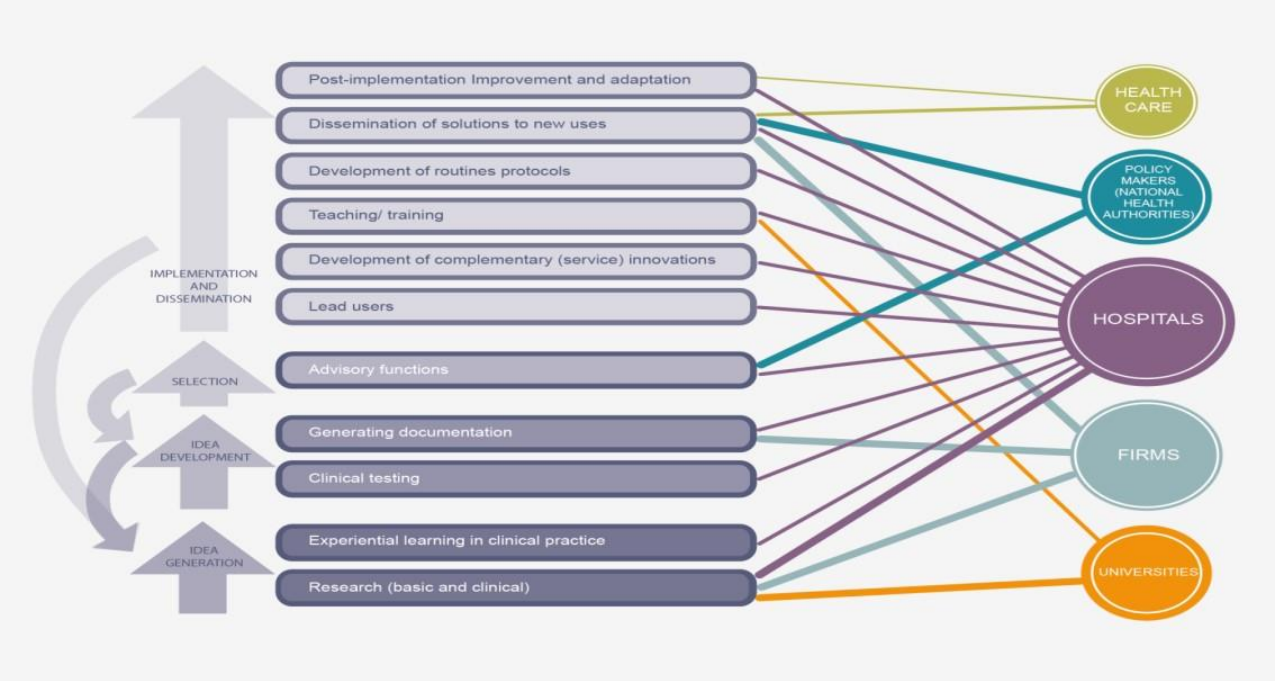

Figure 2. Publications on innovation AND hospitals in Scopus and WoS (1965-2014)

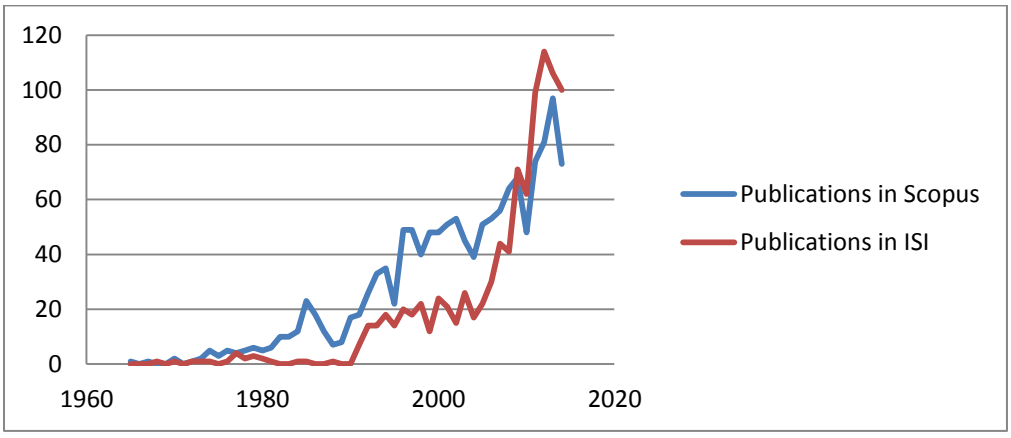

Figure 3. The roles of hospitals in innovation and the main foci within different strands of literature