Investigating Opportunities to Improve Surgical Site Infection Prevention through Social and Technological Innovation

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Declaration

I, Rachael Troughton, declare that this thesis for examination for a PhD degree assessed and awarded by Imperial College London is solely my own work, other than where I have clearly referenced the work of others.

Acknowledgements

I would like to thank the staff and patients for generously giving up your time and energy to let me better understand your world. The insights I have gained I hope will be a rich contribution to the field and have been fascinating and inspiring to me personally.

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Abstract

Background Surgical site infections (SSIs) are a common cause of morbidity and mortality and pose a significant problem for patients, health systems, and society. There is a wealth of literature on SSI prevention interventions, yet SSIs remain a problem. Surveillance of SSI rates on a local and national scale has been shown to be fundamental to reducing rates and improving patient safety. The national surveillance program for SSI rates in England is focused mostly on orthopaedic SSIs and in-hospital surveillance, and data collection is done manually despite advances in automation.

Aims This thesis aims to address four key research questions emerging around SSI prevention through surveillance at the interface of two concepts: social innovation and technological innovation. Four questions arising from gaps in the literature are 1) which surgery types should be targeted for SSI surveillance, 2) what are healthcare workers' perceptions and beliefs about SSI prevention and surveillance, 3) how can technology enhance SSI surveillance, and 4) how can post-discharge SSI surveillance be improved?

Study design Quantitative methods were used to synthesise data on SSI risk, burden, cost, and national reporting requirements in different surgery types in England to inform decisions on how to prioritise surveillance. To better understand perceptions and drivers of SSI prevention and surveillance practices, qualitative interviews with staff stakeholders at a large London NHS Trust were analysed thematically. A mixed-methods case study used quantitative validation of a semi-automated in-hospital surveillance algorithm and qualitative workshops with staff to explore barriers and facilitators to implementation. The final studies used a realist review and patient focus groups to assess post-discharge surveillance methods.

Results Current practices for SSI surveillance do not match the medical or economic burden posed by SSIs in different surgical categories. The highest contributors of SSIs in England are large bowel surgery and caesarean section, which are under voluntary surveillance or no national surveillance respectively. Differences in the perceived responsibility for SSI prevention (whole team and patients) versus accountability for rates (consultant surgeons) create tensions in the team, but surveillance can help stimulate engagement. Electronic systems to improve SSI surveillance are a promising and obvious solution to chronic resource problems, but poor technological infrastructure and difficulties proving their cost-effectiveness prevent a universal solution. Patients are often required to contribute to post-discharge surveillance of SSIs but need to see this task as useful and easy.

Conclusion Improvements in technological infrastructure in the NHS would facilitate enhanced SSI surveillance, while top-down encouragement from national bodies and hospital managers to broaden surveillance could provide the social support needed to re-prioritise surveillance. On a local level, team accountability of SSI rates could precipitate social change by facilitating stakeholder engagement.

Contents

List of Tables

List of Figures

Abbreviations

ACD	Administrative coding data
AI	Artificial intelligence
AMR	Antimicrobial resistance
ASA score	American Society of Anaesthesiologists
BMI	Body mass index
CABG	Coronary artery bypass graft
CDC	Centers for Disease Control and Prevention
CFIR	Consolidated Framework for Implementation Research
CIE	Care Information Exchange
CMOC	Context-mechanism-outcome configuration
COM-B System	Capability Motivation Opportunity Behaviour System
CRP	C-reactive protein
CS	Caesarean section
ECDC	European Centre for Disease Prevention and Control
EHR	Electronic health record
ENT	Ear, nose, and throat
ESS	Electronic surveillance system
GA	General algorithm
GIRFT	Getting It Right First Time
GP	General practitioner
HCAI	Healthcare-associated infection
HCHS	Hospital and Community Health Services
HCP	Healthcare professional
HES	Hospital Episode Statistics
HSCIC	Health and Social Care Information Centre, now NHS Digital
HWQ	Healthcare worker questionnaire
ICD-10	International Classification of Diseases version 10
ICHNT	Imperial College Healthcare NHS Trust
ICT	Information and communications technology

IQR	Interquartile range
LBS	Large bowel surgery
MA	Modified algorithm
NICE	National Institute for Health and Care Excellence
NIHR	National Institute for Health Research
NHS	National Health Service
NPV	Negative predictive value
OECD	Organisation for Economic Co-operation and Development
OPCS	OPCS Classification of Interventions and Procedures version 4
OSA	Organ space algorithm
PAS	Patient administrative system
PDQ	Post-discharge questionnaire
PDS	Post-discharge surveillance
PHE	Public Health England
PPV	Positive predictive value
QI	Quality improvement
RLBF	Reduction of long bone fracture
RNOF	Repair of neck of femur
SD	Standard deviation
SIG	Surgical Infection Group at Imperial College Healthcare NHS Trust
SOG	Surgical Outcomes Group at Imperial College Healthcare NHS Trust
SSI	Surgical site infection
SSISS	Surgical Site Infection Surveillance Service
TAM	Technology Acceptance Model
WCC	White cell count
WHO	World Health Organisation

Glossary

ASA score	A measure of pre-operative physical status of the patient ranging from 1 (full health) to 5 (moribund)
Wound class	A measure of contamination in the wound
Clean wound	A clean, non-infected wound, gastrointestinal and urogenital tracts are not involved
Clean-contaminated wound	A non-infected wound involving the gastrointestinal or urogenital tract
Contaminated wound	A wound at higher risk of infection because of its method of creation e.g. trauma
Dirty wound	An infected wound or wound with faecal contamination
Sensitivity	The proportion of patients who had an SSI that were correctly identified as such
Specificity	The proportion of patients who did not have an SSI that were correctly identified as such
Positive Predictive Value	The proportion of patients identified as having an SSI that truly did
Negative Predictive Value	The proportion of patients identified as not having an SSI that truly did not
Case-finding intensity	The amount of effort or resource committed to try to find cases of SSI
Post-discharge surveillance	Surveillance of SSIs occurring outside hospital, excluding patients readmitted to hospital for SSI

Chapter 1. Introduction

1.1 Background

Surgical site infections (SSI), also known as post-operative wound infections or surgical wound infections, are a type of healthcare-associated infection (HCAI) occurring in a wound resulting from an invasive surgical procedure [1]. Like all HCAIs, SSIs are a major concern for healthcare providers as they go against the principal tenet of bioethics: "first, do no harm". Patients undergo surgery to save or improve their lives and developing an SSI may temporarily or permanently reduce or negate these improvements, worsen quality of life, or even cause death. There are many ways that the risk of SSI might be reduced, but without a proper understanding of the landscape – the scale of the problem and the context in which interventions could be introduced – the design and impact of interventions will be largely guesswork. This thesis aims to describe the landscape of SSIs in England through two lenses: the social lens, which looks at how SSIs prevention and surveillance are perceived by healthcare providers and patients, and the technological lens, which explores how technology can improve SSI surveillance practices.

1.1.1 Definitions of SSI

There are many different definitions of SSI in use in surveillance systems and studies across the world. Most are based on the CDC definition of SSI [2], including the definition used by Public Health England (PHE) [3]. Unless stated otherwise, the definition of SSI in this thesis is the PHE definition. This can be viewed in full in Appendix 1, but in brief:

Superficial incisional infection: this is defined as a surgical site infection that occurs within 30 days of surgery and involves only the skin or subcutaneous tissue of the incision

Deep incisional infection: this is defined as a surgical site infection involving the deep tissues (i.e. fascial and muscle layers) that occurs within 30 days of surgery if no implant is in place, or within a year if an implant is in place and the infection appears to be related to the surgical procedure

Organ/space infection: this is defined as a surgical site infection involving any part of the anatomy (i.e. organ/space), other than the incision, opened or manipulated during the surgical procedure, that occurs within 30 days of surgery if no implant is in place, or within one year if an implant is in place and the infection appears to be related to the surgical procedure

1.1.2 Epidemiology

SSIs are the third most common type of HCAI in England after respiratory and urinary tract infections, representing 15.7% of all HCAIs [4]. In Europe, SSIs are the second most common, making up 19.6% of

HCAIs [5] and are estimated to cause more than 16,000 deaths per year [6]. This thesis focuses on SSIs occurring in England.

The risk of developing an SSI following surgery varies depending on multiple patient, surgical, and environmental characteristics. In England, national reports estimate that SSI rates vary from 0.6% in hip and knee prosthesis to 9.2% in large bowel surgery [7] for SSIs diagnosed among inpatients and readmitted patients. Trends in SSI rates in England vary depending on surgical category. Seven-year rates in orthopaedic surgery have been stable or decreasing, while rates in spinal surgery, cholecystectomy, and cardiac surgery (excluding coronary artery bypass graft, CABG) have shown significant increases [7].

The causative organisms of SSIs in England also vary by surgical category, but they are also different in SSIs diagnosed among inpatients and readmitted patients [7], possibly suggesting different infection mechanisms in these groups.

1.1.3 Risk factors

The development of an infection depends on multiple patient-related and environmental factors. A systematic review published in 2013 summarised the risk factors associated with SSI [8]. Different surgery types have different associated risk factors, but the main risk factors generally are: diabetes; smoking status; increased length of pre-operative hospital stay; use of an implanted medical device; increasing BMI; increasing age; *S. aureus* colonisation; and more severe wound class. Some risk factors are non-modifiable, but several can be modified or mitigated using a variety of strategies which are summarised in Figure 1.

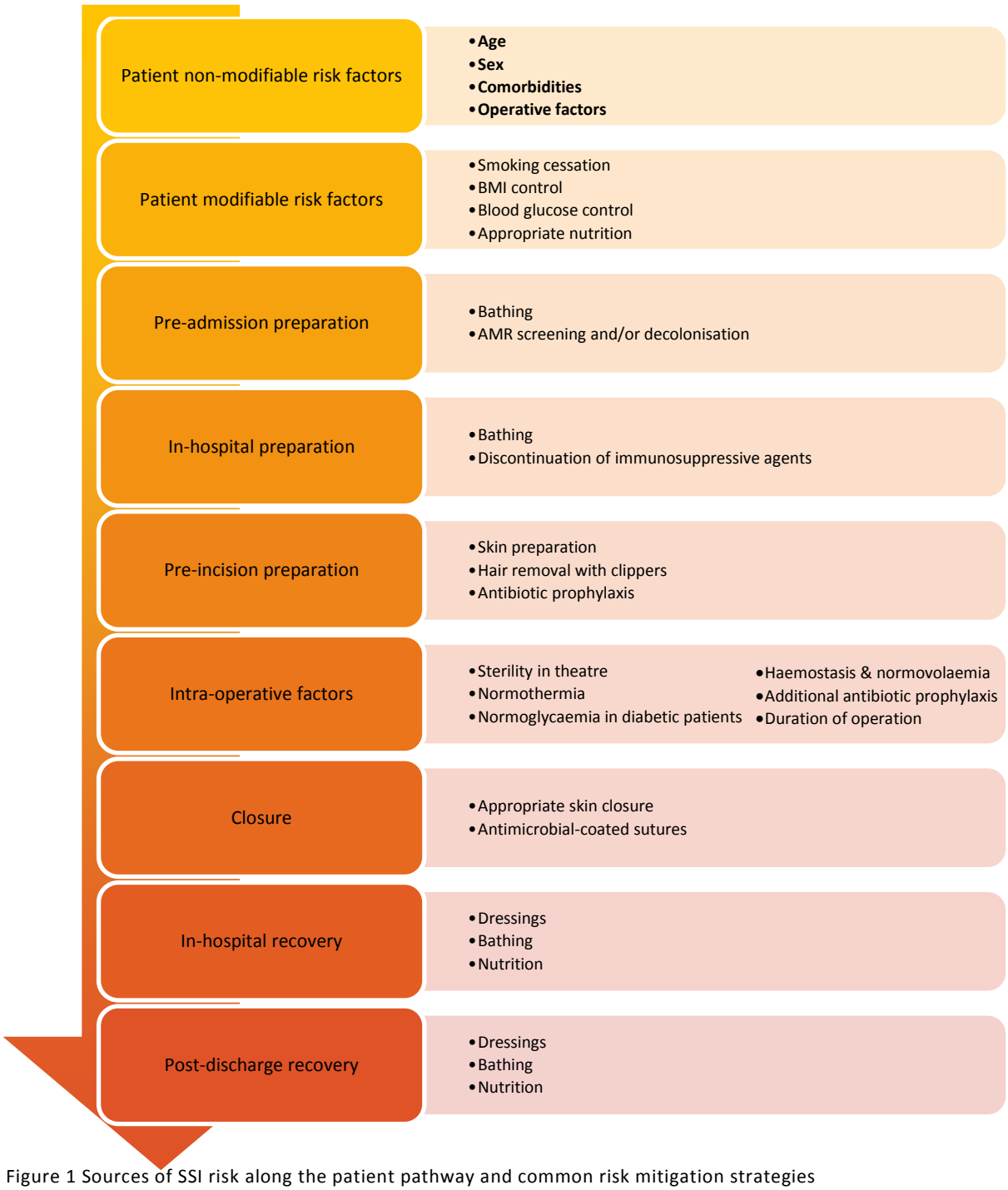


Figure 1 Sources of SSI risk along the patient pathway and common risk mitigation strategies

Compiled using National Institute for Health and Care Excellence SSI guidelines [1] and World Health Organisation Guidelines [9]

1.1.4 Guidelines and Compliance

There are numerous local, national and international guidelines aimed at reducing the rate of SSI, such as local hospital policies, National Institute for Health and Care Excellence (NICE) guidelines in the United Kingdom (UK), CDC guidelines in the United States of America (USA), and global World Health Organisation (WHO) guidelines.

In 2016, WHO published new guidelines for the prevention of SSIs globally based on systematic reviews and a comprehensive consultation process [9]. The new guidelines resulted in 29 recommendations together with an indication of the strength of the recommendation and the quality and strength of the evidence on the subject. The availability of these guidelines, drafted to be applicable in all settings, is extremely helpful for healthcare providers looking to reduce risk of SSI to patients. There were also new CDC guidelines published in August 2017 which used similar methodology and made similar recommendations.

The NICE guidelines for prevention and treatment of SSI were last reviewed in September 2014. Two aspects of the guideline are of particular interest. Part 1.1.1 of the guideline states that patients should be given clear, consistent advice on the risks of surgical site infections [1]. However, evidence from the 2014 PHE surveillance survey revealed that many hospitals do not perform enough surveillance in non-mandatory specialties to be able to give patients accurate information on their risk of developing an SSI [10]. Additionally, part 1.1.3 of the guideline states that hospitals should use "an integrated care pathway for healthcare-associated infections" to communicate to patients the signs and symptoms of SSI and who to contact if they are concerned. A new initiative led by the Royal College of Anaesthetists (RCoA) [11] aims to develop a collaborative programme for the delivery of integrated care pathways across the UK.

What remains missing from all guidelines is an indication of the relative effect sizes in different contexts of interventions with strong evidence, so healthcare providers will find it difficult to know which interventions to invest time and effort in implementing to achieve the maximum benefit. Also missing are indications on cost-effectiveness and ease of implementation of different interventions.

As well as guidelines specific to SSIs, the World Health Organization's Safe Surgery Checklist has several items aimed at reducing SSIs. It comprises 19 simple checks which must be completed over three important perioperative time points [12], several of which are related to SSI prevention: skin preparation and hair removal, antibiotic prophylaxis, and sterility checks. When checklist was first piloted in 2007-2008 in adult non-cardiac patients the incidence of SSI fell on average from 6.2% to 3.4% ($P<0.001$) [12]. Because of significant improvements in morbidity and mortality, the checklist has been adopted worldwide and is mandatory in NHS hospitals. However, qualitative studies have found that different approaches taken when implementing the checklist were associated with variations in attitudes that affected compliance [13,14]. These findings are mirrored in many smaller studies on interventions specifically targeting SSIs [15].

While bundles and guidelines can have a significant impact on reducing SSI rates [12,16], compliance with evidence-based SSI prevention guidelines such as these remains a major issue, and may largely explain the inconsistent impact of guidelines and bundled approaches on SSI rates [15,17–19].

1.1.5 Impact of SSIs on patients

The impact of SSI can be devastating for patients. Patients with SSI are between 2 and 11 times more likely to die following surgery than those without SSI [20,21]. The consequences of SSI range from minor complications such as delayed wound healing and mild pain, to major morbidity such as excessive scarring, loss of function, restricted mobility, gangrenous necrosis, and death [22,23].

As well as the physical impact on the health of patients, several studies have looked at the emotional, social, and economic impact of SSIs on patients. A Swedish study examining patient experiences of a deep wound infection following orthopaedic surgery found that SSIs caused pain, feelings of isolation, insecurity in identifying worsening signs and symptoms, and additional unpleasant side effects from treatment [24]. Given that orthopaedic surgery is usually carried out to improve quality of life rather than to save lives, SSIs that result in a worsening in quality of life are an extremely negative outcome. For a group of patients undergoing caesarean section (CS) in Australia, SSIs resulted in "unsightly and disfiguring" scarring [25] which had a negative impact on the patients' body image. More recently, and English study by Tanner et al. looked at the experiences of 60 patients who had developed SSIs after orthopaedic, CS, or cardiac surgery [26]. This study found considerable lack of knowledge of SSIs among these patients, some of whom even denied that they had had an SSI despite having received lengthy antibiotic courses. Nevertheless, many patients had protracted recovery periods which were extremely costly to them economically and emotionally. Patients tended to blame themselves for the infection, except when the causative organism was methicillin-resistant *Staphylococcus aureus* [26]. Another English study concluded that patients have to rely a great deal on their social networks for emotional support when coping with an SSI [27].

There is also the personal economic cost to patients and their families. One patient in the Tanner study reported spending "a fortune" on travel costs to and from hospital, and several patients had been off work for several months, which hit self-employed patients particularly hard [26]. Some patients' family members had also taken time off work to care for them. These anecdotal reports indicate that patients and the wider economy are bearing part of the financial burden of SSIs.

1.1.6 Impact of SSIs on health systems

In addition to the physical and emotional impact of SSI, there can also be a financial impact on patients and their families [26], and the impact on healthcare systems is also considerable; each infection increases length of stay in hospital by 3.5-10 days and incurs excess costs of £2,385 - £5,239 [28,29]. In studies of patient experiences of SSI, participants commented on a lack of communication about their infection from healthcare professionals, and felt that there was a lack of transparency surrounding SSI [24,26].

In 2014 an National Health Service (NHS) report predicted a budget deficit of £30bn by 2020, and set a target to recoup £22bn of this by achieving efficiency savings [30]. A report by Lord Carter of Coles, published in February 2016, identified reducing surgical site infection rates, particularly those following hip and knee replacements, as a key factor in achieving this goal, and projected savings of £1.5bn over five years [31] if infection rates could be reduced to a maximum of 1%.

1.1.6.1 Antimicrobial resistance and SSIs

Antimicrobial resistance (AMR) is an increasing threat to global health with drivers in the human, animal, and environmental spheres [32]. The One Health Initiative seeks to expand interdisciplinary collaborations between human, animal, and environmental sectors [33]. Antibiotics are not used only in human medicine, but veterinary medicine, agriculture, and aquaculture, creating a selective pressure for resistance mechanisms in animal and environmental bacterial reservoirs which can be transferred to humans by multiple routes.

Initiatives to prevent and mitigate the effects of AMR in humans have partly focused on reducing preventable infections and ensuring antibiotic use is appropriate through antimicrobial stewardship [34]. SSIs are potentially preventable infections, so reducing rates of SSIs is a clear target for decreasing the number of antibiotic prescriptions dispensed. One of the main interventions used to prevent SSIs is antibiotic prophylaxis, the administration of antibiotics to a patient undergoing surgery to prevent rather than treat infections, which results in additional antibiotic exposure.

In the context of increasing levels of antibiotic resistance, clinicians will be able to rely less on prophylactic or therapeutic antibiotics. Thus, effective prevention of SSI is likely to become increasingly important in the future, and development of robust inpatient and post-discharge surveillance methods will be vital in measuring the impact of SSI prevention measures. Additionally, as infections become increasingly likely to be caused by a resistant organism, treating SSIs will become more difficult, protracted, and costly, and be increasingly dangerous for patients.

1.1.7 Surveillance in England – Inpatients

The Surgical Site Infection Surveillance Service (SSISS) run by Public Health England allows hospitals to benchmark their rates nationally, and to use this data to drive improvements in practice [3]. Currently, reporting is only mandatory for certain orthopaedic procedures, but data can be collected for 13 other surgery types. Different surgery types carry different risks, and also different post-operative lengths of stay [3].

In the SSISS protocol, patients are followed prospectively for up to 30 days (1 year if the surgery involved an implant). Like several other national programmes, the surveillance is carried out manually by a surveillance nurse who has attended formal programme training. This system aims to standardise

classification, and maximise case finding, but has the disadvantage of being time consuming, costly, and vulnerable to employee turnover.

Various attempts at using routinely collected data to estimate rates of surgical site infection have found sensitivities ranging from 60% to 98% [35]. The best performing systems involved some level of manual validation, such as verification from medical records or discussions with surgeons. Nevertheless, semi-automated methods generated significant time savings when compared with entirely manual methods [35].

1.1.7.1 Getting It Right First Time national SSI audit

In Spring 2017, a national audit was launched as part of the Getting It Right First Time (GIRFT) initiative. This initiative was created through a partnership between the Royal National Orthopaedic Hospital NHS Trust and NHS Improvement, and aims to improve resource use and patient outcomes in the NHS by reducing unwarranted variation in procurement and care quality [36]. The SSI audit was intended to be a clinician-led project comprising a six-month retrospective audit using note reviews followed by a six-month prospective audit, therefore covering a total period of 12 months from November 2016 to October 2017 [36]. Hospitals were encouraged to submit data on a full range of surgical specialties. No extra resources were provided, but the audit leaders incentivised involvement of clinicians by providing certification of involvement.

GIRFT workstreams are designed with several stages: data collection, data analysis and benchmarking, working with hospitals to understand variation, and then creating action plans with each hospital to change practice [36]. The results of the SSI audit are yet to be published.

1.1.8 Surveillance in England – Post-Discharge Surveillance

Many infections develop outside the hospital setting, as superficial infections take on average 10 days to develop [37], and infections that involve an implant, such as hip or knee replacements, can take up to a year to manifest [38]. Various enhanced recovery after surgery programmes have aimed to help patients to recover faster and be discharged sooner [39], so reliable methods for post-discharge surveillance (PDS) will become increasingly necessary.

Under the SSISS, PDS is encouraged and the collected data can be submitted, but are not used for benchmarking, as methods vary greatly between institutions and surgery types. There is currently no internationally recommended approach for PDS. The SSISS uses two common methods for PDS: outpatient clinics where the patient is reviewed by a healthcare professional, or a post-discharge questionnaire completed by the patient. The questionnaire can be administered either in paper form to be completed by the patient and returned to the hospital at 30 days, after which responses to the questionnaire that are indicative of SSI are followed up by the surveillance nurse to discuss symptoms and confirm diagnosis; or

the same questionnaire delivered over the phone by a healthcare professional, usually a surveillance nurse [3].

1.1.9 Feedback of surveillance data

A number of studies in the perioperative care field have examined individualised monitoring or audit and feedback models as a means of improving clinical outcomes. In 2012, an American group seeking to reduce SSI rates audited compliance with three practices (normothermia, timely antibiotics, and proper hair removal) as an example of process monitoring [40]. Compliance improved over the course of the study, though the effect on the outcome of surgical infection was not measured.

Similar studies have shown positive effects amongst anaesthetists. A project conducted at Imperial College Hospitals NHS Trust (ICHNT) used a co-designing process over several years to create a monitoring and feedback system with individualised reports on a range of process and outcome measures such as post-operative pain and temperature [41]. Anaesthetists were given multiple opportunities to influence the design of the tool, both formally in interviews and questionnaires, and informally through dialogue with the 'champion', an anaesthetist and project lead. The project also had extensive input from a human factors expert. Careful consideration was given to behaviour change frameworks, and a thorough report explains the co-design and implementation processes [41]. The authors attributed the success of the project to having a strong clinical lead and including end-users in the design process not only to ensure optimum usability of the end product but also to foster a sense of ownership. The study showed that after the introduction of enhanced reports, significant improvements were made in five of ten outcome measures [41]. The design process and mixed-methods evaluation of this project will be used as a basis for the surveillance tool described later in this report.

The findings of this study are corroborated by a systematic literature review on organisation, management and structure for prevention of HCAIs, which identified crucial elements for effective infection prevention and control (IPC) programmes [42], including optimum ergonomics, appropriate use of guidelines, education and training, auditing, surveillance and feedback, multimodal and multidisciplinary prevention programmes that include behavioural change, and engagement of champions [42].

1.2 Addressing gaps in the literature

Aside from government mandated reporting in a small subset of procedures, hospitals have no guidance in deciding how to allocate their limited resources in SSI surveillance activities. The current surveillance system needs to be examined alongside the burden of SSIs in different surgical categories to better understand how existing resources should be distributed to have maximum impact.

The impact of SSI surveillance on patient outcomes has to be affected through the surgical teams themselves. Despite some qualitative evidence to describe patient experiences of SSI [24–26], and

healthcare worker experiences of certain interventions aimed at reducing rates [13,14,40], there are few studies examining the attitudes of a range of stakeholders to SSI prevention guidelines and surveillance systems in general, and the contextual barriers and facilitators to best practice. A deeper understanding of the drivers of behaviour around SSI prevention and surveillance would help maximise the impact of interventions.

Hospital staff are also key stakeholders in the implementation of SSI surveillance programs. While multiple studies have shown that electronic surveillance for SSIs can be effective, there has been little research into how these systems would work in practice and why they are not being widely adopted [43,44]. More evidence is needed to explain the barriers and facilitators to the adoption of technological innovations for SSI surveillance in the English setting.

Finally, in order to fully understand the SSI risk to patients more attention needs to be paid to the quality of surveillance in the post-discharge period where most SSIs occur [45]. Despite the existence of a range of post-discharge surveillance (PDS) methods globally, there is no general consensus on the optimum method. Previous studies in England have looked only at which methods are used [46] without attempting to analyse which methods work in which circumstances. More evidence is needed to underpin the implementation of PDS in English hospitals.

1.3 Hypothesis

SSI prevention can be improved by maximising use of existing resources, understanding barriers and facilitators in the surveillance and prevention of SSIs, and using social and technological innovation to facilitate stakeholder engagement

1.4 Aim and research questions

The main aim of this thesis is to examine the current sociological and technological landscape of SSI prevention and surveillance in England and explore how new innovation could improve patient outcomes and resource use. To meet this aim, several research questions were established:

1. Which surgery types should be targeted for SSI prevention initiatives?
2. How can technology enhance SSI surveillance?
3. What are healthcare workers' perceptions and beliefs about SSI prevention and surveillance?
4. How can post-discharge SSI surveillance be improved?

1.5 Scope

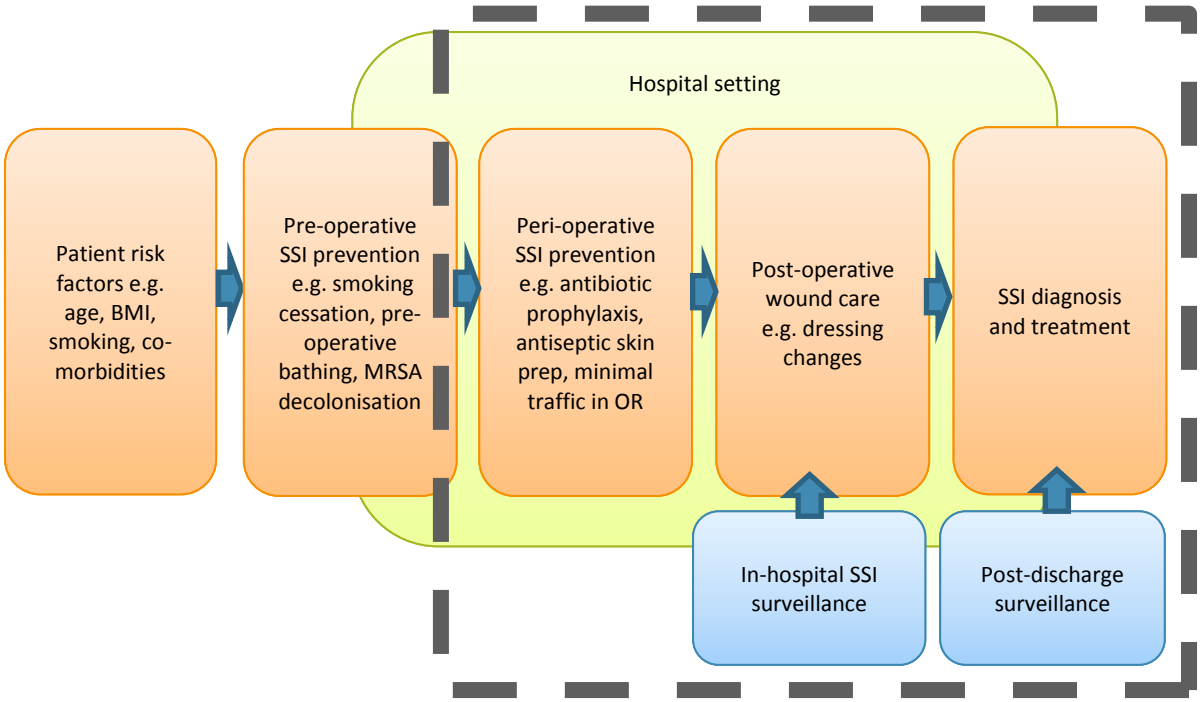


Figure 2 Schematic of the aspects of the patient pathway covered in this thesis, scope defined by broken line

This thesis focuses mainly on peri-operative and post-operative SSI prevention and surveillance in England. It uses mixed qualitative and quantitative methods to analyse how social and technological factors can impact on prevention and surveillance of SSIs at hospital or national level in England. Patient risk factors, and the efficacy or implementation of individual SSI prevention interventions are outside the scope of this thesis. The recent concerns related to *Mycobacterium chimera* contamination of heater cooler units used in cardiac surgery are not considered [47], as the extremely slow growth of the organism causes this rare infection to present beyond time allowed under the PHE definition of an SSI (30 days for non-implant, 1 year for implant).

1.6 Approaches

It is important to consider the approaches I have taken in this thesis in terms of my own perspectives and the methods used to explore the hypothesis. My background is originally in natural sciences, and later infection and immunity, so I approached this research as a basic scientist with no background in clinical practice. The research questions require a number of different data sources and modes of enquiry to answer, so I have used a mixture of qualitative and quantitative methods in my approaches, ranging from novel data collation and analysis and classic validation of algorithms through to realist reviews, interviews, surveys, and workshops.

In terms of epistemology, I have approached this work from a critical realist perspective i.e. “there is a ‘reality’ of social world that can be uncovered through research… but this reality requires more than simply atheoretical empirical work to identify” (from p19, *Qualitative Methods for Health Research* [48]). This approach is important as it has allowed me to view the empirical quantitative aspects of my work at the same time as the qualitative aspects e.g. a patient may truly have an SSI, but the way different staff members perceive this is related to the social, political, and historical context in which they work.

1.7 Thesis overview

There are seven further chapters in this thesis, four of which contain original research, one a discussion of existing literature, one a discussion of the thesis overall, and one chapter of conclusions and recommendations (see Figure 3).

The original research described in this thesis begins with Chapter 2, with a quantitative study examining how SSI surveillance is currently organised and prioritised nationally in England. The study takes data from multiple sources to estimate which surgical categories contribute the highest burden of SSIs annually in terms of risk, number, and cost of SSIs, and map these to current national reporting requirements (mandatory, voluntary, not offered), the percentage of hospitals undertaking surveillance in each category, and hospital-reported priorities for surveillance. This addresses the first research question “Which surgery types should be targeted for SSI prevention initiatives?”.

After the more technical aspects of current SSI surveillance have been described in Chapter 2, Chapter 3 looks at the sociological landscape of SSI prevention and surveillance using qualitative methods. The study used interviews with staff stakeholders at ICNHT to understand the drivers of SSI prevention behaviours in surgery and understand how surveillance works in practice.

Chapter 4 is a literature-based chapter looking at the barriers and facilitators to SSI surveillance in England, and in particular the slow adoption of electronic surveillance systems (ESS), using the Consolidated Framework for Implementation Research. Chapter 5 presents a case study of the development and planned implementation of ESS at ICHNT, looking in detail at the barriers faced.

Problems with SSI surveillance are not confined to the in-hospital setting; PDS is still not used for national benchmarking in England as the data are of such variable quality. Chapter 2 uses realist review methods to look at which PDS methods might work best under which circumstances, and then explores how this might translate to individual English NHS hospitals through patient focus groups.

Finally, strengths, weaknesses, possible contributions, and further questions raised by research are discussed in Chapter 7, with conclusions and recommendations in Chapter 8.

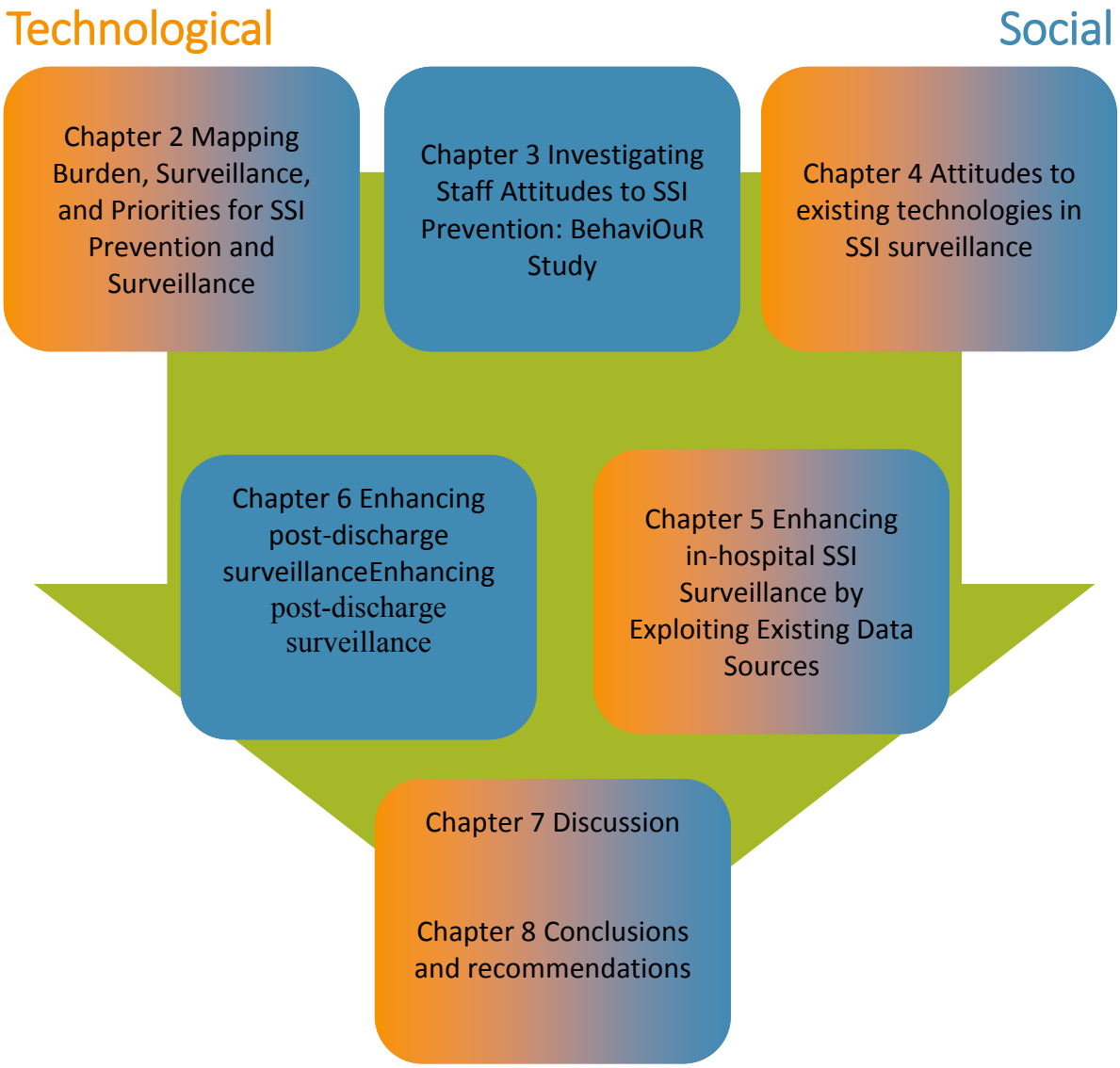
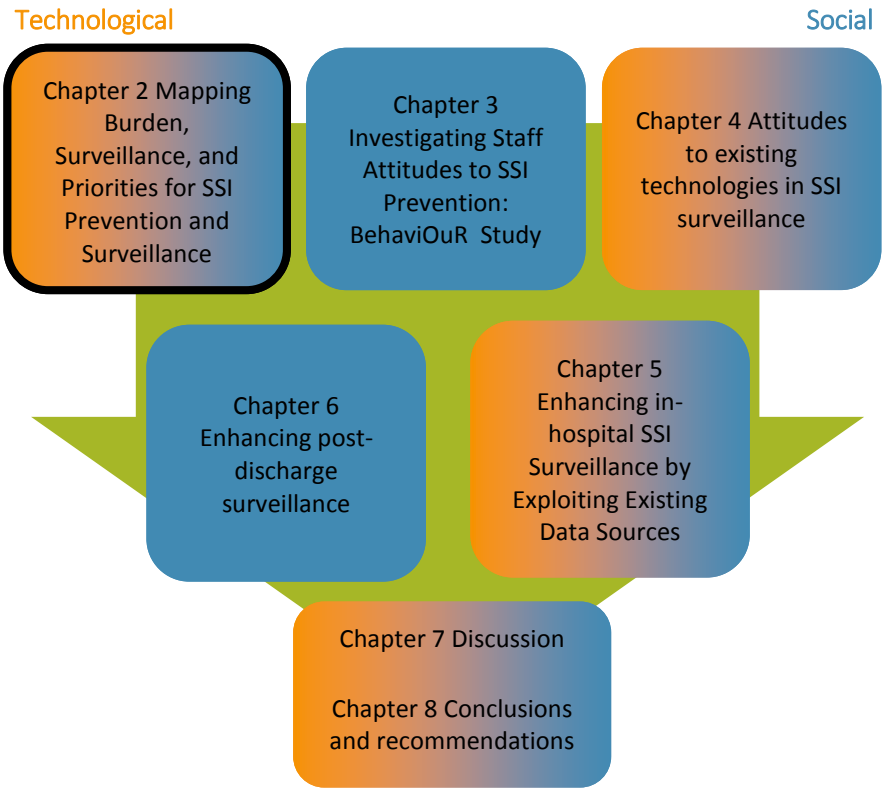


Figure 3 Thesis overview

Chapter 2. Mapping Burden, Surveillance, and Priorities for SSI Prevention and Surveillance

Summary

This chapter uses a novel method to collect the most relevant data from multiple sources to estimate the burden of SSIs in different surgical categories and map this to current national surveillance arrangements and hospital-reported priorities. This forms the backdrop for the other studies in the thesis, showing how the other tools explored could be used most effectively and providing an objective understanding of how SSIs differ between specialties. This study was presented in a peer-reviewed paper in the Journal of Hospital Infection [49].



2.1 Background

Surgical site infections (SSI) are the third most common healthcare associated infection in England, and surveillance of SSI is a key part of Infection Prevention and Control (IPC) programmes [1,42] as sustained surveillance has been shown to drive infection rates down [40,41]. Many countries, including England, coordinate national surveillance programs across a range of surgical procedures or categories, but the decision process behind the choice of procedures to include in the surveillance is not always clear. There is limited evidence to show which areas should be targeted to produce the best outcomes for patients and healthcare systems.

English national surveillance of SSIs is coordinated by the Surgical Site Infection Surveillance Service (SSISS) at Public Health England (PHE). The aim of the SSISS is to improve patient care by establishing national

benchmarks of SSI rates, identifying outliers and working closely with these hospitals to improve practices [3].

Surveillance is mandatory for at least one of four orthopaedic procedures, and hospitals can submit data voluntarily for thirteen other surgical categories or procedures (Table 1) [3]. All patients undergoing the particular procedure are enrolled in the surveillance on the day of surgery and are followed up for 30 days (one year if an implant was inserted). While only infections diagnosed during the patient's initial stay or upon readmission to hospital are included in benchmarking, hospitals can choose to follow patients after discharge (post-discharge surveillance, PDS), either through outpatient clinics or patient questionnaires. The non-standardised nature of PDS precludes this data from inclusion in benchmarking.

Table 1 List of procedures or categories reported to the Surgical Site Infection Surveillance Service, coordinated by Public Health England [3]

CABG= coronary artery bypass graft

Mandatory surveillance – at least one quarter per year of at least one of the following:	Voluntary surveillance
Hip replacement Knee replacement Reduction of long bone fracture Repair of neck of femur	Abdominal hysterectomy Bile duct, liver or pancreatic surgery Breast surgery (since 2010) Cardiac surgery (non-CABG) (since 2010) Cranial surgery (since 2010) Cholecystectomy (non-laparoscopic) Coronary artery bypass graft Gastric surgery Large bowel surgery Limb amputation Small bowel surgery Spinal surgery (since 2008) Vascular surgery

In England, surveillance of patients is undertaken manually by specially trained nurses, which is time consuming and costly. Many hospitals choose to perform only mandatory orthopaedic surveillance [50], or must choose which other surgical categories to survey, with little evidence to support these decisions. A recent survey by PHE [10] of trusts using the SSISS revealed that 46% ranked caesarean section SSIs as their top priority over the next 3 years, despite there being no national surveillance facility for this. In contrast, only 9% of trusts ranked reduction of long bone fracture as their top priority, and this was the highest scoring mandatory category. The mismatches between the services offered and the priorities of trusts highlighted in this survey warrant further analysis. This study maps current national surveillance arrangements, stated priorities of trusts, and the risk, burden and impact of SSI by procedure type to identify areas of mismatch and inform future surveillance initiatives.

2.2 Methods

2.2.1 Data sources

The numbers of procedures occurring annually in a given category were quantified using Hospital Episode Statistics (HES) 4-character primary procedure OPCS codes provided by the Health & Social Care Information Centre (HSCIC). OPCS codes were included or excluded based on the supplement provided by the SSISS [51]. For surgical specialities not included in the SSISS, the procedures for which infection rates were available were identified in the literature and corresponding OPCS codes were obtained from medical coders.

The majority of procedure-specific infection rates were obtained from the SSISS annual report [50], and procedure-specific infection rates including cases detected by enhanced PDS were calculated by the SSISS from their unpublished data. The remaining data were obtained from sources searched for according to a hierarchy of applicability of the data source to the English setting given in Figure 4, beginning with English national data and ending with single-site studies from countries not belonging to the Organisation for Economic Co-operation and Development. This hierarchy was developed based on discussions between the multidisciplinary research team. Where research papers were the data source, only observational studies for the purpose of surveillance were included. Interventional studies, or short-term studies for the purpose of investigating risk factors were excluded as these are likely to use different definitions, methodologies, and protocols. Where infection rates including PDS were not available from the SSISS, these rates were estimated by scaling up the best available inpatient and readmission SSI rates in line with the proportions of post-discharge infections given in the literature. For example, if one study in England reported inpatient and readmission SSI rates of 3% but no rate including PDS, and a French study reported inpatient and readmission SSI rates of 8% but 17% including PDS, we calculated ((17-8)/17)*100 = 52.9% of SSIs to be diagnosed through additional PDS, so the equivalent rate in England would be 3*((100+52.9)/100) = 4.59%.

Data on surveillance priorities of English NHS hospitals was obtained from the PHE survey of participating hospitals in 2014 [10].

Figure 4 Data sources for surgical site infection rates, costs, and length of stay were searched for based on a hierarchy of applicability to the English setting developed by the research team, beginning with national data from England and ending with single-site studies in non-OECD countries

OECD= Organisation for Economic Co-operation and Development

2.2.2 Estimation of excess costs

The advice of a health economist was sought for the costing portion of the study. Quality assessment of papers calculating the costs of SSIs was carried out using the Newcastle-Ottawa Scale [52]. A systematic review of quality assessment tools for observational studies found only three tools which allow assessment of both cohort and case-control studies [53]: the CASP checklist, the SIGN methodology tools, and the Newcastle-Ottawa Scale. After discussions with a health economist, I elected to use the Newcastle-Ottawa Scale as it focuses on the quality of the methods used rather than the quality of reporting and can be adapted to suit multiple study designs.

To enable comparison between surgical categories, costs were inflated to 2014-15 prices using the Hospital and Community Health Services (HCHS) pay and price inflation indices [54], and where necessary converted to Great British Pounds (GBP, £) using the 2014 average exchange rates from UK Forex [55]. The excess

cost of SSI to hospitals annually was calculated by multiplying the number of infections among inpatients and readmissions by the inflated and converted mean cost per SSI.

2.2.3 Data analysis

A descriptive analysis was performed by dividing data for each factor into quartiles and assigning a number Q1 to Q4, which are represented by colours (Q1=green (lowest or least concerning), Q2 & 3=yellow, Q4=red (highest or most concerning)). Radar charts were constructed to explore relationships between the current surveillance arrangements, number, and cost of SSIs in each category. Radar charts, occasionally known as star, web, or spider charts, are an effective method for visualising multiple quantitative variables measured on the same scale. The axes radiate out from the centre and data points are joined together to form a polygon, the shape of which can be quickly compared with others to gain a rapid understanding of differences and similarities between units of interest. In this instance, the units of interest are surgical categories and the variables of interest were chosen through discussions with the research team to represent factors that policy makers or hospital managers might consider when setting surveillance priorities. Regularly-shaped, symmetrical plots show a good concordance of current surveillance arrangements with burden of SSIs in that category. Plots skewed to the right of the chart show a high level of burden which is not matched by surveillance, and vice versa.

Surgeries were split by minimum wound classification (clean vs. clean-contaminated) to examine possible differences in SSI rates and surveillance approaches. To investigate whether the decision, either by the Department of Health (through mandatory/voluntary/not offered reporting requirements), or by hospitals (through percentage of hospitals already undertaking surveillance), to conduct surveillance in a given category was related to any of the factors (e.g. SSI rate, perceived priority), a statistical analysis was carried out using a Spearman correlation test for continuous variables and a Kruskall-Wallis test for categorical variables. P values ≤0.05 were considered statistically significant.

2.3 Results

2.3.1 Data sources used for analysis

The data sources used in the analysis were mostly English national data, either from SSISS annual reports or from unpublished data collected by the SSISS. Overall, 69% of data points were taken from English national or multi-centre studies. Of the 23 surgical categories included, data could not be found for at least one data point for ophthalmic, pacemaker, prostate, and maxillofacial/ear nose and throat (ENT)/oral surgery, all of which are surgery types not included in the SSISS.

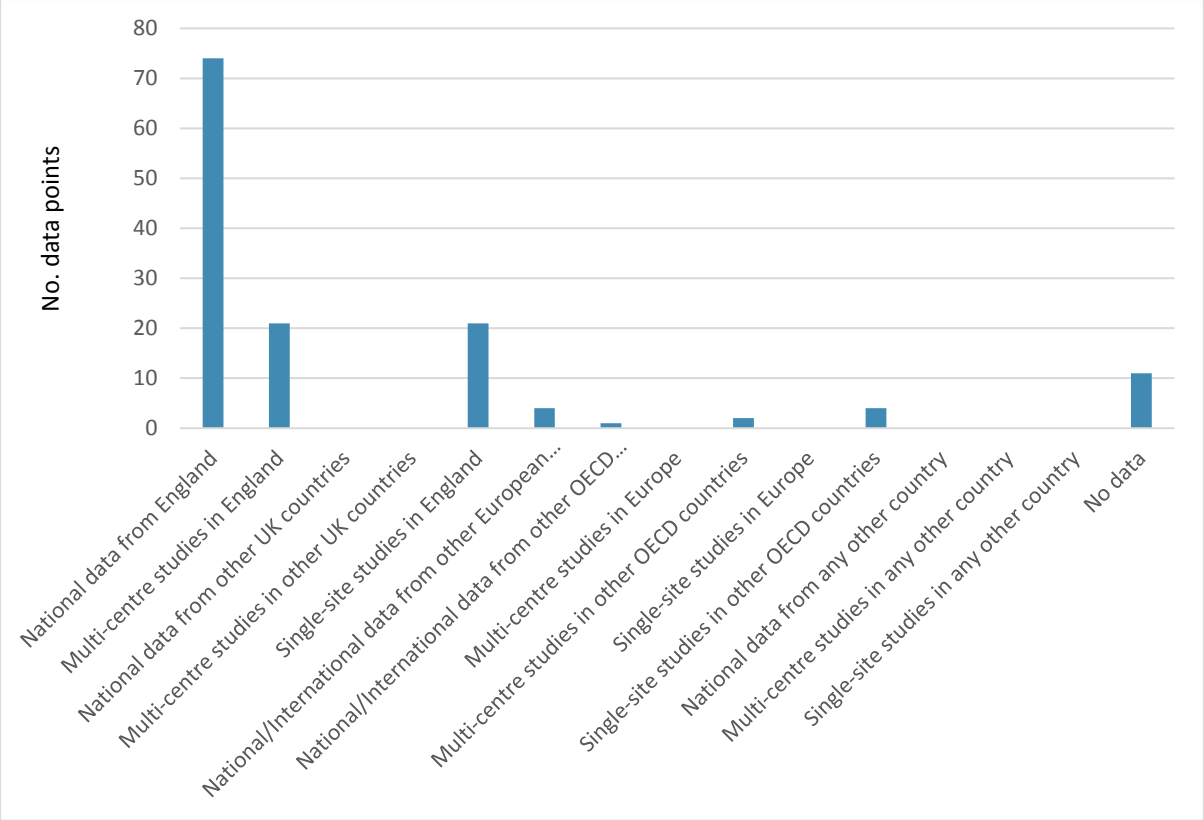


Figure 5 No. of data points from each source in order of applicability to the English setting

2.3.2 Description of the current national surveillance arrangements

The 23 surgical categories analysed in the study represented a volume of 2.01 million procedures annually in England (Table 2). This volume varied from 6,599 procedures for open prostate surgery to 387,991 procedures in ophthalmic surgery (cataract). The median SSI rate (inpatient and readmission, includes superficial, deep, and organ/space) for all procedures varied from 0.4% [56] (95% confidence interval (CI) not available) in pacemaker surgery to 10.4% [50] (95% CI 9.9-10.8) for large bowel surgery (LBS) (Table 1). When including additional post-discharge infections (community and outpatient detection) from all evidence sources it was estimated that surgery in England results in 102,678 SSIs annually. The proportion of infections diagnosed outside of hospital varied from 0 in ophthalmic [57] and pacemaker surgery [58] to 89% for caesarean section (CS) [37].

Collating data from the published literature, the excess length of stay (LOS) due to SSI was estimated to range between 1 [28] (95% CI -3-17) day for SSI after cranial surgery and up to 29 days [28] (95% CI not available) for SSI occurring after gastric surgery. Across all surgery types, excess LOS due to SSIs equates to an estimated 501 978 extra bed days annually.

Similarly, excess costs quoted in the literature ranged from £1 315 [59] (95% CI not available) per SSI in abdominal hysterectomy to £30 171 [60] (95% CI £26 434 - £33 583) in pacemaker surgery (2014/2015

GBP). SSIs across all surgery types were estimated to cost hospitals in England an extra £233 150 269 annually.

In 2014/15, the proportion of responding hospitals in the survey who reported undertaking SSI surveillance in a given category varied in clean surgery from 7% in pacemaker surgery to 92% for hip replacement procedures, and in clean-contaminated surgeries from 0% for appendectomy to 57% for CS. Of the 84 respondents to the survey, half (50%) [10] reported hip replacement as a top future priority, followed by coronary artery bypass graft (CABG) (47%) and caesarean section (46%). Cholecystectomy, gastric, reduction of femoral neck fracture, limb amputation and bile duct, liver, pancreatic surgeries were classified as lower future priorities.

From the visual analysis of radar charts of the surgical categories and assessment factors, clear mismatches can be seen. Large bowel surgery and cholecystectomy had an annual number of SSIs and estimated costs in the highest quartile (Q4), while surveillance is voluntary (Q3) (Figure 1). Caesarean section had an annual number of SSIs in Q4, costs in Q3, and priority ranking in Q4, but is not included in the national surveillance programme. Conversely, knee replacement has SSI numbers in Q2 and costs in Q1, but the percentage of hospitals conducting surveillance and future priorities in Q4, and reporting is mandatory.

Surgery type	Annual procedure volume [a]	% SSIs inpatients and readmissions [b]	% SSIs inc. PDS [c]	Estimated no. SSIs	Estimated no. SSIs inc. PDS	% SSIs identified by PDS	Excess LOS (days) [d]	Estimated total excess LOS annually (days)	Excess cost per infection (£) [d]	Estimated excess cost to hospitals annually (£)	% already undertaking surveillance [10]
Clean											
Breast	197,397	1 (0.8-1.2)	4.26 (3.9-4.6)	1974 (1579-2369)	8409 (7698-9080)	77	3 (1-4)	5,922	1,524 (1,165-4,210)	3,008,262	25
CABG	34,859	4.1 (3.9-4.3)	7.26 (7-7.6)	1429 (1360-1499)	2531 (2440-2649)	44	13 (12–15) [59]	19,152	5,340[59]	7,631,563	76
Cardiac (non CABG)	27,539	1.2 (1-1.4)	1.73 (1.5-2)	330 (275-386)	476 (413-551)	31	23 (19-30)	7,601	11,415 (8,836-15,971)	3,772,192	59
Cranial	23,255	1.4 (1.1-1.7)	1.84 (1.5-2.2)	326 (256-395)	428 (349-512)	24	1 (-3-17)	326	2,762 (5-21,056)	899,095	33
Hip replacement	88,145	0.7 (0.6-0.7)	1.23 (1.2-1.3)	617 (529-617)	1084 (1058-1146)	43	12 (10–12) [59]	7,096	4,583 [59]	2,827,619	92
Knee replacement	85,255	0.6 (0.6-0.6)	1.72 (1.7-1.8)	512 (512-512)	1466 (1449-1535)	65	11 (9–13) [59]	5,576	4,344 [59]	2,222,159	89
Limb amputation	18,638	3.2 (2.5-4)	4.22 (3.4-5.2)	596 (466-746)	787 (634-969)	24	21 (13–31) [59]	12,525	8,369 [59]	4,991,274	13
Ophthalmic surgery (cataract)	387,991		0.1 (0.1-0.2) [57]	543 (427-660)	543 (427-660)	0 [57]					10
Pacemaker	60,396	0.4[56]	0.4[58]	242	242	0 [58]			30,171 (26,434-33,583) [60]	7,288,903	7
Reduction of long bone fracture	105,071	1.1 (1-1.3)	1.52 (1.3-1.7)	1156 (1051-1366)	1597 (1366-1786)	28	10 (6–14) [59]	11,442	3,945 [59]	4,559,678	22
Repair of neck of femur	41,239	1.3 (1.3-1.5)	1.56 (1.5-1.6)	536 (536-619)	643 (619-660)	17	19	10,186	12,557	6,731,839	59
Spinal	66,237	1.2 (1.1-1.3)	1.8 (1.7-2)	795 (729-861)	1192 (1126-1325)	33	13 (6-27)	10,333	7,341 (3,518-18,616)	5,834,761	29
Vascular	37,193	2.7 (2.3-3.1)	4.51 (4-5.1)	1004 (855-1153)	1677 (1488-1897)	40	12 (10–15) [59]	12,251	4,861 [59]	4,881,575	28
Clean-contaminated											
Abdominal hysterectomy	31,968	1.3 (1-1.7)	4.95 (4.3-5.7)	416 (320-543)	1582 (1375-1822)	74	3 (3–4) [59]	1,371	1,315 [59]	546,508	21
Appendicectomy	54,231	2.41[58]	7.1[45]	1302	3828	66 (61-70) [45]	9 [20]	11,714	4,022 [20]	5,235,430	0
Bile duct, liver, pancreatic	12,550	5.8 (5-6.8)	7.62 (6.6-8.7)	728 (628-853)	956 (828-1092)	24	12 (4-24)	8,735	2,944 (146-14,750)	2,143,075	17
Caesarean section	166649 [12]	1.1 [37]	10 [37]	1833	16665	89 [37]	4 (2-7)	7,333	3,855 (927-5,089)	7,066,826	57
Cholecystectomy	77,067	4.7 (3.5-6.2)	6.61 (5.1-8.3)	3622 (2697-4778)	5094 (3930-6397)	29	8	28,977	6,469	23,432,884	11
Gastric	19,607	1.9 (1.2-2.9)	3.31 (2.4-4.5)	373 (235-569)	649 (471-882)	43	29	10,803	22,297	8,306,443	15
Large bowel surgery	304,716	10.4 (9.9-10.8)	12.81 (12.3-13.3)	31690 (30167-32909)	39034 (37480-40527)	19	9 (8–11) [59]	297,890	3,746 [59]	118,721,140	38
Maxillofacial/ENT/oral	133,287		8 [61]		10663						8
Prostate	6,599	1.2 [62]	4.3 [63]	77	284						9
Small bowel surgery	34,940	7.1 (6.3-7.9)	8.59 (7.8-9.5)	2481 (2201-2760)	3001 (2725-3319)	17	13 (13–31) [59]	32,746	5,260 [59]	13,049,042	22

Surgery type	% already undertaking surveillance [10]	Future priority (1 = top priority) [10]	% ranking as top priority [10]	Current national surveillance [3]
Clean				
Breast	25	4	12	Voluntary
CABG	76	2.9	47	Voluntary
Cardiac (non CABG)	59	3.9	24	Voluntary
Cranial	33	4.3	7	Voluntary
Hip replacement	92	2.8	50	Mandatory
Knee replacement	89	3.1	40	Mandatory
Limb amputation	13	4.8	4	Voluntary
Ophthalmic surgery (cataract)	10	4.5	0	Not offered
Pacemaker	7	3.1	26	Not offered
Reduction of long bone fracture	22	4.8	9	Mandatory
Repair of neck of femur	59	3.7	26	Mandatory
Spinal	29	4.1	16	Voluntary
Vascular	28	3.8	18	Voluntary
Clean-contaminated				
Abdominal hysterectomy	21	4.7	7	Voluntary
Appendicectomy	0	3.9	0	Not offered
Bile duct, liver, pancreatic	17	4.8	9	Voluntary
Caesarean section	57	2.7	46	Not offered
Cholecystectomy	11	5	2	Voluntary
Gastric	15	4.9	7	Voluntary
Large bowel surgery	38	3.9	18	Voluntary
Maxillofacial/ENT/oral	8	4.1	8	Not offered
Prostate	9	4.4	0	Not offered
Small bowel surgery	22	4.7	5	Voluntary

Table 2 Factors associated with the risk, number and cost of SSIs in England by surgical category along with average Trust-reported priority ranking and current surveillance arrangements.

Colours relate to the relative quartile of the figure in its column where red = Q4/top priority/mandatory surveillance, yellow = Q2 or Q3/medium priority/voluntary surveillance and green = Q1/low priority/no national surveillance.

[a] From HES data 2014/15 [64]

[b] Incidence from April 2010 – March 2015 from SSISS annual report 2014/15 [50] unless otherwise stated

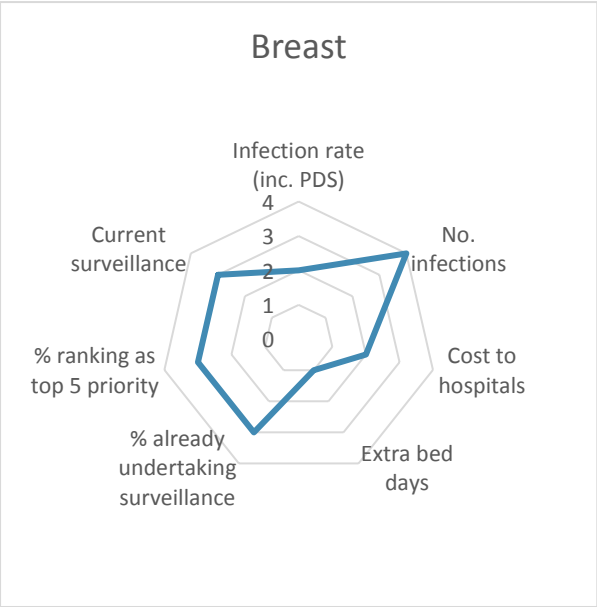
[c] Unpublished data from April 2010 - March 2015 provided by PHE. Data from surgical categories not included in SSISS were scaled up from % SSIs using proportion diagnosed after discharge in source referenced in "% SSIs inc. PDS" column when possible, otherwise quoted directly from the referenced source

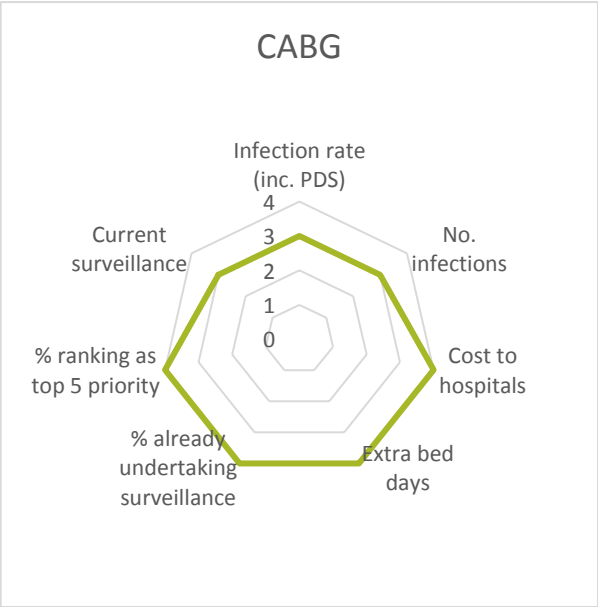
[d] From Jenks 2014 [28] unless otherwise stated.

Table 3 Number and cost of revisions of hip and knee replacements due to SSI, shown separately as comparative figures were not available for other surgical categories.

[a] from HES data [64]. [b] from SSISS Annual report 2014/15 table 3 [50]. [c] Costs inflated from original papers according to HCHS pay and prices inflation indices [54]

Surgery type	Annual procedure volume [a]	% of procedures that are revisions due to infection [b]	No. revisions due to infection	Excess cost per infection (£) [c]	Estimated excess cost to hospitals annually (£)
Hip replacement	88 145	0.9	793	25 015 [65]	19 844 824
Knee replacement	85 255	0.9	767	30 276 [66]	23 230 805


Breast
Infection rate (inc. PDS)
No. infections
Cost to hospitals
Extra bed days
% already undertaking surveillance
% ranking as top 5 priority
Current surveillance
0
1
2
3
4


CABG
Infection rate (inc. PDS)
No. infections
Cost to hospitals
Extra bed days
% already undertaking surveillance
% ranking as top 5 priority
Current surveillance
0
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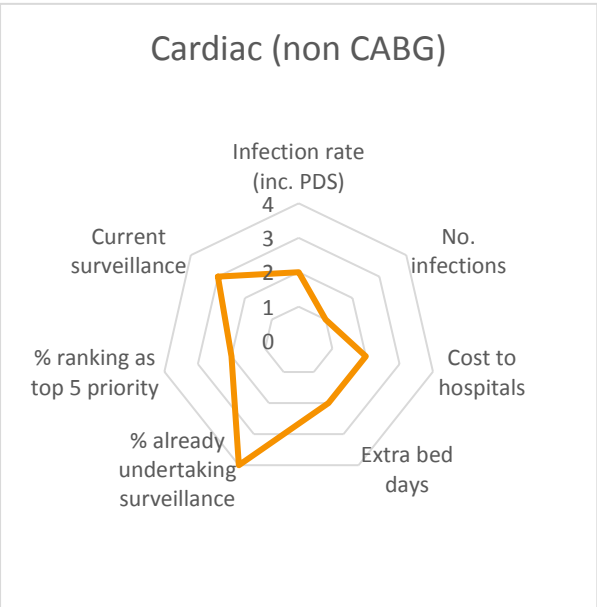
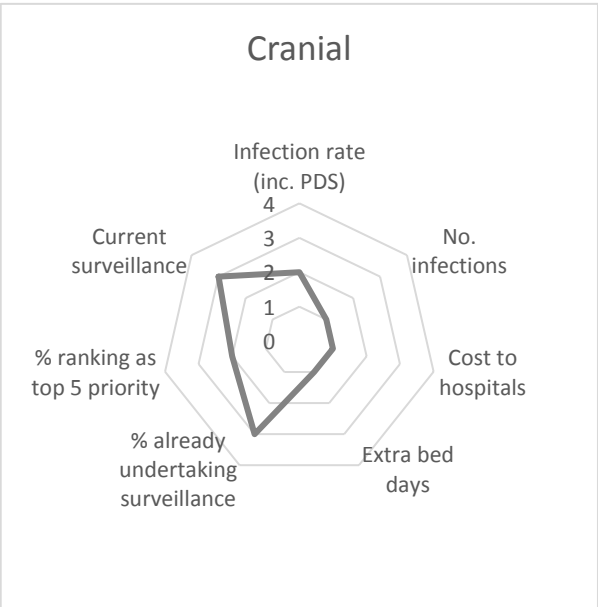
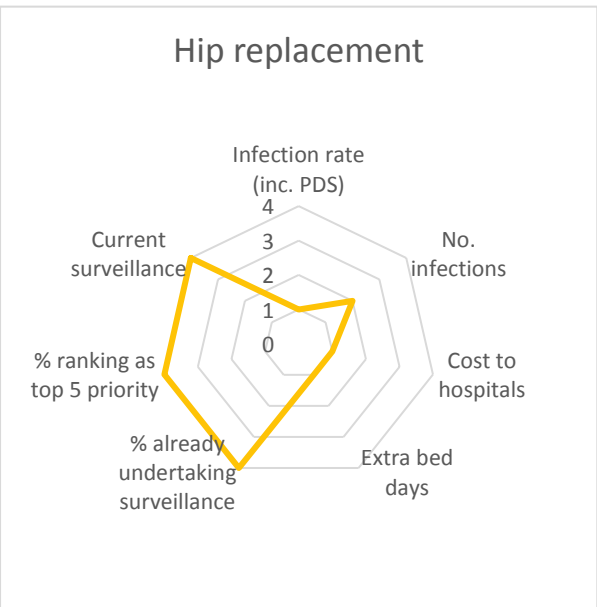

Cardiac (non CABG)
Infection rate (inc. PDS)
No. infections
Cost to hospitals
Extra bed days
% already undertaking surveillance
% ranking as top 5 priority
Current surveillance
0
1
2
3
4


Cranial
Infection rate (inc. PDS)
No. infections
Cost to hospitals
Extra bed days
% already undertaking surveillance
% ranking as top 5 priority
Current surveillance
0
1
2
3
4


Hip replacement
Infection rate (inc. PDS)
No. infections
Cost to hospitals
Extra bed days
% already undertaking surveillance
% ranking as top 5 priority
Current surveillance
0
1
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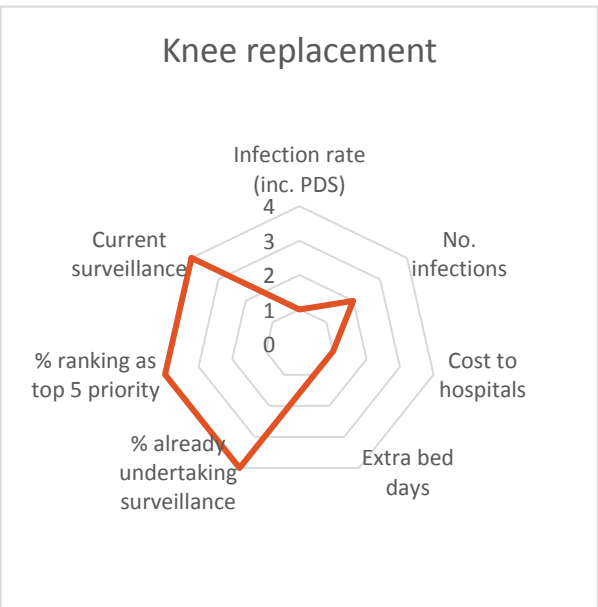
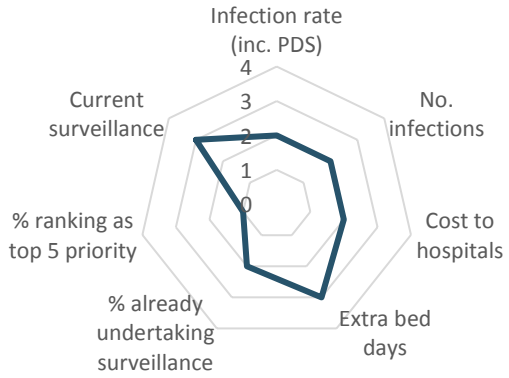
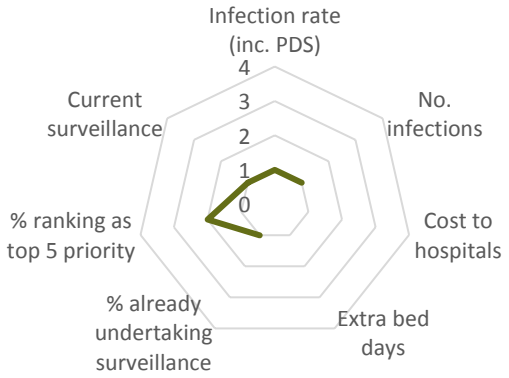
3
4


Knee replacement
Infection rate (inc. PDS)
No. infections
Cost to hospitals
Extra bed days
% already undertaking surveillance
% ranking as top 5 priority
Current surveillance
0
1
2
3
4

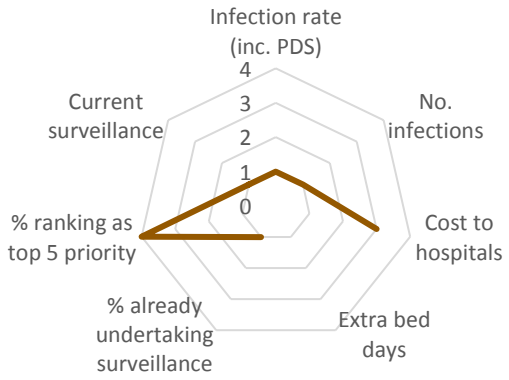
Limb amputation



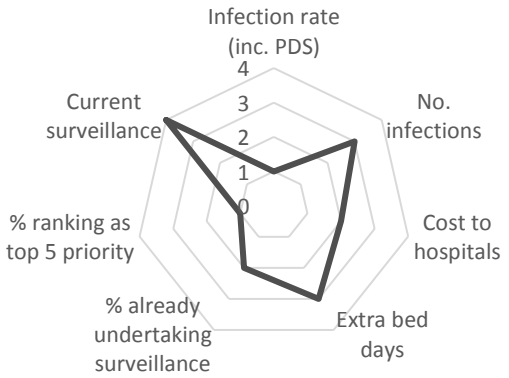
Ophthalmic surgery (cataract)



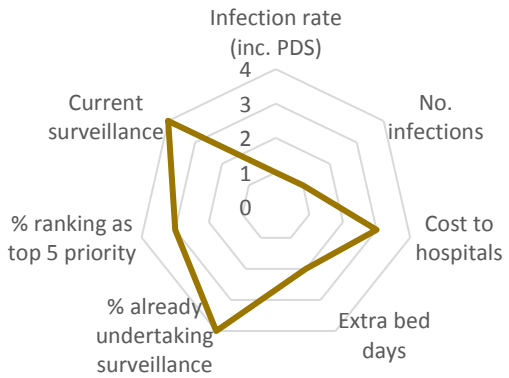
Pacemaker



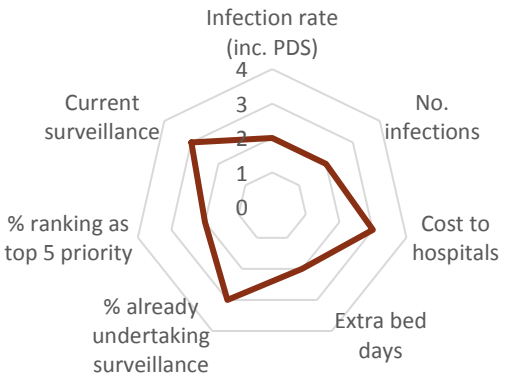
Reduction of long bone fracture



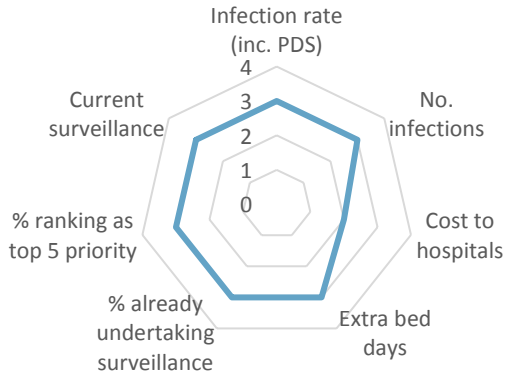
Repair of neck of femur



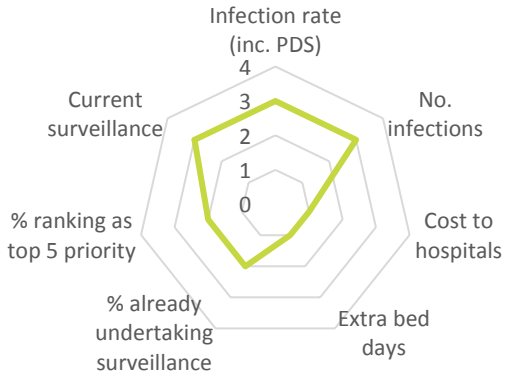
Spinal



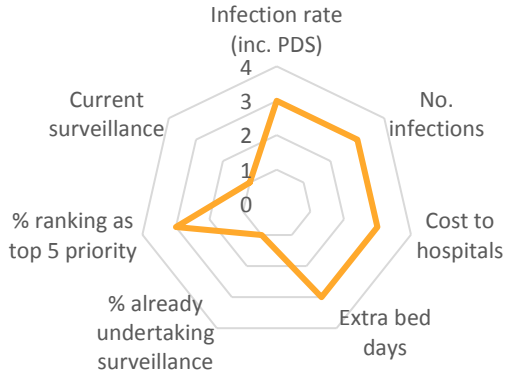
Vascular



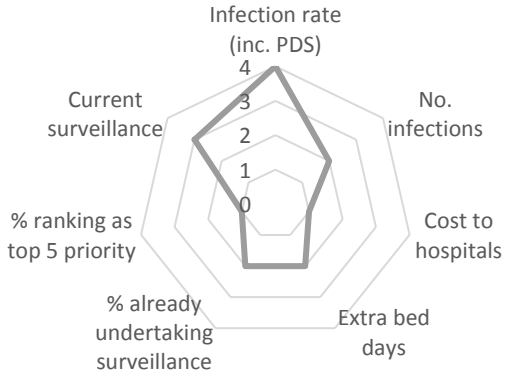
Abdominal hysterectomy



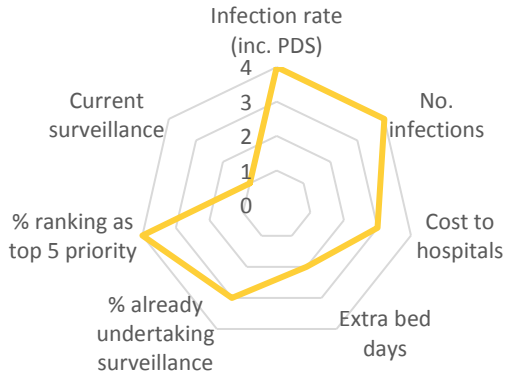
Appendicectomy



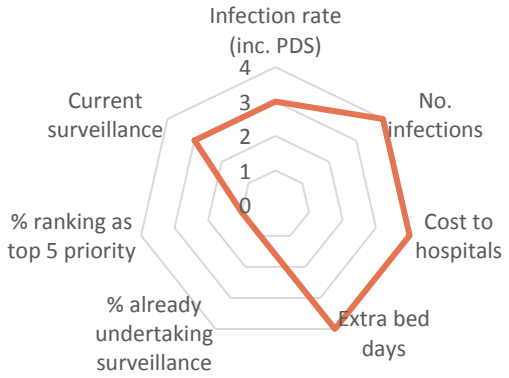
Bile duct, liver, pancreatic

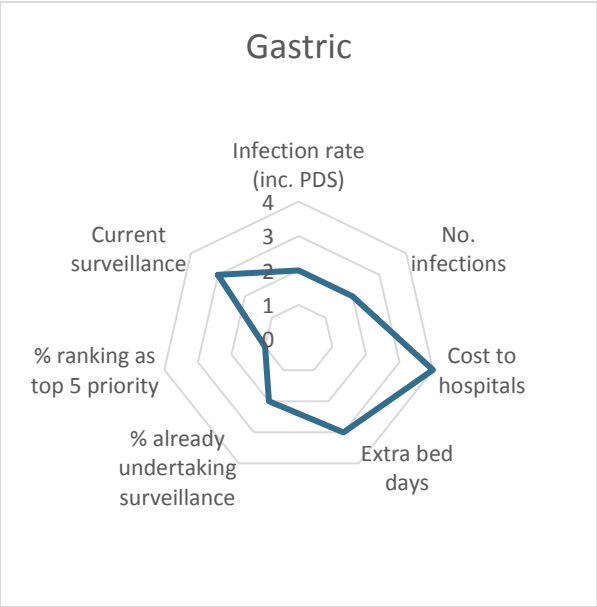


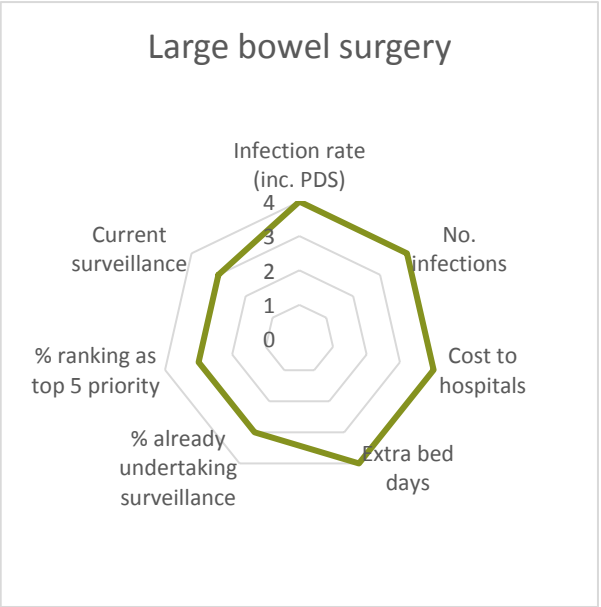
Caesarean section

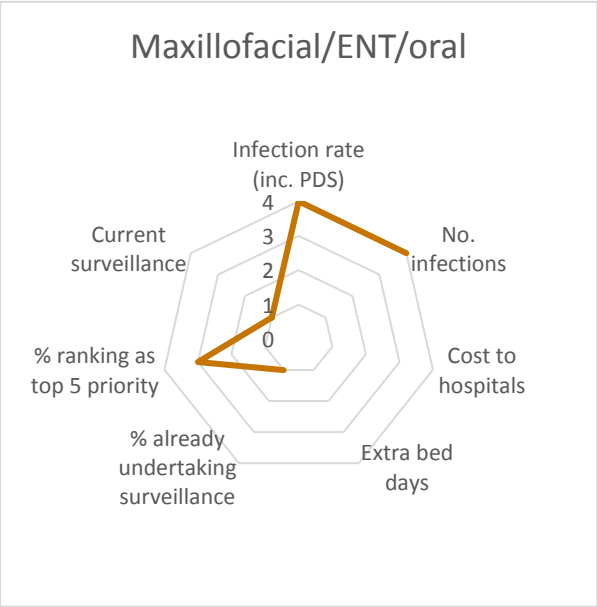


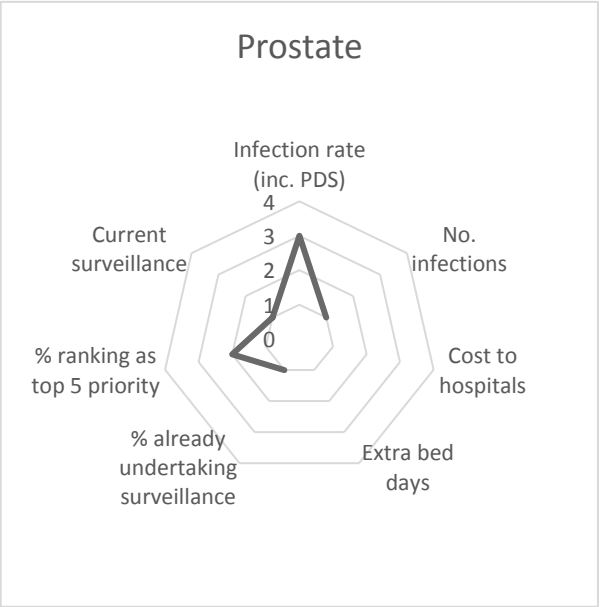
Cholecystectomy











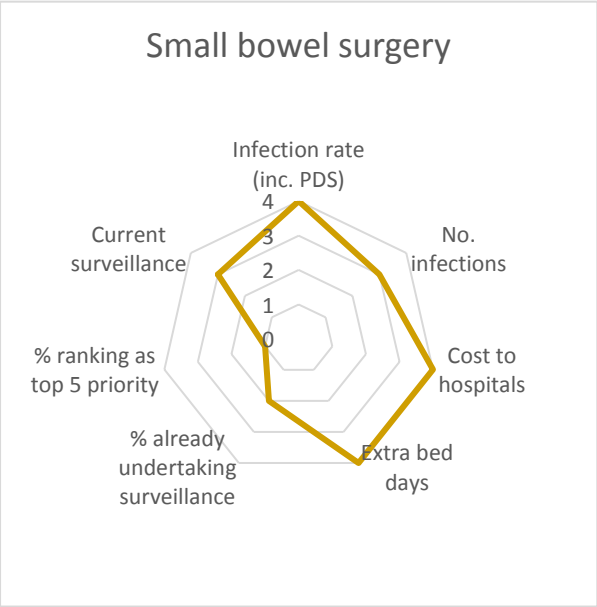


Figure 6 Radar charts comparing risk, annual burden, annual cost, current surveillance, and future priorities for surveillance of SSIs in English hospitals by surgical category.

Numbers represent quartiles for a given factor compared to other surgical categories, except for current surveillance where 1= not offered, 3= voluntary surveillance, 4= mandatory surveillance. Missing data are represented by a space.

PDS = post-discharge surveillance; CABG = coronary artery bypass graft; ENT = ear, nose, and throat.

2.3.3 Assessment of factors associated with SSI surveillance and priorities

The percentage of hospitals performing surveillance was significantly higher for clean categories (29%, Q1-Q3: 22-59) in comparison to clean contaminated surgeries (16%, Q1-Q3: 9-22) (p=0.04) (Table 4). These corresponded mostly to mandatory categories (74%, 40.5-90.5) in comparison to voluntary categories (25%, 17-33) and categories not offered (8.5%, 7-10) (p<0.01). The excess cost to hospitals was not associated with the percentage of hospitals undertaking surveillance in a given category. Additionally, the annual volume of procedures and number of SSIs were not associated with percentage of hospitals involved in the surveillance.

Mandatory reporting was significantly associated with clean surgeries (100% vs 47.4%, p=0.05). On the other hand, the mandatory surveillance was not associated with the excess costs attributable to SSI, the annual volume of procedures or estimated annual SSIs.

Trusts judged clean surgery as a top priority for surveillance (18%, 95% CI 9-26 vs 7, 95% CI 2-9, p=0.04). Categories already surveyed by hospitals (r=0.88, p<0.01) and mandatory surveillance (33% vs 9 and 4%, p=0.1) were also associated with a high level of priority. The choice of top priority categories was not associated with the annual volume of procedures, estimated number of SSI, or the excess cost to hospitals.

Future priorities were more oriented toward clean-contaminated surgeries, but still did not correlate with annual volume of procedures, estimated no. of SSIs, or the excess cost to hospital, but was associated with surveillance already performed (r=0.76, p=<0.01).

Table 4 Contingency table assessing factors explaining the surveillance method and the perception of priorities.

An analysis of the data in Table I was carried out using a Spearman correlation test for continuous variables and a Kruskall-Wallis test for categorical variables. P values ≤0.05 were considered statistically significant. Categorical independent variables were described using proportions and continuous variables via medians and 25th-75th centiles. Abbreviations: PDS, post-discharge; LOS, length of stay; SSI, surgical site infection; Q, quartile

	Hospitals already undertaking surveillance	p	**Procedures selected as future priority**	p	**Procedures ranked as top priority**	p	**Missing values**
Economic impact, r coefficient							
Excess LOS	0.09	0.69	0.03	0.87	0.15	0.53	4
Estimated excess cost to hospitals annually	-0.18	0.43	0.01	0.96	-0.04	0.85	3
Medical and societal impact, r coefficient							
Estimated no. infections + PDS	0.09	0.68	-0.1	0.62	0.09	0.65	0
Endogenous factors, r coefficient							
Median age in years	0.18	0.43	-0.33	0.14	0.29	0.20	0
Exogenous factors							
Clean, median (Q1-Q3)	29 (22-59)	0.04	3.9 (3.1-4.3)	0.09	18 (9-26)	0.04	0
Clean contaminated, median (Q1-Q3)	16 (9-22)		4.5 (3.9-4.8)		7 (2-9)		
Factors impacting the surveillance method							
Annual patient volume	0.12	0.58	-0.33	0.12	0.25	0.24	0
% SSIs detected by PDS	0.27	0.23	-0.27	0.24	0.23	0.31	1
National surveillance requirement							
Voluntary, median (Q1-Q3)	25 (17-33)	<0.01	4.3 (3.9-4.8)	0.17	9 (7-18)	0.10	0
Mandatory, median (Q1-Q3)	74 (40.5-90.5)		3.4 (2.9-4.2)		33 (17.5-45)		
Not offered, median (Q1-Q3)	8.5 (7-10)		4 (3.1-4.4)		4 (0-26)		
Hospitals already undertaking surveillance	-	-	-0.54	<0.01	0.76	<0.01	0
Procedure considered as future priority	-0.54	<0.01	-	-	-0.78	<0.01	0
Procedure ranked as a top priority	0.76	<0.01	-0.78	<0.01	-	-	0

Table 5 Contingency table assessing factors explaining the surveillance method and the perception of priorities in mandatory vs non-mandatory surveillance.

An analysis of the data in Table I was carried out using a Spearman correlation test for continuous variables and a Kruskall-Wallis test for categorical variables. P values ≤0.05 were considered statistically significant. Categorical independent variables were described using proportions and continuous variables via medians and 25th-75th centiles. *10^3, ** 10^6 Abbreviations: PDS, post-discharge; LOS, length of stay; SSI, surgical site infection; Q, quartile

	Procedures with mandatory surveillance	**Procedures with non-mandatory surveillance**	p	**Missing values**
Economic impact, median (Q1-Q3)				
Excess LOS	11.2 (10.4- 15.25)	12 (4-13.4)	0.76	4
Estimated excess cost to hospitals annually	3.7 (2.5-5.6)**	5.5 (3.4-7.9)**	0.26	3
Medical and societal impact, median (Q1-Q3)				
Estimated no. infections + PDS	1.2 (0.8-1.5)*	1.6 (0.5-5.1)*	0.63	0
Exogenous factors				
Clean, n (%)	4 (100)	9 (47.3)	0.05	0
Clean contaminated, n (%)	0 (0)	10 (52.6)		
Factors impacting the surveillance method				
Annual patient volume	86 (63-96)*	37 (23-133)*	0.26	0
% SSIs detected by PDS	35.5 (22.5-54)	31 (24-44)	1	1
Hospital already undertaking surveillance	74 (40.5-90.5)	25 (17-33)	<0.01	0
Procedure considered as future priority	3.4 (2.95-4.25)	4.1 (3.9-4.7)	0.2	0
Procedure ranked as a top priority	33 (17.5 – 45)	8 (4 – 18)	0.04	0

2.4 Discussion

The concordance between SSI rates, impact and cost, trust priorities, and current surveillance arrangements varied by specialty, with some procedures or specialties having appropriate levels of surveillance and concern from trusts, and others not receiving any national surveillance despite high levels of concern and large numbers of infected patients.

Large bowel surgery is currently included in the SSISS as a voluntary category. The minimum wound classification for large bowel surgery is clean-contaminated, or contaminated for emergency surgery, therefore the infection rates are expected to be higher than clean surgery. However, this study showed that large bowel surgery contributed 38% of all SSIs in the England. Only 62% of hospitals ranked large bowel surgery as a top 5 surveillance priority over the next 5 years and only 38% are currently undertaking surveillance, demonstrating that the impact of SSI in large bowel surgery is underappreciated. As more than half of infections occur amongst inpatients or readmitted patients, surveillance of large bowel surgery SSI in the hospital setting would capture the majority of infections. Not only is surveillance in this category practicable, there is also evidence to suggest that the use of bundles can reduce SSI rates in open colorectal surgery by more than 50% [16].

In September 2016, the Department of Health and Social Care set a target to reduce healthcare-associated GNBSI by 50% by 2020. 3.1% of BSIs originate from SSIs [4]. Since Enterobacteriaceae are now the most common cause of SSIs in England [50], reducing SSIs could have a noticeable impact on GNBSI rates, particularly in large bowel surgery in which 75% of SSIs are caused by gram-negative bacteria [4].

The second highest contributor of SSIs was C-section (CS). The English pilot study which generated the data used here followed the Scottish model of community midwife PDS, and CS surveillance has been mandatory in Scotland and Wales for several years with rates consistently trending downwards [67,68]. CS is not currently included in the SSISS protocol, despite being the joint top ranked priority for hospitals in England and contributing the third highest number of infected patients annually, and being recommended as a mandatory surveillance category by the Advisory Committee on Antimicrobial Resistance and Healthcare-Associated Infections [69]. The length of stay following CS is relatively short, in the order of 2-3 days[37], which results in 89% of infections presenting after discharge. In addition, the estimated excess cost to hospitals of £7.1m annually is likely to be an underestimate of the total cost to the NHS, as the vast majority of these patients will be treated in primary care and may also be more reluctant to be readmitted to hospital for treatment than patients in other surgical categories. The authors of the pilot study noted that CS are frequently carried out away from other types of surgery and without the presence of full-time operating theatre staff, therefore opportunities may exist to improve SSI rates in CS by ensuring best practice is being followed and updated among obstetric teams. The high numbers of infected patients, high levels of concern, and opportunities for improvement make CS a strong candidate for inclusion in national surveillance. Also, 57% of hospitals reported that they are already undertaking in-house surveillance, so

while additional resource would be needed to collate the data nationally at the SSISS, many hospitals would not find the added data collection too onerous.

The four mandatory orthopaedic categories had low infection rates as expected, though these rose slightly once PDS was included in the rates, and around 4,242 patients are infected annually. This is low compared to other surgery types, however SSIs in these patients are known to be associated with morbidity and mortality. The ongoing surveillance of orthopaedic surgery has driven rates down to their current low level, and surveillance should continue to sustain this improvement.

The cost of SSIs in the four mandatory categories was estimated at £16,341,295, but this was estimated from an English multicentre study using only costs associated with attributable excess LOS. Often the costliest facet of SSI treatment for orthopaedics is revision surgery, which is not accounted for if only additional LOS is considered. To assess the extent of this omission, a separate analysis was conducted using the cost of revision surgery due to SSIs in hip [65] and knee [66] replacement, the number of joint replacements [64] and proportion of these that were revisions due to infection [50]. This analysis calculated excess costs due to SSIs in hip and knee replacement surgery to be at least £19 844 824 and £23 230 805 respectively (Table 3). The same may be true in other surgical categories, but unfortunately comparable data on costs for septic revision were not available.

Interestingly, costs per SSI for hip and knee replacements in the Jenks paper [28]using matched patients to calculate direct cost of SSI were lower than those in the Coello et al. paper using excess LOS only [59]. This may be due to changes in SSI treatment pathways (the Jenks paper was published 8 years after the Coello et al. paper), or because of sample sizes (the Jenks paper was a single-site study, Coello et al. used national data). It could also be due to the use of median costs of SSIs in the Jenks paper, which would inappropriately reduce the skew caused by a small number of high-cost revision surgeries. In any case, this variability highlights the need for high-quality costing data using standardised methods on SSIs at least per specialty, if not procedure.

Cholecystectomy and small bowel surgery were the second and third highest contributors of SSI-associated costs in England, with both featuring in the top quartile for excess LOS, but only 11% and 22% of hospitals respectively are currently undertaking surveillance. This represents a significant underestimation of the impact of SSIs in these surgery types, with hospitals ranking them on average at 5th and 4.7th respectively on a scale of priorities.

Breast surgery had a high patient volume with low SSI rates among inpatients and readmissions. However, around 77% of breast surgery SSIs occur in the community, making breast surgery the fourth highest contributor if SSIs in England. While only a quarter of hospitals are currently undertaking surveillance in breast surgery, 65% ranked it as a top 5 priority. The high proportion of infections presenting post-discharge would necessitate extensive PDS as part of a surveillance programme, however attempting to

reduce infection rates would be worthwhile particularly for oncology patients in whom infections are more dangerous.

SSIs occurring after gastric surgery had the highest associated LOS per infection and the highest associated excess costs per infection, therefore any reductions from the current SSI rates should result in marked reductions in costs to hospitals. Collateral improvements in bed availability would also increase patient turnover and result in cost savings thereby increasing hospital efficiency.

Surveillance of SSIs occurring in pacemaker, maxillofacial/ENT/oral, prostate and ophthalmic surgery is currently not offered as part of the SSISS, meaning no national data are available. However, very little other data was available to help elucidate the contribution of these surgical specialties to the national SSI burden, particularly for infections occurring in the post-discharge period. From the available data, infection rates among inpatients and readmissions do not give great cause for concern.

Very little data were available for pacemaker surgery SSI. The data that were available suggested moderate patient volumes with very low infection rates of 0.4%, and only 7% of hospitals in England are currently undertaking surveillance. Nevertheless, 80% ranked pacemaker surgery as a top 5 priority, alongside CS. The main reasons for hospitals selecting this category were the need to establish SSI rate, opportunities for prevention, and the significant impact of SSI. In light of the low number of hospitals currently undertaking surveillance, an appropriate next step may be to conduct pilot studies in a small number of hospitals to establish rates.

The extremely large patient volume in ophthalmic surgery could mean that small underestimations of SSI rates could have a large impact on the number of infected patients. Ophthalmic surgery was one of the specialties selected for the Getting it Right First Time (GIRFT) audit in 2017, which may provide much-needed data in this area.

This study showed that overall around 103 000 patients annually develop an SSI, of which only 52 000 presents in hospitals as inpatients or readmitted patients. Breast surgery, knee replacement, abdominal hysterectomy, appendicectomy, and CS fell in the highest quartile for SSIs detected in the post-discharge period, therefore surveillance in these surgical categories must include an element of PDS to ensure that the rates detected fully reflect the outcomes experienced by patients. PDS methods should ideally be standardised, or at least have a minimum response rate to minimise bias. Patients expect accurate information on the risks of surgery to enable them to make an informed decision, and SSI rates based on inpatients and readmissions alone could be misleading for these surgery types.

Despite the moderate infection rate, a fairly high demand expressed by hospitals for surveillance in vascular surgery was justified by a need to establish rates, opportunities for prevention of SSI and the high impact caused by SSI, suggesting that trusts believe improvements can and should be made here. SSI in vascular

surgery carries a risk of death of almost 7 times that of uninfected patients [23], so clinical concern for the impact is warranted. As vascular surgery is a voluntary reporting category in the SSISS, more hospitals may wish to consider targeting vascular surgery for SSI surveillance and prevention.

Good concordance was found between infection rates and national surveillance arrangements in cardiac (non-CABG), appendectomy, cranial surgery, ophthalmic surgery, small bowel surgery and abdominal hysterectomy.

2.5 Limitations

One important limitation of this study was the lack of data on morbidity and mortality related to SSI, so we were not able to take into account the disability, impact on quality of life, and mortality, and associated societal and economic that can occur as a result of SSI. This study would have been greatly enriched by the availability of quality-adjusted life years data to inform the comparison between different surgery types. Likewise, there is very limited data on the extent to which SSIs are preventable in different categories, so it was not possible to calculate how many SSIs could be prevented or model consequent reduction in LOS and costs. Additionally, time dependency bias is a recognised problem in estimating LOS attributable to HCAI, since the association between the two variables can work in both directions [70]. Time dependency was not directly addressed in this study as the data were taken from published papers which included their own methods for addressing bias.

HES data is used here to estimate the annual number of procedures for each category, although not all procedures included would necessarily fit the criteria for inclusion in surgical site infection surveillance. Therefore, these numbers may overestimate the number of affected patients.

For infection rates, some studies such as Jenks et al. [28] were conducted in single centres and so are based on small numbers of patients. Even the voluntary data collected by PHE as part of the national SSISS scheme can be based on small numbers; for example, the rate of SSI in inpatients/readmissions for cholecystectomy was calculated from only 999 patients from 6 hospitals over 5 years of data collection [50]. The small number of possibly specialist hospitals contributing rates to PHE for some categories has attracted criticism of the service [71]. Ideally, we would have used confidence intervals to assess the uncertainty in estimations but unfortunately, not all studies reported ranges and confidence intervals, so it was not possible to include confidence intervals or ranges in the univariate statistical analysis performed.

As well as uncertainty in inpatient and readmission SSI rates, infection rates including post-discharge surveillance are more variable as the methods of PDS are usually less standardised than inpatient and readmission surveillance. Even when the same methods are used, the case-finding intensity can vary in a way that has a direct impact on the rate observed [37].

The excess costs attributable to SSI will vary greatly between institutions dependent on staff and treatment costs and different treatment pathways, and whether infected patients are treated in the same hospital as the surgery occurred. Additionally, cost estimates taken from older papers may be less relevant to the current setting because of differences in treatment techniques and pathways. Costs were estimated from a range of papers using several different methodologies which may limit their comparability (e.g. only costs associated with additional LOS vs. "total" medical costs), although the papers were all assessed to be of high quality using the Newcastle-Ottawa score. LOS after hip and knee replacements has been generally decreasing [72], so it is possible that the excess LOS due to SSIs in older papers would be also considerably less nowadays.

Aside from limitations inherent in the data used for this study, there is also one methodological limitation in that the hierarchy used to determine applicability to the English setting was determined based on consensus among the multidisciplinary research team and is affected by subjectivity. No valid tool exists for determining applicability, which would be useful for studies such as these and also for general policy making.

2.6 Conclusions

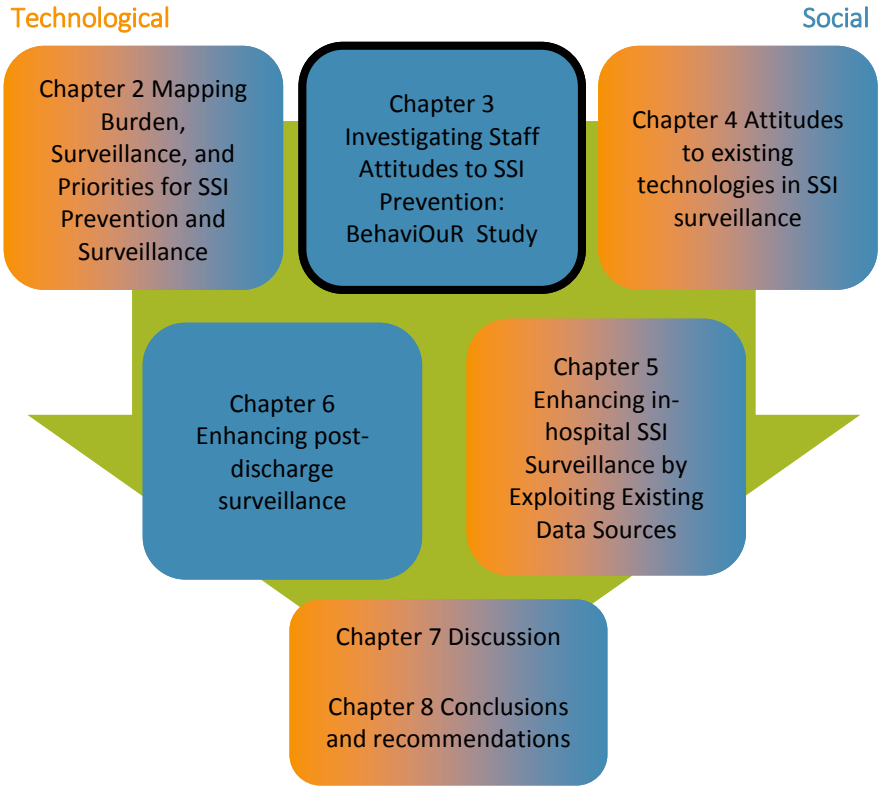
In conclusion, this study suggests that current SSI surveillance and reported hospital priorities are not targeting surgical categories with the highest burden in terms of risk, number of SSIs, and cost. This mismatch could be addressed and improvements to patient safety and hospital efficiency could be made by broadening surveillance, either through national schemes and incentives, or by hospitals choosing to review their own surveillance practices. The recent national Getting It Right First Time (GIRFT) audit on SSI rates [36] could provide hospitals with the cross-sectional data needed to replicate this study on a smaller scale in their own units to assess burden and shape surveillance accordingly. This methodology could also be replicated on any scale in any setting to inform systematic priority setting, providing benefits to both patients and health systems.

Further work should focus on quantifying the morbidity and mortality associated with SSIs in different surgery types by capitalising on electronic patient records and conducting multicentre or national costing studies. Additionally, there is a need for a tool to assess applicability of a study in one setting to another, which would be useful for studies such as this and also for policymaking.

Chapter 3. Investigating Staff Attitudes to SSI Prevention: BehaviOuR Study

Summary

This chapter covers a qualitative study on behaviour in and around the operating room (BehaviOuR study) involving interviews with staff stakeholders at Imperial College London NHS Trust (ICHNT). The study aimed to explore how staff perceive SSIs and the roles of themselves and others in their prevention and surveillance. Understanding these concepts better will help to explain how SSI prevention and surveillance works in practice, so will inform the later chapters on implementation of possible new surveillance strategies. The results of this study were presented in poster form at the European Congress of Clinical Microbiology and Infectious Diseases 2018 [73].



3.1 Background

Risk factors for post-operative infections are linked to patient characteristics (e.g. age, diabetes, obesity and other comorbidities); the surgical procedure (contamination class, duration of operative procedure, surgeon's skill, control of hypothermia); the operating room (OR) environment; and wound care in the postoperative stage [8]. The World Health Organisation (WHO) [74,75] and National Institute for Health and Care Excellence (NICE) [76] regularly review and update their evidence-based recommendations to mitigate some of these risk factors.

However, policies and expert recommendations for intraoperative and perioperative issues often fail to consider the social and behavioural determinants and the multiple factors that can influence infection prevention and control (IPC) practices [77]. Moreover, most recommendations usually present the level and quality of evidence rather than ranking the relative effectiveness of preventive measures. Therefore, IPC and surgical staff face difficulties in prioritising IPC activities in the context of multiple demands on their attention and time. This is particularly the case for measures not associated with high-quality evidence, which are nevertheless an important part of an effective preventive strategy.

Staff behaviours in the OR are likely to be strongly influenced by psychosocial determinants (attitudes, social norms, and beliefs) [78]. SSI prevention measures occur within the context of a social network with multiple "agents" [79] who continuously interact, including surgeons, nurses, anaesthetists, and carers. Myths and rituals abound in OR [80], such as requiring patients to remove their underwear for cataract surgery, the use of wound edge protectors which show little benefit, and unnecessarily long surgical scrub routines. The use of surgical attire (scrub suits, caps/hoods, shoe covers, masks, gloves, and gowns), intraoperative behaviour (OR traffic and distractions) and environmental disinfection practices are very heterogeneous [78] with some ORs rigorously organised with a strict discipline and others appearing more flexible. Local context and culture, characteristics of teams, and local systems, all impact on frontline practice in the OR [81], and challenging existing norms and practices may be difficult [82].

The diagnosis and treatment of SSI is a multidisciplinary task gathering surgeons, anaesthetists, intensivists, microbiologists, and infectious diseases and infection control specialists. This complexity requires a high level of communication and coordination in order to avoid dangerous fragmentation of tasks and disengagement of key specialists.

Strategies for improving IPC measures have tended to focus on individual factors, including knowledge, skills, and motivation, by simply generating new guidelines and policies, neglecting the wider systems and social and organisational context that shape practices. Consideration of the multiple factors that impact on practice, and integration of strategies across the diverse group of agents implicated in preventing SSIs, are likely to be critical in designing effective interventions to optimise aseptic practices in the OR [79]. To intervene effectively, it is necessary to understand what appears to work for whom and when [83]. When designing and implementing quality improvement interventions, engagement with multidisciplinary staff and inclusion of local practice and knowledge has been shown to facilitate implementation and compliance [84–86]. Applying this approach to interventions to improve IPC practices in surgery requires research into the social and contextual determinants of surgical staff behaviour, to understand how to design interventions that address the barriers to implementing IPC practices, and which are likely to be implemented and adopted by healthcare professionals [87,88].

3.1.1 Rationale

Previous research into SSI prevention has largely used quantitative methods to assess the impact of, or compliance with, strategies. Few studies have explored the factors that influence surgical staff behaviours and IPC practices, in order to identify the factors that impact on compliance [78]. The aim of this study is to offer insight into experiential phenomena to determine the viewpoints of the different professions individually and as a team, to explore the impact of social and organisational context, and to identify the factors impacting on readiness and ability to adopt new practices.

3.2 Methods

3.2.1 Study objectives

This study explores the views of healthcare professionals on their intra and perioperative practices for controlling the risk of postoperative infection, with the aim of addressing the following questions:

1. How do surgical staff perceive the relationship between their practices and infection risk?
2. How do social factors influence practices around SSI prevention?
3. How do the local setting and systems, and the organisational and wider context, influence practices around SSI prevention?
4. How can surveillance of SSIs impact on SSI prevention practices?

3.2.2 Setting and context

Imperial College Healthcare NHS Trust (ICHNT) includes five hospitals in West London and serves a population of over 2 million. ICHNT currently reports on SSIs in total hip and total knee arthroplasty, coronary artery bypass graft (CABG), and non-CABG cardiac surgery. Like many other NHS trusts ICHNT has been affected by budget cuts, and nursing shortages in London have affected recruitment for SSI surveillance nurses, resulting in disrupted surveillance. Strategic deployment of resources to maximise patient safety is therefore a priority for the trust. High demand for services combined with the cramped and ageing hospital estate has led ICHNT to frequently experience extreme bed shortages which were recently highlighted in a television documentary [89], resulting in cancelled operations and highly stressful working conditions for staff. Mid-way through the study, the Trust took part in the national Getting It Right First Time (GIRFT) SSI audit [36], which raised the profile of SSIs at the Trust and provided some data on SSI rates in specialties other than those under regular surveillance, which was not previously available.

3.2.3 Methodology

In order to answer the research questions a number of options for collecting and analysing qualitative data were considered, each with their own pros and cons (Table 6).

Because the research questions demand a deep understanding of staff perceptions and motivations, surveys and ethnography were ruled out as methods. There were two reasons for choosing interviews over focus groups for data collection; the first was that prior research suggested there were cultural influences

over behaviour [78], so having multiple team members within the focus group could cause the discussion to be influenced by hidden social dynamics in a way that would be detrimental; the second was pragmatic as it would be very difficult to bring together multiple team members at once because of work commitments.

Table 6 Possible data collection methods for investigating staff attitudes to SSI prevention and surveillance, constructed using Part II of Qualitative Methods for Research [48]

Data collection method	Pros	Cons
Surveys and documentary analysis	Can have a large sample size Least resource intensive	Questions would be based on assumptions of major themes Unlikely to elicit rich responses
Interviews	Rich, in-depth data capture Opportunity to probe and explore themes	Limited number of participants
Group interviews	Rich, in-depth data capture Opportunity to probe and explore themes Larger number of participants	Staff may not feel able to express their true opinions in front of colleagues Logistically difficult to coordinate alongside clinical commitments
Ethnography and observation	Allows observation of actual rather than reported practice	Does not capture inner perceptions and motivations

Interviews can be structured, semi-structured, in-depth, or narrative [48]. Structured interviews involving a rigid list of questions would not offer the flexibility to explore any themes as they emerge during the interview. Since this study is concerned with the relatively narrow topic of SSIs (as opposed to patient safety in general), in-depth or narrative interviews would run the risk of not answering the research questions. Therefore, I chose to conduct semi-structured interviews. To prepare for the interviews, I attended a training course on qualitative interviewing and sought support throughout the study from experienced colleagues.

Like data collection, there were also several methods to use for data analysis. I chose to use an approach based on grounded theory to allow me to "construct theories from the data themselves" [90]. For thematic

analysis, I chose to use the "constant comparison" method commonly used in grounded theory which involves comparing statements with each other to form a coding framework which stays close to the data, and then comparing new data with that framework [90]. Data collection and analysis occurs simultaneously to allow themes emerging from the data already gathered to be explored and tested when gathering new data. This is referred to as an inductive-deductive approach, as the coding proceeds from the data up and then from the framework down [48]. This approach has the advantage over purely deductive approaches as it stays closer to the original data and allows new concepts to be identified that might otherwise have been missed. The alternative to constant comparison would have been to gather all the data from participants at the outset before moving on to analysis as is recommended by Braun and Clarke [91], which might have resulted in missed opportunities to explore emerging themes further and improve saturation of themes with supporting data.

Unlike some grounded theory approaches, I did not use distinct phases of coding such as open, axial, and selective [90], instead allowing the codes to evolve naturally into themes. Coding was done with the support of experienced qualitative researchers and the themes were discussed with an experienced social scientist.

There were also other departures from conventional grounded theory: I did not undertake member-checking to verify codes and themes derived from each interview with the interviewees but did check codes and themes with subsequent participants to explore or refine them; I also did not use theoretical sampling to select subsequent participants who I felt would explore the emerging themes best, instead using purposive sampling to ensure staff groups and surgical categories were adequately covered.

3.2.4 Study design

The design was a qualitative study using semi-structured interviews with a range of staff stakeholders.

3.2.5 Recruitment

Participants were approached through established email lists, and then identified purposively through snowball sampling to ensure representation from a range of stakeholders.

Participants were contacted by email and invited to arrange an interview. Reminders were sent after 2 weeks. Interviews were arranged at the participant's convenience, either face to face or by phone, and were sent the patient information sheet. Participants were given at least 24 hours after receipt of the information sheet in order to decide whether to take part. Face to face interviews were conducted in non-clinical areas on Trust sites. Interviews were not carried out in work time unless permission had been given by the participant's manager to do so.

At the interview, the participant was given the participant information sheet a second time and asked to give written consent. At the end of the interview, the participant was asked if they would like to be involved

in any future work on issues raised. If so, their contact details and consent to be contacted again were recorded.

In order to address issues of bias in the data collection and analysis stage, researchers kept reflective journals which documented their thought processes at each stage (Appendix 1 and Appendix 9).

The number of participants was expected to be around 15-20, however recruitment continued until thematic saturation was achieved [92]. Thematic saturation describes the point at which themes are fully accounted for, understood by, and agreed on by the researchers, and no significant new concepts emerge from successive interviews.

Interviews were conducted by me and Victor Mariano, a Nursing Research Fellow who had previously been employed as an Operating Theatre Staff Nurse, Critical Care Nurse, and Clinical Research Nurse at ICHNT. For training, Victor observed one of my interviews, and then conducted one of his own which we analysed together before recruiting and conducting interviews of his own.

3.2.6 Inclusion Criteria

Participants must work at ICHNT and either have clinical contact with surgical patients (e.g. surgeons, anaesthetists, nurses, microbiologists, healthcare assistants, pharmacists) or be a member of infection prevention and control team. In order to sample a range of surgical specialties, the sample included representatives from clean surgery (e.g. cardiac and orthopaedic) and contaminated surgery (e.g. digestive and ear, nose and throat). Registrars who took part in the GIRFT audit were also approached for interview.

3.2.7 Exclusion criteria

Staff members who did not have either direct contact with surgical patients or a direct interest in SSI surveillance in the hospital were excluded.

3.2.8 Data analysis

Data analysis proceeded simultaneously with data collection. The recorded interviews were transcribed under a confidentiality agreement by a third-party commercial company. The audio files were deleted once transcribed copies had been checked for any errors.

The transcribed data were uploaded into NVivo, QSR International Ltd., Version 11 for data management and analysis and repeatedly read to increase familiarity with the data. Data analysis was based on the constant comparison method [90]. The first ten transcripts were open coded inductively, with codes created from the patterns and themes emerging when meaningful phrases were compared within and between transcripts, and an initial coding frame developed. For example, the quotes “Again I think ease of access to information, so for antibiotic policy it does need to be easier, it’s a big, big wordy document.

(Anaesthetist)", and "I have to say the trust intranet is absolutely full of policies which I don't bother reading. (Orthopaedic consultant)" both relate to the difficulties in extracting the important information from a large number of wordy policy documents, so were coded under "policy information is difficult to access". Codes emerging from the data were discussed with members of the research team to establish meaning and importance and make changes to future interview schedules. This coding frame was then applied to subsequent transcripts and the wording and descriptions of the codes was iteratively refined. A sample of the coding framework can be found in Appendix 7.

3.2.9 Ethical considerations

Because this study recruited participants based on their role in the NHS, full approval by a Research Ethics Committee was not required. Instead, the project was eligible for Proportionate Review by the Health Research Authority. Health Research Authority approval was granted under approval reference 16/HRA/5160 for IRAS project ID 193411.

This project was considered low risk as it was a qualitative study. The only risk identified was that participants' comments during the interview could have consequences professionally.

In order to address this issue, participants were referred to only by a generic job title. Participation in the study and all data collected was treated as confidential. Interviews were held in private on Trust sites. Both audio and written data were stored on password protected devices, with the participant's pseudonym used throughout. In the event that a participant revealed information in the interview that could lead to them becoming identifiable in the data (such as their name, previous workplace, or lead consultant), this was edited in the transcript and replaced with a generic term. As there were only a small number of staff involved in the GIRFT audit, comments specifically relating to the audit are listed separately from other comments by the same interviewees to preserve anonymity.

In the unlikely event that details of poor practice or harm occurring within the trust were revealed during interviews, participants were informed that the interviewer was obliged to report this, and confidentiality could not have been maintained in this situation.

3.3 Results

Twenty participants were recruited across orthopaedic, neurosurgery, vascular, cardiac, trauma, obstetrics/gynaecology, and general surgical specialties, as well as microbiology, pharmacy, and infection prevention and control. This included: surgeons (n = 8), nurses (n = 5), theatre personnel (n = 3), anaesthetists (n=1), microbiologists (n=1), and pharmacists (n=1). There were 11 male participants and

nine female participants. Their experience in their field ranged from 3-31 years, and time at the Trust from 1-23 years (Table 7).

Table 7 Breakdown of interview participants by specialty and staff group

Specialty	Staff group		Interviewed by	Gender
Anaesthetics	Anaesthetist		RT	M
Microbiology	Microbiologist		RT	M
Tissue viability	Nurse		RT	F
Orthopaedic	Nurse		RT	F
Critical care	Nurse		VM	F
General surgery	Nurse		VM	M
A&E	Nurse		VM	M
Pharmacy	Pharmacist		RT	F
General surgery	Surgeon		RT	M
Vascular	Surgeon		RT	F
Cardiac	Surgeon		RT	M
Orthopaedic	Surgeon		VM	M
Neurology	Surgeon		VM	M
Orthopaedic	Surgeon		RT	M
Obstetrics/gynae	Surgeon		RT	F
Plastics	Surgeon		RT	M
General surgery	Theatre personnel		VM	F
General surgery	Theatre personnel		VM	F
General surgery	Theatre personnel		VM	M
IPC	Nurse		RT	F

3.3.1 Themes

The main themes identified in the data began with the individual's own knowledge and skills, moving outwards to encompass how that individual perceived their ownership over SSI prevention, which was related to perceived risk. Outside of the individual, drivers of behaviour were then influenced by others through the hierarchical team structure. On the macro level, all of these factors were influenced by the resources available in the setting; resources could be human (staffing issues), technological (ICT systems), financial, or physical (the built environment, equipment).

3.3.1.1 Knowledge and skills

Forming the bedrock of staff attitudes to SSI is their existing knowledge and skills around prevention of SSI. Knowledge and skills were acquired from formal training, informal training, and from the policies and literature that are available to staff. Each of these aspects presented its own problems.

While most staff felt well equipped to prevent SSIs, there were some who reported being asked to perform tasks they had not been trained for at all, had not been recently trained for, or were not confident in the

training they had received. Some were relying on their original training from university, or from other hospitals in England and across the world.

> *So, if I do a wound care dressing as what I knew from university… all like the basics that I've learned from taking the degree… I don't think this is standardised across nurses… I cannot remember that someone has shown me that this is how you should do wound care.*
>
> Critical care nurse

> *So, when I scrub we always have to scrub properly, I mean with the aseptic technique… as I've learned in uni… In this country people came from different places in the world, means they've got different ways to work, they have different training… As a nurse in this country, we have to clean things… I don't know if I have to use a special product to that, to clean, to mop that.*
>
> Scrub nurse

One nurse reported that she was unable to informally compare her dressing changing practices with those of others because the patients' curtains are always closed.

> *When I do the dressing no one is there, so anyone who's checking the dressing in that closed curtains, actually in my head I don't know how they're doing it. Do they do it the way I do, is it my practice it is the best, I don't also know*
>
> Critical care nurse

Overall, participants reported that they did not usually receive individual or group feedback on the majority of their IPC practices. Participants reported that they felt other staff were sometimes inadequately supported by their leaders, feelings of confusion, a lack of confidence in their skills, and a reluctance to carry out tasks.

> *So I don't expect every nurse will know about wound… I expect from the matron of the ward just to support them and supervise if there is a need, to help with the dressings, to help with the [Vacuum Assisted Closure®] dressing if they don't know how to do it… I notice also if the nurse doesn't want to do the dressing they will be very reluctant to call you when the dressing is down, and they won't do it, they won't take it down.*
>
> Vascular registrar

When asked which policies and guidelines they were aware of for SSI prevention, many staff stated the NICE guidelines, and that they expect the trust has policies based on these, but they were not sure where to find them or found the documents themselves or the process of obtaining them too cumbersome and time-consuming to be of use in regular practice. Participants reported that other setting use more user-friendly platforms such as apps to enable staff to access policies more easily.

> *I think ease of access to information, so for antibiotic policy it does need to be easier, it's a big, big wordy document. I know that there's, in other hospitals in the private sector, there's a number of apps that you can use and it's very easy, you literally just tap on it for that institution and Trust.*
>
> Anaesthetist

I think there are some policies on the trust intranet. I have to say the trust intranet is absolutely full of policies which I don't bother reading. I will do what we're told to do if it is discussed in our audit meeting or, for example by the ward matron or whoever is the leader on it.

Orthopaedic consultant

We have policies of course because we have a policy for everything that we do. And they all update online here so it's accessible to all staff to be able to go in and check once you go on the source. You have more than enough, but it's now the time for individuals to really go and search...

Theatre personnel

One particular knowledge gap highlighted by the participants involved in the GIRFT audit was that they had been unaware until that point of the criteria for diagnosing an SSI. Participants who had undergone specific training in the diagnosis criteria for SSIs felt that most other staff were not aware of the definition, and therefore not recording SSIs correctly in the notes.

We could definitely do with more education around SSIs, what SSIs are, where you can encounter SSIs, why, and how they can be prevented. I think this is where, as a trust, I think more globally, like, we're just lacking knowledge on.

GIRFT registrar 2

3.3.1.2 Ownership and responsibility

In response to the question "who is responsible for SSI prevention?" most staff, particularly non-surgeons, reported that the whole clinical team was responsible, and some extended this to cleaning staff and patients themselves.

Everyone, starting from the nurses, healthcare assistants, doctors, you can't take the patient's exposed wound on the foot to the toilet because they want to go to the toilet, to walk on the floor, cleaners are the same… whatever these people do is just, is a hard job which probably the majority of us don't notice but they are a very important part.

Vascular registrar

Everybody. Everybody who the patients, along the patient's pathway is responsible for ensuring and in, especially the patient of course themselves, but everybody that the patient comes into contact with.

Theatre personnel

Participants differed in who they felt to have accountability for SSIs. Some surgeons reported how they perceived high SSI rates to negatively impact their own professional reputation.

If you have lots of wound infections, that would look bad on you, because it suggests that there may be a problem with your technique.

Cardiac registrar

Some is what colleagues may think of you so in other words, how you are perceived in your own department.

Orthopaedic consultant

Several surgeons explicitly stated that accountability for SSI rates sits squarely with the consultant surgeon, though all participants said that the responsibility for SSI prevention was everyone's responsibility including the patient's.

So, I think everyone has a role to play in SSI prevention but at the end of the day, the overall responsibility for a patient undergoing a surgical procedure, is the operating surgeon. So, I'd say it clearly sits with them.

Plastics consultant

The surgeon has the responsibility that everything goes well before, during and after.

Neurosurgery registrar

At the end of the day, the, once a patient gets an infection, it's, it will be put against the consultant who was in charge of the care of the patient… If you're saying… who will that go against, then it's on obviously the surgeon involved in the care of the patient. If you're saying who needs to make sure that no one gets an infection, then it has to be everybody… if one person in the line's not doing their job, that increases the risk that patient gets a wound infection.

Cardiac surgery registrar

Participants who were surgeons reported simultaneously feeling both *solely accountable* but *not solely responsible for infection rates* is a tension indicating a degree of cognitive dissonance among this participant group. This tension may explain, in part, the difficulties in encouraging transparency around SSI diagnosis and surveillance as surgeons cannot reconcile the accountability for high rates, which they accept to be theirs, with their belief that the responsibility for SSI prevention is neither completely theirs, nor always completely possible. High SSI rates, or possibly being challenged on perceived inappropriate behaviour, will therefore lead to simultaneous feelings of guilt, and of unfair blame, which may explain the strong negative reactions staff seek to avoid when discussing SSI prevention with more senior surgeons (since the more senior the surgeon, the stronger the sense of accountability).

Some of the non-surgeon participants raised concerns that having consultant-specific rates of SSIs or placing the onus for prevention too much on consultants could have the effect of reinforcing blame culture and decreasing engagement.

…if you start listing rates per consultant then that, it's going to a much more blame culture, which is not necessarily beneficial for anyone. Well, it's not healthy and it's not what we should be doing, I think to, in order to drive change.

Infection pharmacist

I think in general we shouldn't blame anyone in the NHS. I think we should be more [multidisciplinary team] approach in which we have definitely the surgeons involved, but also the infection team and then infection control.

Microbiology consultant

3.3.1.2.1 Risk

Ownership of SSIs was related to the how much control the participant felt they had over whether or not an SSI develops . Most participants reported that they feel some SSIs are not preventable, especially in trauma or dirty surgery. How participants perceive a patient's risk of developing an SSI can have an impact on their level of personal ownership.

Several participants reported examples where they felt an SSI was not preventable.

> *Unfortunately, there will always be a percentage of patients who will get a wound infection, almost whatever you do, no matter how perfect the operation and no matter how … nutritionally appropriate they are … it's not a hundred percent preventable. There will always be an underlying rate of infection.*
>
> Cardiac registrar

> *The majority of the SSIs we see are those who have, like, perforate, so they have a hole in the bowel, and then faeces, and then you do a big cut, a laparotomy, and then when you close that off there's a high rate of an SSI because it's a contaminated wound. But that you can't control for.*
>
> General surgery registrar

Participants also reported instances when the immediate and definite risk of harm to the patient from another cause outweighs the deferred and uncertain risk of SSI. A patient undergoing an elective hip replacement does not have the same risk profile as a patient undergoing repair of an abdominal aortic aneurysm rupture, or who has suffered a cardiac arrest in theatre, for example. In the former case, SSI is one of the highest sources of risk for the patient, whereas in the latter the risk of SSI is small relative to the risk of death from delay caused by meticulous IPC practices. In these circumstances, it is more important for staff to deal with the immediate threat and dispense with the usual processes.

> *There are times where, for example, the patient arrests in theatre which has happened, and we have opened a chest without any preparation whatsoever, you just, normal gloves which are not sterile, but that's a different situation where the patient's essentially dead, or, but otherwise we have to go through the steps.*
>
> Cardiac registrar

Staff may then use their ownership over SSI prevention practices in a way that benefits the patient overall but may increase the risk of SSI. Here, it is not the "process" that has the power, but the surgeon, and this is a clear demonstration of the importance of ownership.

This sense of ownership in relation to risk of SSI may also differ by surgery type as some specialties have an inherently higher risk of SSI than others, such as in trauma or dirty surgery. Different specialties are certainly perceived as having different SSI rate expectations and are also perceived as having different attitudes towards SSI prevention practices.

If I am inside the theatre and I have a staff which is from general surgery you can see their attitude or their behaviour towards dealing with the operation is totally different. So they don't take, for example for us we take everything seriously…

Orthopaedic registrar

In… elective surgery you know you should have essentially a close to zero infection rate in the majority of patients, unless they have got some significant problem. For trauma surgery I think that's very different because you're starting with a, at least a contaminated wound…

Plastics consultant

In the case of procedures with perceived higher risk of SSI, it is possible that the lack of ownership over SSIs could lead to reduced IPC practices and therefore higher risk of SSI. In effect, there is potential for the expectation of high SSI rates becomes a self-fulfilling prophecy to some extent.

The issue of risk is not just whether or not the patient develops an SSI but of how much harm that SSI could cause the patient.

Now I suspect the ones who submit really good data and take this really seriously, are the ones who, for whom consequence of infection is a real clinical issue for those patients compared to, so that's why in cardiac and orthopaedics certainly, for them, infection's an absolute disaster. Whereas if you're a general surgical patient, you get a of bit wound infection, that's normally not a big deal because you can clear it up.

Plastics consultant

This suggests that staff are not only balancing the risk of an SSI developing with the intended clinical outcomes of the surgery but also the risk that an SSI would pose to the patient, and this impacts how much attention is paid to SSI prevention and surveillance. Surgical teams see SSI rates as more of a process measure than an outcome measure, as an SSI for one patient may have a very different clinical outcome than another, and the sense of ownership relates more to the overall clinical outcomes for patients than to the SSI rate metric.

3.3.1.2.2 Impact of surveillance data on risk perception

At ICHNT, continuous SSI surveillance programs are only in place for hip and knee replacements and cardiac surgery. When asked about their knowledge of SSI rates in the Trust, participants outside of these specialties relied on their own ad-hoc experience treating patients with SSIs, complications data discussed in morbidity and mortality meetings, and in the later interviews, the results from the recent GIRFT national audit of SSI rates (see 4.1.1.2).

Staff agree that data is vital for quality improvement, as it can highlight problem areas and allow the causes of high rates to be investigated. In one case, staff were aware that there may be a problem with high rates of SSIs but did not have any solid evidence until the GIRFT audit.

Suddenly the problem is made visible because it was before but no one notices or people pretended not to notice this, it will make them to change the practice…

Vascular registrar

When data on outcomes is available there is not only improved buy-in from staff for the formal action plan, but staff in general become more sensitised to the risk of SSI and as a result every aspect of care is improved.

This happens in a cyclical manner in every hospital I've ever worked in, but there will always be a period of time where there's lots of wound infections… And everyone will come up with a series of steps to try and reduce that, and what will happen is, the infection will go away and everyone will say it's because of all we've put in place… And actually I think it's because everyone's more aware of what's going on, and when you're more aware of what's going on, every step is better…

Cardiac registrar

3.3.1.2.3 Impact and sustainability of the GIRFT audit

The GIRFT audit [36] is described in 1.1.7.1 and a more detailed discussion of its implementation at ICHNT can be found 4.1.1.2. Several of the participants in this study felt that the audit had a direct and indirect impact on the attitude towards SSIs in the Trust by highlighting specific problems, making new links and increasing engagement with the Surgical Infection Group, and generally increasing the profile of SSIs. This was partly due to the GIRFT audit being a national audit commissioned by an external body.

Before the GIRFT audit, we didn't really know what our surgical site infections were in a lot of specialities, and it's just, either we don't have the resource to do it as well, it's not something that ever ended up coming up on our agenda to do. I think it's definitely got people thinking and people are more engaged. I think perhaps they didn't quite realise that there was a problem beforehand… it has been beneficial in actually raising awareness… I personally don't think they would've covered it if they didn't have to.

Infection pharmacist

It was a really poorly designed exercise, which I think has not really delivered what it did do. What it did do usefully for us was maybe to shine a light a little bit on how rubbish our SSI surveillance was, and how patchy it was across the surgical specialties, and made us think about, well actually what should we be doing because elements of the surgical practice do this really well and submits really good data, and that's important. But other elements of it don't.

Plastics consultant

However, the implementation was not without problems. Several of the participants were involved in data collection for the audit and commented on the workload and long-term sustainability of surveillance in the style of the GIRFT audit.

It's challenging because it's a time-consuming audit, it's not a small number of [patients], we do [these procedures] every day at the hospital pretty much, whether elective or emergency…
RT: Do you think that something like that is sustainable long term?
No…Not within the existing workforce.

GIRFT registrar 1

RT: How did you find it?

Tough. Was difficult. Collecting the data was difficult, because there was a retrospective proportion to it… And then prospectively going forward… I'll only see my few patients on the wards, and that's fine, I can collect data for them. But then there's also patients… looked after by other doctors who need to collect their data. And then there's all the acute emergency stuff which I might not be involved in, and their data. So It's actually, it was quite difficult to collect data.

GIRFT registrar 2

No one collected this data and doing this audit is quite time consuming to be fair in terms of the, you have to have the spreadsheet, pick up on the patients, it takes Saturday, Sunday and days out of hours working and going through everything, so it's quite challenging in terms of the time.

GIRFT registrar 3

Participants had several suggestions on how to make surveillance more sustainable. This mainly involved creating a specific role, adding the duty to somebody's job description, providing more funding, and utilising electronic records for easier data capture.

I think having an electronic system's really helpful, and it's one we have to exploit. If there was, for a patient, [something] where you can tick… say for example you just had a simple, a very simple tick checklist, at least then when you go onto the patients, it's flagged as they've had an SSI.

GIRFT registrar 2

So I think if you want to commit to it and if the trust wants to commit to it, then yes, but then you probably need to make it part of somebody's job description… and they had a set time allocated to it every week, then yes it would be sustainable… you'd then establish processes and ways to capture the data and you'd probably speak to the people at Cerner so that you could actually capture that data a lot more readily just by doing a quick search on the online records… but in the way that we did it, I don't think it would just be sustainable if there weren't any changes, sadly.

GIRFT registrar 1

3.3.1.3 Hierarchy

Staff working within the operating theatre or within surgical specialties reported difficulties in challenging staff they perceived as superior to them – usually consultant surgeons. The reasons behind this reluctance varied based on professional group. Surgeons reported their understanding of surgery as an "apprenticeship", in which the consultant is the master and the registrar the student. The reason for a lack of challenge from junior to senior surgeon may then be partly based in the assumption of superior knowledge and experience of the consultant.

I think that, it's not that we necessarily just do as they say, but it's partly just because we don't yet have the experience to know any different or better… I'm not yet experienced enough to say, "oh actually that, I've noticed that, that suture material does this or this closure technique does that" and so I still rely on my consultant, because they've just had ten years more experience than

me and therefore I think that's pretty valuable and I rely on their experience and technique to inform me.

Obstetrics & gynaecology registrar

But I think as a trainee, particularly when you're, you've got a weak evidence base behind you, it's very hard to challenge, and I think it's very hard to challenge even as a consultant I think it's hard to challenge peer behaviour… there are different factors at play obviously, so when you're a trainee, the factor that stops you challenging or questioning is hierarchical normally… you can be well I'm a trainee they're a boss, he or she knows more than I do because I can't tell them from the evidence that what they're doing is wrong or right…

Plastics consultant

This differs from other staff groups working within the operating theatre or surgical specialty, for whom the main barrier for raising concerns was a fear of offending or having to deal with the consequences of a negative reaction from the surgeon. This is also a secondary barrier for junior surgeons, or even consultant surgeons challenging each other.

[Surgeons] don't care sometimes about our opinion… but [other theatre staff] are not comfortable [challenging the surgeons], they are scared sometimes and I'm scared sometimes as well…I have never seen a junior surgeon scrubbing without mask, for example… but they are scrubbing with surgeons who don't use a mask, but they will never say anything to that surgeon, never.
…So, sometimes I just prefer not to say anything, I know it's not right, but I just prefer to not say anything …I will get nervous, because … we say that they have the knife, they have the power

Scrub nurse

…they have some very, very unruly surgeons who will not [react well], thank god we have got good surgeons who would listen to us and not be fussed. But there are some surgeons that the staff would not be confident to mention that to. Which is unfortunate.

Critical care nurse

Confidence in challenging others for almost all participants was rooted in their ability to express themselves in a way that seems informal, unconfrontational, and friendly. Participants described how this was helped if they had a good relationship with the person.

Myself I don't find it a problem because I've got quite a good relationship with the doctors that I work with. But I could see somebody new coming in having a problem with it...

Surveillance nurse

Other participants described how they used humour and tact to try to minimise any offence caused. Things like tone and body language were all important in minimising offence.

I was doing a case with [a consultant from another specialty who] wanted to wash the wounds out with his special mixture… I had to make a joke about, oh well of course the evidence behind that is, that this doesn't work and causes damage and I think he kind of got the fact that even though I was joking, I was being serious and desisted from doing it… if I start going, oh you're doing it wrong, that really undermines him in the face of his normal operating team. So I'd make a little joke about it…

Plastics consultant

> *They're not upset when they do it, because they, you have to do it with tact. You can't be rude, aggressive or loud or do things with an attitude… your body language, your tones, your attitude be of one that they would listen to… you kind of whisper little things in the ear and you make a little joke about it and you be, throw in a bit of sarcasm on the sly and things like that…it's a personality thing.*
>
> Theatre coordinator

But not all staff were confident in their ability to phrase these comments effectively; one in particular felt their English proficiency was insufficient for the level of subtlety required to successfully challenge inappropriate behaviours.

> *If it's important, my case is, I'm not fluent in English… my problem is if… I have to say something and to be kind at the same time I don't know how to do it in English properly. So, sometimes I just prefer don't say anything.*
>
> Theatre personnel

Another factor in having the confidence to challenge inappropriate behaviours was SSI prevention coming under a staff member's official remit or area of expertise, placing them outside the surgical hierarchy.

> *It's not so much that whoever holds the knife, as you know, you have met [nurse] … [nurse] never holds the knife but holds a lot of power...is empowered to actually cause a fuss if people are doing the wrong thing…*
>
> Cardiac surgical registrar

> *It depends if it's my specialty or not. If it's for example a simple mistake of wrong prophylaxis I will challenge that… So, I think the hierarchy is only valid if you are within the team, if you're outside the team and if you are a consultant in another specialty, you are confident in what you are doing without obviously being arrogant.*
>
> Microbiology consultant

> *Personally, I feel comfortable, but I think that's probably because I work within that specialty. If I was a junior pharmacist on the ward, who wasn't specialising in infection, I think I would find it difficult to challenge perhaps a consultant who was coming along on a ward round with a watch or a suit jacket on, but to me, it doesn't really faze me to do it. I'm used to it.*
>
> Infection pharmacist

In addition to an official remit or expertise, staff found having policies, guidelines, or high-quality evidence to refer to was helpful in supporting their position when discussing SSI prevention.

> *Before that I can only suggest maybe we shouldn't be doing this, other people can see you like, "oh, smartass is coming and saying oh, we should do this or that and what is your evidence?" Well, there are multiple evidence, WHO guidance from 2016, for example...*
>
> Vascular surgical registrar

> *Once you find the evidence you can challenge that.*
>
> Microbiology consultant

We rely on our NICE (National Institute for Health and Care Excellence) guidelines because they should be taken from solid recommendations and good grades of evidence.

Anaesthetic consultant

Being able to refer to these sources of data effectively increases the support for the point of view of the person challenging the evidence, emboldening them to challenge behaviour but also helping to make the discussion seem less like a personal attack and more like an academic discussion.

3.3.1.4 Resources

The final major influence on staff behaviours around SSI prevention and surveillance was the availability of resources of all kinds – human, technological, financial, and physical. Behaviours are modified by the staffing levels in the hospital and their skill set, financial resources for SSI prevention, the physical geography and condition of the hospital estates, and the information technology available to them. While some of these like staffing levels and financial investment are well-known, there are other more nuanced factors like skill mix, ward layout, and unsuitable facilities that have been previously underappreciated. All of these additional factors mean that even if staff have the knowledge, skills, ownership, self-efficacy, and team support in place to enable best practice, there are still circumstances outside their control which can help or hinder these efforts.

3.3.1.4.1 Human

Some specialties had trouble because of staff sickness or problems filling posts with an appropriately qualified staff member.

There's meant to be four [tissue viability nurses] but we're one short at the moment and there's somebody off sick, so there's only two at the moment.

Tissue viability nurse

In cardiac surgery the SSI rate, it goes up and down… I think it's a just a problem with the team being really incredibly busy, and not having enough work force to cope with the amount of [surveillance] work.

Microbiology consultant

As well as having adequate routine staffing levels, one important facilitator in preventing, diagnosing and treating SSIs was the availability of other specialist staff as a resource. Staff in some areas were well networked with specialist teams in microbiology, pharmacy, tissue viability and IPC, or had their own SSI specialist nurse to go to with questions about SSIs.

Certainly through the microbiology team and the infection control team if a patient is needing an upgrade on their antibiotics or are on a long course of antibiotics, they're highlighted to them as well. So all this information is then covered into the SSI prevention group.

Anaesthetist

According to micro consultants, swabbing of the wound is not appropriate, we should have a scrape wound or take a fluid or tissue which, these kind of the guidelines… I wasn't aware of it.

Vascular registrar

Every hospital has a different policy and the policy is based on what the microbiologist feels is the current, most important bacterial infections but also we have meetings between different departments to discuss that. The microbiologist tends to give the majority of the advice with some input from clinicians, so it's mainly the microbiologist who decides what the antibiotic prophylaxis is.

Cardiac registrar

but we have tissue viability as well, which is a very strong team

Critical care nurse

This was particularly the case for orthopaedics, who have established SSI surveillance.

I think it is well organised team for surgical infection site in our trust starting from the nurses and to surgeon between, for example in our department of orthopaedic as well as the plastic surgeon and the microbiology department and as well as pharmacy.

Orthopaedic surgery registrar

However, not all specialties were as well networked with other disciplines. Microbiology and pharmacy staff undertake regular ward rounds in some surgical specialties, but not all. The Trust also has a nurse-led tissue viability service which surgeons can refer patients to for expert input on wound care and management of infected wounds. Some specialties referred patients to the tissue viability service more often than others.

The referrals that I see, I don't get referred that many but that doesn't mean to say that it's not, they're not occurring or not being reported but I know there has been a slight increase in the number of SSIs occurring recently… because the [gastrointestinal] surgery, they refer quite a lot and they want our opinion quite often, whereas other types of surgery… never refer.

Tissue viability nurse

So probably tissue viability nurses should be more available… or if there is a complex wound, to give them advice and support

Vascular registrar

3.3.1.4.2 Technological

As well as staffing issues, switches in information and communications technology (ICT) systems disrupt workflow and create new problems without any tangible benefits to end users, at least in the initial stages. This is particularly difficult when several systems change at once.

Before we had ICNet, and then we changed it to IPC-LIVE so the thing with the ICNet, you can see if there are positive results from the wound… but now because the IPC-LIVE is not fully functional… you can still look back from the cases from ICNet, but… I won't have any access anymore… I think the vision is to capture at the real time, but I think they were having problems with the micro because they have a new system as well…

IPC nurse

3.3.1.4.3 Financial

The long-term goal of centralising SSI surveillance and prevention responsibilities by creating a team including epidemiologists, SSI nurses and clinical educators to network with staff embedded in surgical specialties has been the subject of a business case in development for several years. However, for financial reasons, this has not been implemented.

> *It's definitely trying to have a better SSI team for which we've tried, and we keep trying to get a business case for an SSI team… I appreciate that on the other hand, the Trust is in financial difficulties at the time, so SSI may not be a priority… it goes on the wider picture of probably the NHS needs more funding if you want to provide a really high-quality service that everyone will be jealous of.*
>
> Microbiology consultant

3.3.1.4.4 Physical

Several participants mentioned issues with the old hospital buildings being either in a poor state of repair or being not fit for purpose. A problem cited several times was overcrowding in the wards, as the old buildings are now surrounded by other structures making it difficult to expand and increase capacity. The poor state of repair of some parts of the hospital in addition to the resultant building works have meant capacity has been further reduced.

> *We're sitting in a building that's falling down, the [Care Quality Commision] weren't too impressed with our building and site, they're impressed by the staff but there's only so much we can do if people aren't going to invest in everything that's around us.*
>
> Anaesthetist

> *…in this hospital because it's an old hospital... we cannot change these kind of things… the prep room has to be bigger, we need more space... because sometimes we are setting up things and we are touching all the trays on the side… there is nothing I can do, because there is no space*
>
> Scrub nurse

> *In the post-operative period the important thing is if the patients are not cramped, in overcrowded bays on the ward and… the clean operation is not next to the patient… having some tissue loss or infected diabetic foot waiting for debridement*
>
> Vascular registrar

Other layout problems caused issues with storage of dressing materials, which added additional complexity to dressing changing practices already under strain because of lack of training, ward overcrowding, and inappropriate ward round practices.

> *[The nurses] have to go to different, two different places because the dressing, the storage is divided into two different places, spots, which you have to go through half of the ward to go to the other one to collect the stuff you need for the dressings.*
>
> Vascular registrar

The fact that the majority of patients had some comment or other about wider resource or estates issues in the hospital shows that this is an important aspect of SSI prevention for them and indicates a perceived

lack of investment and in some cases lack of interest on the part of the wider hospital management. Not only did staff state that they believe these things have an impact on SSI rates, but it also suggests staff feel the Trust's goals do not align with theirs and that their concerns are not being listened to and could lead to ill-feeling and disengagement.

3.4 Discussion

Many of the skills involved in surgery and the care of surgical patients are extremely practical, hands-on techniques which are carried out in closed-off areas: theatres and in private patient rooms or behind curtains on wards. While this is necessary, it means that staff working in this field cannot see each other's techniques and practices, and opportunities are being missed for peer learning. Additionally, some staff noted that they had not undergone training (or not recently) for some tasks they had been asked to perform. While staff should be encouraged to be proactive about seeking training to fill any skills gaps they have, hospitals have a duty to make sure staff are properly trained and should ensure staff receive regular mandatory training on tasks that are part of their day to day work. Dressing changes was mentioned several times as a problem area, and the tissue viability staff would be ideally placed to provide training for this.

The concept of ownership relates to how much control the participants felt they had over SSI development in individual patients and over SSI rates as a metric. The role that SSI surveillance plays in ownership is critical as knowledge of rates showed a profound impact on practices through a better understanding of risk. In our study, participants commented on how reporting of rates influences behaviour in larger, more explicit ways through formal investigations and interventions, but also by heightening overall awareness of risk. On what level and through what mechanisms these rates should be reported to surgeons or surgical teams was less clear; one surgeon commented that in another setting, reporting of surgeon-specific complication rates in a public way led to meticulous care that was often beneficial in reducing complications, but could occasionally result in feelings of blame, shame, and stress. Other non-surgeons also felt that reporting surgeon-specific rates could result in increased blame culture. Ashish K. Jha recently argued that consultant surgeons are the de facto leaders of surgical teams, and therefore the ones who hold most control over factors that could influence outcomes [93]. In contrast, the participants of this study described a wide range people who share responsibility in preventing SSIs which would seem to show a fundamental disagreement with Jha's argument. An additional problem with Jha's argument is the assumption that consultants are the de facto leaders; reporting rates primarily by consultant surgeon may reinforce unhelpful hierarchies by elevating the consultant above the rest of the team.

Another important component in the participants' perceptions of risk was not just whether or not the patient develops an SSI but how much harm that SSI might cause. For the surgeons in this study, SSI rates appeared to be considered as more of a process than an outcome measure, the outcome measure being ultimately the overall harm done to the patient. This could be a vitally important consideration when planning surveillance programs, since it implies that SSI rates are only a useful metric in surgical specialties

where the process measure of SSI rates is roughly equivalent to the true outcome measure of harm (as is the case with orthopaedic surgery). In other categories, the true outcome measure of harm will depend on morbidity and mortality associated with SSI as well as the crude number of infections, and the data fed back to staff will need to reflect this in order for them to find the information useful and actionable. This may mean data collection needs to be adapted to capture the necessary information, but could ultimately result in a more effective system.

A further aspect of knowledge that is the way in which surveillance data impacts on the risk perception of staff. Several participants commented on suspected high rates in some specialties that had been ignored and denied until the data were available to prove there was a problem. By collecting surveillance data, problems that could previously have been hidden are made explicit, forcing staff to acknowledge the problem and take ownership of it. Ongoing surveillance reinforces the sense of ownership if staff are able to see the impact of their remedial actions in SSI rates.

By combining the two themes of knowledge and skills and ownership, we can see how these findings support the work by Reilly et al. [94] which demonstrated that surveillance and feedback of SSI rates alone is not enough to produce a significant impact without additional educational supports and guidelines: it is not enough for staff to know they need to improve without knowing how to improve. A sense of ownership is necessary but not sufficient without the additional theme of knowledge and skills. Together these concepts would ensure staff have the self-efficacy necessary to effectively prevent SSIs if they were to work in isolation. But SSI prevention is not an individual activity.

The issue of hierarchy among healthcare professionals has been noted in clinical training [95], in prescribing etiquette [96], and in communication [97] and antibiotic decision making [98] in operating theatres. Surgeons in this study spoke of their training as an apprenticeship in which they learn from the greater experience of the consultants and from their own experiences. This is a similar finding to the study on clinical training in Ireland which found that participants were expected not to question the judgement of more senior surgeon [95]. However, the reasons behind this were slightly different in the two settings; in the Irish study, participants did not question seniors out of an established system despite feeling their judgements were sound, whereas in this study, there was an additional element of genuine doubt about their own decisions and a sense that the senior surgeon may have genuine superior knowledge or experience. The study on prescribing etiquette was conducted in the same hospital group as this study but looked at all healthcare staff who actively prescribe antimicrobials [96]. Nevertheless, the finding of hierarchy was observed again, with junior doctors taking their cue from more senior doctors in a similar way as registrars and trainees take their cue from consultant surgeons. A systematic review by Weldon et al. of studies on communication in the operating theatre globally found that power relationships are prominent in surgery and can lead to fear and silence, ultimately allowing unsafe practices to go unchallenged [97], and there was evidence of this chain of events in this study. In particular, the systematic

review noted a particularly low regard for the knowledge of nurses, which was evident to some extent in the experiences of the scrub nurse in this study [97].

Some participants in this study appreciated that teams may learn from others who have had different experiences of different patients, in a different era or different country; in this sense, the diversity of staff backgrounds in the NHS is a resource in itself. The same applies to learning from staff in other disciplines who may have specialist knowledge. In order to access the combined knowledge of the team around them, consultants need to encourage staff to speak up if they observe a behaviour that may increase the risk of SSI, and to behave positively when they do. There is a wealth of data on encouraging staff to "speak up" for patient safety: in 2014, a systematic review was published which looked at the available evidence to date and distilled these into a model [99]. The similarities found between the themes in this study and Okuyama et al.'s model included an individual's sense of responsibility towards patients, their communication skills, their team relationships, their confidence and previous experiences, fear of the responses of others, and the need to collect facts before voicing concerns [99]. One important addition made by this study is that these drivers were found to be different between junior surgeons (who saw themselves as apprentices and were more likely to defer to the perceived superior wisdom of the consultant), non-surgeon theatre staff (who were mainly put off speaking up by the expectation of negative reactions and/or consequences), and non-theatre clinicians and other HCPs such as IPC, microbiology and pharmacy staff (who felt comfortable in their own expertise and outside the surgical hierarchy, therefore less likely to elicit negative reactions).

Our study found several facilitators for challenging inappropriate behaviour in others, which can be mapped to Okuyama et al.'s model to help explain their mechanisms [99]. Role modelling of the "correct" way to challenge others is a useful indirect way of increasing an individual's previous experiences; if a staff member has seen lots of examples of successful challenges by others they may be more inclined to replicate the behaviour. By referring to policies, literature, guidelines, and data on infection rates, staff are "collecting facts" to support their point of view. Staff could also circumvent difficult hierarchies by "selecting the person" appropriately, for example by asking somebody who does feel comfortable challenging the individual to make the challenge for them, thereby taking advantage of other "team relationships" if they do not feel their own are strong enough. This could also be helpful for staff members who do not feel their communication skills are strong enough to convey their meaning without eliciting a negative reaction.

In terms of how challenges were actually made in practice, there were several similarities in our data and generated by Tarrant et al. using ethnographic and interview data from multiple English intensive care departments [100]. Like in this study, Tarrant et al. highlighted the use of "quiet words", humour, and bantering to help diffuse tensions when challenging inappropriate behaviour [100]. Unlike Tarrant et al.'s study, here I did not find much evidence for the use of brutal reprimands or public humiliation as means of

challenging others, although one surgeon reported “we shout at [the nurses]” when they have documented a wound as infected which the surgeon disagreed with. In this study, brutal reprimands and public humiliation were more likely to be mentioned as consequences of challenging seniors. The reasons for this difference are likely down to the differences in methodology: Tarrant also used ethnography, and so behaviour was observed that interview participants might not wish to disclose something they felt ashamed of i.e. they were either doing the reprimanding/humiliation or were doing something wrong which prompted the reprimand/humiliation. Conversely there is no shame in being reprimanded for challenging inappropriate behaviour.

Another difference between this and Tarrant et al.’s study were the dynamics between HCPs outside the setting in question. Tarrant et al. found that IPC staff sometimes decided not to challenge inappropriate behaviours in favour of maintaining more harmonious relationships in the long term [100], whereas the IPC, microbiology and pharmacy staff in this study reported that they would have no hesitation in challenging others. Again, the difference may be that these staff have every intention of challenging inappropriate behaviour and would report as such in an interview around a hypothetical situation, but in the moment may decide against it so different behaviour would be observed in ethnography [100].

The availability of human and financial resources and the existing infrastructure in terms of ICT systems, built environment will vary between organisations, but a recent qualitative documentary analysis by Iwami et al. found that hospitals in the NHS tend to have reactive rather than proactive IPC planning strategies [101]. This chimes with some of the experiences of the participants in this study, who found that while the hospital management were very supportive in investigating and driving change based on the results of the GIRFT audit, they were more reluctant to agree to funding a sustainable surveillance system for monitoring SSI rates. There is also some evidence in the literature that various aspects of the built environment such as cleanliness, lighting, and spatial layout can have an impact on staff wellbeing [102]. The findings of this study suggest that on top of the direct impact of these factors on staff wellbeing, lack of investment by managers in estates, facilities, and infrastructure can also be construed as a lack of interest in the needs and requirements of their staff.

3.4.1 Reflexivity

3.4.1.1 Insider/outsider

At the start of my PhD, I had a working knowledge of anatomy, infection pathogenesis, and the mechanism of action of some antimicrobials from my background in basic science. My only knowledge of the healthcare system was through my limited experience as a patient, and as a counter assistant in a community pharmacy. I had very little knowledge of the NHS, pay bands, or surgical training, and had never heard the term “surgical site infection”. In short, at the commencement of this study I was very much an “outsider”.

For much of the time, I feel this to have been an advantage. Not being part of the "system" had a twofold impact on the way I was perceived by participants: firstly, I was not subject to the hierarchy structures identified through this study so was able to approach each interview on a fairly equal footing, and secondly that participants were more likely to explain practices and cultural dynamics in more detail, as they did not assume I had any prior knowledge. Questions that may have seemed loaded, or to come from a biased personal agenda if posed by a current member of staff were instead viewed as innocent queries. This was particularly the case for questions on challenging colleagues' behaviour.

Being an outsider was also advantageous for data analysis. By the end of the study, I knew enough of the actual structural and organisational arrangements around SSI prevention and surveillance to be able to contextualise how the staff perceive these arrangements, but without having any first-hand experience of either of these concepts.

My basic science background did present a challenge at one point, as I commented in my reflective journal (26th June 2017) "I think my background in science has desensitised me to the passive voice – "patients are informed" should really be met with "who informs them?" to avoid missing out on the full picture, but it sounds too normal to me."

Eight of the 20 interviews were conducted by Victor Mariano. Victor had been previously employed by the Trust as a theatre nurse. This had several positive impacts on the study. We conducted an initial trial interview in which I was the interviewer and Victor was the interviewee. The main benefit of this was to decide which questions would be appropriate/inappropriate for which staff groups, and to allow me a chance to hear some preliminary feedback on my interviewing technique, such as leaving more time for responses, and taking care when formulating ad-hoc questions not to be closed or leading. Victor was present at my second interview, and again was able to provide feedback on my interviewing style, but we also debriefed together afterwards, discussing the meaning of some statements and finding areas that warranted investigation in further interviews. This was also useful for us to understand each others' perspectives and styles, understanding the similarities and differences.

Victor was able to recruit more participants quickly, already had a rapport with some, and was able to elicit more candid responses from some participants than I was as an outsider. From the data, I noticed that this did bring up some difficulties in the tendency for participants to assume an implicit understanding when talking to Victor, with participants saying, "you know how it is" and "you know what I mean". While Victor endeavoured to make this data explicit, some things may have been left unsaid. Victor kept his own reflective journal and passed this on to me after his interviews were concluded, so I was able to explore these differences in more detail.

On several occasions, Victor comments that he feels surgeons are being "cagey", whereas nurses and theatre personnel were much keener to discuss their personal opinions. I felt the contrary, that surgeons

were much keener to talk in depth to me, while nurses preferred to give the "correct" answer, at least at first. I felt that surgeons saw me as someone who they could express their opinions and assertions to, and that I would accept and agree with what they said since I was not part of the surgical culture. This was less true when I came to interview nurses, who seemed to view me with more suspicion initially and were more guarded. This difference is not due to insider/outsider effects since the relationships are the same, but due to power structures and where participants felt I fitted in, and possibly differing perceptions of researchers.

3.4.1.2 Skill development

This study spanned the whole length of my PhD; it was the first study I began planning when I knew nothing, and I was conducting interviews until the very end. My outlook has therefore inevitably changed throughout.

Looking over my reflective journal, I can clearly see my own development through the four stages of competence.

In the reflection from my first interview I wrote "I need to remember that if a participant doesn't say something, and I don't probe [for more detail] because I already know [what they're talking about], I don't have any evidence.". This sentence assumes that I already knew most of what this participant was trying to tell me, and that it was just a case of having documented evidence of these facts. This is a clear indication of my status in the initial stage of "unconscious incompetence".

I did, however, notice and comment on the fact that the interviewee seemed nervous "which surprised me, as I had been nervous beforehand and thought, surely it should be me who's worried how this will go?". On reflection, I thought that this may be because they thought there would be "right" answers to give. Looking back, I can see that there may be several explanations for this nervousness; that I had not sufficiently communicated that the interview is not a test in any sense, that the participant was simply reflecting my own agitation, that my position as an outsider was automatically unsettling, or that something in my manner that day was intimidating – or perhaps a combination of these factors. That these other more nuanced alternatives had not occurred to me at the time indicates the skill deficit in analysis.

Almost one month later, an entry in the journal characterises the beginning of the "conscious incompetence" phase: I had just read an article on interviewing for introverts and wrote "I have been wondering recently how suitable I am for this type of research, given that I find meeting strangers quite draining, especially when I am asking a lot of them." Two weeks later when conducting my second interview I made notes on my own behaviour during the interview and wrote tips for the next one such as "try not to nod or say "yeah", just look and listen and say "ok" or "interesting", count to 5 after the end of each answer, make notes about questions to ask rather than asking straight away in case you forget".

By the following year, my position is much more towards conscious competence, in that I am confident in my knowledge and skills, but it still requires conscious effort: “I felt that the participant at times was confident in explaining the surveillance setup in the Trust…some of which I know not to be the case. I think this may be partly to do with the participant seeing me as an “outsider” who knew less, and also not wanting to seem out of touch with the workings of the hospital.”

3.4.1.3 Life experiences

As well as sharing a workplace, Victor had other experiences which were shared with the participants, such as working in different countries, and working in a language other than their first, which helped some participants to identify closely with him and share how this had impacted their views on SSI. While I also interviewed participants who had had these experiences, none mentioned language, and those who referred to working in different countries spoke of this as a benefit in helping them broaden their experiences. None alluded to any challenges posed by these experiences, and it is likely that participants inferred (correctly) from my accent that I am British-born and have only ever worked in England in my first language, therefore they may have felt that I would be less understanding or possibly even judgemental if they had mentioned anything less positive.

3.5 Conclusions

The drivers of staff behaviour around SSI prevention and surveillance act at every level, from individual knowledge and skills, personal and team ownership, hierarchy, and the wider hospital setting.

There are instances where staff do not feel they have received appropriate training or have access to the appropriate resources they need to adequately prevent SSIs. Admitting that they have not had training for a task they have been performing for some time is difficult and embarrassing for staff, as it highlights that they may have been doing it wrong, so well-planned regular training should be provided by hospitals routinely. Training could also include peer-learning opportunities and sharing best practice.

Staff felt that everyone was responsible for the prevention of SSIs but tended to perceive consultant surgeons as accountable for infection rates. This causes difficulty as it removes accountability from some of the staff responsible for SSI prevention, and puts too much accountability on consultant surgeons who are not always able to prevent SSIs: complex causes translate to complex accountability. All staff who are responsible for SSI prevention should also feel a sense of accountability. Hospitals can help foster team ownership by collecting and analysing data for in-house quality improvement programmes with engagement from the whole perioperative team.

Unhelpful hierarchies that prevent staff from challenging inappropriate behaviour are similar to those that have been noted in other studies on IPC practices and the wider healthcare system. Facilitators that help staff to challenge others include role modelling by other staff to create culture change, having access to

relevant data, policies, guidelines, and literature to support their comments, using discretion and humour or tact to initiate conversations, and being outside of the surgical team and a specialist in infection prevention or treatment.

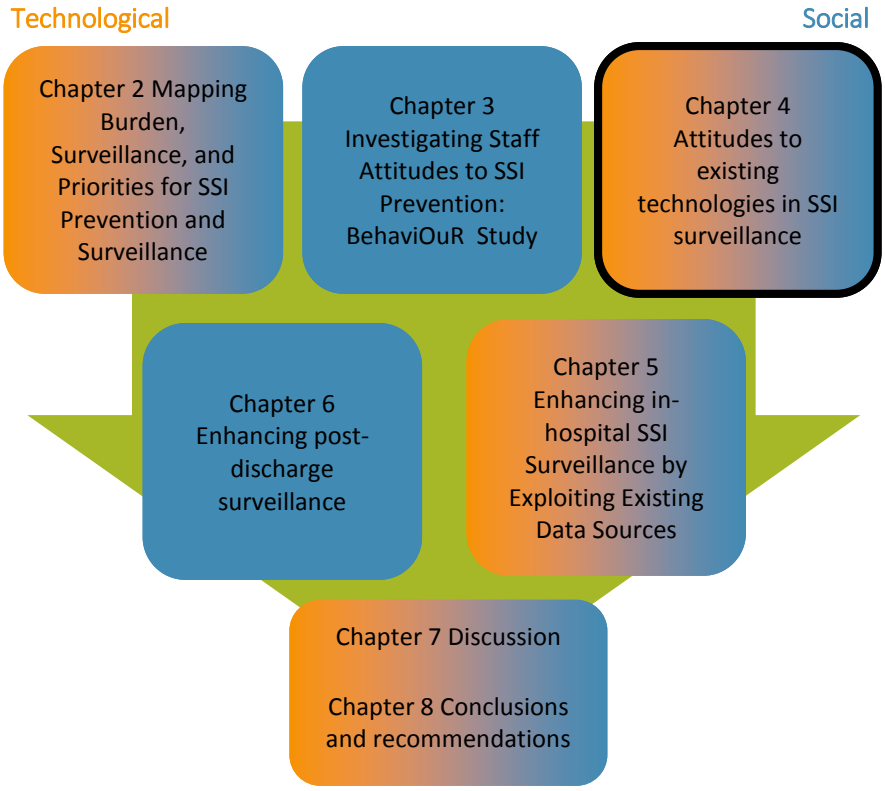
Finally, the wider hospital context needs to be considered. Each hospital will most likely have its own external factors contributing to SSIs, but here the main issues were the state of the buildings and equipment, and staff shortages. Tackling barriers in the wider context is important as it not only has a direct impact on SSI prevention but also an indirect effect on culture and staff morale, as staff can feel that their efforts to prevent SSIs are being undermined by inaction or apathy on the side of the hospital management.

The broad range of themes identified in this study from individuals right up to wider hospital infrastructure demonstrate the complexity of SSI prevention and surveillance. Researchers, healthcare professionals, and policymakers could benefit from recognising this and using complexity theory in the planning and implementation of new initiatives.

Chapter 4. Attitudes to existing technologies in SSI surveillance

Summary

The previous two chapters have given insight into the epidemiological and social landscape of SSI prevention and surveillance in England: this chapter moves on to discussing the technological landscape of SSI surveillance. There have been many attempts over the years to develop automated surveillance algorithms but none of these have been adopted widely in England, and the national surveillance system does not accept data collected in this way. This chapter examines the technological innovations that have been developed, and the barriers and facilitators to their adoption through an established framework.



4.1 Types of in-hospital surveillance

4.1.1 Manual

Manual prospective surveillance is where patients are identified at the point of surgery, and data are collected on all patients regardless of whether they go on to develop an SSI. It is often considered the "gold standard" of SSI surveillance, and is the method used for national surveillance in England [3] and for the standard European surveillance data collated by the European Centre for Disease Prevention and Control (ECDC) [103]. Data are collected manually by a person or team, usually healthcare professionals, who have usually undergone specific training and/or follow a surveillance protocol. SSIs are determined by the

surveillance professionals themselves by direct assessment of the wound and patient. Follow-up periods tend to be 30 days as standard based on the CDC definition of an SSI [104], or either 1 year [3] or 90 days [103] if an implant has been used to allow for the slower progression and presentation of these infection; the majority of patients are discharged from hospital before the end of the follow-up period. The types of data collected typically contain basic information on the procedure (date and type), patient risk factors such as age, sex, American Society of Anaesthesiology (ASA) score, and also if and when the patient developed an SSI, the infection depth (superficial, deep, or organ/space), and any causative organisms identified. Some other risk factor variables may also be collected such as the operation length, grade of surgeon, smoking status, or body mass index (BMI).

The combination of manual and prospective data collection allows for a greater range of variables to be captured which may not be entered into an electronic system e.g. smoking status and grade of surgeon. This can be useful for local quality improvement projects as prospective cohort studies can be initiated at any time.

Prospective data collection also reduces recall bias and eliminates the problem of poor documentation of SSI diagnoses in notes or medical coding, as the person conducting the surveillance assesses the wound itself.

Manual data collection can also be carried out retrospectively, with staff examining the notes to identify SSIs. This relies on adequate record keeping or recording of diagnoses, since most patients will have already been discharged. Retrospective manual surveillance is also time consuming, but does not require direct patient contact, does not require the patient to be in the hospital, and can be done at any point after the follow up period has ended for each patient. It can also be done away from clinical areas, or even remotely, facilitated by electronic patient records.

Manual surveillance is extremely time-consuming, and the diagnosis of SSI can be subjective. One European study presented twelve case-vignettes of possible SSIs to 100 infection control physicians and 86 surgeons across 10 European countries and found the intra-class correlation coefficient (ICC) for infection control physicians to be moderately good (0.41, 0.28–0.61) but poor for surgeons (0.24, 0.14–0.42) [105]. Similarly, when a panel of four orthopaedic surgeons and an infectious diseases specialist were asked to diagnose SSI in 29 cases of lower extremity surgery, a Fleiss kappa value of 0.44 (95% CI 0.35-0.53) was calculated, indicating only moderate agreement [106]. Poor inter-rater reliability diminishes the value of benchmarking exercises. Some hospital surveillance programs will have only a small number of specialty-specific SSI surveillance professionals, which minimises issues of inter-rater reliability but can also introduce bias, limiting comparisons between other specialties in the same facility. It also makes the process particularly vulnerable to staff absence or turnover.

4.1.1.1 Surgical Site Infection Surveillance Service (SSISS)

National surveillance of SSIs in England was initially established as part of the Nosocomial Infection National Surveillance Scheme in 1997. This evolved into the Surgical Site Infection Surveillance Service (SSISS) at the Health Protection Agency (now Public Health England, PHE). Since 2004, reporting of SSIs is mandatory for NHS hospitals for at least one quarter in at least one of four orthopaedic categories: hip replacement, knee replacement, reduction of long bone fracture, and repair of neck of femur. There are also thirteen other voluntary reporting categories.

Surveillance is carried out manually as described above by a healthcare professional (HCP) who has attended a training day provided by the SSISS. The protocol includes several optional methods of post-discharge surveillance (PDS): systematic follow-up by healthcare professionals through drop in clinics, outpatient clinics, or community-based follow-up by a trained HCP, or patient questionnaires in paper form or conducted by telephone.

Data collated by the SSISS are used for benchmarking between hospitals; those flagging as considerably higher or lower than the pooled mean for participating hospitals in a given surgical category are deemed outliers and receive letters asking them to investigate and explain. Those flagging as low outliers are contacted as there is a possibility they are not adequately conducting surveillance and are therefore missing cases. As a surveillance "service" the SSISS will also work with hospitals individually to help them improve either their SSI prevention practices or their surveillance practices, if either of those are found to be inadequate. There are no penalties or incentives attached to performance. As well as assessing performance between hospitals, trends can also be observed within hospitals over time.

There have been several published articles which discuss issues with the SSISS. In a survey published in 2013 on surveillance practices of 156 trusts, 106 responses were received which showed 10% of trusts did not submit data for superficial infections and 8% submitted only data on inpatient SSIs (contrary to the protocol) [107]. Fifteen percent were also not using the correct definition of SSI [107]. The authors concluded that this makes the data unreliable for benchmarking between hospitals, which is one of the stated aims of the SSISS. The authors also suggested that hospitals conducting high-quality PDS would be unfairly penalised as they tend to have a higher rate of SSI due to increased case finding intensity [107]. However, while data collected through PDS can be submitted to PHE, they are not used for benchmarking.

A second study using similar methodology surveyed only trusts performing orthopaedic surgery in 2015 [108]. The authors reported that a number of different definitions in use, however out of 127 trusts who answered the question, 90.6% were using either the Centers for Disease Control and Prevention (CDC), Public Health England (PHE), or its predecessor the Health Protection Agency definition of SSI which are in fact the same [108]. Only 4.7% were not sure, 4% used a combination of definitions, and 0.8% were using their own Trust definition [108]. The impact of these different definitions on the reliability and

comparability of SSI diagnosis in data reported to the SSISS is not known. The differences in the staff group of the person responsible for collating the data did vary more dramatically. In most hospitals either an SSI nurse or infection prevention and control (IPC) team member collated the data, but in 23.6% this was done by theatre staff, microbiology administrators, or the ward housekeeper [108]. This variability may well introduce bias, as it is known that the inter-rater reliability between staff groups for diagnosing SSI is poor (see 4.1.1).

One other finding in this paper was that 57% of 125 trusts who responded to the questions said that their orthopaedic SSI surveillance had been limited by resource constraints [108]. This is significant, as the previous study by Tanner et al. suggested a "the more you look, the more you find" relationship between case finding intensity, limited by resources, and SSI rate [107].

Following on from this study, another group performed their own retrospective analysis in orthopaedic surgery using case notes review and found extra cases that would have pushed up their SSI rate from 0.74% to 1.05% [109]. However, the authors noted that the discrepancies in the rate calculated using their retrospective method and that calculated using the SSISS protocol decreased after multidisciplinary discussions reviewing surveillance practices [109].

In a letter to the editor of the Journal of Hospital Infection, Jenks et al. pointed out that some rates used for benchmarking by the SSISS are calculated from a very small number of patients from a handful of institutions [71]. The authors also suggested that by allowing hospitals to submit data for selected quarters of a year rather than continuous surveillance, the SSISS introduces selection bias [71]. However, as representatives of the SSISS stated in their response to the letter [110], hospitals must state in advance their intention to submit data for a given quarter, so there is no possibility of deliberately submitting data from a period with low SSI rates. This response also clarified that decisions on whether reporting is mandatory for a given surgical category are made by the Department of Health, rather than PHE as was suggested by Jenks et al. [71].

There are always inherent difficulties in manual surveillance systems because of human frailty, inherent uncertainty and subjectivity [111], and some of these pitfalls can be improved through the automation of some aspects of surveillance. These are discussed in more detail in 4.1.2.

4.1.1.2 Getting It Right First Time (GIRFT) SSI audit

The need for more extensive data on SSI rates in non-mandatory surgical categories was one of the drivers behind a national audit on SSI rates conducted as part of the Getting It Right First Time initiative (GIRFT) [36] which is described in 1.1.7.1. The audit comprised a six-month retrospective review of case notes from November 2016-April 2017 followed by a six-month prospective audit from May-October 2017 using manual SSI surveillance. The manual method differed from the standard SSISS protocol in that detailed

data was only required for SSI cases, with an aggregated denominator to calculate SSI rates. It was also carried out by junior doctors, rather than specially trained surveillance staff [36].

Staff attitudes to the GIRFT audit were captured as part of the qualitative study described in Chapter 3. Three of the participants in the study were junior doctors who had undertaken the audit, and several others had been part of the Surgical Infection Group charged with overseeing the audit and acting on the results.

The junior doctors undertaking the audit found the data collection extremely time consuming and had all had to come up with their own ways of identifying patients – putting notes up in doctor's rooms, asking colleagues to report any SSIs to them, or regularly approaching colleagues to ask for any SSIs. All reported that they did not feel an SSI surveillance system using the same methodology as the audit would be sustainable as a long-term solution to SSI surveillance without protected time and extra resources. This echoes the general concerns about lack of resourcing and understaffing at the Trust that were described by many participants in the study in Chapter 3.

All staff involved in the implementation of the audit felt that not enough time had been given between the Trust receiving notice of the audit and the time the prospective audit was supposed to start. This meant that some of the junior doctors who were leading the audit in their specialties were not even recruited until after the start date. Some specialties felt that there were important procedures not included in the audit, which they decided to also collect data on. The absence of any patient identifiable data on the collection form made it impossible to check whether patients had been missed off or double counted, and impossible to validate any disputed SSIs. This coupled with the fact that data was only collected for patients diagnosed with SSIs rendered any other analyses, such as case-control or retrospective cohort studies impossible.

Nevertheless, all participants interviewed who spoke about the GIRFT audit felt that although the data quality was not as high as it could have been it had been a useful disruptive influence, raising the profile of SSIs significantly in the Trust and increasing engagement. The audit also generated some much-needed data and highlighted previously undetected high rates in some specialties.

4.1.2 Electronic surveillance systems (ESS)

As the use of electronic health records (EHR) increases, so too do the opportunities to automate some aspects of surveillance. Most electronic health records contain basic data on patient names, ages, procedures, and admission/discharge dates, and some also include diagnoses, drug charts, and microbiology data. There are also free-text notes, which could be automatically mined for information. All of this data could be automatically harvested in surveillance programs and could be used to flag patients for manual review (semi-automated) or an algorithm could be applied to identify SSIs for surveillance purposes.

4.1.2.1 Developments in ESS

In May 2017, an excellent comprehensive review describing the state of the art in automated and semi-automated surveillance of healthcare-associated infections (HCAIs) was published by Sips et al. [43]. The paper describes the data sources, algorithm development, and challenges associated with automating some or all aspects of surveillance.

The Sips paper divides data sources into structured, usually administrative coding data (ACD) such as ICD-10 codes and microbiology data, and unstructured, such as clinical signs and symptoms documented in non-systematic or free-text fields in EHRs [43]. Structured data sources are simpler to develop algorithms for, so most of the early attempts to automate surveillance focused on this method. However, their suitability as standalone surveillance systems is questionable.

The advantages and disadvantages of using ACD for detection of HCAIs were summarised in a Society for Healthcare Epidemiology of America white paper [112]. Briefly, ACD are widely used and therefore offer a chance to study large datasets, but are subject to recall, documentation and misclassification bias, and do not always capture the clinical context of the diagnosis (on admission vs. hospital onset) or the clinical rather than statistical significance of any findings.

The finding that ACD-based surveillance systems as standalone automated systems are not reliable was supported by subsequent systematic reviews by Goto et al. in 2014 [113], and van Mourik et al. in 2015 [114]. Each of these reviews found highly variable results in terms of sensitivity and specificity of SSI detection algorithms. However, the reviews did conclude that automation is useful in determining the denominator of patients undergoing a particular surgical procedure and could be integrated into a wider surveillance strategy. For example, an ACD-based system was used to trigger chart reviews in patients undergoing hip and knee arthroplasty which resulted in a 1.1- to 1.7-fold increase in SSI rate compared with traditional surveillance [115].

ACD is no longer the only type of structured data available for electronic surveillance systems (ESS). Electronic health records (EHR) are now more common, and there are multiple other data points contained in these which can be exploited for surveillance such as clinical signs and symptoms, antibiotic therapy, and microbiology data. Algorithms using these are less simple since the data is likely to need more cleaning than ACD but the addition of these parameters adds clinical context and temporality to the more crude options in ACD.

One major supposed benefit of ESS is an increase in standardisation and decrease in subjectivity of SSI diagnosis. However, this depends on which parameters are being entered into the algorithm. The most commonly used parameters have had some element of human decision making involved in their generation: for example, adding ICD-10 diagnosis codes, sending microbiology samples, prescribing antibiotics or wound debridement, and recording clinical signs and symptoms in the EHR all involve a

clinical judgment call on the wound to some extent. Nevertheless, except for ICD-10 codes these processes are all part of the routine treatment pathway for a patient with a suspected SSI, so in theory the "clinical judgment call" would always err on the side of caution, therefore increasing the sensitivity, but possibly reducing the specificity of any algorithms based on these parameters. This may explain the pattern observed in the de Bruin et al. systematic review of 2014 [116] which showed that when more parameters are added to ICD-9 or ICD-10 codes the sensitivity increases and specificity decreases. The de Bruin review also looked at trends in the data sources being used for ESS and showed that between the two periods from 2011-2006 and 2007-2011 systems moved away from a reliance on diagnosis codes towards microbiology and laboratory data, with a resultant increase in sensitivity and decrease in specificity.

In a systematic review on advances in electronic surveillance of HCAIs, Freeman et al. found 44 papers which met the inclusion criteria published between January 2000 and December 2011 [117]. Of these, eight studies looked at electronic surveillance system for SSI and four validated these methods against existing surveillance (Table 8). All papers included in this review used ICD-9 or ICD-10 codes as the method for determining SSIs.

Table 8 Performance of SSI detection algorithms based on administrative coding data. Adapted from [117]

PPV= positive predictive value, NPV= negative predictive value

Study	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)	Clinical Specialties
Brossette et al. [118]	60.0				Whole hospital
Chalfine et al. [119]	84.3(66.0-94.0)	99.9			Gastroenterology
Inacio et al. [120]	97.8	91.5	11.0	100.0	Orthopaedics
Spolaore et al. [121]			72.2 (69.0-76.0)		General surgery

It is also important to note that these electronic surveillance systems were validated against "true positives" and "true negatives" determined using manual surveillance methodology, which as discussed in 4.1.1 has its own issues.

Most of the interventions discussed above use classification or simple rule-based methods i.e. they apply a series of binary questions to the data to decide on the likely presence or absence of an SSI. Depending on the surgery type, rule-based algorithms can have variable accuracy, for example working better in arthroplasty [122] than colorectal patients [123]. More advanced algorithms now apply regression models to a wider range of parameters [124]. However, these algorithms again rely on the availability and accuracy

of multiple parameters, and require a bespoke end point to be chosen to determine the presence or absence of infection [43].

Advances in computing now mean that machine learning can also be used to help develop algorithms to detect SSIs in more dynamic way using traditional coded data but also analysing unstructured electronic data such as free text notes using natural language processing. Valuable information that can be used to help diagnose or detect SSIs can be hidden in the notes. This may include signs and symptoms such as dehiscence, redness, swelling or purulent discharge, or even a clinical diagnosis of infection that has not been given a diagnosis code. Sohn et al. successfully developed a usable algorithm using a Bayesian network coupled with natural language processing, which discovered a number of patients clinicians felt had been missed using traditional surveillance [123].

4.1.2.2 What makes a good algorithm?

Where the systems are for surveillance purposes and not intended to flag patients for treatment, it is not as critical to capture every patient as it would be if this algorithm had clinical implications. The surveillance systems based on ACD alone tended to have high specificity, but low or variable sensitivity. If surveillance is not fully automated, a high sensitivity and negative predictive value (NPV) would be preferable to high specificity as it would ensure as many potential SSIs as possible would be captured and excluded later, therefore maximising the number of SSIs detected. In a fully automated system, a high specificity and positive predictive value is more important, as including a large number of false positives in the overall rate would be misleading and would mask any real changes in rate. However, high sensitivity is still important as it may be difficult to see changes in rates over time if only a small number of serious SSIs are making up the rate.

If surveillance algorithms are to be used for identifying developing infections for early treatment, specificity becomes much more important than sensitivity. Ideally, an algorithm for this purpose should have a PPV of 100% and a sensitivity as high as possible and would function before the SSI becomes clinically apparent. This would allow patients who are developing an SSI to be treated with antibiotics as early as possible, in the confidence that there are no false positives. Any patients whose SSIs are not flagged by the algorithm because of low sensitivity would be treated when their symptoms become apparent, as is current practice.

How surveillance data will be used is also a factor when considering sensitivity/specificity trade-off of algorithms, i.e. whether for intra- or inter-hospital (benchmarking) comparisons. For intra-hospital comparisons, hospitals will want to ensure that their rates are as comprehensive as possible and would not be concerned if their rates appear high as long as the data are accurate enough to see meaningful trends. However, for benchmarking purposes a high sensitivity could make algorithms excessively sensitive to inter-hospital variation in the practices that generate data as discussed in 4.1.2.1 (such as microbiology

sampling practices or the language used to record signs and symptoms) that would affect the external validity of the data.

A seminal article by van Mourik et al. [125] re-examined the purposes of HCAI surveillance and explored how different surveillance modes could meet different aims. Van Mourik highlighted important conflicts in the aims of surveillance for the purposes of local quality improvement and the needs of national benchmarking or public reporting, namely the difference in the need for standardisation vs generation of actionable data (Table 9).

Table 9 Requirements of automated and semi-automated surveillance of surgical site infections to meet different aims. Adapted from tables 1 and 2, van Mourik et al. 2018 [125]

QI= quality improvement

	Aim of surveillance			
Performance Requirement	**Research (Hospital)**	**QI (Hospital)**	**QI/ Benchmarking (National)**	**Public Report/ Pay for Performance**
Clinical relevance and buy-in	x	x		
Actionable data (specific)	x	x		
Large-scale standardization			x	x
Reliable over time	x	x	x	x
Little vulnerability to financial incentives				x
Timely		x		
Risk adjustment	x		x	x
Semi-automated more suitable	x	x		
Fully automated more suitable			x	x

Van Mourik also goes on to discuss some of the challenges in the development and implementation of ESS on different scales [125]. For hospitals, the major challenges are insufficient information and communications technology (ICT) and IPC infrastructure, lack of funding, and the need for comparison and benchmarking with other hospitals. On a national scale, the high heterogeneity of hospital systems in what data is available and how it is stored and accessed is the most significant challenge, as it prevents the implementation of a universal ESS. On an international scale, the heterogeneity of hospital systems is magnified and compounded by the heterogeneity in healthcare models.

In May 2018, a novel systematic review was published which looked at the purported benefits of ESS for HCAIs of resource use for infection prevention activities [126]. In terms of the time taken to undertake surveillance, introduction of ESS reduced the time spent by IPC staff by 59.6% and 84.2% in the two studies looking just at SSI, and in those that included SSI alongside other HCAIs, by 60.6% – 98.4%. Where reported, the sensitivity of these systems ranged from 84% to 93%, and specificity from 88% to 100%, which is again

in line with findings of other systematic reviews looking at the validity of ESS. However, this is the first review to provide evidence that ESS can reduce the time burden of surveillance on staff, freeing up time to analyse and investigate trends in the data, and implement targeted SSI prevention strategies.

Given this potential for ESS to reduce resource use, it is vital to start to understand the barriers to adoption of ESS in greater detail and begin to develop strategies to overcome them.

4.2 Barriers and facilitators to adoption of new technologies using CFIR framework

Adoption of innovation in the healthcare systems has long been recognised as a slow and problematic process, and the implementation of automated and semi-automated surveillance systems for SSIs is no exception. Despite the wealth of data supporting the use of automated and semi-automated surveillance to augment traditional methods of surveillance for SSIs, adoption of these technologies has been slow. It is useful to consider the barriers and facilitators through a framework.

4.2.1 Consolidated Framework for Implementation Research (CFIR)

The Consolidated Framework for Implementation Research (CFIR) was derived from multiple other theories on implementation to help plan and analyse barriers and facilitators to implementation on multiple levels [127] (see Appendix 10 for further details on domains). It is therefore a highly comprehensive framework for analysing factors related to the diffusion, adoption, and implementation of innovations.

As a consolidated framework based on existing work, the CFIR framework shares many of the major domains with other established theories. Work by Greenhalgh et al. in the early 2000s examined the adoption and diffusion of innovation in the health service and other service organisations and concluded that the main domains innovation, adopters and adoption processes, communication and influence, inner context, and outer context [128,129]. These domains map almost exactly on to the five main domains of the CFIR: innovation characteristics, characteristics of individuals, process, inner setting, and outer setting. However, the CFIR splits communication and influence between the inner and outer contexts depending on whether the communication is intra- or inter-organisational. The CFIR also separates the adoption processes from the individual characteristics of the adopters.

One major established theory relevant to the adoption of ESS in healthcare is the normalisation process theory, which has been recommended as a tool to help evaluate complex interventions [130]. Normalisation process theory seeks to explain how innovations are adopted and accepted into routine practice to the point where they become normalised. However, all of the domains of this theory (coherence, cognitive participation, collective action, and reflexive monitoring) are person-centred and do not give enough weight to the existing context and infrastructure than can influence innovation adoption.

Other work by Denis et al. sought to explain why the diffusion of some innovations is supported more than others [131]. The authors concluded that interests, values, and power distribution influence the extent to which innovations are supported. These domains are represented in the CFIR in a number of smaller constructs such as rewards and incentives, culture, peer pressure.

4.2.2 Analysis of barriers and facilitators

In order for new technologies in SSI surveillance to be adopted there must be changes on every level, from individual buy in through team, hospital, and regional structure and support to national and international reporting requirements.

In an article from 2015, Hebden commented that the slow adoption of ESS for HCAI could be related to human factors and examined the possible reasons behind this through the Systems Engineering Initiative for Patient Safety model [44]. Human factors is the study of the interactions between humans, machines, and their work environment. Analysis of examples of ESS implementation through this model suggest that ambiguity in the areas of tasks, responsibilities, methods, expectations, and exceptions could be contributing to the slow adoption of ESS in the USA [44]. These concepts and others will now be reframed within the domains of the CFIR to explore barriers to adoption from the micro to the macro level. Most of the literature on adoption of ESS focuses on the interventions themselves rather than their adoption or implementation, so this section will look at what evidence there is and go on to discuss what the barriers and facilitators could be based on similar interventions.

4.2.2.1 Construct I: Intervention Characteristics

For this analysis, I will consider intervention characteristics to mean the design and features of any ESS that may be adopted in a hospital. The ways in which it fits with workflow and other implementation-related considerations will be discussed in 4.2.2.5.

The first aspect to consider in the CFIR framework is the intervention source, or whether the intervention is perceived as being from an internal or external source. Perceptions by those making the decisions around adoption of ESS, or by end-users on whom the intervention is imposed can have an impact on the acceptability of the intervention and can affect the attitudes towards it. In the case of ESS, these algorithms are often developed by researchers who may or may not have an affiliation with a healthcare or public health institution. Some are developed by external companies. The acceptability of an intervention is likely to be influenced by the reputation and existing relationships between the designers and the users.

The quality and strength of evidence is an interesting concept, as the evidence for the accuracy of ESS, and particularly semi-automated surveillance, is promising [43] and likely to improve in the future as technology advances. However, the perceptions of this evidence among those looking to adopt ESS are equally important. As discussed in *Managing Innovation in Healthcare p182-183* [132], the perceived strength and

quality of evidence depends on the needs of the person reviewing the evidence: surgical staff may want evidence that ESS will accurately adjust for case-mix and risk, so that they can reliably compare their own rates with their colleagues; IPC staff may want to see evidence that the ESS is not inferior to their current surveillance; managers may need evidence on the cost-effectiveness of the intervention; national and international public health bodies will need evidence comparing the intervention in multiple settings to ensure standardisation. The research discussed in the previous section tends to present evidence to the developer's satisfaction of the algorithm performance compared with gold-standard. Such evidence may not satisfy all stakeholders.

The main competitor for ESS in England is currently manual surveillance using the SSISS protocol. The advantage for hospitals of the status quo over adopting a new ESS is the ability to submit this data for national benchmarking, and therefore gain an understanding of their SSI rates relative to similar hospitals. Other advantages may be the perceived greater accuracy of manual surveillance and the ability to collect extra data or perform other clinical tasks at the same time as collecting data for SSI surveillance. However, there are a number of advantages to the ESS, namely the demonstrated reduction in time and resource required for surveillance [126] and concurrent gain in opportunity costs. ESS may also in the future be able to demonstrate gains in accuracy over manual surveillance due to the more accurate capture of the denominator [115]. An important point to note is that there are no penalties or incentives attached to SSI rates in England.

The ability to adapt ESS to individual settings may prove to be one of the larger barriers in adoption since one of the supposed advantages of ESS is a reduction in variation based on increased standardisation [125]. Nevertheless, there is unlikely to be any option but to adapt systems to a certain degree, as the wide heterogeneity of hospital ICT systems and organisational structure mean it is currently impossible to implement a one-size-fits-all ESS for SSI surveillance.

On an individual hospital or NHS trust basis, trialability may be one area that could be capitalised on, since there would then be opportunities to adapt the intervention itself and its implementation based on the feedback of staff. This may be more difficult to achieve if adoption was being imposed nationally, particularly if a decision was made to enforce strict protocol adherence.

One of the most obvious aspects for the end users of the intervention itself is the physical design attributes. Systems could involve a user-facing dashboard or other data visualisation platform, or for semi-automated surveillance, a data entry portal. Alternatively, all activity could be undertaken by data managers, with HCPs and IPC staff only seeing final reports; the structure of these reports would then be the user-facing part of the intervention.

Various aspects of tasks were highlighted by Hebden as being a source of ambiguity in the adoption of ESS for HCAIs [44], such as how to retrieve and manage the data, whether the data are reliable, and how they

should be standardised. The former two tasks may be a particular challenge if a new platform or software is being used for the ESS, as end-users will have to first get to grips with the software itself.

4.2.2.2 Construct II: Outer Setting

For the purposes of this analysis, I will consider the outer setting to mean the setting outside NHS hospitals such as primary care or other care settings, governmental organisations (PHE, Department of Health and Social Care, local councils), non-governmental organisations including charities and patient groups, the wider social and economic context (wider political environment, current affairs, media, national economy), international and global organisations (European Centre for Disease Prevention and Control, World Health Organisation), and any other organisation or circumstances that could have an impact on NHS hospitals.

Data submitted to the national SSISS must be collected according to the standardised manual protocol, so there is little incentive for hospitals wishing to report to the SSISS to adopt new surveillance technologies. However, there is evidence that hospitals are still deciding to undertake their own in-house surveillance [10]. The implication of this is that there are circumstances in which hospitals prioritise data collection for their own quality improvement purposes over national reporting. Nevertheless, it would be a wasted opportunity to collect this data on a national level if hospitals were to decide to adopt ESS.

The extent to which peer pressure and cosmopolitanism is a factor in the barriers and facilitators to ESS adoption are more obscure. A study which used the CFIR to analyse implementation of enhanced recovery pathways in surgery did not find peer pressure to be an important driver, but did find that the lack of peer networks could have contributed to the slow adoption of enhanced recovery pathways as it impeded peer learning opportunities [133]. This could perhaps be a learning point for ESS adoption.

The impact of patient perceptions is likely to have more of an impact when SSI rates are being used for public reporting, as patients who have a choice could potentially avoid hospitals with higher SSI rates, though a Cochrane review on the impact of public release of performance data on patient behaviour was inconclusive [134]. If hospital staff or managers feel there could be consequences to the public perception of their hospital based on inaccurate SSI rates from ESS there may be resistance to adoption.

4.2.2.3 Construct III: Inner Setting

The inner setting in this analysis is defined as NHS hospitals.

One of the biggest influences on the type of ESS that can be implemented in a setting is the ICT infrastructure and data storage and access arrangements. Communications and ICT infrastructure in the NHS is notoriously poor, with hospitals still reliant on fax machines, pagers, and computers running Microsoft XP in 2018 [135], and each hospital chooses its own systems, therefore there is a great deal of heterogeneity. This makes it extremely difficult to design a universal system that can be easily implemented in any hospital, and Sips suggests that informational infrastructure is the main barrier to ESS adoption [43].

The organisational structure will also have a huge impact on the adoption process – decisions around adoption will be made by different people in every hospital, with various different procedures for approval. A large multicentre study in the USA found organisational support for ESS in HCAIs measured on a quantitative scale to be the major predictive factor in the presence and use of ESS, and also correlated strongly with user satisfaction [136]. The authors here used a survey tool based on institutional organisation and support, senior management engagement, and leadership on patient safety, but there may also be more tangible forms of support in terms of investment for infrastructure, access to expertise, and human resource that are important in ESS adoption.

The expectations of organisational support were also commented on by Hebden as an area of ambiguity [44], since the lack of clear leadership engagement and material support from hospital managers can lead to a lack of confidence in the sustainability of ESS. Managers may also expect IPC staff to demonstrate a reduction in SSI rates, and perhaps a return on investment from reduced clinical costs. Staff are unsure what to expect from the managers, and are unsure what managers expect from them.

The infrastructure for any existing surveillance, and the existing IPC structure could influence the different models and approaches taken in different hospitals. One of the areas of ambiguity identified by Hebden was that of responsibility [44]. Hebden postulates that ambiguity of responsibilities is partly a product of the amount of different departments and stakeholders who are involved in developing and using the system, and that good communication between all of these departments, as well as formal designation of authorities and responsibilities, is the key to reducing ambiguity [44].

Multiple factors to the do with the culture and organisational memory for experience with previous interventions will alter the decisions made around adoption and implementation. Likewise, the current climate including relative priority of SSI surveillance alongside multiple other priorities will be a factor, both for managers and for frontline staff. Data collected in the recent national GIRFT audit on SSI rates may be useful in gaining buy-in to create tension for change [36].

Once the decision has been taken to adopt an ESS, the actual aim of surveillance in improving the quality of care and patient safety will be achieved through the processes put in place for using the data, feeding back to surgical teams, and setting goals. The existing research around using SSI surveillance data for quality improvement suggests that feeding back these data alone without additional programs to identify what is causing the high rates and provide guidance on how to improve are insufficient [94]. A comprehensive study on performance indicators in anaesthetics found that feeding back basic data actually caused deterioration in these indicators, and only when enhanced feedback was provided was an improvement seen [41]. Thus, it is vital that evaluations of these systems are carefully planned to capture unintended consequences.

4.2.2.4 Construct IV: Characteristics of Individuals

Characteristics of individuals includes any individual involved in the adoption and implementation process of an ESS. This could include non-clinical managers or budget holders, clinical staff, ICT staff, or even patients.

The characteristics of the individuals are perhaps the most variable domain that could impact adoption of ESS. Each individual will have their own set of competencies, beliefs, and insecurities that affect their attitudes towards adoption of ESS. Attitudes to change in general, but also in particular to change in their job or workflow could hold a lot of weight particularly for staff who are currently involved in surveillance or for those who will ultimately be the end-users. Likewise, how readily and quickly they are able to pick up new skills, their self-efficacy, and their own engagement with technology may be important considerations for end-users. Knowing how to deal with the unexpected is an important trait, and is related to another area ambiguity highlighted by Hebden: exceptions [44]. There will undoubtedly be times where things do not go to plan, where cases do not fit the algorithm or where the algorithm does not fit with practice. Individuals will need to understand how to deal with these exceptions.

Some aspects of ambiguity in expectations may also come in to play on an individual basis [44], in particular in relation to an individual's identification with an organisation. Where an individual feels there is an underlying lack of support by the organisation, introducing a disruption to their workflow could lead to disengagement or even hostility. This is particularly the case if an individual perceived the intervention as being imposed in a top-down fashion, therefore engagement of all stakeholders from an early stage is crucial.

4.2.2.5 Construct V: Process

In contrast to individual characteristics, the implementation process is the domain which is the most easily controlled. This begins with explicit formal planning of the implementation process, which could use some or all of the following components.

Stakeholder engagement has emerged repeatedly throughout this discussion in various guises: securing organisational support and leadership engagement, maintaining lines of communication between departments to help delineate responsibilities, and engaging end-users early to reduce the sense of top-down imposition. These all come under the main bracket of ensuring all stakeholders are engaged as early as possible. The stakeholders will differ in each setting but is likely to comprise a minimum of IPC, current surveillance team, surgical leadership, senior managers, ICT and/or data managers, and end-users of the ESS.

A qualitative study at a centre in Canada investigated the impact of an individualised audit and feedback model involving process measures of SSI prevention [40]. This study found that the intervention lacked

leadership and did not foster multidisciplinary engagement. This could be a risk of implementing ESS, so future studies could benefit from a formally appointed internal implementation leader. Hebden also recommended the identification of "super-users" and champions to encourage engagement and provide a point of contact for information and guidance [44]. National program, or hospitals using a commercial ESS could also consider using external change agents to facilitate implementation.

Finally, as alluded to earlier, any implementation of ESS must include a well-planned evaluation which is designed to capture unintended consequences such as an increase in rates and changes in coding, recording, or wound sampling practices. Evaluations should use both quantitative and qualitative methods and should also evaluate the implementation process as well as the intervention itself so that settings can learn from each other. Economic evaluations would also help build a case for ESS in settings where it would require considerable investment.

4.3 Future of engagement

Many clinical staff are moving towards electronic systems as part of their workflow, both in a top-down fashion due to the introduction of EHRs and other electronic systems, but also in a bottom-up fashion. An example of bottom-up technology adoption is the widespread use of WhatsApp for communicating clinical information among surgeons [137]. Surgeons are also increasingly using social media platforms such as Twitter for professional engagement [138], and in 2016 I personally conducted a study on the use of blogs for professionals in the field of infectious diseases [139]. As HCPs continue to embrace new technology on a personal level, the gulf between the technology currently in use for SSI surveillance grows wider, and the calls to automate at least some of the processes is likely to grow louder.

In addition to using technology in the *analysis* of data, it is also now possible to use technology to *collect* data on signs and symptoms of SSI. Back in 2007, a wearable network of body sensors was developed at Imperial College for the purpose of monitoring post-operative recovery [140]. However, yet again there were barriers in hospital information systems that prevented adoption. Wearable technology for monitoring vital signs such as heart rate and body temperature have moved on since 2007 and are now widely available to the general public. These have been postulated for use in remote monitoring in geriatric care [141], but could be useful for monitoring SSIs in hospital and post-discharge if they could be networked to electronic records.

There are also improvements in wound dressing technology not only for prevention or treatment of SSI but also for detection of SSI. Technology has existed for some time now for colour changing smart dressings to indicate the development of an SSI which could help in detection of SSIs and could form a further source of evidence in medical records, but more recent developments in the field have led to dressings with sensors capable of transmitting data about the wound such as temperature and pH to electronic systems

[142]. This technology has been developed for remotely monitoring chronic wounds but could also be used in monitoring SSI development.

4.4 Discussion and conclusion

By analysing the possible barriers and facilitators to ESS using the CFIR framework, it is clear that the main barriers to adoption are to do with the "inner setting" i.e. hospitals. The heterogeneity of ICT systems in hospitals make standardisation a considerable challenge, and the variability in organisational support has a significant impact in the adoption and use of ESS. Once the decision to adopt ESS has been made the intervention characteristics will become more important, such as the design of the system and the way it fits with workflow. This analysis also found that multidisciplinary engagement from the start as an integral part of the process is crucial to the design of the intervention and could help to account for the different individual characteristics of the different stakeholders, ensuring that all stakeholders feel included throughout.

Evaluations of ESS should be designed to produce evidence that meets the needs of the various stakeholders, so should include economic analysis and a system to capture unintended consequences. These data also need to be shared across multidisciplinary networks to facilitate learning, and to expedite adoption by increasing peer pressure and cosmopolitanism.

There are fundamental differences in the requirements for surveillance depending on its purpose. For hospitals, the key aim is to generate actionable data with internal validity for quality improvement purposes. On a national and international scale, data collection must be standardised to ensure external validation and benchmarking, particularly if there are incentives and penalties involved.

In light of this, one possible solution also suggested by van Mourik et al. [125] is to have different surveillance systems operating in parallel to meet these different needs. To account for heterogeneity and resource limitations in the inner setting, the conflicting needs of the inner and outer settings, this could possibly be achieved using a hybrid system. Such a system could involve data harvesting using an algorithm optimised for semi-automated surveillance (i.e. with maximal sensitivity and negative predictive value) designed to meet the needs of each hospital. A further standardised algorithm with high specificity using ubiquitous data such as ICD-10 codes could then be applied to the patients flagged as possible SSIs to generate data for national benchmarking. The advantages of this would be that useful data are generated for hospitals in a less resource-intensive way that for manual surveillance and would retain some of the clinical judgement in the diagnosis of SSIs, but by applying the fully automated algorithm on a smaller population with artificially increased prevalence, the positive predictive value could be maximised.

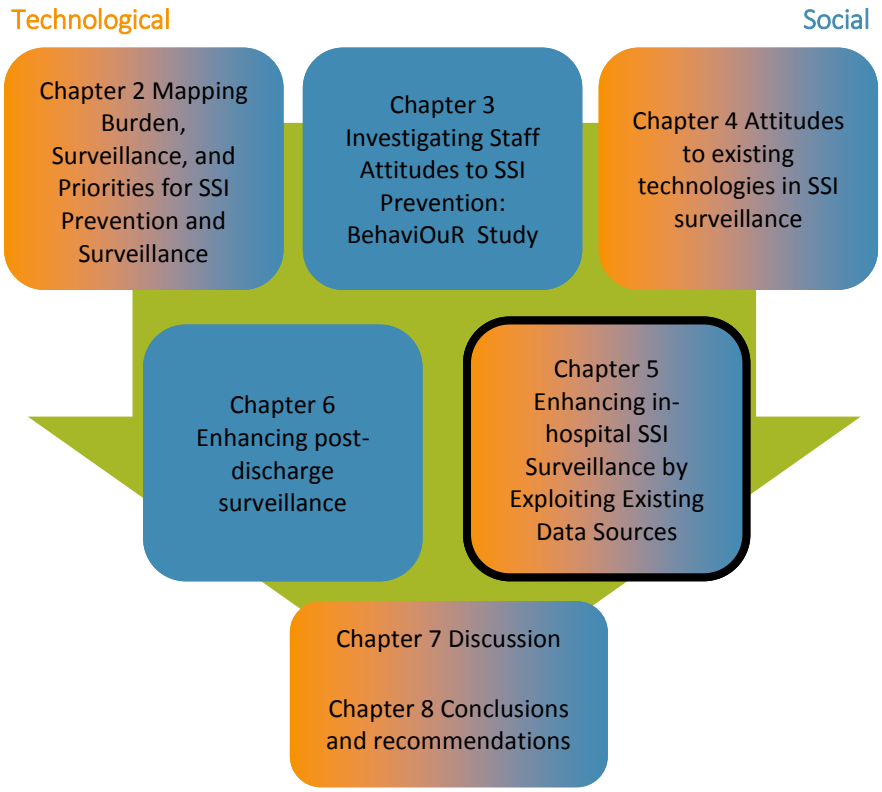
One advantage of this system would be that each hospital could personalise the initial part of the algorithm based on their own ICT infrastructure. The local algorithm would simply need to meet certain requirements

for sensitivity to ensure that all possible SSIs would be contained within the sample put forward to the automated national algorithm.

Chapter 5. Enhancing in-hospital SSI Surveillance by Exploiting Existing Data Sources

Summary

Having explored general barriers and facilitators to technological innovation in SSI surveillance, this chapter uses a case study at Imperial College Healthcare NHS Trust (ICHNT) to look in more detail at some of the things that can and do go wrong with implementation. It follows the development of an in-house surveillance system from planning, design, testing, and the attempted rollout. Barriers and facilitators are examined again through an established framework. The work in 5.4.1 was presented at the Public Health England Research and Applied Epidemiology Scientific Conference 2017 in Warwick.



5.1 Background

There is a global need for high-quality surveillance but with low resource use. As the staff who carry out SSI surveillance are usually trained and experienced nurses or other healthcare professionals (HCPs) their time is a valuable and therefore costly resource. As electronic health records (EHRs) begin to supersede paper notes in many healthcare systems across the world the prospect of automating some of the processes involved in SSI surveillance in order to free up more of this valuable staff time for feeding back rates, identifying trends, and working on SSI prevention activities is very attractive, and several companies, healthcare providers, and research groups have been working on algorithms for this purpose.

At ICHNT, SSI surveillance is undertaken continuously for hip and knee replacements and cardiac procedures following the protocol for the Surgical Site Infection Surveillance Service (SSISS), and data is reported quarterly. Two full-time specialist SSI nurse post exist, one in orthopaedics and one in cardiac surgery, but due to recruitment problems the post in cardiac surgery there was a gap in surveillance. The post was never filled, and the surveillance duties passed to the lead nurse in addition to her usual responsibilities, and the funding for the post was frozen. These issues of staff turnover, difficulties in recruitment, the reliance of one person to collect data, and the difficulties in convincing budget holders of the importance and cost-effectiveness of surveillance are not uncommon. To extend this type of manual surveillance to other specialties would be prohibitively expensive and resource intensive and would be subject to the same challenges. Therefore, ICHNT has been exploring semi-automated surveillance methods to create a simple, reliable, reproducible method for retrospectively identifying suspected cases SSI among inpatients from routinely collected hospital data.

5.2 Development

5.2.1 Staff survey of SSI surveillance

Following a period of high SSI rates in cardiothoracic surgery in the Trust, the Surgical Infection Group (SIG) set about putting together a business case to improve SSI surveillance. This presented the perfect opportunity to research staff attitudes towards SSI surveillance while collecting useful, actionable data for the SIG to use when designing the surveillance strategy.

5.2.1.1 Methods

A short survey was constructed in order to canvas opinions from the spectrum of surgical specialties. The survey had several aims:

1. To compare surveillance priorities in the Trust to those identified by a national SSISS survey [10]
2. To gather data on competing priorities and capacity for surveillance
3. To assess how different surveillance models would be perceived by staff

I developed the content of the survey in collaboration with Dr Giovanni Satta, lead consultant microbiologist and chair of the SIG, with comments from other members of the SIG and the chair of the Surgical Outcomes Group (SOG). Questions that were posed for comparison with the PHE survey were copied verbatim from the original survey. A preliminary question asked for participants' consent to publish their anonymous responses in journal articles, reports, or a PhD thesis, and only those who agreed could continue to the survey (Appendix 11).

The survey link was distributed by Dr Satta in his capacity as Chair of the SIG. The distribution list for the survey included all members of the SIG group with representation from infection prevention and control (IPC), microbiology, and pharmacy, all consultant surgeons in the Trust, and the lead nurses in surgery,

specialist surgery, cardiac, trauma, and critical care. Participants were encouraged to circulate the survey further to other staff involved in the care of surgical patients.

A reward of a £50 gift voucher was offered to incentivise participation. The survey was first emailed out in February 2017, with a reminder sent two weeks later. The survey was closed to responses at the end of April 2017.

5.2.1.2 Results

The survey was emailed to 94 staff members, though some passed the survey on to others. There were 17 responses to the survey overall giving a response rate of 18%, which are detailed in Table 10. Surgeons were the most represented group, although five responders did not detail their staff group.

Table 10 Breakdown of responders to the ICHNT staff survey on SSI surveillance by staff group

Staff group	No. responders
Maternity	1
IPC nurses	2
Pharmacists	3
Surgeons	5 (obstetrics & gynaecology, max/fax, head and neck, neurology)
Infection specialist	1
Not disclosed	5
Total	**17**

When asked if SSIs were a priority for the team they worked with, 76% of respondents stated that they were a priority. Those who said SSIs were not a priority said that lack of beds and activities around the World Health Organisation's Surgical Safety Checklist were higher priorities.

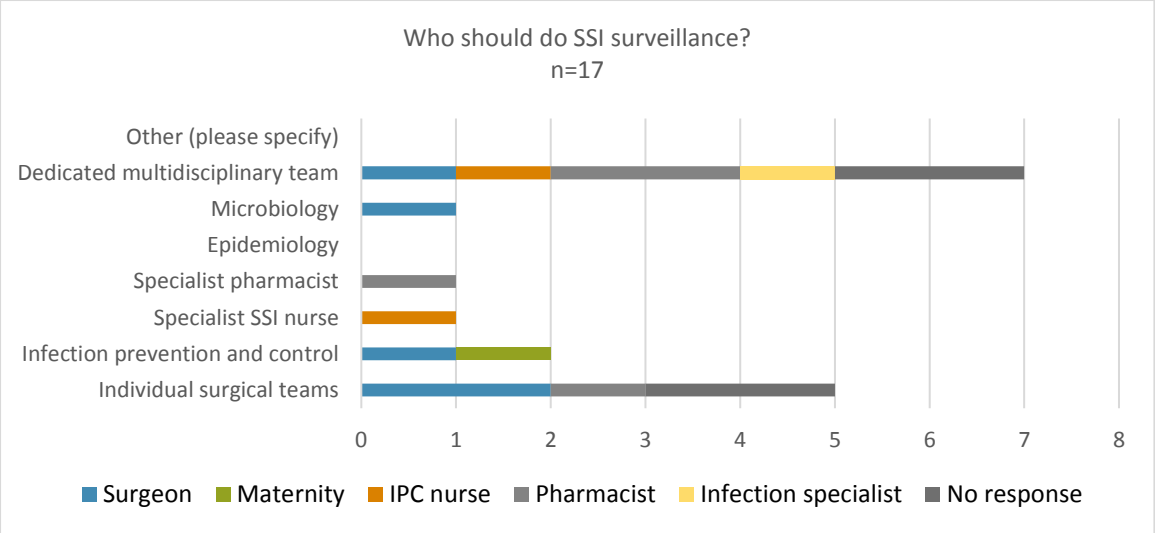


Figure 7 ICHNT staff responses to the survey question "who should do SSI surveillance?"

Part of the purpose of the survey was to ascertain which model of surveillance should be adopted for the Trust-wide surveillance strategy. Of the options which had been suggested in discussion with the SIG, a dedicated multi-disciplinary team was the most popular choice, followed by individual surgical teams (Figure 7). Most respondents (12, 70%) felt that their team did not currently have capacity to do SSI surveillance, but five of these felt that they could do if given extra resources in terms of funding, protected time, or multidisciplinary input. One participant reported that funding for their SSI nurse had been cut:

> *You took away the funding for our SSI nurse and guess what- the SSI rate went up- genius… We had a well-established SSI programme that fed into national figures that could be used as comparators. Due to withdrawal of funding we can no longer do this*
>
> Role/specialty withheld

The other five respondents (29%) felt that their team was already adequately resourced to take on additional surveillance duties.

The survey then went on to ask what kind of outputs staff would want to see from an expanded surveillance system. The responses fell into four categories:

- rates (adjusted) and trends by theatre, day of the week, or individual surgeon analysed
- number of excess bed days due to SSI, readmissions, other outcomes related to success of surgery
- increased engagement from top to bottom and quality improvement initiatives
- drug sensitivity and resistance data

Staff were then asked to rank their top five priorities for SSI surveillance at the Trust, assuming no mandatory requirements. This question was taken from the SSISS survey [10] discussed in Chapter 2 so as to be comparable with the data gathered on a national scale. For each response, points were assigned to each selection, with the top choice receiving 5 points, second choice 4 points etc. in the same fashion as the national survey [10]. A weighted average was then calculated for each surgical category, and the results are shown in Table 11. The highest weighted average score was for solid organ transplant, in contrast to the national top priority of caesarean section (CS). This may be due to ICHNT performing a large number of specialist transplant services and hosting the largest renal transplant centre in Europe [143]. However, CS was still ranked highly by staff at ICHNT. Reduction of long bone fracture (RLBF) was the second highest ranking category, which is one of the mandatory categories offered in the SSISS, but ICHNT currently chooses to report hip and knee replacements instead, which also ranked highly but below RLBF.

Table 11 ICHNT staff survey answers to the questions "Please rank what you believe to be the top five priorities for SSI surveillance in the Trust, assuming no mandatory requirements" (n=12). The weighted average was zero for the following categories: cholecystectomy, gastric, herniorrhaphy, maxillofacial/ENT/oral, oesophageal, pacemaker, prostate, renal/urology, splenic, and thoracic surgery.

ENT= ear, nose and throat.

Category	Weighted Average
Solid organ transplant	5
Reduction of long bone fracture (RBLF)	4
Abdominal hysterectomy	3.83
Caesarean section (CS)	3.67
Appendicectomy	3.5
Large bowel surgery (LBS)	3.25
Hip replacement	3.2
Knee replacement	3.2
Breast surgery	3
Coronary artery bypass graft (CABG)	3
Limb amputation	3
Small bowel surgery	3
Spinal surgery	2.67
Vascular surgery	2.67
Cranial Surgery	2.6
Cardiac (non-CABG)	2.5
Bile duct, liver and pancreas	2
Neck surgery (e.g. thyroid, tracheal)	2
Ventricular shunt	2
Repair neck of femur	1
Shunt for dialysis	1

Some staff gave suggestions on how SSI surveillance could be improved. On top of previous requests for protected staff time, and several calls for a dedicated surveillance team, some suggested that SSI rates become part of appraisal requirements for surgeons. One respondent requested that more information was given when protocols were changed, and finally one respondent suggested existing data should be used in semi-automated surveillance and suggested antibiotic prescription data could be useful for this.

Use existing data, particularly around antimicrobial stewardship to help look for SSI concerns. e.g. use antimicrobial consumption and triggers (i.e. increase in 2% -> investigation) Use Cerner to help embed antibiotic protocols into surgical speciality care plans

Pharmacist

5.2.1.3 Discussion and implications for implementation of surveillance

The low response rate to this survey means these views are unlikely to be representative of staff at ICHNT as a whole, but there are some interesting ideas and suggestions which are useful nevertheless. The most popular surveillance model was a dedicated multidisciplinary team, which was the preferred model of the SIG. Votes for different models did not appear to be related to staff group, though the sample size was too small to test this. The comment from one participant that it would be interesting to see the number of bed days incurred by SSIs was interesting and agrees with one of the findings of Chapter 3 that staff tend to see SSI rates as more of a process measure, with the actual outcome being the harm done to the patient. Responses to the question on capacity were interesting, with some participants indicating that they could make do with existing resources, and some responding that they would like additional resources, and one responding with strong feelings about resource cuts. Ultimately, all of these responses indicate that some staff would like to be more engaged in SSI surveillance.

5.3 Data sources and proxies

By September 2015 at the commencement of this study, the rollout of electronic patient records for notes, microbiology, and prescribing was largely complete at ICHNT. This afforded a number of data sources and opportunities for partially automating surveillance.

5.3.1 Procedure codes

Procedures are coded according to the OPCS[1] Classification of Interventions and Procedures version 4 (OPCS-4, hereafter referred to as OPCS codes), which record all inpatient and some outpatient interventions. These codes form a major part of the billing and reimbursement system, which is how hospitals receive their funding from the NHS, and because of this, it is important that all procedures are captured accurately. Inpatient procedure codes are recorded in the Cerner (Cerner Corporation, Kansas City, Missouri, USA) EHR software, which forms part of the patient administrative system (PAS) at ICHNT. When procedures are scheduled, a provisional code is entered into the SurgiNet® (Cerner Corporation, Kansas City, Missouri, USA) system. Once the procedure is completed, the patient's notes are written up and sent to medical coders who ascertain which procedures have been performed and input the correct OPCS codes onto Cerner. Since often surgical procedures to do not go to plan because of cancellations, or

[1] The OPCS acronym has been retained from a predecessor coding system produced by the Office of Population Censuses and Surveys, which is now defunct

problems arising in theatre, this step enables only the procedures that have actually taken place to be recorded and billed for by the hospital. At ICHNT, this process usually introduces a time lag of around one month between the surgical procedure and the code becoming available in Cerner, but provides a relatively clean, searchable dataset of surgical procedures in the Trust.

5.3.2 Diagnosis codes

Version 10 is the current version of the International Classification of Diseases codes (ICD-10) introduced and maintained by the World Health Organisation, which is used by hospitals globally, including ICHNT, to record diseases, disorders, signs and symptoms, injuries, and other health conditions [144]. Again, this is a standardised and comprehensive list which can be used to identify possible diagnoses of SSIs. These codes are input by medical coders based on what is recorded in a patient's notes, discharge letter etc. By searching for specific ICD-10 codes, it may be possible to identify possible SSIs occurring after surgery at ICHNT, although the various papers discussed in Chapter 4 suggest ICD-10 codes are highly specific for SSI but not sensitive enough to be used alone. However, one advantage of using ICD-10 codes is generalisability as they are fairly ubiquitous in healthcare settings, particularly in England where NHS hospitals use both OPCS and ICD-10 codes as standard. At ICHNT, both of these coding systems are attached to the EHR and can be matched using NHS number or hospital number. Unfortunately, diagnosis codes do not have any temporal indicators – they relate only to a spell with no indication of when that diagnosis was made, which can make determining an SSI difficult if the spell lasts longer than the SSI definition period of 30 days (one year if an implant is used).

5.3.3 Microbiology

Practices for recording microbiology data are much less standardised than for procedure and diagnosis codes. At ICHNT, samples sent to microbiology are recorded in the Sunquest laboratory information system (Sunquest Information Systems Inc., Tucson, Arizona, USA). Codes are allocated for sample type (blood, tissue biopsy, wound swab etc.), and codes are also used to indicate the result of culturing in terms of whether bacteria were grown and their species.

Usually growth of bacteria from a theoretically sterile site would indicate a positive result of infection, but for SSIs this is not usually the case, as there are likely to be some bacteria present on the skin. Therefore, a result of bacterial growth from a surgical wound sample is not necessarily indicative of an SSI, particularly results which refer to skin flora or bacteria frequently found on the skin such as *Staphylococcus epidermidis*, which could be contaminants, colonisers, or causative organisms. Additionally, a finding of no bacterial growth does not necessarily rule out SSI because of incorrect sampling practice, antibiotic exposure prior to sampling, or bacteria that are difficult to culture. In the case of the recent *Mycobacterium chimera* outbreak in cardiothoracic surgery [145], the bacteria have specific culture requirements and require a separate specialist test. For this reason, routine microbiology tests did not detect these bacteria which delayed treatment and epidemiological investigations.

5.3.4 Treatment

In-hospital treatment pathways for SSI can take many forms and treatment depends on the individual risk-benefit analysis for the patient and aspects related to the surgery such as involvement of any implants in the infection, and whether the intended outcome of the surgery has been adversely impacted by the SSI. The different treatment options and how they are recorded at ICHNT are presented on a scale below from least to most severe, though not all are appropriate for all patients, and do not necessarily follow on from each other.

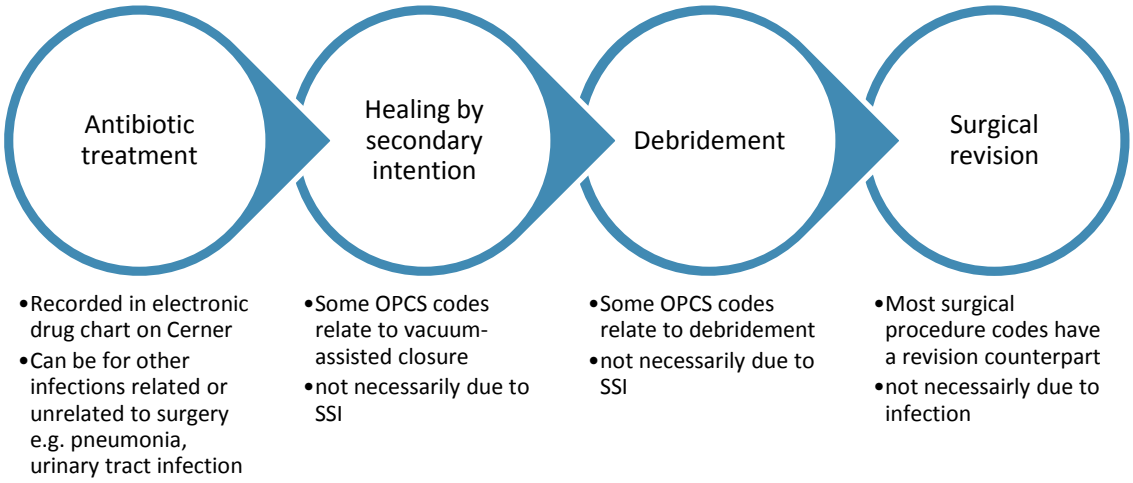


Figure 8 Possible treatment options for SSI at and where these are recorded in the electronic patient record at ICHNT

Most of these treatment options will have some evidence in the EHR, but none of them are treatments uniquely for SSI.

5.4 Case study of semi-automated surveillance at ICHNT

Semi-automated surveillance was developed in close collaboration with the Trust's Surgical Infection Group and formed part of a business case to increase coverage of SSI surveillance. Because of this, the study to implement and pilot the app was deemed a service evaluation and was approved and registered by the Trust's Clinical Audit team (service evaluation no. 158) with the aim of evaluating the usefulness, acceptability and sustainability of electronic surveillance using qualitative and quantitative methods.

5.4.1 Algorithm development

5.4.1.1 Aim

The aim was to validate a simple algorithm linking routinely collected electronic health data against data collected by the SSI nurse for the Public Health England Surgical Site Infection Surveillance Service (SSISS).

5.4.1.2 Methods

Coronary artery bypass graft (CABG) was chosen as the validation procedure because data collected for the SSISS can be used as the gold standard, and CABG surgery has an infection rate high enough to be able to validate the test. The year chosen was Jan-Dec 2014, as this was the most recent year for which complete data were available at the commencement of the study.

Firstly, the algorithm identified patients undergoing CABG surgery by searching for OPCS codes relating to CABG between 1st Jan 2014 and 31st Dec 2014 in the admissions data to create an initial patient list. These OPCS codes were taken from the SSISS procedure code supplement [51]. The pathology system was then trawled for patients receiving a "test of interest" (e.g. wound swab culture, drain fluid culture, blood culture) which were selected through consultations with specialist microbiologists.

Four validation tests were carried out:

1. CABG OPCS code + test of interest within 30 days
2. CABG OPCS code + test of interest within 90 days
3. CABG OPCS code + test of interest within 30 days + growth of bacteria (excluding "skin flora")
4. CABG OPCS code + test of interest within 90 days + growth of bacteria (excluding "skin flora")

The data were compared with the SSISS data as a gold standard, and the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated.

5.4.1.3 Results

The algorithm found 423 patients undergoing a CABG procedure in 2014 by searching for relevant OPCS codes, 407 of whom were identified in the SSISS data. However, 12 of the unmatched patients also had a pacemaker implanted, which is specifically excluded from the SSISS, leaving 4 patients unmatched.

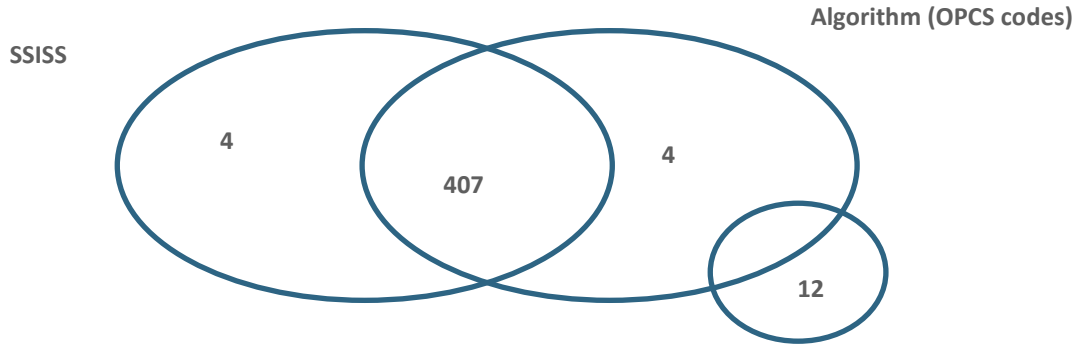


Figure 9 Comparison of CABG patients identified in PHE data (SSISS) and those found by the algorithm.

407 CABG patients were found by both manual and the automated method. 4 patients were found by SSISS which were not found by searching for OPCS codes because no relevant code existed in the electronic record. 16 patients were found by OPCS code search which were not recorded in the SSISS data, though 12 of these were likely excluded because of concurrent pacemaker placement.

Additionally, there were 4 patients who appeared in the SSISS data who were not identified by the algorithm. Further investigation revealed that these patients did not have an OPCS code that related to a CABG procedure.

Using the algorithm to obtain data on CABG patients from the pathology system retrieved data for 114 of the 423 patients. The SSISS data reported 10 SSIs in patients undergoing CABG at ICHNT in 2014. Only 9 of these patients were among the 423 found using OPCS codes. The tenth patient did not have a matching OPCS code. However, this patient was manually added into the validation to accurately reflect this shortfall in the algorithm.

Test 1	**Disease +**	**Disease -**	**Total**
Test +	7	107	114
Test -	3	307	310
Total	10	414	424
Sensitivity	70.00%		
Specificity	74.15%		
PPV	6.14%		
NPV	99.03%		

Test 2	**Disease +**	**Disease -**	**Total**
Test +	8	119	127
Test -	2	295	297
Total	10	414	424
Sensitivity	80.00%		
Specificity	71.26%		
PPV	6.30%		
NPV	99.33%		

Table 12 Results of analysis comparing data collected by the algorithm with gold-standard data collected manually by a nurse, Tests 1 & 2

Test 1: CABG OPCS code + test of interest within 30 days; Test 2: CABG OPCS code + test of interest within 90 days

Table 13 Results of analysis comparing data collected by the algorithm with gold-standard data collected manually by a nurse, Tests 3&4

Test 3: CABG OPCS code + test of interest within 30 days + positive result of test; Test 4: CABG OPCS code + test of interest within 90 days + positive result of test

Test 3	Disease +	Disease -	Total
Test +	5	22	27
Test -	5	392	397
Total	10	414	424
Sensitivity	50.00%		
Specificity	94.69%		
PPV	18.52%		
NPV	98.74%		

Test 4	Disease +	Disease -	Total
Test +	7	28	35
Test -	3	386	388
Total	10	414	424
Sensitivity	70.00%		
Specificity	93.24%		
PPV	20.00%		
NPV	99.23%		

5.4.1.4 Discussion

Since there was a discrepancy of four patients both ways between the algorithm and the SSISS data, it can be concluded that these methods for finding patients were equivalent for 2014. Nevertheless, the reason for the discrepancy should be investigated in order to optimise the algorithm, and the same process of validation should be tried for other time periods to ensure equivalency.

Test 2 gave the highest sensitivity and NPV values, which are the most important for this initial screening (80% and 99.33% respectively). However, two infections were still missed by this algorithm. The first false negative patient in Test 2 above was only identified in the post-discharge surveillance carried out as part of the SSISS. This case was beyond the detection limits of an in-hospital surveillance system such as this and therefore could never have been picked up by this algorithm. The second missing case was found to be one of the 4 patients with no relevant OPCS code recorded in the admissions data. This highlights the importance of correct coding and data quality in underpinning any surveillance that uses routinely-collected data, and will be followed up with the cardiac surgery data manager.

Interestingly, according to test 3, 27 patients were found to have had a positive finding in their microbiology culture within 30 days of operation, though only 5 of these were reported as SSI. The following organisms were isolated from these patients:

Organism	Count
Pseudomonas aeruginosa	4
Coagulase negative staphylococcus	3
Staphylococcus aureus	3
Proteus mirabilis	2
Enterobacter cloacae	2
Serratia marcescens	1
Staphylococcus epidermidis	1
Coliform sp.	1
Enterobacter aerogenes	1
Enterobacter sp.	1
Enterococcus faecalis	1
Klebsiella pneumoniae	1
Lactose fermenting coliform	1
Mixed anaerobes	1
Morganella morganii	1
Pantoea sp.	1
Pseudomonas sp.	1
Vancomycin Resistant Enterococcus	1

5.4.1.5 Conclusions

Using OPCS codes to draw up a list of patients undergoing CABG in 2014 was as effective as manual data collection. The best algorithm had a sensitivity of 80% and a NPV of 99.33%. Overall, 114 CABG patients in 2014 were flagged as possible SSIs, which would result in an average of 9.5 patients per month (21%) requiring a review for confirmation of infection. The remaining patients can be safely excluded from further review owing to the high NPV.

5.4.2 Development of the dashboard

There were not many options for collating and displaying data for semi-automated surveillance. The first would be a report from Cerner, but this would only allow data held in the Cerner EHR to be used for surveillance purposes, so microbiology tests could not be included without actively matching microbiology tests to patient records on a regular basis. The solution needed to automatically draw in and match data from different sources and display the results in a flexible and elegant format, accessible to those who need it. For this purpose, I chose to use the platform already in use across the Trust in various sectors. QlikView is a data visualisation platform with the opportunity to develop dashboards or “apps” in-house, and is

already being used to coordinate theatre use, monitor patient-level costings, collate data on missed appointments, and many other metrics. The Trust has a team of developers contracted to help staff produce dashboards that meet their needs and use of their time is accessed via a bidding process; groups can submit a bid on a quarterly basis and successful bids win one quarter's worth of development time. Ad-hoc amendments can be made after this, but substantial changes or expansions require further bids.

The main benefit of using QlikView as a platform is that all staff can access it through any NHS PC, and the development team have full control over who can see what, which is important as some staff will need access to patient-level data, and others should only see aggregated data. Additionally, the in-house development team can quickly and easily make changes. QlikView also has the functionality to produce automated reports, and staff can also personalise their dashboard and use menus to change the data that are displayed and can easily export datasets and graphs to Excel for further analysis.

The main limitation of the QlikView system is the inability to enter new data directly into the dashboard. The data displayed in QlikView dashboards are all drawn from the data warehouse without any functionality for front-end data entry. This is a problem for the planned semi-automated surveillance, as suspected SSIs can be displayed but there is no option to validate them on the system. Validated SSIs must instead be uploaded somehow to the back end of the system so that fully validated SSI rates can be displayed alongside the suspected SSI rates.

The aim of the QlikView app is to recreate an ongoing surveillance system based on the rule-based algorithms developed in 5.4.1, but also includes ICD-10 codes indicating an SSI as an additional data point. The list of ICD-10 codes which may indicate SSI was taken from a paper by King et al. which developed a syndromic surveillance algorithm for SSIs in CABG surgery [146]. The app identifies patients undergoing a particular surgical procedure (identified through OPCS codes with a time lag of approximately one month from procedure to coding) and flags patients who had one or both of the following: i) a microbiology test of interest (e.g. wound swab culture, drain fluid culture, blood culture) within 90 days of the procedure or ii) an ICD-10 code indicating a suspected SSI.

The app provides a retrospective shortlist of patients with "suspected" SSI, complete with microbiology records for each patient, in an Excel spreadsheet. A healthcare professional must confirm each SSI through discussions and note checking before re-uploading the spreadsheet into QlikView. The app then displays the denominator of patients, number of suspicions, and number of confirmed cases.

A prototype of the app was developed for CABG surgery as it was important to test its performance against known data. The prototype dashboard also allowed me to explore different data visualisation options and test how the app might work in practice.

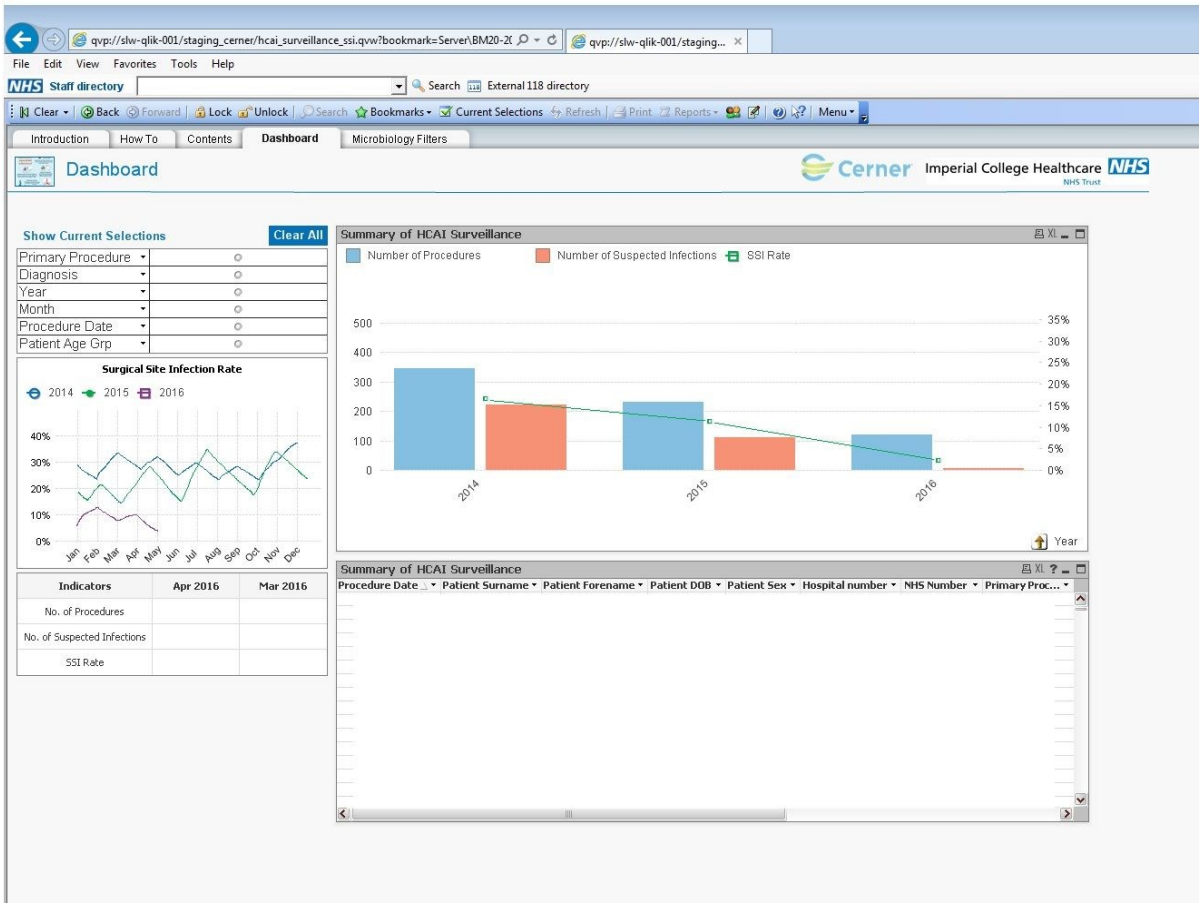


Figure 10 Sample QlikView dashboard for CABG patients, patient identifiable data removed

Once it was certain the app was picking up the same procedures and microbiological tests as the manual structured queries conducted by the data manager the app was deemed feasible and workshops with staff in cardiothoracic surgery were arranged.

5.4.3 Pilot study and implementation protocol

The implementation of the app was expected to start with workshops to iron out any obvious difficulties, followed by a pilot of the functioning app in CABG surgery. An interim evaluation of this would then inform the rollout and maintenance phase to create a sustainable semi-automated surveillance solution in the Trust.

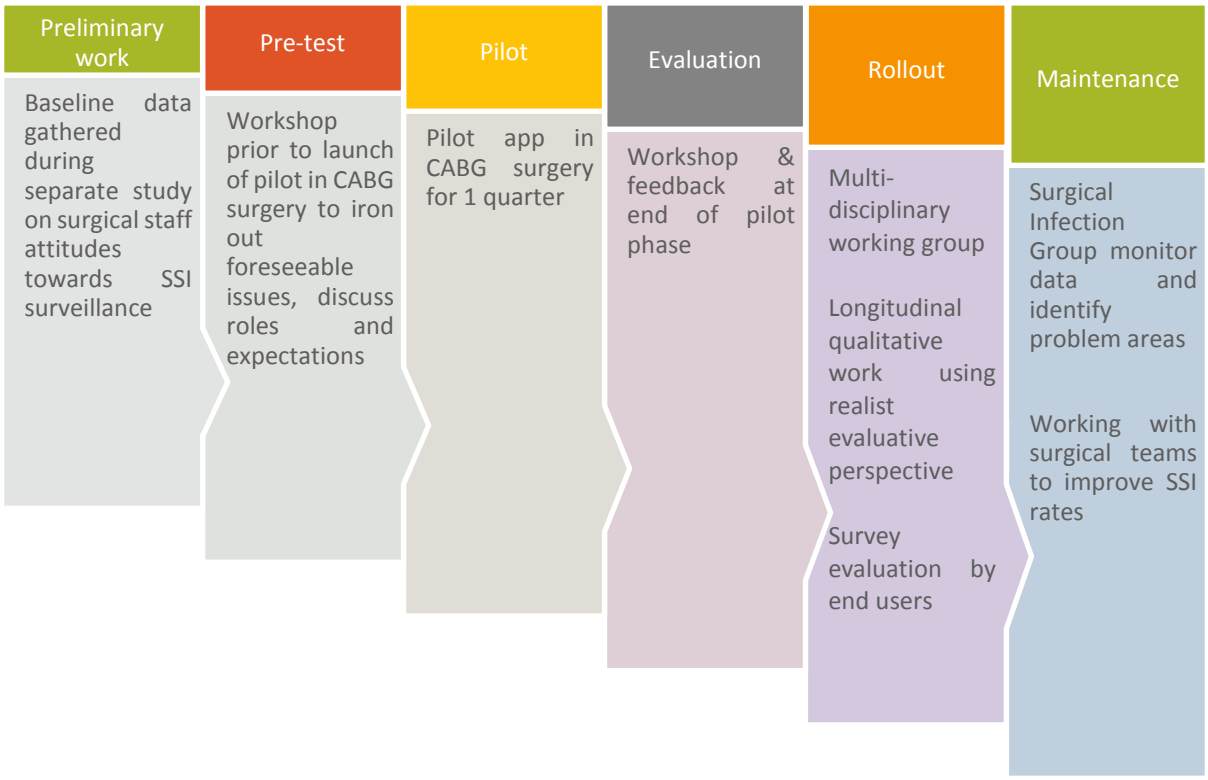


Figure 11 QlikView app implementation protocol

5.4.3.1 Workshops with staff

The aim of the workshops was twofold: to gather baseline pre-implementation data on the context and attitudes towards a novel surveillance platform, and to allow staff to provide early feedback on the tool to help the development process.

The workshop panel consisted of a surgical registrar, a consultant microbiologist, and a lead nurse. Two workshops were planned, each with two parts. In the first section of the first workshop, staff were given a brief introduction to the aims of the app and asked to complete a survey (see Appendix 12) based on the most pertinent constructs of the Consolidated Framework for Implementation Research (CFIR) (see Appendix 10). In the second part they were shown a demonstration of the dashboard and asked to provide feedback on the design of the dashboard and the surveillance process. The second workshop followed the same format, but instead of an introduction staff were given an update on the progress of the app.

5.4.3.1.1 Workshop results

From the two workshops (n=3, and n=2) there was a general cautiously positive attitude towards the app (Table 14). Because one participant was missing from the second workshop it is not appropriate to compare differences in the construct scores between the two time points. Overall, the least positive construct was engagement of stakeholders, with the participants commenting that they felt IT and the data warehouse team needed to be more engaged in order to make the intervention work. The most positive construct was tension for change, as most participants agreed that something needs to be done about SSIs. They also felt generally positive that the intervention could be implemented easily, and that it could also be easily reversed if it wasn't working.

When asked about the intervention itself, the participants did not feel they could judge its usability, utility, or its fit within their existing workflow as although the prototype dashboard was available, they had not yet had a chance to try using it, including the step of exporting the shortlist, manually verifying SSIs, and saving the spreadsheet so that it could be pulled into the system. However, from the initial workshop the participants had asked for the "tests of interest" to be limited to only wound swabs and tissue samples, and for problems to be ironed out with patient surname being listed twice.

It is important to acknowledge the limitations of the data presented in Table 14, since the workshops included a very small number of participants, with three participants at timepoint 1 and two at timepoint 2. However, I felt it important to include these data to illustrate staff attitudes to the intervention which are otherwise not formally represented in this thesis.

A further point to consider is the difficulties for the participants in answering the survey items that assumed some level of familiarity with the interface and process of using the tool since at this stage it was only a prototype. This highlights a problem inherent with using frameworks designed for implementation of fully-functioning innovations in the early stages of innovation development.

5.4.3.2 Development period ends

After the second staff workshop, the period of time allotted to develop the dashboard ended and I sought to bid for another quarter of development time. The QlikView development team became busy with other projects, and were not taking new bids. The changes requested by the participants in the first workshop could not be made, and the rollout to other specialties was not possible. Since cardiac surgery already had a system in place for surveillance, there was no need to implement the dashboard here as it would have duplicated effort. This effectively ended the development and implementation of the dashboard.

5.4.4 Development of surgical ward round form

The fact that the manual validation step must be conducted in an Excel spreadsheet outside the existing ICT systems is a major barrier for the ease of implementation of this system. Concurrently with the start of

the service evaluation to pilot the QlikView system Mr Usman Jaffer, one of the surgical consultants in the Trust, began to develop a structured wound review form in the EHR system Cerner for capturing SSIs. The motivation for this was an increased number of SSIs in the unit at the same time as an outbreak of carbapenemase-producing Enterobacteriaceae, leading to several severe SSIs. The form would be used on ward rounds to assess the state of wounds, decide on the presence or absence of an SSI, and if present, the level (superficial, deep, organ/space) of infection with definitions provided.

This form would generate an additional structured data point that could be reported on automatically through Cerner but could also be a solution to the problem of manual validation of suspected SSIs in the QlikView system.

Table 14 Results of preliminary workshops with staff to assess baseline context prior to implementation of QlikView surveillance app.

For construct scores, mean responses to survey questions phrased in the negative sense were reversed by subtracting the score from 6 so that higher scores reflect a positive outlook. Shaded boxes are constructs not directly related to the intervention. Time points 1 and 2 are six weeks apart.

		Survey responses (1= strongly disagree, 5=strongly agree) (n=3)				Construct score (1=lowest, 5=highest) (n=2)	
		Time point 1		Time point 2		Time point 1	Time point 2
CFIR construct	**Survey statement**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Mean**
Intervention Source	This system was developed internally	3.0	2-4	3.0	2-4	3.0	3.0
Evidence Strength & Quality	I am confident this system will be useful	3.7	3-4	4.0	4-4	3.7	4.0
Relative Advantage	This is the best solution to problems with SSI surveillance	2.7	2-3	2.5	2-3	2.7	2.5
Adaptability	The system is adaptable and can be tailored to local needs	4.0	4-4	3.0	2-4	4.0	3.0
Trialability	We can always abandon this system if it doesn't work	4.0	4-4	4.0	4-4	4.0	4.0
Complexity	This system will be very difficult to implement	2.7	2-3	2.0	2-2	2.3	4.0
Design Quality & Packaging	The interface is user-friendly	3.0	2-4	2.5	2-2	3.0	2.5
Cost	The project will have unjustifiable resource implications	2.7	3-3	2.5	2-3	2.3	3.5
Implementation Climate	This Trust welcomes new innovations	3.3	2-4	3.5	3-4	3.3	3.5
Tension for Change	We really need to do something about SSI surveillance	4.3	4-5	4.5	4-5	4.3	4.5
Compatibility	This system won't fit in with our workflow	2.3	2-3	3.5	3-4	2.7	2.5
Relative Priority	There are so many more important things we should be spending time and money on	2.3	2-3	2.5	2-3	2.7	3.5
Goals and Feedback	We are tired of trying new interventions	2.7	2-3	2.0	2-3	2.3	4.0
Learning Climate	My feedback will be valued by senior managers	4.0	4-4	3.5	3-4	4.0	3.5
Planning	The implementation of this system has been planned in advance	3.7	3-4	3.5	3-4	3.7	3.5
Engaging	There are other people who should be involved in implementing this system	3.7	3-4	4.0	4-4	1.3	2.0
Champions	I feel comfortable championing this system	3.7	3-4	4.0	4-4	3.7	4.0
Reflecting & Evaluating	I am confident we will have plenty of opportunities to give and receive feedback about this system	3.7	3-4	4.0	4-4	3.7	4.0

The form was developed by Mr Jaffer alongside colleagues from Cerner and the data warehouse team, with feedback from the SIG. It had been hoped that the form would be implemented prior to the start of the Getting It Right First Time (GIRFT) SSI audit (May 2017) as it would have made data collection much easier, but because of holdups with development and approval by the Cerner team, the form was delayed.

A pilot of the form finally began in June 2018 in vascular surgery and is ongoing.

5.4.5 Discussion of barriers to implementation using CFIR framework

The pathway to implement a semi-automated surveillance system for SSI monitoring was full of obstacles. Again, it is useful to look at these through the CFIR framework (Appendix 10). As well as straightforward barriers, there were also several instances of vicious circles which are much more difficult to overcome.

5.4.5.1 Construct I: Inner setting

In this case study, the most major barriers came from the inner setting, especially the "readiness for implementation" construct. The biggest barrier came from the software developers who are contracted to the Trust. The system for developing a QlikView app meant that projects could only be worked on for three months at a time, and there was no guarantee of any subsequent development time after this has elapsed. In fact, the development team stopped taking on new projects and did not have time to make even small changes to existing platforms. Added to this was a significant lack of human resource, which meant even the time that had been allotted to this project was not fully committed.

As well as the lack of resources for developing the app, a conflict emerged when trying to convince the Business Intelligence board to allocate more development time to this project. Since the app had only been developed initially in CABG in order to compare its performance, the usage of the app was extremely limited. However, the main metric used by the Business Intelligence team to judge the success of an app, and therefore whether it is worth further time investment, is the usage statistics. This is a considerable source of conflict between business-style thinking and research-style thinking. To a business leader, it

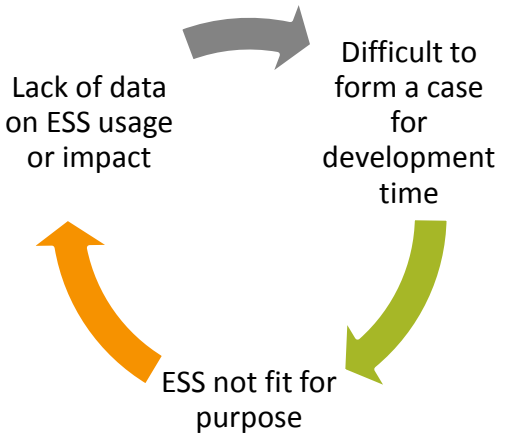


Figure 12 Barriers to accessing development time because of conflict with "business" goals

seems reasonable to use usage statistics as a success measure, but for the purposes of developing and evaluating a new intervention it is not appropriate to try to maximise usage before proper testing and validation has taken place.

As well as the structure and processes of the organisation creating barriers to accessing development time, when it came to implementing a wound review form in the EHR there were significant barriers to overcome. This is partially because the EHR is operated by a third-party company who control changes to the system and also control data access and reports. As the EHR is a large and complicated system used by the entire Trust there are multiple things for the company to consider before implementing a new form, which meant multiple levels of approvals and extended consultations. New forms must also work within the limitations of the system in terms of structure and functionality, which resulted in a less user-friendly form that was originally planned. There were also concerns about whether reports could be generated with the detail and frequency required. All of these barriers meant significant delays to the project, and an opportunity was missed to implement the wound review form at the same time as conducting the GIRFT audit, which would potentially have allowed a validation of the form.

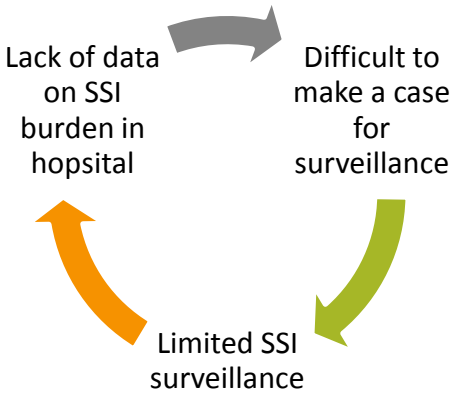


Figure 13 Barriers to making a case for improved surveillance when the burden is unquantified

Lack of leadership engagement has been a major factor in slowing the progress of efforts by the SIG at ICHNT to expand SSI surveillance, which agrees completely with a study in the USA which correlated organisational support strongly with the adoption and use of ESS [136]. The ESS developed in this section was part of a wider business case put forward by the SIG to expand and improve SSI surveillance in the Trust (Figure 13). While the ESS did not require extra funding as theoretically the resource was already available to develop and implement it, the wider business case required significant investment. Without an accurate understanding of the scale of SSIs in the hospital, it is difficult to estimate cost-effectiveness of improved surveillance. Additionally, senior management were more concerned with identifying and

tackling the causes of high SSI rates in vascular surgery than with developing a sustainable system for monitoring SSI rates across all surgery types. This is symptomatic of the reactive rather than proactive style of IPC planning identified by Iwami et al. in a review of IPC capacity in English NHS trusts [101].

Other aspects of the inner setting, such as culture, tension for change, relative priority, and learning climate were not major barriers among non-managerial stakeholders. Within the Trust there has been an increasing awareness that there may be a problem with SSIs and an increasing will to make this problem more visible. Particularly among specialties where SSIs are thought to be a big problem, there was significant engagement from clinical teams. Compatibility of the app with existing Trust systems was one of the aspects I was able to maximise from the start as this intervention was developed in-house.

5.4.5.2 Construct II: Intervention characteristics

The main drawback of the intervention itself was that validation of suspected SSIs needs to be carried out outside the system. This is a laborious and inelegant workaround to account for the fact that QlikView is a data visualisation platform and doesn't allow data entry. As it stands, a staff member would have to ensure all data are entered into an Excel spreadsheet in the exact format required and save it in an exact location for QlikView to retrieve. This allows no margin for error and staff would have to receive specific training and instructions to carry out this task, which would add complexity to the implementation process. However, this limitation could be removed if the Cerner form currently being piloted is successful.

The other main limitation comes from the data sources used, in that OPCS codes are not always accurate and also introduce a time lag between the procedure and the patient appearing in the system. This means some patients will have already been discharged and the wound will not be available for inspection. This then also means the patient's notes must be relied on for diagnosis, which again are not always accurate. How big a barrier this is for implementation depends on the quality of coding and record keeping in a hospital, but the earlier validation showed that the system was not inferior to a human in capturing eligible patients at ICHNT and was not vulnerable to staff turnover.

There are further limitations of the QlikView app which are also common to other methods of surveillance but are nonetheless suboptimal for a perfect SSI surveillance solution. The app is only able to detect SSIs which develop in hospital or patients who are readmitted and have a "test of interest" sent within the designated time frame and has no post-discharge surveillance (PDS) functionality. The app also requires validation of SSIs by a HCP or trained individual which of course means some engagement with individual specialties is necessary. Like some other ESSs the app relies on structured data which is of variable quality and introduces a time-lag, meaning it could only be used retrospectively which may introduce some elements of bias. There are alternative systems which propose to use clinical data such as blood biomarkers to flag suspected SSIs prospectively, and this will be discussed in 5.5.

In the staff workshops the participants were not sure whether the intervention was internally or externally developed, which reflects the initial perception of me, the person developing and testing the tool, as an "outsider", but staff were generally confident that they were now being included in the development process and would have many opportunities to give feedback. In terms of the evidence strength and quality to support adoption of the tool, the participants agreed that it would be useful based on the information they had been given about its performance against manual case finding. However, they did not feel that it was the optimal solution, instead preferring a full-time surveillance nurse. It is important to note that this unit had previously had such a post, but the funding had been frozen, so the surveillance was now being undertaken by the lead nurse on top of her usual duties. For the participants in the study, the optimal solution would be a return to the earlier system. Adaptability and trialability were not considered problems, but the complexity of implementation was a concern for participants. Finally, the cost of the intervention was actually minimal, but the participants felt that the money (or perhaps, effort) could be better spent elsewhere. Given that at the time, cardiac surgery was not thought to have significantly high SSI rates and already had SSI surveillance, but was struggling with shortages of staff and beds, this is not surprising.

5.4.5.3 Construct III: Outer setting

Aspects of the outer setting were not as important as the inner setting and intervention characteristics at this stage but were still important. The main contributing external factor is the requirements for data submitted to the SSISS to have been collected according to the SSISS protocol. Data collected using the QlikView app would not currently be eligible for submission, which is a significant barrier to adopting any ESS as a solution for SSI surveillance. For ICHNT, submission to the SSISS was secondary to the need to put a system in place for ongoing monitoring of SSI rates across all specialties and obtaining funding to hire enough HCPs to undertake surveillance according to the SSISS protocol was not an option.

Peer pressure may also be an indirect contributing factor in the push towards expanding SSI surveillance at ICHNT, as the IPC staff have many informal connections with IPC staff at other hospitals and attend conferences where work is presented by other institutions. The IPC staff are aware that SSI surveillance at ICHNT is less well organised and comprehensive than that of neighbouring institutions who have published extensively on their surveillance programs, and the models used by these other institutions were discussed frequently during the process of drawing up the business plan.

5.4.5.4 Construct IV: Characteristics of individuals

From the staff workshop, we can see that individuals' knowledge & beliefs about the intervention were cautiously positive. This was also reflected in the interviews described in Chapter 3, in which staff were given a brief introduction to the QlikView tool and asked their opinions. On the whole, participants thought

it would be a very useful tool to have, especially given the lack of human resource available for surveillance and the opportunities offered by EHRs. Some individuals had doubts about the accuracy of the tool, which were often related to their own personal experience of sending samples or diagnosing infections based on clinical presentation without explicit documentation in the notes. The concerns of other individuals were around what would happen to the data afterwards, how it would be fed back and if it would lead to any medico-legal issues. All of these concerns fit with Hebden's assertions that slow adoption is related to ambiguity in tasks, responsibilities, methods, expectations, and exceptions [44]. Each participant seems to have their own area of ambiguity related to the own personal experience which makes them hesitant to commit to adopting or championing the new tool.

Another interesting aspect to the adoption of the QlikView tool is individual state of change, and individual identification with the organisation. In specialties with existing sustainably funded surveillance, individuals saw the tool as a useful adjunct to the existing strategy because the individuals felt they already had the secure support of the Trust and were ready to embrace change. In specialties with no funding but ongoing surveillance, individuals saw the tool as a threat to the already precarious situation, as it may stop the Trust from ever wanting to re-invest in human resource for surveillance; the individuals did not trust the organisation to listen to their needs and felt they had already been expected to deal with change without any support. In specialties with no current surveillance, the tool was seen as a good starting point that was unlikely to cause any harm and may do some good; they felt pleased that the Trust was taking more notice of them centrally.

5.4.5.5 Construct V: Process

The implementation process did not proceed far enough to encounter too many problems. During the planning stages, a great deal of care was taken to ensure that nothing would be implemented that had not first had the engagement of stakeholders in the implementation area, and that end users would be involved early in the design stages. However as discussed previously, engaging the developers was the main barrier in implementing this tool.

Engaging opinion leaders was facilitated by attending the SIG and SOG meetings, which allowed discussions to take place regularly and easily, and this also helped with maintaining engagement as I could provide frequent updates to the groups.

5.4.6 Conclusion

Barriers to implementation of ESS here were mostly linked to the inner setting and the ways in which the intervention characteristics were limited by the existing organisational and technical infrastructure. Since the national surveillance program in England requires a set protocol to be followed, data collected through ESS will not be eligible for submission, so this could present a further obstacle in settings where this is the

main priority. The intervention was perceived differently in different specialties based on the existing surveillance structure, and by different individuals based on their own personal experiences and identification with the organisation. The findings of this study strongly support the need for detailed planning and implementation strategies for ESS, and engagement at the senior management level to ensure resourcing is sustainable.

5.5 Prospective Syndromic Surveillance

5.5.1 Background

The tool described in 5.4 was based on procedure codes which introduce a time lag of around a month, so surveillance can only ever be retrospective. A syndromic surveillance algorithm developed by previous PhD student Carina King at Imperial College [147] presented opportunities to not only collect data prospectively, which is less prone to bias, but also to identify SSIs which are still in the early development stages and intervene earlier to achieve better outcomes.

King created two syndromic surveillance algorithms that use close to real-time, electronic, routinely-collected data to for detecting SSIs in patients who had undergone CABG surgery at ICHNT: one for superficial and deep infections and one for organ/space infections. The algorithms used different thresholds of the same biomarkers white cell counts (WCC), platelets, fibrinogen, and C-reactive protein (CRP), along with wound culture requests [147]. These biomarkers are readily available for CABG patients in the days following surgery as they undergo daily blood tests during their inpatient stay.

The algorithm was developed several years ago, so when it came to selecting an ESS to trial in the Trust I wanted to re-validate King's findings in a more recent cohort of patients, and specifically test whether this algorithm would have been useful for picking up an increase in SSI cases in CABG surgery before their infections became clinically apparent.

5.5.2 Ethical considerations

As with the previous study, this study was conducted as a service evaluation approved by ICHNT's Audit team (service evaluation number 158).

5.5.3 Objectives

The project had three objectives:

1. To compare the timing of SSI diagnoses using the general and organ space models with clinical diagnosis and treatment times (main cohort)
2. To identify improvements and drawbacks to the models upon evaluation of two modified syndromic algorithms (main cohort)
3. To measure the effectiveness of the original and modified algorithms in the context of a period of elevated SSI rates (sub-cohort)

5.5.4 Methods

This was a retrospective cohort study examining the performance of the algorithm overall and during a period of elevated SSI rates in cardiac surgery. An Imperial medical student (Jay Lakhani) on a BSc project attachment to our research unit carried out this project under my supervision.

5.5.4.1 Assessing algorithms on SSI positive patients

5.5.4.1.1 Defining the patient population

ICHT's database for the SSISS was used to identify patients for this study. This cohort included patients who developed cardiac surgery-related SSI (CABG or other cardiac surgery) between 2014 and 2016 according to the SSISS definition (Appendix 1).

5.5.4.1.2 Data sources and extraction

Data for this study were extracted from the spreadsheet used by the Trust for SSISS reporting, and from the EHR. From the SSISS database, patient demographic data and information regarding the clinical SSI diagnosis date and depth of infection were extracted. Data for the haematology, immunology and microbiology algorithm parameters were extracted from the EHR. We chose to harvest data up to 90 days post-operation where information so that patients who were readmitted with SSI after the 30-day cut off but may have developed the infection earlier could also be included, as these would have been captured in the SSISS database. From the EHR, data were also extracted on patient co-morbidities and date that SSI treatment (either antibiotics or debridement, whichever was soonest) commenced.

5.5.4.1.3 Definition and application of algorithms

Once full patient records for 90 days post-surgery had been obtained, the algorithms were applied in the following ways:

General (superficial/ deep) algorithm (GA) [147]:

- Any occurrence of white cell count >$11*10^9$/L
- Any occurrence of platelets >$400*10^9$/L
- Any occurrence of fibrinogen >5g/L
- ≥ 2 wound culture requests

Organ/space algorithm (OSA) [147]:

- ≥ 2 occurrences of CRP >100mg/L
- Any occurrence of platelets >$400*10^9$/L
- ≥ 3 wound culture requests

Conditions of all parameters needed to be met to constitute a detected SSI.

For each patient, biomarkers were displayed in bar charts to identify the days when the markers exceeded the algorithm threshold values and to observe trends in parameters post-operation. Dates when wound culture requests were made were recorded in a table. The day on which each algorithm parameter was fulfilled was ascertained based on the charts and the date of full algorithm satisfaction was noted in the medical summary for each patient. This was then plotted on synoptic timelines. Time differences between clinical diagnosis and treatment times compared to day of algorithmic diagnoses were calculated, and reasons for late or insufficient fulfilment of algorithms were assessed.

5.5.4.1.4 Application of modified algorithms

Once the reasons for non-fulfilment of the algorithm had been assessed, two modified versions of the algorithm were created and applied to the same dataset to see if detection could be increased:

> Modified Algorithm 1 (MA1)- 'Fulfil any 3 out of the original 4 general algorithm parameters'
>
> Modified Algorithm 2 (MA2)- 'Any occurrence of white cell count >11*109/L AND any occurrence of fibrinogen >5g/L AND ≥ 1 wound culture request'

These were tested in the same way as the original algorithms and compared with the clinical diagnosis and treatment dates from the SSISS database.

5.5.4.1.5 Statistical analysis

Statistical analysis was conducted with Dr Birgand using Stata software (version 10) to calculate means, medians, standard deviations and interquartile ranges. Figures for sensitivity and specificity were calculated in Excel. Note that positive and negative predictive values could not be calculated as the population of patients in the cohort and sub-cohort had been purposively chosen to include only SSI cases or matched cases and controls, so were not representative of the true prevalence of SSIs.

5.5.4.2 Assessing algorithms during a period of high SSI rates (sub-cohort)

During the last three months of 2016, there was a period of high SSI rates in cardiothoracic surgery. To gain an understanding of the specificity of the algorithm and its utility in recognising increased rates, a sub-cohort of patients who received a clinical SSI diagnosis in the last quarter (Q4) of 2016 were selected for a matched cohort analysis.

5.5.4.2.1 Selection and matching

Ten patients diagnosed with SSIs in Q4 2016 were matched with ten control patients identified from the SSISS database, defined as patients who had undergone cardiac surgery in Q4 2016 but did not develop an SSI. These control patients were matched to the cases on the following variables: age (+/- 10 years), gender,

American Society of Anaesthesiologists (ASA) score (+/- 1 class difference), operation and discharge dates (+/- 10 days) as well as length of stay in hospital (+/- 10 days).

5.5.4.2.2 Data extraction and application of algorithms

Assessment of the functioning of the algorithms in the sub-cohort was performed by identifying whether each algorithm accurately and efficiently flags the patients with SSI, and correctly disregards the controls. Data on day of diagnosis using the four algorithms were extracted for the control patients using the same methods as for the main cohort. For the SSI positive patients, the number of patients flagged earlier than the dates of clinical diagnosis and treatment were quantified, and the sensitivity and specificity recorded.

5.5.5 Results

5.5.5.1 Algorithm performance on SSI positive patients

5.5.5.1.1 Patient demographics

The mean age of the 36 patients was 65.9 years (standard deviation, SD: 12.0), of which nine were female. Mean BMI was 31.8 (SD: 5.6); 50% of patients were obese and 33% were overweight. 44% of the cohort had a definitive diagnosis of diabetes. All but two were given antimicrobial prophylaxis prior to surgery according to the SSISS database and EHR, although this is not always accurately recorded. Details of the procedures and SSIs can be found in Table 15.

Table 15 Procedure details and SSI depth and locations of patients in the cohort

Type	No. patients (n=36)
CABG : valve replacement	26 : 10
Elective : emergency	32 : 4
Superficial SSI : deep SSI : organ/space SSI	21 : 12 : 3
Sternal SSI : donor site SSI	24 : 12

5.5.5.1.2 Performance of original algorithms

Overall, the sensitivity of the algorithms was low. Thirteen out of 36 (36.1%) of the SSIs were identified by the general algorithm, and 15 (41.7%) by the organ/space algorithm (Table 16). Of the three patients who had an organ/space SSI, only two of these were picked up by the organ/space algorithm.

After comparing the dates of clinical diagnosis with the flagging dates of either algorithm, it was found that the general algorithm would have flagged 11.1% of the cohort (4 patients) prior to clinical diagnosis date (Table 16). The corresponding value for the organ/space model was lower (8.3%, 3 patients). When comparisons to time of clinical treatment were made, the general algorithm flagged earlier for three patients and the organ/space algorithm for two patients within the cohort. The statistical analysis showed that the mean time to diagnosis was 15.2 days clinically, rising to 23.7 and 26.7 days for the general and organ space models respectively.

Table 16 Number and proportion of patients identified by each algorithm in the retrospective cohort analysis (n=36) and case-control sub-cohort analysis (n=20)

Clinical diagnosis refers to the date of SSI onset as indicated on the Trust's SSISS database. Clinical treatment was the first day where medical (antibiotics) or surgical (debridement) therapy was administered for SSI treatment as specified in the patient notes. Percentages are based on the entire cohort of 36 patients. GA= General Algorithm, OSA= Organ Space Algorithm, MA1= modified algorithm 1, MA2= modified algorithm 2

Algorithm	No. (%) patients flagged by each algorithm				
	Retrospective cohort analysis of SSI-positive patients (n=36)			Case-control sub-cohort analysis (n=20)	
	Within 90 days	Before diagnosis date	Before treatment date	Cases – within 90 days (n=10)	Controls – within 90 days (n=10)
GA	13 (36.1)	4 (11.1)	3 (8.3%)	5 (50.0)	1 (10.0)
OSA	15 (41.7)	3 (8.3)	2 (5.6)	4 (40.0)	1 (10.0)
MA1	27 (75.0)	8 (22.2)	11 (30.6)	8 (80.0)	5 (50.0)
MA2	26 (72.2)	13 (36.1)	11 (30.6)	8 (80.0)	6 (60.0)

However, when differences in flagging and clinical treatment days were compared on a per-patient basis, the general and organ space systems flagged a mean of 7.25 and 5.67 days earlier respectively (Table 17). These mean differences were particularly skewed by the only two patients for whom the algorithms flagged more than one day earlier than the treatment, with one flagging 27 days earlier and the other 52 days earlier. Excluding these two patients, the equivalent values became 2.4 and 5.8 days later.

Table 17 Mean time difference between algorithm flag date and clinical diagnosis or treatment date per patient

GA= general algorithm, OSA= organ/space algorithm, MA1=modified algorithm 1, MA2= modified algorithm 2

Timepoint comparison	Mean Time Difference (days)
GA vs clinical diagnosis date	5.27
OSA vs clinical diagnosis date	7.33
MA1 vs clinical diagnosis date	1.11
MA2 vs clinical diagnosis date	-0.74
GA vs treatment date	-7.25
OSA vs treatment date	-5.67
MA1 vs treatment date	-7.69
MA2 vs treatment date	-12.27

5.5.5.1.3 Identifying explanations for non-fulfilment of algorithm

Reasons why the algorithms were not functioning as intended were investigated, with parameters of the algorithms evaluated in each patient to identify those responsible for delayed (post-clinical diagnosis or treatment) or unsatisfied algorithmic diagnoses, which are summarised in Figure 14. In 4. 87% of patients who did not fulfil the general SSI algorithm, this was due to lack of or below threshold platelets and/or wound culture requests. These two parameters were also jointly responsible for all cases where the organ model was not fulfilled.

In nine patients with delayed general algorithm diagnoses, eight were due in part to platelets, of which 37.5% were due to incomplete data (tests not ordered) (Figure 14). In 12 patients with late organ/space algorithm fulfilment, wound culture requests contributed to delays in 91.7% of these cases. Deficient data on white cell count and fibrinogen was also partly accountable for some missed general SSI diagnoses. CRP was the most consistent parameter, unfulfilled in just one case. Overall, Figure 14 demonstrates that the major factors contributing to delayed or non-fulfilment of the algorithm include wound culture requests and platelet measurements under threshold levels, or platelet counts not requested.

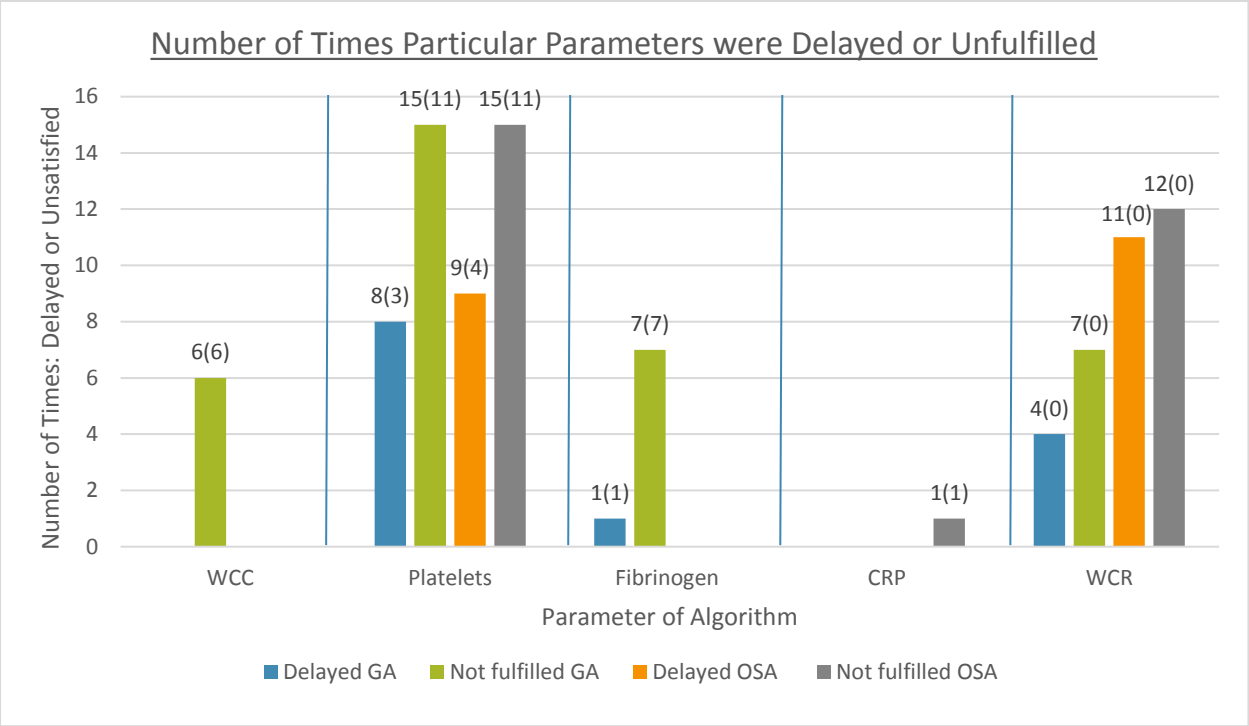


Figure 14 Causes of late or incomplete fulfilment of the algorithm

Number of times a specific parameter was responsible for delaying or not fulfilling each algorithm is shown. Number above each bar= total number of times, number in parentheses= number of times complete information for a marker was unavailable. Delayed= syndromic model was satisfied post-clinical diagnosis/ treatment time, WCR= wound culture request, WCC= white cell count, GA= general algorithm, OSA= organ space algorithm

5.5.5.1.4 Performance of modified algorithms

In light of the reasons described above for delayed or non-fulfilment of the original algorithms, two modified algorithms were tested against the same cohort of 36 patients. The percentage of patients flagged by the original general algorithm was 36.1%, whilst values for modified algorithms 1 (MA1) and 2 (MA2) were equal to or more than twice this figure (Table 16). The modified algorithms were also able to detect more cases of SSI earlier than clinical diagnosis; MA1 would have identified eight patients (22.2%) prior to clinical diagnosis and 11 (30.6%) prior to treatment, while for MA2 these figures were 13 (36.1%) and 11 (30.6%) respectively (Table 16). Although this is greater than the original general algorithm (13.9% of patients were identified earlier originally), more than half of the cohort would still have been diagnosed later than clinically.

Statistical analyses of the revised algorithms were also undertaken. The mean time to SSI diagnosis was 23.7 days post-surgery for the original general algorithm; this was shortened to 19.2 and 16.2 days for

modified algorithms 1 and 2 respectively. However, these means for the modified algorithms were still later than the day of clinical diagnosis (15.2).

5.5.5.2 Algorithm performance on cases and controls

Ten SSI positive cases from Q4 2016 were compared to 10 control patients from the same period, with the demographics summarised in

Table 18.

For the SSI positive patients, 20% would have been diagnosed prior to clinical diagnosis and/or treatment using the general algorithm, and 10% using the organ/space algorithm, with modified algorithms 1 and 2 flagging 60% of the patients earlier (Table 16). The modified algorithms correctly identified more cases than the original algorithms, but also flagged more control SSI negative patients incorrectly.

While the original algorithms had higher specificity, they also had low sensitivity, whereas the modified algorithms had higher sensitivity, but low specificity. Overall, this means that none of the four syndromic algorithms would have precisely and efficiently differentiated SSI positive cases from uninfected individuals during the 2016 period of high rates.

Table 18 Patient demographics of matched cases and controls in sub-cohort

SD= Standard Deviation, BMI= Body Mass Index, ASA= American Society of Anaesthesiologists, LOS= Length of Stay

	SSI patients (n=10)	Control patients (n=10)
Male : Female	7:3	7:3
Mean Age (SD) (years)	60.9 (9.5)	66.4 (7.35)
Number with diabetes	3	3
Mean BMI (No. patients overweight or obese)	33.0 (10)	32.0 (9)
CABG : non-CABG cardiac surgery	6:4	6:4
Mean ASA score	2.1	2.2
Mean LOS in hospital (days)	18.7	10.4

5.5.6 Discussion

These results suggest that the syndromic surveillance algorithms were less effective in the detection of cardiothoracic SSI when compared to current clinical methods of diagnosis, both in terms of proportions of patients identified and time to diagnosis of infection. The poor sensitivities found using the original algorithms and the low specificity values of the modified models demonstrate that none of the four algorithms are accurate enough for use in either a general setting or a period of high incidence.

In the original work, King used an end-point of 30 days post-surgery (as opposed to 90 days) and did not look at date of treatment commencement, but similarly found an increased time to diagnosis for the original algorithms compared to the clinical diagnosis [147], which agrees with the findings presented here.

These findings mean that the syndromic surveillance models, in their current format, may not provide a solution to the existing delays in cardiac SSI diagnosis and treatment. This analysis has possibly helped to avoid the unnecessary consequences that could have arisen from implementing this tool within ICHNT. One such implication is resource-related. The financial cost of introducing the algorithms into the computer systems and training healthcare personnel to utilise them would have been a waste of resources. Furthermore, and of somewhat more concern, the incorrectly missed diagnoses and false positives associated with these algorithms could result in false assurance in some cases, and a decline in quality of care in others, as unlike the retrospective algorithm developed in 5.4 this algorithm works in real-time and could have an impact on treatment decisions.

5.5.6.1 Limitations

As with most retrospective studies, these results are limited by missing data. Some of the algorithm parameters, such as platelets and fibrinogen, were not routinely collected post-operatively in hospital. Although this lack of data made it difficult to validate the algorithm (i.e. is it theoretically possible to detect SSIs from blood biomarkers and test requests), it did show us the utility of the algorithm in a real-life scenario, which is of greater clinical relevance. A further limitation was the cohort size; altogether 36 SSI positive patients and 10 control patients were included for analysis, so statistical significance could not be determined. With none of the algorithms working efficiently in a large enough proportion of the cohort to be clinically significant, assessing statistical significance was deemed impractical and unnecessary.

A third limitation is in reference to the unreliability of the clinical diagnosis times used. Although these were obtained from the Trust's SSISS database, the dates varied between the actual date a clinician made a diagnosis and the estimated date of onset based on the patient's symptoms, as many of the patients were initially diagnosed outside the hospital. Finally, the date when SSI treatment was commenced was also somewhat unreliable. Details of treatment for patients who were started on antibiotics in the community were unavailable and thus often the date taken was related to the time when secondary care

treatment was administered. Having uniformity across the cohort for the definitions of clinical diagnosis and treatment times would have improved the study.

The final limitation of this study is the lack of generalisability to other surgery types, even if the algorithm was performing well. The algorithm was developed only for CABG surgery, using biomarkers that were collected during the routine post-operative stay of at least one week, during which daily blood tests are taken. Other surgery types may have more variable post-operative stays and less close monitoring of blood biomarkers meaning even less data is available. Additionally, at ICHNT all patients undergoing cardiac surgery are sent to designated wards post-operatively. This is not the case in other specialties. Since OPCS codes are not input in the EHR for around one month post-procedure, prospective surveillance for cardiac surgery could use patient location in one of the designated wards as an indicator of a procedure of interest, but this would not be possible in other specialties.

5.5.6.2 Artificial intelligence & machine learning

In spite of these issues, this analysis has highlighted a few questions for further research. It seems imperative that the current prospective algorithms should be refined and revised to enhance their value. One method of doing this is through Artificial Intelligence (AI) and machine learning. This involves providing computers with relevant patient information and training them to solve complicated problems using a combination of technological and human perspectives [148]. A more recently developed algorithm for detecting SSIs in any specialty used supervised machine learning to develop algorithms with specificities of 78.8-98.8% with negative predictive values over 98% [1], allowing negative cases to be eliminated early. This approach would not be as useful for early intervention, as a lower specificity could result in unnecessary treatment for some patients (increasing the risk of antibiotic resistance) but could be useful for surveillance purposes.

AI is already being researched in other aspects of healthcare, for example the EPIC-IMPOC study is focusing on developing decision supports systems through AI to aid clinicians with antibiotic prescriptions and antimicrobial management [149,150]. Likewise, Google's DeepMind sector has employed AI in collaboration with healthcare professionals to develop Streams, an application to aid with the diagnosis and treatment of acute kidney injury [151]. DeepMind intend to expand such machine-based algorithms to include sepsis and organ failure [152], whilst AI is also being investigated in strokes, drug delivery systems and cataracts amongst other fields [153–155]. For SSIs, the current syndromic algorithms assessed in this study may form the basis of such machine learning, AI could evolve and fine tune these parameters, as well as others, based on the increasing amounts of patient information fed into the database. Ultimately, over time the aim would be to achieve models with rising levels of accuracy and efficiency in cardiac-SSI recognition.

5.5.7 Conclusion

The results of this study show that in their existing format, the prospective surveillance algorithms are of limited use in the detection of SSI related to cardiac procedures. Surveillance using clinical diagnosis is more accurate. As a result, it would not be recommended to employ the current algorithms within the Trust. Further modifications of the algorithms are required, including assessing other biological markers of infection through AI, to evaluate whether any improvements can be made to the existing algorithms.

5.6 Discussion

These studies show that retrospective ESS are simpler and more reliable as a means to collect accurate SSI rates than prospective surveillance algorithms in their current state. However, even when there is promising evidence for an ESS, the extreme complexity of the NHS on every level, from individual through hospital and Trust level and between institutions, is such that there are still many barriers to implementation. The number of different attempts there have been in the literature, and even just at ICHNT, to develop and implement ESS is testament to the immense grass-roots support among frontline healthcare workers and associated researchers for these systems. This was certainly echoed in the findings of 5.4, which found that while there was plenty of engagement from surgeons, nurses, anaesthetists, microbiology, pharmacy, and IPC, the main barriers to implementation were the lack of support and resource from senior managers, with some of these barriers being cyclical in nature. This was not only financial, but in terms of the expertise, human resource, and development time that were made available.

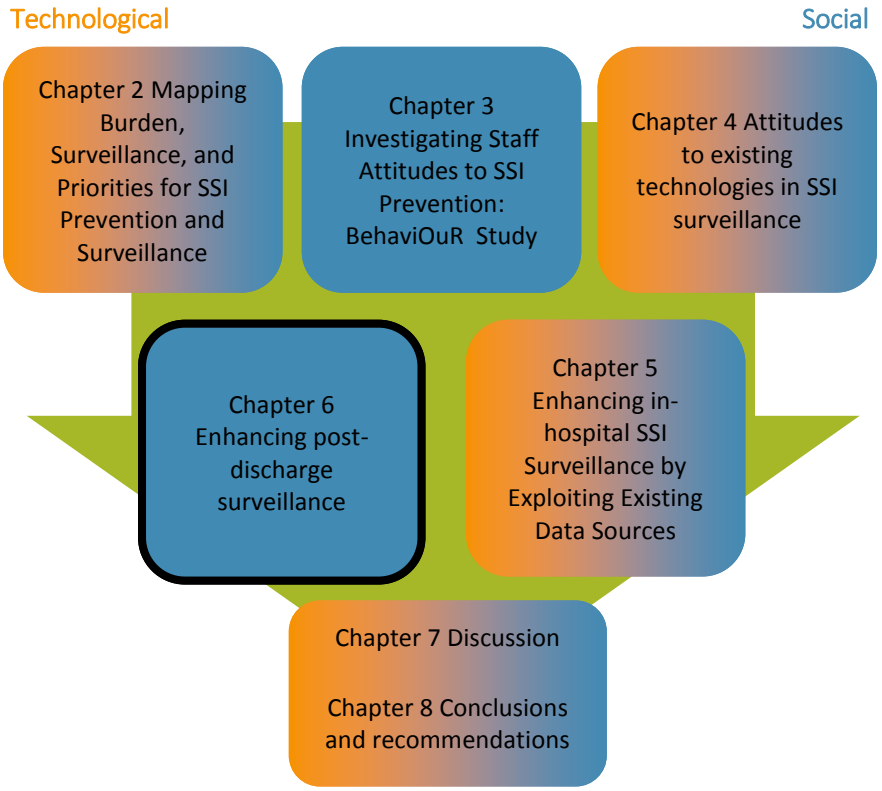
5.7 Conclusion

For surveillance purposes, retrospective algorithms are simpler to design than prospective syndromic surveillance algorithms and achieve reliable results. Short-term efforts should focus on implementing these algorithms, while a long-term goal might be to further develop syndromic surveillance algorithms for the early prospective surveillance and diagnosis of SSIs. Nevertheless, the analysis of the attempted implementation of a retrospective algorithm in the first part of this chapter shows that hospitals must first convince senior managers and budget holders of the need for a comprehensive, sustainable SSI surveillance system, as this was found to present the biggest barrier to implementation of ESS.

Chapter 6. Enhancing post-discharge surveillance

Summary

The previous chapters, like many national surveillance systems, have mostly explored with in-hospital surveillance, so this chapter now moves on to look at some of the issues surrounding post-discharge surveillance of SSIs. It begins with a realist review of the literature to understand how existing methods have been used in different settings and the factors behind their success, and then describes a patient focus group study that was planned at Imperial College Healthcare NHS Trust (ICHNT) and the results of an interview with a patient that helped to validate the findings of the realist review. The results of the realist review were presented in poster form at the European Congress of Clinical Microbiology and Infectious Diseases 2017 [156].



6.1 Background

Most SSIs though do not develop during the initial stay, especially in surgery types which have a short post-operative length of stay [45]. A recent systematic review and meta-analysis suggested that approximately 60% of SSIs globally occur after the patient has been discharged from hospital [45]. Capturing these SSIs

remains a problem. In the case of severe infection, and where the original hospital is convenient, patients can be readmitted to the same hospital and the SSI can be detected and counted there for surveillance purposes, as is common in national surveillance systems. But not all SSIs are severe enough to warrant readmission, and even then, not all cases will return to the same hospital where the surgery was carried out. Missing these SSIs results in an underestimation of SSI rates which varies between surgery types, making it difficult to compare surgery types within a hospital to inform resource allocation. The extent of this missing data also depends on whether patients with SSIs access other healthcare providers such as primary care, urgent care, and smaller, more local hospitals, particularly if the surgery was carried out at a tertiary referral centre, which has implications for benchmarking. Furthermore, this incomplete data may increase the relative size of noise to genuine signals in SSI rates with the consequence that even when rates are being monitored in the same surgery type in the same facility, their value in detecting trends is reduced. As the length of stay following surgery is decreased through the proliferation of ambulatory surgery, minimally-invasive surgery and enhanced recovery programs, the need for high-quality standardised post-discharge surveillance (PDS) will increase.

There are many different ways of conducting PDS across the world, but no research has been done to understand how these methods might work in different contexts. The aim of this chapter is to examine the barriers and facilitators of successful PDS methods in different contexts through a realist review and explores how this might translate to the NHS in England through patient focus groups at ICHNT.

6.2 Realist review of post-discharge surveillance methods globally

6.2.1 Introduction

Surveillance of healthcare associated infections (HCAIs) is recommended by the World Health Organisation (WHO) as one of the core components for effective infection prevention [157]. Surgical site infection (SSIs) make up a significant proportion of HAIs globally [5,158,159], and surveillance of SSIs in hospitals is well-established, with many countries having national or international reporting systems with standardised surveillance protocols [103,160]. However, a recent global meta-analysis showed that on average 60% of SSIs do not develop until after the patient has been discharged from hospital [45] and the proportion of SSIs developing post-discharge varies between surgery types, with the lowest proportion in colorectal surgery at 46% (confidence interval, CI 37-56%) and the highest in hernia repair at 80% (CI 74-85%) [45].

PDS is particularly important for procedures with a short post-operative inpatient stay such as caesarean sections. In a multi-centre study of post-caesarean SSI in England, the median post-operative length of stay was 3 days and 84% of infections were detected after discharge from hospital [161]. Consequently, SSI rates based on inpatient surveillance alone will underestimate the rates of SSI and introduce bias when comparing rates across different procedures. In the context of a trend towards minimally invasive and

ambulatory surgery and the proliferation of enhanced recovery programmes [162], the post-operative length of stay will reduce, making detection of SSIs by PDS even more vital.

Many national and international reporting systems globally include a recommendation for PDS (e.g. the Surgical Site Infection Surveillance Service (SSISS) in England, Krankenhaus Infektion Surveillance System in Germany, National Healthcare Safety Network in the USA) but unlike in-hospital surveillance, there is no gold-standard method for conducting PDS: these range from traditional methods such as outpatient clinics, paper patient questionnaires, and follow-up phone calls, to more high-tech solutions such as electronic health record surveillance and patient apps.

Nevertheless, when the same method is used in similar settings, case-finding intensity, response rates and data quality can vary dramatically. Even when settings seem similar, there can be subtle differences in the context, such as patient demographics, staff relationships, and supporting infrastructure, which have a dramatic impact on the outcomes of a new initiative. A study on caesarean section (CS) SSIs in English hospitals following a standardised PDS protocol found questionnaire response rates from community midwives ranged from 8.8% to 97.8%, and from patients 5.6% to 73.4% [37].

Given that subtle differences in surveillance methodology can have a major impact on results, a systematic review of the methods used globally would be of little use, since it provides no indication of what makes some methods more successful than others. Traditional systematic reviews are often designed for simpler interventions such as drug trials which are conducted under controlled conditions, but are less useful when analysing more complex interventions with in real-world setting as they fail to account for this complexity [163]. Realist methodology has been developed to answer the question of "what works for whom, in what circumstances, and why" [164] by analysing the mechanisms (the underlying drivers of behaviour) through which the "context" (e.g. demographics, structure, and infrastructure, but also existing relationships and attitudes) affects the "outcome" (measurable indicators of impact) of an intervention or initiative. Reviewers are then able to construct context-mechanism-outcome configurations (CMOCs). A simple example might be when a star chart is used to reward a child (context), the child will behave well (outcome) because they want to get a star (mechanism). Multiple CMOCs can be derived to explain how different contexts drive different behaviours and outcomes, and together these can form the basis of a program theory. While it is never possible to produce a guaranteed "recipe for success", by identifying factors which influence the success of an initiative, and understanding how they work, these factors can be manipulated and mitigated to help push the initiative towards a successful outcome.

For the purposes of this study, context, mechanism, and outcome were defined as:

- Context: The prevailing circumstances and conditions in which patients and/or healthcare providers make decisions about or interact with PDS for SSIs

- Mechanism: How the context causes patients or healthcare providers to behave in a certain way when interacting with the PDS method
- Outcome: Measurable factors that indicate whether PDS was successful: response rates, case-finding intensity, sustainability

6.2.2 Methods

This review uses realist methodology to analyse literature on methods for surveillance of SSIs after the patient has been discharged from hospital. The review was conducted in four phases based on the method outlined by Pawson et al. [163].

6.2.2.1 Phase I: Defining the scope

The research question to be answered was: what are the drivers of success or failure when implementing a PDS system? In order to focus the literature search, three surgical categories were selected to represent a range of patient groups and surgery types: 1) caesarean section for young, generally fit and healthy patients with a short post-operative length of stay (LOS); 2) large bowel surgery for patients with more comorbidities, longer LOS and a high SSI rate; and 3) orthopaedic surgery for older patients with a very low SSI rate. For each of these surgery types, 79% (95% CI 68-90), 46% (CI 37-56), and 58% (CI 44-73) of SSIs are detected after discharge respectively [45].

A preliminary search for existing theories was carried out by searching Medline, Embase, and Scopus using keywords detailed in Appendix 13.

6.2.2.2 Phase II: Search for and appraise the evidence

A search of the literature was conducted to identify papers describing experiences of a variety of PDS methods for detecting SSIs. Searches were conducted in Medline, Embase, and Scopus up to May 2017 (see appendix for search strings). Together with another colleague, I screened the results for relevance, and disagreements were resolved by discussion. Papers were included if they used PDS to attain SSI rates, compared two or more methods of PDS, or commented on the authors' experiences of PDS. PDS was defined as surveillance of SSI events occurring after the patient has been discharged but not including readmissions to the hospital due to SSI. Papers were excluded if the study was for a primary purpose other than estimation of SSI rates e.g. risk factor assessment or intervention study. Only papers written in English were included.

6.2.2.3 Phase III: Extract and synthesise findings

Data on the setting, methods, and results were extracted from the papers by one researcher (myself). Comments in the papers that were important to how the context of the intervention impacted on outcomes were also extracted and added to an Excel spreadsheet. Comments were then compared with

each other and coded to create themes relating to either the patient or provider's experience, and the themes were refined as further items were coded.

Within the themes individual comments were also coded to indicate whether they related to either context, mechanism, or outcomes of the intervention. Comments were separated out by the theory components of context, mechanism, and outcome. Comments under the same theme and theory component were summarised with a short phrase and numbered. Once these were identified, CMOCs were constructed into short sentences to create a series of small theories that explain the mechanisms by which the context affects the outcome of an intervention, which were discussed and refined with other researchers. A worked example to illustrate this process is shown in Figure 15. The CMOCs were then compared with domains and constructs in the candidate theories identified in 6.2.2.1 to help develop a program theory for the implementation of PDS methods.

Figure 15 Illustrative example of CMOC construction from raw data

Raw quotes	Patient questionnaires may be inappropriately interpreted and of course may not be returned [165]	Our study suggests the wording of questions may contribute to the response supplied [166]	Perhaps the response rate could have been increased had the wording of the questionnaire been simplified [167]
Theme	understanding what is expected		
Quotes by context, outcome, mechanism	Contexts: "the wording of questions" "wording of the questionnaire been simplified"	Outcomes: "contribute to the response supplied" "the response rate could have been increased" "may not be returned"	Mechanisms: "Patient questionnaires may be inappropriately interpreted"
Refined CMOC	In a context where patients are given clear, adequate information about PDS (C1)	response rates are increased (O1) AND data quality is increased (O5)	because patients are able to understand what is expected of them, and communicate effectively (M2)

6.2.2.4 Phase IV: Draw conclusions and make recommendations

The program theory can be refined by other researchers, but in the meantime can also be used by groups planning and implementing PDS systems in their own settings.

6.2.3 Results

6.2.3.1 Theory search

No existing theories on engagement with SSI surveillance were identified, so other relevant theories were identified through the ABC of Behaviour Change Theories [168], and an exploratory search of literature on engagement with health technology. Three candidate theories were shortlisted; the COM-B System [169], the Integrative Model of Behavioural Prediction [170], and the Technology Acceptance Model [171]. These theories dealt either specifically with acceptance of a new technology or initiative by users, or were broad enough to cover these topics.

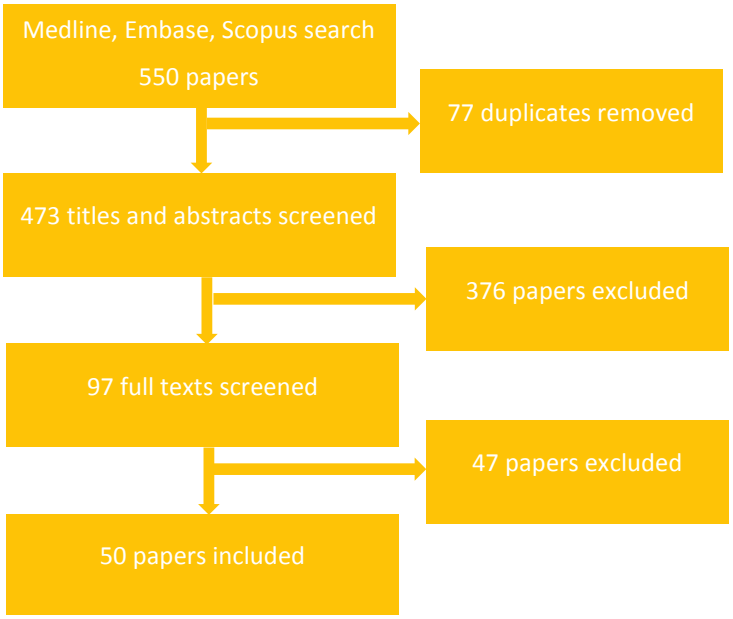


Figure 16 Summary of papers found and included in a realist review of post-dishcarge surveillance methods for SSI

6.2.3.2 Studies included & excluded

The initial search found 473 papers after de-duplication. Titles and abstracts were screened by two researchers (me and Vivian Alividza, a Clinical Research Fellow and infection prevention and control (IPC) nurse) leaving 67 papers for full-text review (Figure 16). Fifty papers were ultimately included in the study, 30 European, eight from North America, four from South America, four from Australia, three from Asia and one from Africa. The majority surveyed caesarean section (28, 45%), while 23 (37%) surveyed orthopaedic surgery and 12 (19%) surveyed large bowel surgery. Ten papers looked at more than one of the surgery types listed.

6.2.3.3 Table of PDS method types

Table 19 Papers included in the realist review of post-discharge surveillance (PDS) methods

HWQ= healthcare worker questionnaire, PDQ= post-discharge questionnaire, HER= electronic health records

Surgery type	Lead author	Country	Year of data	Site (single, group, national)	Primary method	Response rate (%)	Infection rate (%)	% detected by PDS
Bowel	Stockley [172]	England	1995-2000	S	Phone call/HWQ	70.0	26.4	42.9
	Mannien [173]	Netherlands	1996-2004	G	HWQ		11.3(active) 11.8(passive)	
	Koek [38]	Netherlands	1999-2008	S	HWQ, other			
	Moro [174]	Italy	1999-2008	N	HWQ, phone	97	11.6-26.1	
	De Oliveira [175]	Brazil	2001-2002	G	Phone calls / clinic	90 /96.9	33.7/17.9	80/75
	Reilly [176]	Scotland	2002-2004	S	Clinic/visit/PDQ			
	Limon [177]	Spain	2007-2011	G	EHR		20.7	22.5
	Tanner [178]	England	2008	G	Phone, home visit	93	27.6	41
	Marchi [179]	Italy	2009-2011	S	Clinic, PDQ			
	Sanger [180]	USA	2014	G	app		n/a	n/a
Caesarean section	Ferraz [181]	Brazil	1988-1992	G	Clinic	68.8	3.8-7.4	52.9
	Manian [182]	USA	1988-1995	S	HWQ	58.0		44.0
	Hulton [183]	USA	1990	S	HWQ	90	6.3	59
	Yokoe [184]	USA	1993-1995	S	EHR	N/A	4.2	94
	Couto [185]	Brazil	1995-1997	G	Clinic	46.8	9.6	83.7
	Kent [186]	Australia	1996-1998	S	HWQ	98.7		

Noy [187]	Australia	1999-2000	S	Paper PDQ	89	0.17	83
Creedy [188]	Australia	1999-2000	G	Paper PDQ/phone	89	17.7	85.7
Koek [38]	Netherlands	1999-2008	S	HWQ, other			
Moro [174]	Italy	1999-2008	N	HWQ, phone	97	0.5-7.1	53
Mitt [189]	Estonia	2002	S	HWQ		6.2	42.1
Reilly [176]	Scotland	2002-2004	S	Clinic/visit/PDQ		12.2	
Opoien [190]	Norway	2003-2004	S	PDQ	100	8.9	79.3
Ward [161]	England	2003-2005	S	HWQ	88	8.9	84
Lower [191]	Norway	2005-2009	S	Paper PDQ	88.3		83
McNeish [192]	Scotland	2006?	G	phone (novel)	60		
Leth [193]	Denmark	2007-2008	S	EHR	61.7	7.1	56
Bianco [194]	Italy	2007-8	N	telephone	97.2	5.7	88.4
Pittalis [195]	Italy	2008	S	telephone		2.4	96.6
Cardoso [196]	Brazil	2008	G	telephone	91.7	23.5	93.9
Wilson [37]	England	2009	G	midwife		9.8	54.7
Marchi [179]	Italy	2009-2011	S	Clinic, PDQ		CS 1.7	51
Halwani [197]	USA	2010	G	Paper PDQ/phone	82.4	10	26.3
Srun [198]	Cambodia	2010-2011	G	clinic	79	6.25	36.4
Ferraro [199]	Italy	2011/2013	N	Clinic/phone	94	3.9	89
Gravel-Tropper [167]	Canada	Early 90s	S	HWQ/PDQ	Surgeons 78.4%, patients 1.7%	5.1	41.7

	Nguhuni [200]	Tanzania	paper 2016	S	Phone	87.0	12.0	?
Orthopaedic	Lower [201]	Norway		S				
	Manian [182]	USA	1988-1995	S	HWQ	80.0		21.0
	Mitchell [202]	Australia	1996-1997	S	HWQ/PDQ	PDQ 50.2/HWQ 40.4	6.1	33.3
	Kent [186]	Australia	1996-1998	S	HWQ	98.7		
	Friedman [203]	USA	1996-1999	N	EHR	n/a	4.5	72
	Mannien [173]	Netherlands	1996-2004	G	HWQ		2.7 (knee, active) 1.5 (knee,passive) 2.7 (hip, active) 2.7 (hip,passive)	
	Barnes [204]	USA	1998-2004	G	EHR	n/a	1.7	52.9
	Huotari [205]	Finland	1999-2002	S	Paper PDQ/clinic	?	3.3	56
	Koek [38]	Netherlands	1999-2008	S	HWQ, other			
	Moro [174]	Italy	1999-2008	N	HWQ, phone	97	0.9-9.1	
	Huenger [206]	Germany	2000-2001	G	Paper PDQ/HWQ	85.2	3.2	25
	Thu [207]	Vietnam	2000-2001	N	Clinic/PDQ		12.5	24.7
	Wilson [1]	England	2000-2004	S	PDQ/phone			54.7
	Reilly [176]	Scotland	2002-2004	S	Clinic/visit/PDQ		2.2	
	Reilly [208]	Scotland	2004???	G	Phone, clinic	100	5	38
	Knaust [209]	Germany	2005-2006	S	PDQ/phone	50.9	7.0	84.2

	Lower [210]	Norway	2005-2011	S	Paper PDQ	87	3.6	79
	Alazzawi [166]	England	2009	S	Paper PDQ	84.7	2.3	n/a
	Guerra [211]	Cambodia	2011	G	HWQ/phone	87	29	49
	Le Meur [212]	France	2011	G	EHR	n/a	1.7	33.3
	Noel [165]	England	Pre-1995	S	PDQ/HWQ	PDQ 76/HWQ 64		
Reviews	Petherick [46]	UK	1991-2004	N	Review	n/a	n/a	n/a
	Tanner [107]	Scotland	2010-2012	S	Comment	2-100	n/a	

6.2.3.4 Context-mechanism-outcome configurations

Themes were analysed and refined through discussions with other experienced researchers by examining the wording of each theme in detail alongside the data, combining themes which were similar, separating out those which had slightly different meanings, or deleting those which were not strongly supported by the data. After analysing and refining the themes through discussions with other experienced researchers, there were a total of 37 contexts which led to 11 outcomes via 25 mechanisms. These were combined to produce configurations, or CMOCs, creating 32 small theories which explain some of the phenomena observed when a PDS system is implemented (Table 20). Again, these CMOCs went through an iterative process of re-wording, combining, separating, and deleting.

Table 20 Context-mechanism-outcome configurations (CMOCs) that explain how the context of a post-discharge surveillance (PDS) intervention impacts on its outcome.

CMOC	Context	Outcome	Mechanism	Illustrative data	Papers identifying these themes
1	In a context where patients are given clear, adequate information about PDS (C1)	response rates are increased (O1) AND data quality is increased (O5)	because patients are able to understand what is expected of them, and communicate effectively (M2)	Our study suggests the wording of questions may contribute to the response supplied. For instance, the question about nerve injury was intended to identify patients with motor or sensory compromise of major nerves, but 19 patients reported post-operative numbness of the scar in this way. [166]	[165–167,172,180]
2	In a context where patients are given unclear information about SSIs (C2)	response rates are reduced (O2) AND data quality is reduced (O6)	because patients are not confident identifying and reporting SSIs (M1)	The second theme relates to challenges patients face, often with the help of caregivers, in effectively caring for themselves. In particular, this included being vigilant for wound problems, and recognizing wound problems when they surface. [180]	[46,180,202,213]
3	In a context where the hospital does not communicate in a language the patients speaks (C3)	human and financial resource use is higher (O11) AND data quality is reduced (O6)	because patients are not able to understand what is expected of them, or cannot communicate effectively (M7)	It is worth noting that the longest telephone call (5 minutes) was with a patient who had a low level of English proficiency. [197]	[197,172,191]
4	In a context where patients do not have a permanent address (C4)	response rates are reduced (O2)	because staff cannot easily collect the data they need (M11)	Lack of follow-up was greatest in specialties where communication was difficult or mobility of the population was high [213]	[213]
5	In a context where patients are very elderly (C5)	response rates are reduced (O2) AND selection bias is increased (O4)	because patients ability to respond to surveillance may decline during follow up (M5) AND staff cannot easily collect the data they need (M11)	Many hospitals find 1-year active PDS after hip arthroplasty difficult, because many of the patients have died, have been admitted to nursing homes, or have dementia. [210]	[210]

6	In a context where technology e.g. automated telephony or smartphone apps are being used for surveillance (C6) AND patients have difficulty engaging with technology (C7)	response rates are reduced (O2) AND selection bias is increased (O4)	because patients find the surveillance inconvenient or difficult to respond to (M6)	Most patients found the system easy to use. However, two patients informed the project leader that they had been unable to access the system. It is unknown how many others may have had similar difficulties. **[192]**	**[192]**
7	In a context where telephone ownership is high (C8) AND telephones are being used for surveillance (C9)	response rates are increased (O1) AND selection bias is reduced (O3)	because staff can easily collect the data they need (M10)	It is important to emphasize that this model of surveillance was possible in this particular setting because the majority of the study population had a telephone. [196]	[172,189,194,196, 200]
8	In a context where patients have a low socioeconomic status (C10) AND telephones are being used for surveillance (C9)	response rates are reduced (O2) AND selection bias is increased (O4)	In a context where staff cannot easily collect the data they need (M11)	Fewer than 10% of the patients (16 out of 193) did not answer their telephone or had no working telephones... The small group of patients who did not answer telephone calls or had nonworking numbers might represent part of the nature of the socioeconomic status of Baltimore as a city, and reflects another limitation of the study. [197]	[181,197]
9	In a context where technology e.g. automated telephony or smartphone apps are being used for surveillance (C6)	response rates are increased (O1)	because patients find the surveillance convenient and easy to respond to (M3)	Most participants indicated that mHealth would be an acceptable solution to enable patients to engage in wound monitoring. More specifically, participants perceived that mHealth can address post-discharge challenges by allowing more frequent, thorough, and convenient follow-up, thus leading to less patient anxiety and fewer unnecessary emergency department visits than current practice. [180]	[180,192]

10	In a context where patients have access to primary care (C11) OR patients have a health insurance policy with pharmacy benefits (C12) AND data are being collected from other healthcare providers (C13)	human and financial resource use is lower (O10)	because patients are able to visit primary care for wound concerns (M8) AND staff can easily collect the data they need (M10)	This post-discharge surveillance method was also appropriate for the current circumstances, in which most women sought post-discharge care from their general practitioner. **[187]**	**[167,184,186–188]**
11	In a context where reminders are sent to patients (C14)	response rates are increased (O1)	because patients or HCPs are prompted to engage with surveillance (M9)	Success factors: Tracking and reminding regarding questionnaires not returned Second or third phone call if the data not received within the agreed time frame [186]	[165,172,186,188, 191,202]
12	In a context where patients have a low socioeconomic status (C10) AND clinics are being used for PDS (C15) AND travel costs are reimbursed (C16)	response rates are increased (O1) AND selection bias is reduced (O3) AND human and financial resource use is higher (O11)	because patients find attending clinics prohibitively expensive or inconvenient (M12)	We observed that our post discharge follow-up rate increased when reimbursement of transportation fees was proposed. However, the sustainability of such a surveillance system is not in place to support the families or to rationalize the costs. [198]	[198]
13	In a context where telephones are being used for surveillance (C9)	response rates are increased (O1)	because patients feel they and their experiences are valued (M13)	In addition, the women were receptive to telephone contact and showed that they felt valued by the attention given to them by the investigator [196]	[172,191,196,200]
14	In a context where patients have the capability to travel (C17) AND clinics are being used for PDS (C15)	response rates are increased (O1) AND selection bias is reduced (O3)	because patients find the surveillance convenient and easy to respond to (M3)	Rates of follow up are likely to be influenced by ... availability of transport and population mobility. The present study involved patients admitted to a medium-sized private hospital in a provincial city... a well-defined geographical region [186]	[175,186,192,198, 200]

15	In a context where there are opportunities for patients to interact directly with staff (C18)	human and financial resource use is lower (O10) AND response rates are increased (O1)	because patients expect to receive advice or signposting for their concerns (M14)	‘‘[The app] would save money for both patient and healthcare facility, and it would save the patient from unnecessary trips to the ER or clinic.’’ P12 **[180]**	**[172,180,200]**
16	In a context where data could be deliberately or accidentally passed on (C19)	response rates are reduced (O2) AND selection bias is increased (O4)	because patients feel there is a risk of harm to them from sharing their data (M15)	It is possible that these patients did not provide accurate contact information because of their mistrust of the medical community [197]	[180,197]
17	In a context where staff are adequately trained (C20)	data quality is increased (O5) AND case-finding intensity is increased (O7)	because staff are competent to conduct PDS (M23)	Wide clinical experience was considered essential to enable the nurse to assess the patients accurately and categorise them accordingly. [192]	[175,177,192,195, 200,209,213]
18	In a context where inadequate human and non-human resources are available (C21)	data quality is reduced (O6) AND sustainability of surveillance is reduced (O9)	because staff suffer from surveillance fatigue or demotivation (M19)	In a national mandatory system, the hospitals are required to submit data, even when they do not have the resources available to have a good data collection system in place. This may adversely affect the data quality. [191]	[161,172,185,189, 192,195–199,206,211]
19	In a context where existing patient contact opportunities are used (C22)	human and financial resource use is lower (O10)	because staff can easily collect the data they need (M10)	By using the fact that women undergoing caesarean section have routine contact with a community midwife for a minimum of 10 days, this study demonstrates the feasibility of a collaborative approach to post- discharge surveillance [161]	[37,161,173,175,179,181,192,198,206,213]
20	In a context where records are available and data can be easily linked (C23)	data quality is increased (O5)	because staff can easily collect the data they need (M10)	the civil registration number enables unambiguous linkage between all Danish healthcare registries, and allows us to conduct surveillance based on already electronically stored infection data. [193]	[46,161,172,177,181,182,189,193,203,205,210,212]

21	In a context where there is multidisciplinary engagement (C24)	case-finding intensity is increased (O7) AND response rates are increased (O1) AND sustainability of surveillance is increased (O12)	because staff are motivated and engaged (M18) AND stakeholders have a sense of ownership of the system (M17)	The positive effect of clinical involvement in the surveillance is perhaps demonstrated in the higher response rates from community midwife in surveillance periods co-ordinated by the maternity department. [37]	**[37,161,167,172,182,183,186,203,208,213]**
22	In a context where there is an existing strong Infection Prevention and Control culture (C25)	sustainability of surveillance is increased (O12)	because staff are motivated and engaged (M18)	Success factors: An enthusiastic and persistent infection control practitioner... Frequent personal contact by members of the HEC and ICP with individual surgeons [186]	[167,186,198]
23	In a context where the PDS system is well designed (C25)	case-finding intensity is increased (O7)	because staff can easily collect the data they need (M10) AND staff find the system fits conveniently into their workflow (M16)	In addition, the simplicity of our questionnaire also placed few added demands on either surgeons or their office staffs. [183]	[182,183,186]
24	In a context where the follow up period is one year (C27)	case-finding intensity is reduced (O8)	because staff suffer from surveillance fatigue or demotivation (M19)	Concern has also been raised with regard to surveillance fatigue that may result in less diligent case-finding by traditional methods over time, and more so with the additional burden of active 1-year PDS [210]	[210]
25	In a context where staff receive regular feedback on SSI rates (C28)	case-finding intensity is increased (O7)	because staff feel the data collected are useful (M20) AND staff are motivated and engaged (M18)	Providing the maternity staff with regular feedback on the surveillance findings and sharing them with other Cambodian stakeholders sparked discussions about the SSI burden on patients and on health services [198]	[161,167,182,186,187,198]
26	In a context where SSIs are at high incidence (C29)	case-finding intensity is increased (O7) AND human and financial resource use is higher (O11)	because staff feel the data collected are useful (M20) AND managers feel obliged to provide support for PDS (M21)	staff were more receptive to the need for infection control measures in view of the unexpectedly high incidence of wound problems reported. [161]	[46,161,178,181]

27	In a context where national mandatory reporting is used (C30) AND reported rates are used for accreditation & contract awards (C31)	case-finding intensity is reduced (O8)	because staff fear there will be consequences if rates appear high (M22)	The current health care environment may unintentionally promote under-reporting since external agencies use such data to make decisions regarding payment and rewarding of contracts and accreditation. **[187]**	**[187]**
28	In a context where stamped addressed envelopes are provided (C32) AND paper questionnaires are used (C33)	response rates are increased (O1)	because patients find the surveillance convenient and easy to respond to (M3)	A self-addressed, stamped envelope was included with the survey form. [167]	[165,167,172,186, 209]
29	In a context where paper questionnaires are used (C32)	response rates are reduced (O2)	because patients find the surveillance inconvenient or difficult to respond to (M6) OR healthcare workers find the system inconvenient to respond to (M24)	A major limitation of this approach as demonstrated in this study is the relatively poor compliance with return of forms (57% by patients and 50% by surgeons). Such compliance rates are, however, consistent with those of other published studies [202]	[37,165,202]
30	In a context where a combination of methods are used (C34)	response rates are increased (O1)	because patients find the surveillance convenient and easy to respond to (M3)	the combination of different methods is relatively simple to use and causes minimal inconvenience to patients and healthcare workers. [202]	[37,165,172,177,178,186–190,202,208,209, 211]

6.2.3.5 Theory development

Once the CMOCs had been established, these were then compared with the shortlisted theories i.e. the COM-B System [169], the Integrative Model of Behavioural Prediction [170], and the Technology Acceptance Model (TAM) [171]. The Integrative Model of Behavioural Prediction [170] was found to be too individual-centric and did not fit with the multidimensional drivers identified in the realist review. However, a good fit was found using a combination of the COM-B system and the TAM. The CMOCs were split into patient-related and provider-related, and then grouped according to capability, opportunity, and motivation of these groups. The perceived ease of use domain from the TAM encompassed many of the aspects of capability and motivation for patients, but also some further factors that did not fit into these

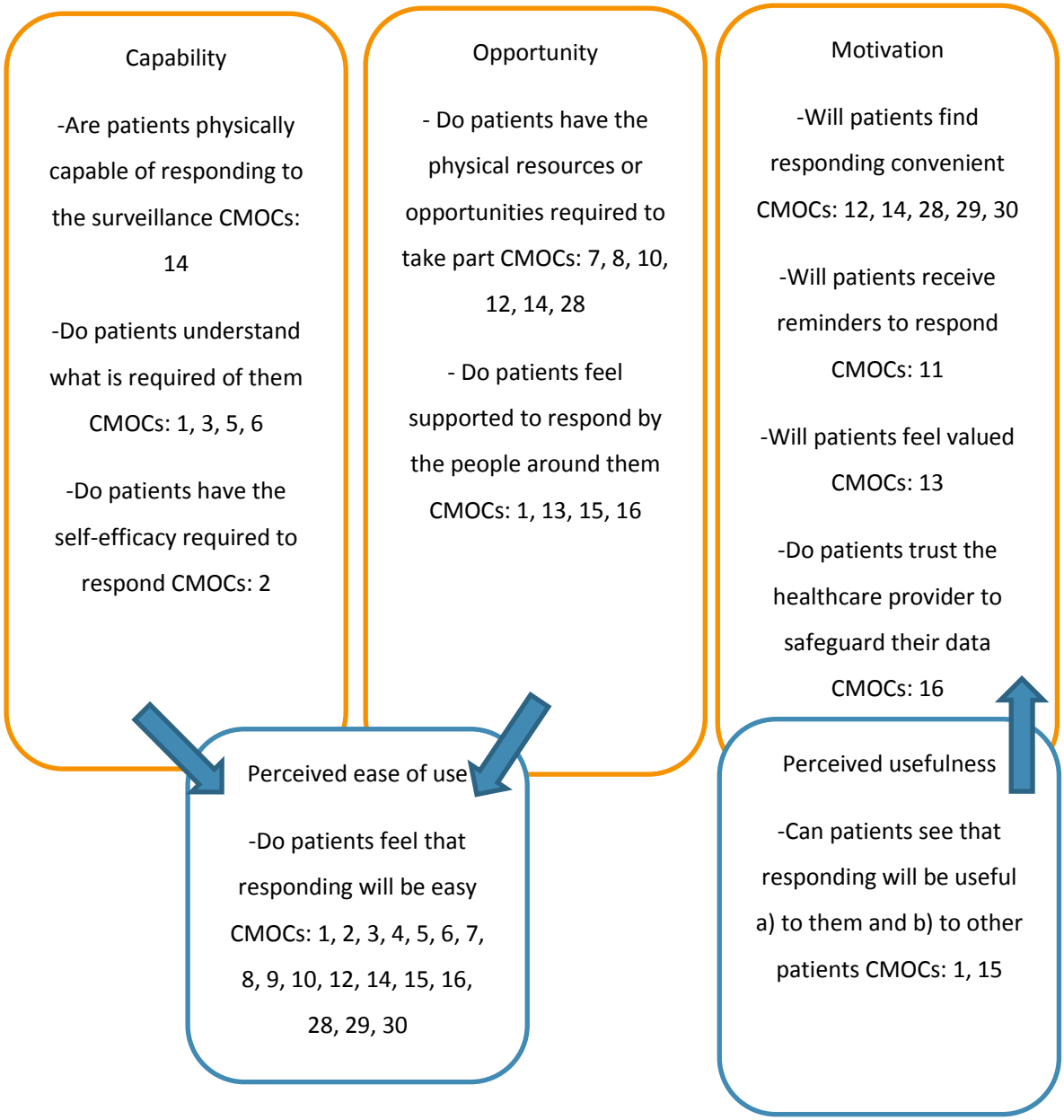


Figure 17 Patient-related factors to consider when developing a post-discharge surveillance method for surgical site infections

domains, or also fit into the motivation domain, so perceived ease of use was included in the model Perceived usefulness was also a major factor related to but not entirely covered by the motivation domain of the COM-B system, so this was also included as a domain. Figure 17 and Figure 18 show how these domains interlink for patients and providers respectively.

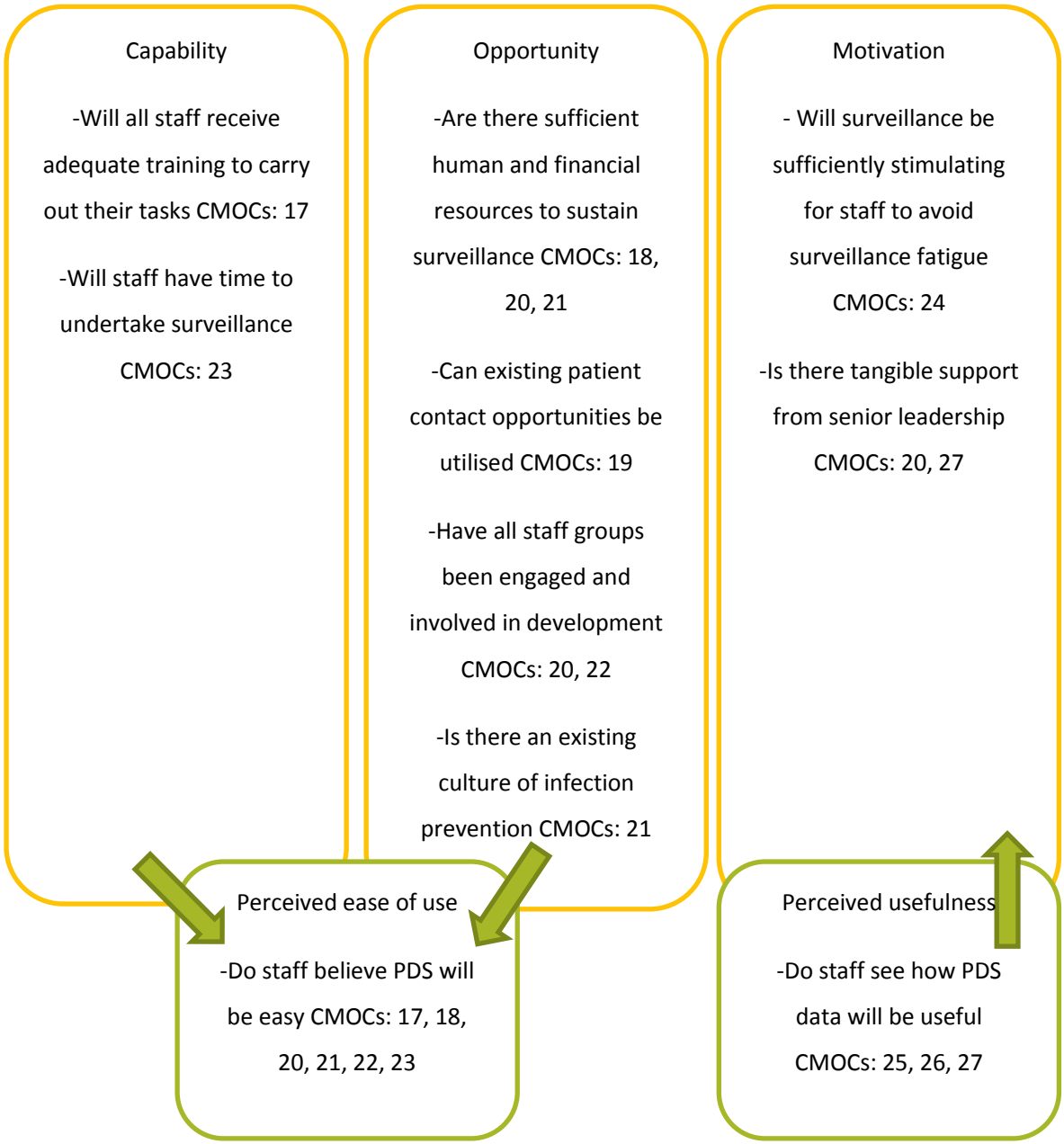


Figure 18 Provider-related factors to consider when developing a post-discharge surveillance method for surgical site infections

One basic question to ask when planning a PDS system in which patient will be required to respond to surveillance is whether the patient group in question will have the capability and opportunity to respond. Patient demographics are the main factor in this, as it relates to language (CMOC 3) and existing disability (CMOC 14), but also disability caused by the surgery or by the SSI, and age-related factors like dementia (CMOC 5) and reduced mobility (CMOC 14). Age was also a factor in tracing patients for PDS which was a particular concern in orthopaedic surgery, as one study commented that elderly patients are more likely to move address e.g. into or between care homes [210].

Patients' socioeconomic status can influence their opportunity to respond as it impacts on telephone or possibly smartphone ownership (CMOC 8), and their ability or willingness to travel to clinics (CMOC 12). In settings outside the UK, a patient's socioeconomic status may also determine what type of insurance plan they have (CMOC 10), and therefore whether data can be automatically collected on their outpatient or primary care consultations.

The patient-provider relationship is an important factor in surveillance; simple measures such addressing letters and other communication to the patient by name (CMOC 13) and providing written communication in the language of their choice (CMOC 3), can improve patients' motivation by helping the patient to feel valued and cared for, and to feel confident in the provider. Offering the opportunity for the patient to discuss their wound problems with a healthcare professional may increase the "perceived usefulness" of surveillance to the patients, which increases their motivation to engage (CMOC 15). The choice of who provides advice to the patients (e.g. nursing staff, administrative staff, infection prevention and control staff) could influence patients' motivation, but also has consequences for providers in the amount of staff training (CMOC 17) and resources (CMOC 18) required, and potential disruption to staff workflow (CMOC 23).

For providers, the major theme was how key multidisciplinary engagement was in creating a sustainable system (CMOC 21). Engagement from all stakeholders, and particularly senior managers, was described as absolutely key by multiple studies, and this may be because it indirectly influences the capability, opportunity, and motivation of staff: it facilitates design of the system around existing workflow (CMOC 23) and helps with identification of training needs (CMOC 17); it reinforces a strong IPC culture (CMOC 22) and opens channels to make more resources available (CMOC 18); and it motivates staff by creating a sense of shared responsibility (CMOC 24), and allows the staff involved in PDS to complete the feedback loop with those who can use the data for quality improvement (CMOC 25).

6.2.4 Discussion

The balance of conducting comprehensive SSI surveillance with other IPC activities is increasingly difficult in many UK settings as other priorities such as hand hygiene audits, bloodstream infection reduction targets, and outbreaks of drug-resistant infections compete for time and resources. However, SSIs still

represent a significant burden of preventable infection, and are increasingly likely to occur outside of hospital [214], making effective and sustainable PDS an integral part of SSI surveillance.

PDS is most important in surgery types for which there is a very short post-operative length of stay, or where the infection may be very slow to develop (for example, prosthetic joint infection after joint arthroplasty) as these SSIs are unlikely to develop before discharge. It is also important for tertiary referral centres, who may only see a small proportion of their own patients readmitted as many patients with SSIs will be readmitted to a hospital more local to them.

This study found that PDS methods must take into account the "capability, opportunity, and motivation" [169] of both the patients and the staff conducting the surveillance, and ensure that the perceived ease of use and perceived usefulness [171] of the surveillance is maintained for both patients and staff if PDS is to be fully embedded in the service.

6.2.4.1 Patients

The debate about whether patients are able to reliably detect infections for the purposes of surveillance has been ongoing for many years, and studies have shown conflicting rates of concordance between patients and healthcare professionals [202,215]. However it is important to note that both SSI diagnosis [105] and estimation of the level of infection [106] can vary substantially even among healthcare professionals. Given the practical difficulties in recalling every patient for a wound assessment, data gathered through patient-reported SSIs can be a pragmatic way of collecting data [107].

Patients and carers will firstly need to have the knowledge needed to recognise an SSI. However, it is not sufficient for patients to be told which symptoms to look out for and how to report an SSI; the patient must be confident in their own judgement on the state of the wound, perhaps never having seen a surgical wound before [180]. Previous studies have shown that providing information to patients on which signs and symptoms to look out for can lead patients to over-report SSIs [216], and this review also found that careful wording and clarity in communication is vital in ensuring that data are correctly and accurately reported by patients as described in CMOC 1.

CMOC 15 which examines how patients are motivated by the opportunity to interact with a healthcare professional did not have much explicit evidence, but I feel that this may become one of the most important drivers. Many papers that reported on methods that allowed interaction with a HCP stated that patients liked it, with the implied meaning that they felt happier when they could receive reassurance, advice, or signposting. This should be explored in more detail through the subsequent patient focus group study.

Using telephone calls or clinics for direct contact with healthcare providers as the primary method was reported as being costly too costly by several of the papers in this study [185,192,206,213], and patients did not respond well to paper questionnaires (CMOC 29) even when reminders (CMOC 11) and self-

addressed envelopes (CMOC 28) were provided. There were two papers which used novel methods as screening tools for triaging patients; one used automated telephony [192], and another consulted patients on a new smartphone app [180]. Both of these interventions were reported as being acceptable both to patients and healthcare providers, but in both cases concerns were raised about the difficulties for some patients in engaging with technology (CMOC 6). Smartphone ownership is likely to be lower among elderly and less affluent patient populations, and elderly patients or those with hearing or cognitive impairments may find using automated telephony difficult, thereby introducing selection bias.

There is a dearth of work and evidence surrounding patient acceptability or preference of PDS methods; what evidence there is tends to have been gathered reactively, asking patients for their views on a system that has already been developed, rather than asking patients for their ideas or preferences. This data also tends to be gathered opportunistically at the same time as the surveillance, making it subject to selection bias. There is a lack of qualitative data on the drivers behind patient engagement with surveillance. Although this review provides a starting point, more research is required to validate the determinants of engagement among different patient groups in order to ensure surveillance methods are optimised to allow maximum engagement while minimising selection bias.

There were some further aspects of patient experience that may influence responses that were not found in the literature examined here: religion, culture, or other social factors such as health seeking behaviours can also vary between cultural backgrounds [217], and disabilities that affect vision, hearing, cognition, or that restrict movement are likely to affect the uptake of some tools. Further research is required on these dimensions so that PDS tools are as accessible and inclusive as possible, to avoid exacerbating health inequalities.

6.2.4.2 Healthcare professionals as respondents

Some PDS systems found in this review used questionnaires filled out by HCPs such as community midwives, surgeons, and general practitioners. The drivers around response rates for these systems were a hybrid of those of patients and providers: HCPs required reminders (CMOC 10), stamped and addressed envelopes (CMOC 28), adequate resources (CMOC 17), and a user-friendly system (CMOC 13). Engagement with these professionals was key to maximising response rates [37,186] but these were still sub-optimal.

6.2.4.3 Healthcare providers

Most PDS systems have been designed mainly around the needs of the healthcare provider [218], but this does not necessarily mean they will meet every need of every provider. In many settings, including high-income countries, availability of resources was a significant factor in the choice of PDS method (CMOC 18). When resources are insufficient, surveillance is not sustainable and case-finding intensity reduces, meaning rates are not comparable over different time points.

This review revealed many underappreciated factors outside the basic needs of resources (CMOC 18) and workflow (CMOC 23) that must be considered when designing and implementing a PDS system in a health service.

Almost all papers that mentioned facilitating factors cited multidisciplinary engagement (CMOC 21) as one of the major influences on success [37,161,183,203,208,213]. Where a number of staff groups are involved in PDS, multidisciplinary engagement was crucial as it indirectly influenced the capability, opportunity, and motivation by achieving buy-in, allowing staff to shape the tool to fit their workflow, and fostering a sense of shared responsibility. One US study [183] also highlighted the importance of senior encouragement (in this case, the Chief of Obstetrics) in championing the system and galvanising other staff to become more engaged. Multidisciplinary engagement and use of senior-level champions were both found to be major factors in the success other surgery-related interventions [133,219,220], demonstrating that existing inter-disciplinary networks are often not sufficient to support new interventions, and that staff in surgery tend to follow the lead of seniors.

Another important factor in gaining buy-in and maintaining engagement was regular feedback of SSI rates which motivated staff to continue surveillance (CMOC 25), particularly when SSI rates were unexpectedly high (CMOC 26). This is similar to findings of an audit and feedback study for in-hospital SSI surveillance [40] and a study on performance indicators for anaesthetists [41], which both found that engagement increases with increasing information.

Each setting will have its own pre-existing social and technological infrastructure which the PDS system will have to work alongside. A recurring theme in the review was the expectation that better record keeping, or electronic record keeping which enables automatic data linkage would be extremely beneficial for PDS (CMOC 20). A handful of papers had used EHRs as the primary method to identify SSIs [177,184,193,203,212], but for many setting the hospital infrastructure is not yet linked with primary care or outpatient data.

Existing patient contact opportunities are another aspect of hospital baseline infrastructure that can facilitate PDS, for example if patients routinely attend an outpatient clinic after surgery, have a midwife visit, or primary care check-up.

6.2.4.4 External factors

Aside from patient and provider drivers, there were a number of other sociological factors that were touched upon in the papers analysed but were not strong enough to constitute themes. Liability culture and other medico-legal issues were a topic touched upon by Sanger et al. in several papers on the development of their smartphone app [180,221] which may have implications for how the app is designed and implemented, and likely will differ between settings. Another question raised by the smartphone app

was around patients' expectations of healthcare, as patients in their study expected to be able to message and consult their named surgeon in a way that is less usual in the NHS.

The impact of the organisational structure of the health system may extend beyond primary care access, as illustrated by McNeish et al. [192] who describes how patients are followed up by regional health boards as the patients come from a wide geographical area. Geography and transport infrastructure could also play a role when patients are expected to travel long distances to attend clinics, and communications infrastructure e.g. telephone networks, mobile coverage, and postal services will also affect patient responses. Further work is required on the implications of all of these factors for PDS.

6.2.5 Limitations

The most important limitation in this review is publication bias. Healthcare providers who implement PDS systems which are unsuccessful or unsustainable are unlikely to publish papers detailing the methods and context of their system, which limits our review to mainly facilitators and minor barriers, rather than major barriers. We did however find one letter written in response to one of the papers included which stated that the authors had tried a similar method in their setting and found it too laborious to be sustainable.

We were also restricted by only including papers written in English. While we did find papers from many countries across the world, there will undoubtedly be many papers written in other languages that would otherwise have met our inclusion criteria. Likewise, there will also likely be many surveillance systems which have never the subject of any kind of published report or paper in any language due to lack of resource or perceived lack of interest.

We were also limited in our data extraction to whatever details on context, mechanism, or outcome the authors felt were of interest to the readers. The majority of papers were written with a focus on quantitative outcomes such as infection rate and response rate, with limited information about the setting, the attitudes of staff or patients towards the system, and the impact of any external factors. Future work might include a global survey similar to that conducted by Petherick et al. in the UK [46] with opportunities to discuss barriers and facilitators, and more in-depth qualitative work with staff and patients involved in PDS. Furthermore, all papers describing the implementation of a new system within a health service should recognise that health systems are complex, and endeavour to describe in more detail the context of their setting (beyond the number of beds) and list any barriers and facilitators that may be helpful for others hoping to replicate the methodology.

6.2.6 Conclusions

For patients, the perceived ease of use was the most important factor in responding to surveillance, but their understanding of the utility of PDS for themselves in terms of receiving advice, and for the hospital for quality improvement are also important. For providers, multidisciplinary staff engagement was the most important as it influenced almost every other factor. Engagement can be increased by feeding back

rates so that all staff understand the usefulness of PDS. Nevertheless, PDS still requires careful planning to ensure it is well-resourced and sustainable. The program theory developed in this study will be further refined in the follow-up study in 6.3, but should also be used and developed in future case studies.

6.3 Exploring local post-discharge surveillance (PDS)

Having come up with the beginnings of a program theory to explain which PDS methods may work in which circumstances, my attention then turned to how to validate this, which I decided to do through focus groups with patients at ICHNT. A secondary aim of this study was, in light of my knowledge of the inner and outer settings at ICHNT, to understand which PDS methods might work best for patients at ICHNT. Unfortunately, due to recruitment problems, the planned protocol had to be adapted for an individual interview. The protocol as planned together with the results of the interview are described in this section.

6.3.1 Background

6.3.1.1 PDS in England

According to the Surgical Site Infection Surveillance Service (SSISS) protocol, readmissions for SSIs that appeared within the time allowed by the definition are included in the "inpatient and readmission" rate [3]. PDS is used to cover the period where the patient is in the community, including in social care such as nursing homes [3]. PDS is not mandatory but is "strongly encouraged". The methods currently permitted are either detection of SSIs at outpatient clinics or a patient questionnaire administered either on paper or by telephone, and the SSISS recommends aiming for a response rate of at least 70% to maximise accuracy [3].

Arguably, PDS is most important in procedures with very short postoperative stays such as caesarean section (CS), as these SSIs are most likely to develop in the community. In a recent PHE survey, 57% of the trusts performing CS undertake their own local surveillance, but these data are not reported to the SSISS. In the same survey, 46% of trusts ranked CS as their top priority for future surveillance categories, and 80% ranked it in their top 5. Clearly there is a high demand for CS surveillance and reporting services. Additionally, mandatory CS surveillance in England was a recommendation of a sub-committee of the Advisory Committee on Antimicrobial Resistance and Healthcare-Associated Infections (ARHAI) which focused on mandatory and voluntary reporting of healthcare-associated infections [69].

A large pilot study of 15 hospitals was conducted by the Health Protection Agency (now Public Health England) based on the system used by Health Protection Scotland, in which community midwives complete a data sheet on the patient at visits on the day after discharge and days 5 and 10 postpartum [222]. In addition, women were given a questionnaire at discharge to be filled in on day 30 and returned to the hospital. Non-responders were sent postal or telephone reminders and some questionnaires were administered by telephone. One hospital discontinued surveillance after only 6 weeks, though the reason

for this is unclear. The pilot followed 4107 patients, 404 of whom developed an infection, giving an overall rate of 9.8%. Patients whose questionnaires indicated a suspected SSI were interviewed over the phone by a nurse, and on average half of these patients were deemed not to be infected.

The response rates in the pilot study varied dramatically between hospitals [222]. The proportion of patients for whom a completed community midwife wound surveillance form was available ranged from 8.8% to 97.8%, and the response rate for the questionnaire ranged from 5.6% to 73.4%. Interestingly, there was a significant association between the proportion of patients followed up and the infection rate, indicating that surveillance systems with a low response rate are likely to underestimate the infection rate. Of the 404 infections detected, only 11% were detected in hospital, with midwives identifying 55% of cases, and the post-discharge questionnaire identifying the other 34%.

6.3.1.2 Opportunities in post-discharge maternity care in England

In a Care Quality Commission (CQC) survey of over 23,000 people who gave birth in February 2013 were surveyed on their experiences of maternity care. Twenty-six percent of these had a CS. 99% of all respondents saw a midwife at least once post-CS. Of respondents undergoing all types of delivery, 25% had seen a midwife 1-2 times, 53% 3-4 times, 16% 5-6 times and 6% 7 or more times [223]. A Getting It Right First Time (GIRFT) workstream, separate from the previously discussed SSI audit, is also looking at patient experiences and outcomes in obstetrics and gynaecology services, but the results of this work are not yet available [224].

Mothers are generally discharged by the midwife at 10 days postpartum, and responsibility passes to the health visitor (a specially-trained nurse or midwife) who will visit at 10-14 days postpartum and then again at 6-8 weeks in addition to the 6-8 week check usually given by general practitioners (GPs) [225]. Unfortunately, the number and timing of visits by midwives and health visitors is not consistent between women, and the number of women not visited at home by any HCP is small but increasing [226]. Engagement of midwives in PDS could also be a challenge, as a pilot study of this model in England reported a wide variation in response rates by midwives, with one hospital only receiving 8% of forms [37].

All babies and most mothers are scheduled to have a 6-8-week check either at maternity unit where they gave birth or at the GP surgery. However, this is too late to pick up most infections, and the definition of SSI is up to 30 days and could introduce recall bias.

6.3.1.2.1 PDS models for caesarean sections in other UK countries

SSI following CS is a mandatory reporting category in Wales [67] and Scotland [68]. In Scotland, questionnaires are completed by community midwives up to postoperative day 10 [227]. In Wales, wound swabs are routine in cases of suspected infection, and women are advised to attend the maternity unit rather than their GP surgery if they suspect an infection. PDS covers up to 30 days postoperatively [67]. In

2015, 82.3% of post-CS SSI infections in Scotland were detected by PDS [68]. In both Scotland and Wales, rates are trending downwards [67,68].

6.3.1.3 Local method options

6.3.1.3.1 Telephone call

A post-discharge questionnaire delivered by phone call is the method currently used by staff at ICHNT to detect SSIs following hip and knee replacements and cardiac (CABG and non-CABG) surgery. Anecdotal reports from the surveillance staff indicate that patients value the attention given by staff and value the opportunity to ask questions and discuss the wound. These findings agree with those of the realist review.

However, staff at ICHNT involved in SSISS surveillance and those involved in previous audits have reported that telephone calls are extremely time consuming and can be difficult when patients do not speak English well as ICHNT serves an extremely diverse patient population in North West London, many of whom speak English as an additional language. Even if there are no problems with language, making contact in the first place is still a problem and often multiple calls are needed before patients will respond. A large proportion of staff time is spent trying to make contact with the patient and then reading out the questions to them, rather than engaging in more time-effective activities such as discussing symptoms and giving advice.

6.3.1.3.2 Paper form

Paper patient questionnaires are one of the current options for PDS allowable under SSISS protocol but are not currently used at ICHNT. Standardised questionnaires are available as an appendix to the protocol and can be distributed to patients either at discharge from hospital or mailed out to patients, with responses filled out after 30 days (or 1 year if an implant is used) and mailed back to the hospital. The advantage of this method is that most people have a postal address and are capable of filling out and mailing back a form. Large numbers of forms can be printed and mailed out quickly, and letters are the most usual and accepted method for hospitals to communicate with their patients. However postal responses must be manually processed, which adds significantly to surveillance staff workload.

There is no option on a paper form for patients to receive real-time clarification, advice, or signposting about the form itself or about their wound care, but responses can be followed up with a phone call. There are also accessibility issues with paper forms, as not all patients are sufficiently literate and not all read English sufficiently well. Patients with visual impairments may struggle to fill in the form, and those with mobility issues or who for whatever reason find it difficult to reach a post box may struggle to return the form by mail. Even if people have the capability to fill out a paper form, not all will have sufficient motivation or opportunity to fill it in and return it.

One other problem for sending out paper forms is ensuring the letter reaches the correct address of the patient. While most patients might not be likely to move to a new house in the 30 days following surgery,

patients undergoing hip and knee replacements, or other implant surgery require a follow-up period of one year in which a change of address is more likely. This also does not take into account patients in temporary accommodation because of homelessness, or who are recovering from their surgery elsewhere such as in a nursing home or rehabilitation unit or staying with friends or relatives.

6.3.1.3.3 Online form

Online forms are a possibility being actively pursued by the SSISS as an option for PDS [7] with the aim of reducing the burden of data collection, maximising ease of use for patients and healthcare workers and improving the quality and timeliness of data collection. The SSISS has conducted surveys and interviews with patients as part of the development process to maximise acceptability. One stated aim of implementing an electronic form is to improve data quality and standardisation sufficiently to include PDS data in the national benchmark. There has long been criticism of the SSISS (as discussed in 4.1.1.1) that method and case-finding intensity of PDS heavily influence SSI rates, making hospitals who are more diligent with PDS appear to have high rates. Introduction of an electronic post-discharge questionnaire (PDQ) for patients could offer a solution that is low-resource on the provider side in a format that is more convenient and familiar to some patients than a paper form might be.

It is currently unclear how these forms will be used and whether this will be left up to individual hospitals to decide. Possible dissemination methods could include emailing patients with the link or providing patients with the website address on printed literature either at discharge or on a letter.

An electronic form would provide many benefits for the provider conducting the PDS, as it removes the costs associated with printing and sending large numbers of letters, and of processing paper responses. Data could instead be harvested and searched automatically to flag possible SSIs for further enquiry, and it may be possible to automatically add these data to the electronic patient record. It would also be more convenient for patients who are comfortable using the internet to manage their private information as they would not have to find a post-box and can choose a time to fill in the questionnaire at their convenience, unlike a taking a phone call. It also reduces the possibility of letters being delivered to old or incorrect addresses, or being left undelivered, as people tend to keep the same email address for longer. Accessibility tools such as translation, large font, or read-aloud software can also be used more easily with an online form than with a phone or postal questionnaire.

One drawback of an electronic form would be for patients who do not have access to the internet, are unfamiliar with using it, or are uncomfortable using the internet for personal or confidential communications. This could introduce selection bias, as such people are more likely to be elderly or have disabilities or cognitive impairments.

Another drawback of an electronic form could be the lack of two-way communication. One finding of the realist review showed that patients can see responding to PDS as an opportunity to receive advice and

signposting for their wound care. However, this could be remedied by having a clinically trained staff member follow up possible SSIs or queries raised in the survey by telephone. The reduction in opportunity to receive advice, or "perceived usefulness" might also be balanced out by gains in "perceived ease of use" of an online form compared with a telephone call for patients, especially those without SSIs. This could be important in increasing overall response rates to surveillance to build an accurate picture.

6.3.1.3.4 Healthcare professional visits

At ICHNT, not all patients are automatically seen in hospital for a follow-up visit following their surgery. In orthopaedic and cardiothoracic surgery which undertake surveillance for the SSISS, patients attend dressing clinics where a nurse will re-dress the wound while checking for signs of infection and will advise the patient on how to proceed. However, this is the exception rather than the rule. Implementation of wound review or dressing clinics across the board is not a popular option as it is seen as expensive and a poor use of resources, and there are not enough studies on the cost-effectiveness of such clinics.

One area where patients are followed up by a healthcare professional is in obstetrics, as all women receive home visits by midwives and health visitors after being discharged from hospital. ICHNT could follow the model used elsewhere in the UK of tasking midwives with data collection for post-CS infections. The difficulty in this lies in the separation between primary and secondary care and the additional workload on an already overstretched service.

6.3.1.3.5 Care Information Exchange (CIE)

ICHNT is in the process of implementing an integrated care platform to allow patients and clinicians to view patient notes from primary, secondary and social care via the Care Information Exchange (CIE), hosted by social enterprise company Patients Know Best [228]. Currently the rollout of this platform is limited to patients with certain long-term conditions who have frequent appointments with multiple healthcare professionals and care agencies, but it is hoped it will eventually be rolled out to all patients to allow them to access test results, manage appointments, and share information.

There are two possibilities for using the CIE for PDS of SSIs at ICHNT. The first is to capture GP consultations following surgery where wound healing is discussed, antibiotics prescribed, or samples sent for microbiological testing. The second possibility is to use the functionality for monitoring symptoms using online surveys within the tool which would then flag deterioration and prompt the patient to seek help, either through primary care or by contacting the hospital for advice. In order to be effective as a surveillance system, both of these options would require some form of structured database rather than manual review of all patients.

The benefits of using CIE for PDS would be integration with existing systems. This is currently only true for patients who, for example, have had surgery as part of the management of their long-term condition who already use the CIE, but would eventually be true of all patients if the rollout continues. It would also allow

easy capture of SSIs that have already been diagnosed by a HCP in primary care which are currently not visible to hospitals. Additional functionality of an online survey could be used, with pictorial or video advice about wound care or when to seek advice built in, and facilities for online messaging and even video calls with HCPs to support detection of SSIs.

One major limitation of the CIE is that it is limited to patients in North West London. Patients who are not usually resident in the area or were referred to ICHNT for tertiary care from outside NW London would not be able to use the CIE. It is currently also only available for subset of patients with a selected long-term condition. Despite there being plans to continue rollout, progress has been slow, and the reliance of a third party to maintain the platform is also a concern for sustainability.

6.3.1.3.6 EpiCollect

EpiCollect is a free online data collection tool developed at Imperial College [229] to allow the creation of bespoke forms for epidemiological investigations. Users can create a form on the app and share this with multiple users to collect geotagged data. The tool was designed with classic epidemiological investigations such as for disease outbreaks in mind but could possibly be developed for use in surveillance of SSIs.

As a PDQ for patients to fill in themselves this is not a viable option as patients would need to download the specific app and select the specific form but would only be putting in their own data once and would have no further use for the app. However, this could be a possibility for midwives or other visiting healthcare professionals who could collect data through one app for all the eligible patients they visit. The major drawback of this is that it requires the user to have a smartphone and requires an app that is separate from their usual workflow. It also automatically geotags data, which is not necessary in this instance and could create additional data protection issues.

6.3.1.3.7 Apps and automated telephony

An app is an option that has been explored at ICHNT as a possibility for PDS. Smartphone apps are popular among staff for work-related activities, as some mentioned in the study described in Chapter 3, and other studies have shown that WhatsApp is a preferred app for communicating clinical information between staff, and even between patients and staff (this is not permitted under hospital policy, but many find the convenience and end-to-end encryption more convenient than existing hospital systems - the legal implications of this are outside of the scope of this thesis). While the Surgical Infection Group (SIG) was exploring options for PDS, several staff indicated knowledge of and a preference for a smartphone app for collecting PDS data.

Benefits of using an app would be the ability to upload pictures as well as completing symptom trackers, which have been shown to aid in the detection of SSIs. However, ICHNT does not currently have the resources to invest in an existing PDS system to coordinate the surveillance, and there would be questions around data protection, long-term sustainability, and integration with EHRs. The current EHR system does

not allow integration of apps, so any data collected through an in-house system would be kept separate and not automatically added to the patient record. However, there are plans to create a platform that would allow integration of smartphone apps into the Trust's information and communications technology (ICT) systems, so an in-house app could be a possibility.

Other concerns about apps would be that of selection bias. Patients who do not own a smartphone for reasons of preference or cost would be unable to take part in the surveillance. This could introduce selection bias as these would more likely be patients with low socioeconomic status, or elderly patients. This would necessitate the use of a backup method to capture these patients and therefore negate calls for standardised national surveillance. As previously mentioned, the patient population served by ICHNT is extremely diverse, and steps should be taken to ensure nobody is left out by the selection of PDS method.

Finally, automated telephony was an effective and acceptable option from the realist review, but it necessitates a large investment to put the infrastructure in place to automatically update patient records. ICHNT does not currently have a system for this, nor does it have any plans to invest in one, therefore this is not a viable option for the Trust.

Ultimately, the options shortlisted for further exploration with ICHNT patients were: post-discharge questionnaires (telephone, paper, or online), apps, clinic/midwife visits, and the CIE.

6.3.2 Methods

The previous study describes the various methods used by hospitals across the world to determine rates of SSI occurring after discharge and suggests possible explanations as to what might work for whom and in what circumstances. The realist review also highlighted the fact that patients are rarely given the opportunity to shape decisions on selection of follow-up method. If they are consulted, it is only on the design of a method that has already been chosen for them. To study how this might work in action and to test the findings of the realist review, a series of focus groups was planned at ICHNT to assess how patients feel about the findings and about possible methods for conducting PDS.

6.3.2.1 Study objectives

The primary objective of this study was to describe patient perspectives on different communication channels for post-discharge surveillance of surgical site infections (e.g. letters, manual phone calls, automated phone calls, text surveys, email and apps).

The secondary objective was to validate the findings of the realist review with patients at ICHNT.

6.3.2.2 Study design

This was a qualitative study using focus groups. The participants targeted were patients at Imperial College Healthcare NHS Trust who had recently undergone one of four surgeries at the Trust: CS, colorectal surgery, vascular surgery, or hip/knee replacement.

The planned study involved a series of focus groups each containing 6-10 participants and lasting approximately 1hr30, with the duration and number of focus groups determined by thematic saturation, i.e. when no new themes emerge from the focus group discussions. The plan was to design the recruitment and focus groups alongside patient representatives from each surgery type to ensure they were as convenient and inclusive as possible. Prospective patient representatives would be identified and approached by the lead clinician for each surgical specialty.

The first part of each focus group was intended to be a general discussion on patient experiences of communications with the hospital and their recovery from surgery, then a discussion about SSIs and post-discharge surveillance with reference to the results of a realist review on PDS methods, and finally a discussion of specific examples of PDS (app, electronic form, phone, paper questionnaire).

6.3.2.3 Recruitment

Several stages of recruitment were planned over the course of this study. The first step was to recruit clinical leads in each of the surgical specialties who were responsible for identifying patient representatives, helping with recruitment of participants, and liaising with the wider specialty teams. Recruitment of clinical leads proceeded through the Surgical Infection Group at the Trust and by contacting staff who were involved in the Getting It Right First Time (GIRFT) audit.

Clinical leads would then be asked to identify and approach patients who would be suitable for the role of patient representative, and to provide an information leaflet to these patients which included my contact details. The inclusion and exclusion for this role were the same as for the participants to help ensure their perspectives on recruitment strategy and arrangements for the focus group matched those of the participants as closely as possible.

Finally, the patient representatives would help to design the recruitment strategy for the participants (e.g. flyers in waiting rooms, writing to patients etc.), oversee arrangements for the focus group in terms of timing, length, and accessibility, help produce the discussion guide, facilitate the discussion group, and aid in analysis and dissemination of the results.

Rewards for patient representatives and reimbursement of participants' return travel costs were budgeted in line with the Imperial Patient Safety Translational Research Centre (PSTRC) Patient and Public Rewards and Recognition policy [230]. Tea, coffee, juice, and snacks were also provided.

In order to maximise inclusivity and encourage patients from underrepresented groups to attend, reimbursement of travel expenses and refreshments were offered for carers or interpreters without whom a participant would not be able to attend. This was budgeted at one extra person per focus group.

6.3.2.4 Inclusion criteria

Participants must be adult, English-speaking patients who have recently undergone CS, colorectal surgery, vascular surgery, or hip/knee replacement at one of ICHNT's hospitals.

The first three surgery types were chosen as they have suspected high rates of SSI and would be target groups for interventions by the Trust's Infection Prevention and Control department. The latter surgery type was chosen as these patients already receive post-discharge phone calls for SSI surveillance, and would be able to contrast their experiences with the proposed alternatives. The combination of these surgery types would also form a good spread across the demographics of the patients served by the hospital in terms of age, gender, and comorbidities.

6.3.2.5 Exclusion criteria

Patients who were unable to travel to the focus group, or travel costs would have exceeded £20, and who were under the age of 18 were not eligible for the study.

6.3.2.6 Development of discussion guide

The discussion guide (Appendix 15) was derived from the findings of the realist review in 6.2. The first part of the discussion broadly covered communication channels between the hospital and patients. The discussion then considered some of the context/mechanism/outcome configurations (CMOCs) elucidated from the realist review, asking patients what patients thought of them, whether they agreed with them and how they would change them. The final part of the discussion covered the possible alternatives available to ICHNT in light of the CMOCs and the aspects of communication already covered.

The discussion guide was developed alongside other members of the research group.

6.3.2.7 Data analysis

Recorded audio files were transcribed by the same external agency as used in 3.2.8. I planned to collate, code, and thematically analyse transcribed audio and written materials to identify themes using a constant comparative approach as described in 3.2.8. The themes would then be triangulated with the findings from the realist review and used to refine the theory further.

Data and all appropriate documentation will be stored for a minimum of 10 years in line with Imperial College policy.

6.3.2.8 Consent

Consent to enter the study will be sought from each participant only after a full explanation has been given, an information leaflet offered, and time allowed for consideration. Verbal consent was obtained for audio recording and photography at focus groups. All participants are free to withdraw at any time from the study without giving reasons.

6.3.2.9 Confidentiality

Only the first name and if necessary, initial of surname, were used during the focus group and in any notes or written materials. Contact details were kept only on password-protected devices. Names and information that may allow the patient to be identified will not be used at all in any publications. Storage arrangements for the recorded audio and transcribed files were the same as described in 3.2.9, and again the recorded audio was deleted after the transcript had been checked for completeness.

6.3.2.10 Funding

Funding for this study was provided through a small grant from Imperial Charity, and the compensation arrangements were taken from a guideline produced by the National Institute for Health Research (NIHR) Imperial Patient Safety Translational Research Centre [230] at Imperial College London.

6.3.2.11 Ethical considerations

Since this study involved only patients at ICHNT and was being carried out to support work around improving SSI surveillance, this study was deemed to be a quality improvement (QI) project. There is no formal registration process for QI projects, but the Trust's QI Hub was consulted regularly throughout, and guidance was sought from the Data Protection Office at the Trust on recruitment methods. The Data Protection Office advised that patients should be contacted by letter a member of clinical staff (Appendix 14).

6.3.2.12 Recruitment problems and adapted protocol

Despite sustained efforts and high initial engagement, a clinical lead (obstetric registrar) was recruited only for one of the four planned surgical categories, CS. Since there is currently no accepted national protocol in England for PDS of post-CS infections, I decided to proceed by focusing on CS patients.

Unfortunately, the clinical lead was also unable to recruit a patient representative, so decisions on recruitment and focus group planning were made between only the two of us. Nineteen patients who had undergone CS in the past 6 months were identified by the registrar. I drafted a letter which was reviewed and agreed on by the clinical lead, and after receiving approval from the wider clinical team and the Data Protection Office at the Trust, letters were sent out to the women. Only one response was received, so the patient was contacted to ask if she would be happy to have an interview rather than a focus group. The patient consented, and a semi-structured one-to-one interview subsequently took place.

To adapt the discussion guide, focus group ground rules were replaced with a reminder that the patient is free to take a break or leave at any time and does not have to answer any questions if they are not comfortable. The questions themselves remained unchanged, but were anticipated to elicit longer, more in-depth responses rather than a broader, rapidly evolving discussion. My role changed from being the facilitator, in which I expected to be generally passive, to the interviewer, engaging directly with the participant.

The analysis of the transcribed data proceeded in a similar way as planned, except that the responses given by the patient were only compared with other responses in the same interview rather than between participants.

6.3.3 Results

The main responses described by the patient were of feeling forgotten and unheard, and the sense that while individual staff cared and understood their duty of care, that the hospital as an organisation did not. The patient was clear in her beliefs about the hospital's duty of care and extended this to suggest that while patients have a responsibility to seek advice about any worrying symptoms whether or not they relate to SSIs, it should not be a patient's responsibility to report adverse outcomes to the hospital.

6.3.3.1 Feeling forgotten and unheard

The patient's first response to questions about communication with the hospital was about feeling forgotten by the midwife who was supposed to visit.

> *Basically, when I got home the midwife didn't come until, I can't remember if it was three, four days later because they forgot about me… So then there was a bit of confusion as to what I was told, which I wasn't told anything.*

While keen to stress that she understood staff were very busy, the fact that she felt it necessary to call the hospital to ask about the midwife visit is an indicator that the patient was unhappy with the level of post-discharge communication, particularly as there had been some complications.

> *And you can't really blame the midwives because they are literally rushed off their feet. Sometimes there's hardly anybody at the desk… So it's not really their fault but it can be a bit chaotic. I was calling all weekend, couldn't get nobody...*

The patient also observed that staff were not fully informed of her medical history, needs, or prior experiences which she felt resulted in delays and inappropriate care. For the patient, this also resulted in extreme frustration and feelings of not being heard and valued by the hospital.

> *If they listened in the first place and explored then I wouldn't have been four hours... And then there wouldn't have been mis-care.*

If discussing their wound with a member of staff who is not aware of a patient's particular case, this may result in frustration and a feeling of not being heard if the patient is then required to explain things which should already be evident from the medical record.

> *It will be easier obviously talking to a midwife that was dealing with you while you was a patient to know what you're talking about… but when I called no-one didn't even know who I was… she's got no idea who I am so in that way it is a bit hard.*

6.3.3.2 Distressing symptoms not related to SSIs

The patient had not had an SSI, but this did not mean she did not have distressing symptoms or other queries that required intervention.

> *I went home with staples. I was in agony.*

> ***RT: Did you ever wonder whether it was infected?***
> *It never really crossed my mind to be honest with you. It was dealing with all the pain and the itching, how I was going to get over it sort of thing. It was more that.*

These other non-SSI outcomes were just as important to the patient as an SSI, indicating that from the patient's point of view, poor outcomes are all distressing and should be captured by hospitals.

6.3.3.3 Division of responsibility

The patient perceived that all the individuals she had encountered throughout her care were doing their best and had a sense of personal duty towards her. However, she felt that this sense of duty was not being reflected on an organisational level because of inadequate resourcing and poor organisation. The patient mentioned on several occasions the fact that the hospital has a "duty of care" towards its patients which she did not feel was being properly discharged.

> *We're there to be cared for, do you know what I mean... They have a service of care while you're under their care*

During the early stages of the interview, the patient declared herself to be "a person who hates emails", preferring instead to use the phone or receive letters from hospital. Despite this, she expressed surprise at the lack of technology adoption in the NHS.

> *They fax over your discharge sheet… I mean the technology there is today, I mean fax?! And they didn't get the fax?! …But what can you say to that? So change the system then.*

The patient suggested midwives should carry out the checks on post-CS infections using an app for EHR and workflow management, which would have the added benefit of helping to avoid patients being "forgotten" by staff.

> *…give these midwives an app system or something. An app system I think would be so beneficial because it's just press, press, press, press,I think for midwives there should be either an app service or email, whatever it is, so they don't forget you, something a bit more than fax.*

The interesting idea behind the patient's suggestion of an app for midwives is that the patient did in fact own and use a smartphone and was positive about the use of apps and proliferation of technology in general but did not feel confident in detecting deteriorating symptoms of an SSI herself, and furthermore, did not feel that it should be up to her to decide this. Once again, she mentioned that it is part of the hospital's duty of care to monitor outcomes, indicating that it should not be her responsibility to report adverse outcomes to the hospital. The aspect of care that she felt was her responsibility was to seek advice and treatment for distressing or worrying symptoms from an appropriate healthcare professional, in this case, the GP.

6.3.3.4 Drivers of PDS preferences

When asked about a preference for how PDS was conducted, the patient stated that her ideal method would be through midwives, or possibly through GPs, the reason being that patients would have the opportunity to receive advice, and for the wound to by physically inspected.

> *So, and it has to be physical involved. There has to be communication and a physical person going to check I mean it's obviously got to be NHS, do you know what I mean?... Or GPs. Got to be someone legit.*

6.3.4 Discussion

The responses identified in this patient's semi-structured one-to-one interview match closely with several themes in other studies. Notably the expression of the patient that staff were doing their best with poor resources and not wishing to be a burden on this was similar to the theme of stoicism identified by Brown et al. in a study on patient experiences of SSIs [27]. Patients in the Brown et al. study refused to blame healthcare providers for their SSI and insisted they were doing their best, which was similar to the patient in this study taking pains to praise the staff for doing a good job in difficult circumstances.

Feelings of being forgotten and unheard are also similar to the findings of a survey of maternity experiences in England carried out in 2014 [226]. From the 4571 responses to the survey, women rated the in-hospital post-natal period as being the time when they felt least listened to and treated as an individual (only 68% felt always listened to), and in the post-discharge period only 77% had contact details of a 'named midwife'

or health visitor in case of queries. Twenty-three percent of women also felt there should be more home visits by a healthcare professional. These trends follow a general decline in community post-natal care provision, with the proportion of women reporting no home visits increasing from none in 2006 to 3% in 2014. While these results also include women who had non-CS births, this poses questions around the suitability of midwife follow-up for PDS if resources are already stretched enough that some women report no home visits at all.

Perhaps the most pertinent finding of this interview for PDS was the fact that the patient did not distinguish and did not care about the distinction between infectious symptoms and other distressing symptoms as part of the healing process such as itching and scarring. For the patient, these symptoms are just as important as symptoms of infection and they should be recognised as such by healthcare providers. While it is of course necessary to monitor infections rates specifically as these have a distinct aetiology and require specific interventions to prevent, and have significant public health impact, from the patient's point of view complications are complications. This should be reflected in the way data is captured from patients. Not only would it be frustrating for a patient who was experiencing distressing itching as in this instance to be only asked about infectious symptoms, and if these were not present, to be deemed a success case, but it is also a missed opportunity for hospitals to improve patient care more holistically. Data capture should be broad and encompass a wider range of outcome measures which hospitals can then sift through and separate possible SSIs from other outcomes, ensuring patients get the appropriate treatment, advice, or signposting for all their queries.

As discussed earlier in this thesis, technology adoption in general in the NHS is extremely slow. While patients are cautious about the use of technology to handle their personal data, they expect that the NHS should catch up with other sectors in the appropriate adoption of new technologies. The patient interviewed here was surprised to hear that fax machines are still being used to refer patients and pass information between departments, and she mentioned staff saying, "we didn't get the fax". Newer technology collects far more metadata and would allow a proper audit trail to monitor data transfer.

In terms of triangulation with the program theory developed from the realist review, this data provides some support for the idea that patients expect to be able to receive advice and signposting about distressing symptoms (CMOC 15 in 6.2.3.4), as the patient felt that of all the CMOCs she saw this was the most important. The usefulness of responding to PDS for this patient was a more important factor than convenience of choosing a method.

As well as broadly agreeing with four of the CMOCs she was presented with (CMOCs 30, 11, 13, and 15) the patient also explicitly commented on several of the others for PDS in general, namely those pertaining to language (CMOC 3), difficulties using technology (CMOC 6), elderly patients (CMOC 5), and a lack of resource availability (CMOC 18). When suggesting that HCPs should be the ones to report SSIs, the patient

also implied that self-efficacy is a factor in PDS (CMOC 2) as she did not see herself as a suitable person to judge this. Her responses also demonstrated that access to primary care affects patient pathways (CMOC 10), and she expressed frustration at the lack of record linkage between primary and secondary care (CMOC 20).

6.3.4.1 Limitations

Although this was a thorough exploration of a patient's experience, the main limitation of this study is of course that there was only one participant. This greatly limits the generalisability of the findings, although they do show some similarity to other work in the area of SSIs and post-natal care. It is therefore not possible to draw any sound conclusions from this study.

One other major limitation is that the recruitment strategy inherently introduces selection bias. Patients who responded to a recruitment letter would most likely also respond to letters used for PDS, and the same goes for telephone calls or emails. For the majority of surgery types, the best way to recruit patients would be through a clinician directly approaching them before discharge with a flier as was the original plan, but after discussions with the clinical lead for CS we decided this strategy would not have been appropriate for patients undergoing CS as they would mostly have had the additional responsibility of a newborn baby on top of surgical recovery so would be unlikely to attend a focus group for the first few months.

As with most focus groups, this study is likely to have been affected by bias by selecting patient who have strong feelings about the subject. It is important to remember that while this patient did not have an SSI she did have other adverse outcomes that might influence her perspectives.

As there was only one participant in the study, I am not attempting to draw any conclusions as to the best method of PDS at ICHNT, or to use this data for a comprehensive validation of the program theory developed in 6.2. I can only suggest the responses identified above are borne in mind and explored further in other studies.

6.3.4.2 Reflexivity

Looking back over my recruitment strategy, I can see that I should have taken some of my own advice earlier about ensuring leadership and stakeholder engagement. Some clinical leads showed engagement early on but stopped responding to my attempts to make contact. Others never responded at all. While I did have support from the SIG, I did not leverage this support effectively to spark engagement. I may also have failed to make stakeholders see the "perceived usefulness" of the study.

When reflecting on this interview, my main feeling is embarrassment of how the CMOCs were phrased. Although I had previously talked the phrasing over with another researcher and had tried to make the language as plain as possible, it became clear as soon as I showed the paper to the patient that the phrasing was still full of jargon. Each one began "In a context where…", which I saw in the moment could simply

have been changed to “when”. Most were also far too long. Immediately after showing each one to the patient I had to rephrase it into simple language.

I think the problem with this lies in my own expectations about the participant. Being a newcomer to qualitative research, I had heard that frequently researchers have trouble recruiting participants who are not highly educated (usually retired) white middle-class women, so subconsciously I think this is who I was expecting – somebody who perhaps was already a patient expert on the subject of SSIs, or frequently took part in focus groups or other research projects, and I was keen not to seem patronising by over-simplifying things. This would perhaps have been avoided if I had had a patient representative as planned to help me develop the discussion guide.

My first assumption had left me unprepared, but my second assumption had actually been useful, as I had also heard that focus groups often attract participants with strong views or who have had strongly negative experiences. Luckily, I was prepared for this with the contact details of the patient liaison service and was also ready to stop the conversation turning into a discussion about the patient’s care.

Even though there was only one participant in my “focus group” I am still extremely pleased with the results. It provided some small but meaningful validation to my theory and served as a reminder to me how important it is that patients’ time and experiences are not wasted, and the outcomes that mean something to them are visible to the hospital.

6.3.5 Conclusion

For the patient, the most important aspect was the perceived usefulness of taking part in surveillance, which for her meant the opportunity to receive advice about her wound and signposting for treatment. This was more important than the convenience of surveillance but may have important resource implications for PDS. Patients experience a range of symptoms with wound healing which may or may not be related to SSIs but are equally distressing for them. Hospitals need to recognise this during PDS and ensure the outcomes that matter to patients are included both to make patients feel valued, and to improve care holistically.

Chapter 7. Discussion

7.1 Revisiting the hypothesis

This thesis aimed to explore how social and technological innovation can be applied to improve SSI prevention and surveillance. In order to judge its success, we need to revisit the hypothesis:

> "SSI prevention can be improved by maximising use of existing resources, understanding barriers and facilitators in the surveillance and prevention of SSIs, and using social and technological innovation to facilitate stakeholder engagement."

In Chapter 3, the barriers and facilitators of SSI prevention behaviours were explored through staff interviews. SSI prevention behaviours are improved when staff have the knowledge and skills they need combined with a sense of ownership over the development of SSIs. Hierarchical social structures in surgery based on either assumed superior knowledge of seniors or fear of negative reactions are sometimes a barrier to SSI prevention behaviours. Hierarchy was a force for good in Chapter 6 where championing of interventions by senior clinicians increased overall engagement.

The results of studies in Chapter 3, Chapter 5, and Chapter 6 illustrate that staff also need to work within a context of adequate resource provision in terms of the physical environment, human and non-human resources, and appropriate infrastructure. These findings can inform design and implementation of future interventions. Several recommendations were made for hospitals to improve training and peer learning opportunities, foster team accountability for SSI rates, and invest in or mitigate resourcing issues that compromise best practice and demoralise staff.

As resourcing is a chronic problem in the NHS, this thesis identified multiple ways to maximise the use of existing resources. In Chapter 2, current surveillance arrangements were found to fit poorly with the medical and economic burden of SSIs across different surgery types in England. By combining a top-down broadening of national reporting focus with a bottom-up reallocation of resources to tackle specific problems in individual hospitals, more SSIs might be prevented resulting in a decrease in the number of bed-days used for patients with SSIs. The human resources currently involved in time consuming manual data collection could also be reallocated to investigations and intervention planning through introducing electronic surveillance systems (ESS). The simple algorithm developed in Chapter 5 shows promise as it is equivalent to a trained human in computing the denominator, considerably reducing the number of patients who need checking for SSIs and continues to collect data throughout staff changeovers and absences.

Barriers to the adoption of ESS tools, despite evidence of their utility, were explored in detail in Chapter 4 and Chapter 5. The findings of Chapter 5 indicate that adoption of electronic SSI surveillance on a local scale may be hampered by lack of support from senior management due to focus on short-term solutions

to known problems, rather than long-term solutions for identifying and tackling unknown problems. Many hospitals are unable to garner support for ESS as estimating cost-effectiveness is difficult in a context where the burden is unknown. Staff trying to implement these systems can find themselves in a network of cyclical problems that consume their time and creative energy, and the goals and success measures of those trying to implement the system can be at odds with those of relevant authorities. On a national scale, electronic surveillance is currently incompatible with national reporting requirements, and the design of a universally implementable solution will be difficult as hospitals all have different data collection and storage systems. These factors may hamper the widespread adoption of ESS.

The final aspect of the hypothesis to consider is that of facilitating stakeholder engagement through social and technological innovation. Stakeholders in relation to SSIs include surgical staff, wider hospital staff concerned with the care of surgical patients, Infection Prevention & Control teams, hospital management, and the patients themselves.

Stakeholder engagement was a recurring theme throughout this thesis. In Chapter 3, stakeholder engagement was increased when staff perceived that there was a problem with SSI rates, and when there was external and internal pressure because of a national audit. In Chapter 5, a lack of engagement among senior managers was a major factor in stalling the implementation of an effective ESS, as they engaged with short-term but not long-term solutions for SSI rates. In Chapter 6, the realist review showed that stakeholder engagement requires deliberate effort as existing networks cannot be relied upon to support the implementation of new interventions.

Social innovations to facilitate stakeholder engagement identified in this thesis include broadening the accountability for SSI rates from individual surgical consultants to the wider surgical team through stratifying rates by a wider range of risk factors. Reliable surveillance data can increase the sense of ownership staff feel over SSIs. Hospitals also need to find ways of encouraging staff to challenge inappropriate behaviours, which may include positive role-modelling, introducing an intermediary with a specific role, or improving access to relevant documents so that staff feel more confident in their assertions. Improving investment in estates and long-term solutions could have a synergistic side-effect by demonstrating organisational commitment and improving staff morale. Technological innovation can also facilitate staff stakeholder engagement by increasing the data available on these risk factors and in a broader range of surgical specialties.

Patients are also stakeholders in SSI prevention and surveillance. Through analysing methods for conducting post-discharge surveillance in terms of “what works for whom and in what circumstances”, engagement through social innovation occurs through patient-centred design and co-production of surveillance tools where patients are the end users. Technological innovation can increase buy-in by using

new communication channels such as automated telephony and apps, meaning patients are being contacted in the ways they are more accustomed to using.

The findings of all of these studies and the ways in which they can influence the success or failure of programs suggest that it may be possible to improve SSI prevention and surveillance through some of the mechanisms described above, therefore the hypothesis can be accepted.

7.2 Strengths and limitations

The overall strengths of this thesis are the commitment to reflecting the current status of SSI prevention and surveillance in the real world. The studies were designed to generate data that can be acted upon immediately and describe how the landscape of SSI prevention and surveillance might influence the outcome of those actions. I feel this work will make a significant contribution to the field of SSI prevention and surveillance in England, which is discussed in more detail in the next section.

During the qualitative studies I believe my background as a basic scientist rather than a clinician has enabled me to see into the NHS from an objective perspective and see things as they are without feeling any particular affinity towards the point of view of any staff group. Likewise, not being a social scientist, I was also able to explore quantitative aspects of SSI prevention and surveillance to give a full multidimensional picture.

The main limitation of this thesis is that many of the studies took place at one Trust, ICHNT, which is one of the largest NHS Trusts in the country. Some of the issues encountered may be specific to this Trust and not necessarily representative of the experiences of others in England. However, there are some problems which are more or less ubiquitous in the NHS, such as understaffing, under resourcing, overcrowding, and poor ICT infrastructure, which were all identified here as playing a role in SSI prevention and surveillance.

There were issues with recruitment in the qualitative studies. In Chapter 3 Investigating Staff Attitudes to SSI Prevention: BehaviOuR Study, there was a lack of representation from ward nurses due to the structure of their day making interviews inconvenient. This may have led to a bias towards theatre staff in the sample. In 5.4.3.1 Workshops with staff there were only three panel members in the first workshop, and one was absent at the second. In 6.3 only one patient was available, so the results of this study cannot be presumed to be representative, although provide invaluable insight.

7.3 Contribution

7.3.1 Empirical

This thesis has generated a number of findings that could have immediate real-word impact on SSI prevention and surveillance in England. The findings of Chapter 2 are particularly pertinent. Hospitals can

immediately begin to rethink their own surveillance strategies using either the national-level data presented in this thesis and in the corresponding paper, or by replicating the methods in their own hospitals using data from the Getting It Right First Time SSI audit or from their own surveillance.

An important finding in Chapter 3 is that surgical teams view SSI rates as a process measure, with the overall harm related to SSIs as the true outcome measure. This is in contrast to the traditional public health perspective that SSI rates are an outcome measure. In the longer term, SSI surveillance programs may need to be redesigned to focus more on collecting and feeding back data on morbidity and mortality associated with SSIs, rather than SSI rates alone, in order to provide surgical teams with the outcomes that are most important to them.

Hospitals themselves can also immediately take steps to improve the implementation of any interventions they are using or planning by addressing any training needs of their staff and implementing peer learning opportunities. Making policies, guidelines, and literature more available to staff supports them in challenging inappropriate behaviours, as does role modelling, both of the positive behaviour itself and of how to challenge others' inappropriate behaviour. Addressing or mitigating any resource problems (human or physical) has the two-fold benefit of improving patient safety and assuring staff that the organisation is "doing its bit" to prevent SSIs.

7.3.2 Theoretical

The theoretical contributions of this thesis come from the two major qualitative studies: interviews with staff on their attitudes to SSI, and the realist review on post-discharge surveillance methods.

The major themes identified through interviews with staff around SSI prevention were knowledge and skills, ownership, hierarchy, and resources. From these broad themes, program theories can be derived to cover the development and implementation of SSI prevention and surveillance interventions. Where previous literature has focused on qualitative evaluation of specific SSI surveillance or prevention initiatives, this thesis presents a richer exploration of the how the social and technological context might impact on such initiatives in general. Previous qualitative work has examined culture and communication in surgery, but this thesis has incrementally advanced understanding of how culture in surgery impacts specifically on SSI prevention and surveillance behaviour.

Previous qualitative work on post-discharge surveillance has again focused on specific tools or interventions, while the research presented in Chapter 6 advances knowledge by looking at post-discharge surveillance methods in general and the contextual factors that influence their success or failure. This study contributes to broader theoretical discussions around patient- vs provider-centric healthcare and can also contribute to program theories for designing and implementing post-discharge surveillance systems. In particular, the perceived usefulness of surveillance for patients has not been formally considered in terms

of opportunities for them to receive advice on any aspect of their recovery and their understanding of how surveillance data can be used to improve services.

7.3.3 Methodological

The method described in Chapter 2 is a particularly novel and easily applicable method drawing together multiple data sources based on applicability to the English setting and using a combination of statistical and visual analysis to compare the fit between surveillance programs and the burden of the diseases they are designed to target. This method can be applied to settings at any level in England by substituting Hospital Episode Statistics data on the number of procedures for local data and replacing the data on rates to local data where it is available. Other countries could adapt this method by changing the applicability hierarchy to suit their own setting.

Section 6.3.2.6 provides an example of how findings from a realist review can be used directly to inform future research by using the context-mechanism-outcome configurations as part of a focus group discussion guide. This method could provide a tool for validating realist review findings and igniting theory-driven discussions.

7.4 Raising new questions

During the course of this thesis a number of questions arose based on either the limitations or the results of the individual studies which could be explored with further research.

The number of SSIs and associated costs and length of stay are undoubtedly important but do not adequately reflect differing morbidity and mortality attributable to SSIs in between surgical specialties. This was further demonstrated by the finding that the perceived relative risk of harm of an SSI was a driving factor in staff SSI prevention behaviour. More data are needed to allow a full and proper assessment of the burden of SSIs and how priorities should be targeted between different surgical specialties. There is also a need for systematic priority setting balancing all these different factors to further improve surveillance and optimise resource allocation.

The qualitative research into drivers of SSI prevention behaviours in this thesis found that staff in surgery sometimes feel unable to challenge those they perceive as senior because of fear of negative reactions, even when they are confident in their own conviction that the behaviour is inappropriate. There have been multiple studies examining facilitators to “speaking up” in healthcare which could be useful in this situation, and further interventional studies should investigate the impact of initiatives for encouraging staff to challenge behaviour and practices that could increase risk of SSI.

Many studies have shown that ESS are feasible, and there is some evidence that these would be more cost-effective than manual surveillance, but further economic evaluations are required to support hospitals attempting to garner managerial and financial support for expanded surveillance programs, particularly

those that include electronic surveillance. As this thesis mostly describes barriers to an ESS that was ultimately not successfully implemented, future studies should look at facilitators of successful ESS interventions and associated implementation strategies.

For many surgery types, relying on in-hospital surveillance will significantly underestimate SSI rates. Post-discharge surveillance systems need to be carefully designed to ensure they are practical for patients and healthcare providers while collecting worthwhile data. Higher response rates might be achieved by having a personalised surveillance system for each patient that takes into account their requirements and motivations, but this would need to be balanced by the need to standardise data collection methods so that the data can be used for benchmarking. Previous studies have compared new surveillance methods with the "gold standard" of intensive follow-up and validation of infections by a healthcare professional. What is now required is research on the equivalence of these approaches; if it can be shown that different methods (e.g. phone calls vs apps, paper vs online questionnaire) generate similar sensitivity, specificity, and positive and negative predictive values, they could be used by a hospital in tandem, with patients responding to whichever method they find most convenient.

Chapter 8. Conclusions and recommendations

From the data that are presented in this thesis, a number of conclusions can be drawn about the current status of SSI prevention and surveillance in England and how it should be developed in the future. Current surveillance in England is not being appropriately targeted to make the most of the resources being dedicated to it. Even if all SSIs occurring in the orthopaedic procedures for which reporting is mandatory were reported to the English national surveillance, this would account for only 4% of the approximately 2.01 million SSIs occurring in England per year. While SSIs in orthopaedic surgery are undoubtedly serious events, the intense national focus on reducing rates means there is now little room for further improvement. Surveillance should be extended to other surgical specialties on a national level. In particular, this study supports the Advisory Committee for Antimicrobial Resistance and Healthcare Associated Infections' recommendation to extend surveillance to caesarean sections which contribute more than 16,500 SSIs annually in England. Rather than focusing on mandatory surveillance, hospital teams need to be encouraged to target their SSI prevention and surveillance efforts based on their own needs. Depending on quality and completeness, data and experience gained as part of the recent Getting It Right First Time (GIRFT) SSI audit could provide some of the evidence needed to assess which surgical categories could most benefit from surveillance in each hospital. In order to further inform these decisions, more specific data are needed on the morbidity and mortality associated with SSIs in different categories.

Interviews with staff revealed that knowledge and skills around SSI prevention varied from person to person. While some staff were confident in every aspect of SSI prevention, diagnosis and treatment that they were involved with, some revealed that they had not received the appropriate training. In this sample, staff raised concerns about dressing changes, theatre cleaning, and definitions of SSI. Hospital organisations need to ensure there are processes in place to provide regular training and identify any unmet training or policy requirements. Participants were very keen to learn from peers or other specialists, and specialists were keen to provide training, but opportunities were not being created for peer learning to occur. Hospitals could create a culture of peer learning by encouraging peer-led workshops and shadowing to share best practice.

Differences in responsibility and accountability for SSIs can create tensions in surgical teams and other personnel involved in the care of surgical patients. While all participants felt that everyone involved in the patient's pathway, including the patient, are responsible for the prevention of SSIs, some staff and particularly consultant surgeons felt that accountability for SSI rates rests with the consultant. This creates tensions because not every aspect of the patient's care is within the control of the consultant surgeon, but they are nevertheless held accountable for an SSI. If not carefully handled, this approach has the potential to reinforce blame culture, support a consultant-centric hierarchical system, and discourage transparency. Too much focus on consultant-specific SSI rates could also mean other factors contributing to SSIs are

overlooked. While the consultant is an important and well-recognised factor in causes of high SSI rates, epidemiological investigations need to stratify rates in multiple ways to identify issues, and data capture needs to be of sufficiently high quality to allow meaningful risk adjustment.

Unhelpful hierarchies among surgical teams impede good SSI prevention practices as staff can feel unable to challenge those they perceive as senior to them. Staff feel that they will provoke a negative or angry response by challenging senior staff, usually consultants. Some facilitators to these discussions were using tact, humour, and discretion, having literature, policies, and guidelines to refer to, being outside the surgical team and/or having a specialist role in infection prevention or treatment, and positive role modelling by other staff members. In addition to these facilitators, it is vital that staff who are being challenged behave in a positive manner to make sure staff are not discouraged from speaking up in the future. Interventions aimed at creating a culture that facilitates these discussions have been developed in other settings and could be applied and trialled in this context.

Just as the causes of SSI are multifaceted, chronic under-resourcing in the NHS has led to multifaceted problems with their prevention and surveillance. A wealth of external factors limits or influences staff behaviour around SSIs, from the condition and layout of buildings to limitations in the information and communication infrastructure and lack of appropriately trained surveillance staff. These factors need to be recognised and dealt with as far as possible to prevent staff feeling demoralised and disengaged.

Good-quality surveillance data is important for gaining buy-in for long-term investment, but current SSI surveillance is too resource-intensive to be continuously and universally implemented. Automation of some aspects of surveillance are reliable and feasible, and there is widespread support for their adoption. Widespread implementation is being stalled by a lack of resources, difficulties in gaining support for surveillance from senior managers, and a lack of standardisation in systems across hospitals that would allow transferability of algorithms between settings. A vicious circle exists where staff find it difficult to make the case for SSI surveillance because of a lack of data on the scale of the problem, which is in turn due to a lack of SSI surveillance. In order to break this cycle, economic evaluations of semi-automated surveillance systems and external/national endorsement of or incentives to adopt such systems could be beneficial. A further barrier to adoption is that the current national surveillance system, the SSISS, does not accept data that has not been collected in line with the standardised manual protocol. A shift in this policy, and the ability for data to be submitted directly from electronic surveillance systems rather than in spreadsheets via a portal would further reduce the time taken on surveillance activities.

Post-discharge surveillance of SSIs frequently requires patient action in the form of a response to a questionnaire. In order to maximise patient engagement with surveillance, these tools need to be co-produced by patients, and must ensure the patient perceives the tool as useful and easy to use. Rather than attempting to come up with a one-size-fits-all approach, diverse patient groups may require different

communication channels to maximise response rates and minimise selection bias. More evidence is needed on whether high response rates or rigorous standardisation generate the most useful data. Advances in communication technology should be exploited, but not all patients will be capable or willing to use new technology. Studies are needed to compare results gathered via new technologies with traditional methods such as paper/telephone questionnaires rather than against the “gold standard” of clinical validation, and if they are equivalent, patients could be offered a choice.

Technological advances also mean an increase in data sharing between primary and secondary/tertiary care. Opportunities to access records of primary care consultations could reduce or eliminate the need to contact patients directly, as diagnosis of SSI in the community could be detected by the hospital for surveillance purposes. However, the implementation of data linkage between different sectors of the NHS is extremely slow. The complexity of this needs to be better understood before post-discharge SSI surveillance through primary care records is a viable option.

In the short term, SSI surveillance in England could be improved by encouraging hospital organisations to expand and prioritise their surveillance and analyse the training needs of their staff. In the long term, hospitals could look at reducing the culture of hierarchy in surgery and investing in sustainable surveillance systems, whether or not this includes ESS. On a national scale, SSI surveillance could be improved by restructuring national surveillance to focus on surgical categories with the highest burden, and exploiting technology to collect data from hospitals, primary care providers or patients themselves.

Overall, SSI prevention in England can be improved by strengthening the social and technological infrastructures in hospitals to allow broader, more effectively targeted surveillance systems that make the most of existing resources.

Publications and conference presentations

Title	Type
'Mapping national surveillance of surgical site infections in England: needs and priorities.' **Troughton R**, Birgand G, Johnson A, Naylor N, Gharbi M, Aylin P, Hopkins S, Jaffer U, Holmes AH. *Journal of Hospital Infection.* In press, published online 12 June 2018	**Peer-reviewed paper**
'Understanding the determinants of infection control practices in surgery: the surgeon sets the tone.' **Troughton R**, Mariano V, Holmes H, Birgand G. Presented at European Conference for Clinical Microbiology and Infectious Diseases 2018	**Conference poster**
'Blogging in Infectious Diseases and Clinical Microbiology: Assessment of 'Blogosphere' Content.' Birgand, G, **Troughton R**, Moore LSP, Charani E, Rawson TM, Castro-Sánchez E, Holmes AH. Infection Control & Hospital Epidemiology 38, no. 7 (July 2017): 832–39	**Peer-reviewed paper**
'Post-discharge surveillance of surgical site infections: is anyone getting it right?' **Troughton R**, Castro Sanchez E, Birgand G, Holmes H. Presented at European Conference for Clinical Microbiology and Infectious Diseases 2017	**Conference poster**
'Semi-automated retrospective surveillance of surgical site infections (SSI): Design and validation of an application in coronary artery bypass graft (CABG) patients.' **Troughton R**, Birgand G, Holmes A. Oral presentation at Public Health England Research and Applied Epidemiology Scientific Conference 2017	**Oral conference presentation**

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Appendices

Appendix 1 Definition of SSI

Superficial incisional infection: this is defined as a surgical site infection that occurs within 30 days of surgery and involves only the skin or subcutaneous tissue of the incision, and meets at least one of the following criteria:

Criterion 1: Purulent drainage from the superficial incision.

Criterion 2: The superficial incision yields organisms from the culture of aseptically aspirated fluid or tissue, or from a swab and pus cells are present.

Criterion 3: At least two of the following symptoms and signs:

- pain or tenderness

- localised swelling

- redness

- heat

and a. the superficial incision is deliberately opened by a surgeon to manage the infection, unless the incision is culture-negative

or b. the clinician diagnoses a superficial incisional infection.

Note: Stitch abscesses are defined as minimal inflammation and discharge confined to the points of suture penetration, and localised infection around a stab wound. They are not classified as surgical site infections.

Deep incisional infection: this is defined as a surgical site infection involving the deep tissues (i.e. fascial and muscle layers) that occurs within 30 days of surgery if no implant is in place, or within a year if an implant is in place and the infection appears to be related to the surgical procedure, and meets at least one of the following criteria:

Criterion 1: Purulent drainage from the deep incision but not from the organ/space component of the surgical site.

Criterion 2: The deep incision yields organisms from the culture of aseptically aspirated fluid or tissue, or from a swab and pus cells are present.

Criterion 3: A deep incision that spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least one of the following symptoms or signs (unless the incision is culture-negative):

- fever (>38oC)

- localized pain or tenderness

Criterion 4: An abscess or other evidence of infection involving the deep incision that is found by direct examination during re-operation, or by histopathological or radiological examination.

Criterion 5: Diagnosis of a deep incisional surgical site infection by an attending clinician.

Note: An infection involving both superficial and deep incision is classified as deep incisional SSI unless there are different organisms present at each site.

Organ/space infection: this is defined as a surgical site infection involving any part of the anatomy (i.e. organ/space), other than the incision, opened or manipulated during the surgical procedure, that occurs within 30 days of surgery if no implant is in place, or within one year if an implant is in place and the infection appears to be related to the surgical procedure, and meets at least one of the following criteria:

Criterion 1: Purulent drainage from a drain that is placed through a stab wound into the organ/space.

Criterion 2: The organ/space yields organisms from the culture of aseptically aspirated fluid or tissue, or from a swab and pus cells are present.

Criterion 3: An abscess or other evidence of infection involving the organ/space that is found by direct examination, during re-operation, or by histopathological or radiological examination.

Criterion 4: Diagnosis of an organ/space infection by an attending clinician

Note: 1. Occasionally, an organ/space infection drains through the incision. Such infection generally does not require re-operation and is considered to be a complication of the incision, and is therefore classified as a deep incisional infection.

2. Where doubt exists, refer to the Definitions of specific site of organ/space infection to determine if the organ/space infection meets the definition

Appendix 2 Procedures included in the calculation of rates for surgical categories not included in the SSISS protocol

Description of procedures included in surgical categories which are not included in the SSISS protocol [51]. Note that OPCS codes for hip and kne replacement which are used for both were exclu

Category	Summary of surgical procedures	OPCS codes
Appendicectomy	Open excisions of appendix	H011, H012, H013, H018, H019, H021, H022, H023, H024, H028, H029
Caesarean section	Elective and emergency caesarean deliveries	R171, R172, R178, R179, R181, R182, R188, R189
Maxillofacial/ENT/oral	Intra-orally performed Le Fort I osteotomies (with a 1-piece or segmented maxilla), mandibular osteotomies, bilateral sagittal split osteotomy (BSSO) and intraoral vertical ramus osteotomy, and functional genioplasty (FG).	V10.4, V16.1, V16.2,
Ophthalmic surgery (cataract)	Insertion of prosthetic replacement lens	C75.1
Pacemaker	Insertion of cardiac pacemaker	K601, K605, K606, K607, K608, K609, K611, K615, K616, K617, K618, K619
Prostate	Open excisions of prostate. Excludes transurethral prostatectomy	M611, M612, M613, M614, M618, M619

Appendix 3 Ethical approval letter for BehaviOuR study

NHS
Health Research Authority

Professor Alison Holmes
Department of Infectious Diseases
Hammersmith Campus
W12 0NN

Email: hra.approval@nhs.net

24 October 2016

Dear Professor

Letter of HRA Approval

Study title:	**Infection Control Behaviours in Surgery: understanding drivers to implement effective change: the BehaviOuR study**
IRAS project ID:	**193411**
REC reference:	**16/HRA/5160**
Sponsor	**Imperial College London**

I am pleased to confirm that **HRA Approval** has been given for the above referenced study, on the basis described in the application form, protocol, supporting documentation and any clarifications noted in this letter.

Participation of NHS Organisations in England

The sponsor should now provide a copy of this letter to all participating NHS organisations in England.

Appendix B provides important information for sponsors and participating NHS organisations in England for arranging and confirming capacity and capability. **Please read *Appendix B* carefully**, in particular the following sections:

- *Participating NHS organisations in England* – this clarifies the types of participating organisations in the study and whether or not all organisations will be undertaking the same activities
- *Confirmation of capacity and capability* - this confirms whether or not each type of participating NHS organisation in England is expected to give formal confirmation of capacity and capability. Where formal confirmation is not expected, the section also provides details on the time limit given to participating organisations to opt out of the study, or request additional time, before their participation is assumed.
- *Allocation of responsibilities and rights are agreed and documented (4.1 of HRA assessment criteria)* - this provides detail on the form of agreement to be used in the study to confirm capacity and capability, where applicable.

Further information on funding, HR processes, and compliance with HRA criteria and standards is also provided.

It is critical that you involve both the research management function (e.g. R&D office) supporting each organisation and the local research team (where there is one) in setting up your study. Contact details

and further information about working with the research management function for each organisation can be accessed from www.hra.nhs.uk/hra-approval.

Appendices

The HRA Approval letter contains the following appendices:

- A – List of documents reviewed during HRA assessment
- B – Summary of HRA assessment

After HRA Approval

The attached document *"After HRA Approval – guidance for sponsors and investigators"* gives detailed guidance on reporting expectations for studies with HRA Approval, including:

- Working with organisations hosting the research
- Registration of Research
- Notifying amendments
- Notifying the end of the study

The HRA website also provides guidance on these topics and is updated in the light of changes in reporting expectations or procedures.

Scope

HRA Approval provides an approval for research involving patients or staff in NHS organisations in England.

If your study involves NHS organisations in other countries in the UK, please contact the relevant national coordinating functions for support and advice. Further information can be found at http://www.hra.nhs.uk/resources/applying-for-reviews/nhs-hsc-rd-review/.

If there are participating non-NHS organisations, local agreement should be obtained in accordance with the procedures of the local participating non-NHS organisation.

User Feedback

The Health Research Authority is continually striving to provide a high quality service to all applicants and sponsors. You are invited to give your view of the service you have received and the application procedure. If you wish to make your views known please email the HRA at hra.approval@nhs.net. Additionally, one of our staff would be happy to call and discuss your experience of HRA Approval.

HRA Training

We are pleased to welcome researchers and research management staff at our training days – see details at http://www.hra.nhs.uk/hra-training/

Your IRAS project ID is **193411**. Please quote this on all correspondence.

IRAS project ID	193411

Yours sincerely

Natalie Wilson
Assessor

Email: hra.approval@nhs.net

Copy to: *Miss Rachael Troughton, Imperial College London, Student researcher*
Ms Becky Ward, Imperial College London, Sponsor representative and Lead NHS R&D contact

Appendix 4 Invitation emails for BehaviOuR study

Subject: Invitation for study into surgical site infection prevention

Dear healthcare professional,

Are you involved in the care of surgical patients?

As part of my PhD, I am conducting a study on prevention of surgical site infections (SSI), and I would like to invite you to a research interview. The study aims to capture your views on SSI prevention and surveillance in general, and how SSI prevention fits in with other activities and pressures in practice.

The interview will be very informal, conducted face-to-face on the hospital site or by telephone according to your preference. The interview should not take more than 30-40 minutes. Your responses to the questions will be kept confidential.

There is no compensation for participating in this study. However, your participation will be a valuable and important contribution to our research, and our findings could lead to improvements in how future policies are set and implemented to ensure they have the intended impact. The study is funded by the NIHR Health Protection Research Unit in Healthcare Associated Infection and Antimicrobial Resistance and has ethical approval from the Health Research Authority.

If you are interested in taking part, please contact rachael.troughton@imperial.nhs.uk to arrange an interview at a time that is convenient for you, or for more information.

Kind regards,

Rachael Troughton

Rachael Troughton | PhD Student | NIHR Health Protection Research Unit |Healthcare Associated Infection and Antimicrobial Resistance at Imperial College London, Hammersmith Campus, W12 0NN

www.imperial.ac.uk/hpruantimicrobialresistance/

Subject: Reminder: Invitation for study into surgical site infection prevention

Dear healthcare professional,

Are you involved in the care of surgical patients?

You may remember I contacted you two weeks ago regarding a study I would like your help with.

As part of my PhD, I am conducting a study on prevention of surgical site infections (SSI), and I would like to invite you to a research interview. The study aims to capture your views on SSI prevention and surveillance in general, and how SSI prevention fits in with other activities and pressures in practice.

The interview will be very informal, conducted face-to-face on the hospital site or by telephone according to your preference. The interview should not take more than 30-40 minutes. Your responses to the questions will be kept confidential.

There is no compensation for participating in this study. However, your participation will be a valuable and important contribution to our research, and our findings could lead to improvements in how future policies are set and implemented to ensure they have the intended impact. The study is funded by the NIHR Health Protection Research Unit in Healthcare Associated Infection and Antimicrobial Resistance and has ethical approval from the Health Research Authority.

If you are interested in taking part, please contact rachael.troughton@imperial.nhs.uk to arrange an interview at a time that is convenient for you, or for more information.

Kind regards,

Rachael Troughton

Rachael Troughton | PhD Student | NIHR Health Protection Research Unit |Healthcare Associated Infection and Antimicrobial Resistance at Imperial College London, Hammersmith Campus, W12 0NN

www.imperial.ac.uk/hpruantimicrobialresistance/

Appendix 5 BehaviOuR study: participant information sheet and consent form

Healthcare Professional Information & Consent Form

Study Title

Infection Control Behaviours in Surgery: understanding drivers to implement effective change: the BehaviOuR study

Invitation

You are being invited to take part in a research study.

Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish.

Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

What is the purpose of the study?

Imperial College London is undertaking a study aiming to understand surgical staff perceptions of surgical site infections (SSI). The study will examine staff attitudes towards their own practices and those of others with respect to the prevention, diagnosis, treatment and surveillance of SSI by conducting semi-structured interviews with a range of stakeholders (e.g. surgeons, anaesthetists, theatre nurses, ward staff, infection prevention & control professionals). The aim of this study is to understand how infection prevention guidelines concerning SSI are applied in practice, in order to inform how the impact of future guidelines and related interventions can be optimised. This study is being undertaken as part of a PhD.

Why have I been chosen?

You have been invited to participate in this study as you are a healthcare professional working within Imperial College London Healthcare NHS Trust and are involved in the care of surgical patients.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason (see below).

What will happen to me if I take part?

To make sure you are happy to participate in this research, this Information sheet outlines the purpose of the research and a member of the team can answer any questions you may have (r.troughton15@imperial.ac.uk or g.birgand@imperial.ac.uk).

If you agree to take part, a member of the team will contact you by email to arrange an interview. Interviews should be arranged outside of working hours (at the beginning or end of shifts, or during breaks) unless your manager agrees otherwise. Interviews will be conducted at your workplace. At the start of the interview, you will be given a chance to read over this information again and ask any questions, and a researcher will ask you to sign a consent form (if the interview will be conducted by phone, you will be asked to post your signed consent form prior to the interview).

The time burden will be a semi-structured interview lasting approximatley 30-40 minutes to investigate your views on surgical site infection prevention, diagnosis, treatment and surveillance. An audio recording of the interview will be made, but once transcribed these recordings will be erased. You will be assigned a pseudonym based on your job title (e.g. cardiac surgeon 1), and your pseudonymised transcribed interview will be stored separately from your consent form. Only the researchers will be able to trace which interview came from which participant.

What are the possible disadvantages and risks of taking part?

The main disadvantage of taking part is the time and thought you have to put into the study. There are no risks to your health or person. Only the researchers will have access to the original data, which will be pseudonymised once it is collected.

What are the possible benefits of taking part?

We cannot promise the study will help you but the information we get might help improve clinical practice and implementation of guidelines in the future.

What happens when the research study stops?

All anonymised data from this study will be retained for 10 years within Imperial College London before being securely destroyed. Your consent form will also be retained for 10 years before being destroyed.

If you would like to be involved in further research on this topic, you will be given the option to provide your contact details on the consent form.

What if something goes wrong?

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been treated during the course of this study then you should immediately inform the Investigator (Alison Holmes; alison.holmes@imperial.ac.uk). The normal National Health Service complaints mechanisms are also available to you. If you are still not satisfied with the response, you may contact the Imperial AHSC Joint Research Compliance Office.

Will my taking part in this study be kept confidential?

The records of your interview will be kept confidential and data derived from it will be anonymised. If during the course of the interview areas of practice were to be revealed that were a cause of clinical concern, escalation to the participant's line manager would be initiated. Your consent form will be retained by Imperial College London for 10 years in line with policy.

What will happen to the results of the research study?

The results of the research will be disseminated through scientific conferences and peer reviewed publications. Direct quotations may be used for illustrative purposes, but these will be anonymised to a generic job title and will not include any information which may identify you. If you wish, we can notify you by email of any publications from this study.

Who is organising and funding the research?

Imperial College London is organising this study, which is funded by the National Institute for Health Research.

Who has reviewed the study?

This study has been reviewed by the Health Research Authority.

Can I withdraw from the study?

Participants are entitled to withdraw their consent at any time – before, during or even after involvement. Should you with to withdraw our researchers may ask why in order to address any concerns you may have, but you do not need to give reasons if you do not wish. If you still wish to withdraw, any identifiable data will be removed from the study. Data which is not identifiable to the research team will be retained. Participants can withdraw themselves at any point without giving reasons.

Are there any costs or payments for participating in this study?

There is no cost for you participating in this study. There are no payments available for participating in this study.

Contact details for the study

Gabriel Birgand

g.birgand@imperial.ac.uk

020 3313 2732

Rachael Troughton

r.troughton15@imperial.ac.uk

020 3313 2732

Professor Alison Holmes (Principal Investigator)

alison.holmes@imperial.ac.uk

020 8383 1283

Consent form

Study Title: Infection Control Behaviours in Surgery: understanding drivers to implement effective change: the BehaviOuR study

Principle Investigator: Prof Alison Holmes

By initialling the following statements and signing this consent form I confirm that:

1. I confirm that I have read and understand the subject information sheet dated ..... version ..... pages…….for the above study and have had the opportunity to ask questions which have been answered fully. ☐

2. I understand that my participation is voluntary and I am free to withdraw at any time, without giving any reason, without my legal rights being affected. ☐

3. I understand that if I lose capacity to consent after the interview, my data will be retained and included in the study. ☐

4. I understand that my data including identifiable data (e.g. consent forms) will be stored securely at Imperial College for 10 years following the completion of the study. ☐

5. I understand that recordings of my interview will be collected and transcribed by a third party, and that anonymised direct quotations may be used in publications. I understand that the audio file of my interview will be destroyed after transcription. ☐

6. I agree to take part in the above study. ☐

_____	_____	_____
Name of Participant	Signature	Date
_____	_____	_____
Name of person taking consent	Signature	Date

Optional clause:
I agree to be contacted about future studies on the themes covered in this interview at the email address provided below. I understand that there is no obligation for me to participate in future studies. ☐

Email address: _____

_____	_____	_____
Name of Participant	Signature	Date
_____	_____	_____
Name of person taking consent	Signature	Date

You will be given a copy of this form to keep. One other copy will be kept on file by the research unit for 10 years following the completion of the study, in line with University policy.

Appendix 6 Sample interview schedule

Qualitative Interviews on SSI and Surveillance – SURGEONS, NURSES, ANAESTHETISTS, MICRO/IPC

Background

1. Please can you state your role/speciality for the recording?
2. How long have you been a surgeon? And at this Trust?

General

3. Tell me about your average day/week
4. In your view, what are the most important factors in preventing SSI?

   Prompts: patient factors, pre-surgery practices, surgeon, other team members, environmental, etc
5. How significant a problem do you feel SSIs are in this Trust?
   a. Prompt for perspectives of staff/patient/manager
   b. Where would SSIs come in your list of priorities?
6. Who is accountable for SSI prevention, in your opinion?
7. What activities in your day-to-day work do you do to help to prevent SSI?
   a. How easy is it for you to do these activities? Is it ever difficult? Why?
   b. What about the actions of the teams you work with – what do you see as important in terms of others' roles in preventing SSIs?
   c. In your experience, does this work well or are there any problems? Why?
   d. Some have said that they don't receive adequate training to perform certain tasks around SSI prevention or wound management – are there any tasks you feel underprepared for?
8. What sort of feedback do you get on these activities - at an individual or team level?
   a. How often does this occur? Is the feedback confidential or open?
   b. How often do you get the chance to watch others work?
9. How comfortable would you feel challenging behaviours in others that you feel may increase SSI risk?
   a. Some have said that guidelines and policies are helpful to refer to when challenging others – do you agree?
10. How would you describe the culture of transparency around SSI here?
    a. Some have said that reputation among peers is an important factor in transparency – would you agree with that?
    b. There has been a lot of work around hierarchy in surgery, "whoever holds the knife holds the power" – is that something you recognise? Do you think that has an impact on staff behaviours around SSIs?

c. Some have said that having somebody with an official role to prevent/monitor SSIs is vital – do you agree?

11. Is there anything you feel can be done to improve SSI rates at ICHNT?
12. Are you aware of any policies or guidelines that apply to SSI prevention?
13. Thinking specifically about these policies/guidelines, to what extent do you feel these are practicable?
14. Is there any new technology, gadgets, apps etc. that you know of that relate to SSIs?

GIRFT

15. How did you first hear about the GIRFT audit?
16. How did you find the implementation?
17. What has been the impact of the audit on practice?
18. How would you improve the audit process?

EXPLAIN PREMISE OF QLIKVIEW SYSTEM

19. If a semi-automated system were in place for flagging suspected infections, what, if any, would your concerns be?
    a. Prompt for consequences for working practices/other staff/the department/patients

Closing

20. Is there anything you were expecting me to ask?
21. Anything else you feel important to the topic not discussed today, or that you want to add?

After recording ends

Is there anybody in particular you think I should interview?

Appendix 7 Sample coding framework – Knowledge and skills theme

Quotation	Code	Category	Theme
A&E nurse **Any policies or guidelines that you are aware that applies to surgical site infection prevention?** No. **Anaesthetist** There seems to be not much standardisation between Trusts as well and sometimes it'd be nice to know why, it would be nice to know why one Trust prefers a Cephalosporin over a Penicillin for the exact same pathology in the exact same patient. From my own education and for the education of others that may be useful, and just communication really. **Orthopaedic consultant** That's where it will tend to get brought up first. Now obviously if you're missing from that meeting you may miss that but usually if there's something important we will as colleagues inform each other. **Tissue viability nurse** There is the Trust policy for surgical site infections, which I'm aware of and it does state in it if they suspect a surgical site infection they're to refer to tissue	Lack of information about policies, policy differences or changes	Awareness of policies	Knowledge and skills

viability… I'm not sure a lot people know about them to be honest, I don't know how well the surgical site infection guideline, how, whether people really know that it's there or follow by it, and then there's the NICE guidelines as well for a surgical site infection but I don't know whether it's very well known about. **Vascular registrar** we should have a scrape wound or take a fluid or tissue which, these kind of the guidelines were not, I wasn't aware of it, the wound swab. No. So the audit of the antimicrobial prophylaxis, we got the feedback that we're giving the wrong doses of vancomycin in terms, but the guidelines changed, in terms of the dose … so it has changed really and it's very helpful, so this was the feedback from the pharmacy on the ward, that we should follow the guidelines which were changed recently, otherwise the prophylaxis is still pending and it's due to be changed 2019 so in the middle of this prophylaxis change.			
Anaesthetist I think it's people who aren't familiar with the antibiotic prophylaxis for the Trust could be more accessible, I know it's on the source but if, if you had it actually written down for people without having to access a computer within the certain theatres where *especially these occur,* that could be of use. Again I think ease of access to information, so for antibiotic policy it does need to be easier, it's a big, big wordy document. I know that there's, in other hospitals in the private sector, there's a number of apps that you can use and it's very easy, you literally just tap on it for that institution and Trust. **Orthopaedic consultant** I think there are some policies on the trust intranet. I have to say the trust intranet is absolutely full of policies which I don't bother reading. I will do what	Policy information is difficult to access		

we're told to do if it is discussed in our audit meeting or, for example by the ward matron or whoever is the leader on it. **Specialist nurse** but anyone that nurses on the ward wouldn't have an idea of how to search up on the intranet for where the SSI protocol is. So I think it should be more easy at hand. **Theatre personnel 1** We have policies (<u>inaudible</u>) because we have a policy for everything that we do. And they all update online here so it's accessible to all staff to be able to go in and check once you *go on* the source. You have more than enough, but it's now the time for individuals to really go and search or ...			
Critical care nurse So, if I do a wound care dressing as what I knew from university when your studying how to do it from washing your hands, to removing the dressing, to washing your hands again and preparing all your sterile field and what kind of, this is are all like the basic that I've learned from taking the degree I don't think this is standard across nurses, I don't think so, because we don't, I cannot remember that someone has shown me that this is how you should do wound care. **Scrub nurse** So, when I scrub we always have to scrub properly, I mean with the aseptic technique. So, as I've learned in uni	Relying on previous training, staff have different practices	Staff training, experience and confidence	

Vascular registrar what I notice also if the nurse doesn't want to do the dressing they will be very reluctant to call you when the dressing is down and they won't do it, they won't take it down, and at 6pm it's very difficult to get the dressing down because everyone is preparing for the handover, it's not fair on the staff as well or on the patient wait, God knows for how long, until midnight to have the dressing done, so either you do it yourself or it won't be done.	Lacking in confidence in their practices		
Critical care nurse when I do the dressing no one is there, so anyone who's checking the dressing in that closed curtains, actually in my head I don't know how they're doing it. Do they do it the way I do, is it my practice it is the best, I don't also know.	Unawareness of peer practices		
Scrub nurse I was telling you in my previous job we didn't have to do it. So, it wasn't, it's like a health care assistant who has to do it, they are special training, trained to do that. So, they know how to do that, I don't know and when I came to this country they said you have to clean the theatre at the end of the procedure and you have to be sure at the beginning of the procedure the theatre is clean. Of course, I will be sure that the theatre is clean at the end, at the beginning of the procedure, I will try to do my best, but I have no clue about that. **Critical care nurse** like changing the wound dressing, if you are a nurse then you should do it properly and I don't know maybe it's good showing you staff who doesn't have, especially in the ward there are new staff nurses, this is their first job, that they need to be aware of how to look after the wounds, maybe they don't know how to do wound dressing, the simple things,	Performing tasks they haven't been trained for		

Anaesthetist Certainly through the microbiology team and the infection control team if a patient is needing an upgrade on their antibiotics or are on a long course of antibiotics, they're highlighted to them as well. So all this information is then covered into the SSI prevention group. **Cardiac registrar** we have meetings between different departments to discuss that. The microbiologist tends to give the majority of the advice with some input from clinicians, so it's mainly the microbiologist who decides what the antibiotic prophylaxis is. **Critical care nurse** We have doctors there all the time that you can easily get and then when you refer the surgeon, we are the priority to be seen. but we have tissue viability as well, which is a very strong team we have, but the surgeon is there to give us some instructions in what to do with this wound, or there might be, they have to obviously, it's not resuture, they can't resuture it so, using of a VAC pump would be beneficial for the patient. No, it's our intensive care doctors, but I am aware that every day in ITU they have the microbiology meeting, when the microbiology people come **Orthopaedic registrar**	Strong connections with specialists	Other specialists as a resource	

We have post operatively, if we are in doubt so far we have ANPs, advanced nurse practitioners, we have a special nurse that is responsible for orthoplastic cases and also we've started dressing clinic twice a week for any query wound problem, they will come, they will be targeted with *members of* staff. **Tissue viability nurse** I don't think it's, the referrals that I see, I don't get referred that many but that doesn't mean to say that it's not, they're not occurring or not being reported but I know there has been a slight increase in the number of SSIs occurring recently. **Vascular registrar** According to micro consultants, swabbing of the wound is not appropriate, we should have a scrape wound or take a fluid or tissue which, these kind of the guidelines were not, I wasn't aware of it, the wound swab. If they don't know what kind of dressing to use and the junior doctor or whoever is on the ward doesn't know what to do it, they won't do it, so they don't, they will feel more supported and will learn from this as well. but if they have this nurse and if she helps to reduce the SSI rate this is perfect, so she can be there, she can teach the people to do it … which is beneficial for everyone.			
Cardiac registrar We have (nurse) who will pick up surgical site infections, and, but we will not stop swabbing just because (nurse)'s going to pick up a surgical site infection, and I don't think people will change their swabbing behaviour, especially	Advantages of multidisciplinary working		

because the nurse on the ward doesn't care if (consultant) has a high rate of wound infection, they just want to treat the patient, and the way we've separated the person who's most affected from the actual actions that need to be taken. **Orthopaedic registra** I think it is well organised team for surgical infection site in our trust starting from the nurses and to surgeon between, for example in our department of orthopaedic as well as the plastic surgeon and the microbiology department and as well as pharmacy. **Anaesthetist** that is the literature that's printed and we've stuck with that and that has been questioned by senior people within microbiology that at a multidisciplinary meeting they decided to go with that evidence.			
Vascular registrar When I spoke to the matron about this, maybe it's worth trying to point out the nurse who'll be doing all the dressings just to reduce the wait, she told me that it would never work here because it will, not decondition, but it will deskill the other nurses But it wasn't supported by the matron at the time and now, after a year, when the bombshell was blown, it's just everyone is, she just needs to use the golden	Access to specialists de-skills non-specialists		

part, have this wound dressing which everyone is very reluctant to have that person on the ward because it's not a part of their culture how it works here.			

Appendix 8 Reflective journal Rachael Troughton

19th May 2017 – Interview 1, Surveillance Nurse

Debrief notes

We had just come from a SIG meeting together, had a brief chat about weekend plans while I bought coffee

At the start of the interview, interviewee seemed nervous which surprised me, as I had been nervous beforehand and thought, surely it should be me who's worried how this will go? I think she possibly was concerned about what I would ask her, and whether she would give the "right" answers.

I found myself referring a lot to my interview schedule. I had already crossed out a lot of the questions that I didn't think were relevant, and struck out a few more as we went. In the end, the interview was only 10 minutes long but I couldn't think of anything else to ask at the end. I realise I should have been listening and asking for more detail on some things. I need to remember that if a participant doesn't say something, and I don't probe because I already know it, I don't have any evidence.

I think probably next time I will need to spend a bit longer putting the person at ease, and start with some easier questions, maybe "tell me about your typical day". I definitely need to listen a bit closer and dig a bit deeper with some answers, instead of thinking "oh yes I know what you mean".

26th May 2017 – CABG pre-pilot workshop

Debrief notes

Not the best day I have ever had. Nurse doesn't like me and thinks I am trying to prove that her job can be done by an algorithm and an untrained person. Possibly also defensive about the quality of her surveillance. I completely understand where she's coming from and tried to reassure her that I know her surveillance is the gold standard and I'm just trying to create something that is better than nothing. She was also really really concerned that she would end up doing the data inputting. I reassured her that she wouldn't and in any case, it would be biased if she did as she has already seen all the patients' wounds and would remember who had an SSI and who didn't. She commented along the lines of surely it's better to have it as good as possible, wouldn't you want it to be biased? I said no, we need to see how it would work in other specialties where they don't have any surveillance. Surgical reg agreed with me and was more supportive of the project. Micro was less vocal and I think was holding off making too many comments until she could see how it would work. Micro keeps her own records of SSI patients as she does not trust the quality of SSI surveillance as it stands. I did get a lot of useful feedback, and some simple things that are very easy to

change. Group suggested they have a play, and I will send out survey again in about a month, and I will arrange a meeting in six weeks time.

I'm still confident that this will work in other specialties. I can understand the resistance in CT where they already have surveillance.

12th June 2017 – thinking about next interview

I think a good question to add into the start of the interview would be "tell me about your typical day". This would add in opportunities for me to understand the context and priorities of the participant's work. Plus it might help them settle in and feel comfortable. I read a blog post on interviewing for introverts https://ethnographymatters.net/blog/2012/03/22/interviewing-for-introverts/ as I have been wondering recently how suitable I am for this type of research, given that I find meeting strangers quite draining, especially when I am asking a lot of them. I am still dreading trying to recruit new participants but confident that I will be able to do it.

26th June 2017 – Interview 2, Orthopaedic consultant

Debrief notes

I found the surgeon at the end of the ward round on a sunny day. Victor accompanied me to observe. On the way down in the lift the surgeon noticed a woman who had written "not this one" on the foot not to be operated on, which prompted a short discussion between them about patients involvement in safety, and how patients on occasion indicate the wrong foot.

We spoke in the 1st floor café, and the discussion went much better than the previous one. I probed in a lot more detail about intra-operative practices and was happy with the data I collected. Victor and I listened to the recording afterwards to critique my interviewing style, and also to flag up further questions for the next interview. I found it extremely useful. We then discussed some of the themes over lunch.

Some reflections I have were that I should stop nodding and saying "yeah", particularly very early on in the respondent's answer as it makes it seem like there is a "right" answer to give, when there isn't. I also must focus more on listening, and in general take the whole thing a bit more slowly. I may try counting to 5 after the end of each answer the participant gives. Another thought was that I think my background in science has desensitised me to the passive voice – "patients are informed" should really be met with "who informs them?" to avoid missing out on the full picture, but it sounds too normal to me.

Main themes: reputation, career stage, witnessing somebody have a career-ending bad reputation, lack of transparency

Tips for next time: try not to nod or say "yeah", just look and listen and say "ok" or "interesting", count to 5 after the end of each answer, make notes about questions to ask rather than asking straight away in case you forget

14th July 2017 – CABG pre-pilot workshop 2

Debrief notes

Nurse not there this time, despite me specifically arranging it for a day she said she could make. I got her out of office. We went ahead anyway and had a good chat. Micro consultant was very positive about the app, said it was definitely useful. Both agreed that it's a good way to sense-check manual surveillance anyway, even if it's not going to add much to CABG as they already have surveillance. I did realise that I accidentally brought an old version of the questionnaire for one participant to fill in. Overall, I felt they as individuals were more positive about it but that they were generally less positive about how others would use it and how it would fit in with their workflow than in the previous workshop. I think this might be because as their knowledge has grown they now perceive the gap between their knowledge and others' as wider? They made some good comments about the instructions provided on the tool. I told them about the problems we're having with development and they understood. Surgeon agreed to check one quarter's worth of suspected infections for me to validate.

19th September 2017 – Analysing transcripts

Analysis is taking much longer than I expected. 8/10 interviews were conducted by Victor, so I am seeing these answers for the first time. I have noticed that a lot of answers seem to be fact based – "we have weekly meetings". What I really want to know is why is that? What's the impact? How do they feel about these things? In my next round of interviews, I'll be using "why do you think that is?" or "how do you feel about that?".

Main themes so far: different specialties take SSIs seriously/not so seriously, many of the opinion that post-discharge SSIs are the patient's fault (cf. Raheelah's work on SSIs and MRSA), "closed curtains" (lack of peer-to-peer learning)

3rd October 2017 – Analysing transcripts

Today I have started analysing the scrub nurse transcripts. This nurse has been much more candid than the others and although the interview is long there are a lot of interesting insights. Firstly, that general surgeons use antibiotics instead of wearing masks or adhering to proper sterility practices in theatre. Secondly, this is the first interview I have seen where the interviewee has admitted to a lack of confidence in challenging staff, particularly surgeons, on their SSI prevention practices in theatre. This was down to a fear of not being tactful enough, and this is interesting because tact has come up a lot in other interviews as being an incredibly important factor in challenging the behaviour of others. Many other interviewees said being confident that they could express themselves tactfully and had a good relationship with the staff member was a factor in their overall confidence in challenging behaviour.

Main themes: tact when challenging behaviour, especially of surgeons, and again a difference between general surgery and orthopaedic surgery in practices.

21st November 2017 – Writing abstract

Cognitive dissonance between surgeons knowing others hold them responsible for SSIs and really feeling that responsibility – but other staff already feel team responsibility for SSIs so can we persuade surgeons that they're not solely responsible (which they already secretly feel). It might be this tension caused by thinking others blame them that makes them defensive when challenged. Inflated sense of responsibility? Or is it just that somebody damaged their God-like sense of self?

Also, immediate risk of harm to the patient may be more important than deferred and uncertain risk of SSI – is there a correlation between the immediate risk and lack of IPC practices? For a low-risk elective hip replacement, staff might be more conscious of IPC vs. immediate risk in cases of trauma or cancer surgery? How about perceived risk of SSI being a self-fulfilling prophecy? E.g. expect patients to get SSI in large bowel surgery, therefore less IPC, therefore they get SSIs?

27th February 2018 – Analysing transcripts

I have just finished analysing the cardiothoracic registrar transcript. This was an extremely interesting interview which showed the difference different types of surveillance make. This surgeon had experience in another hospital which had open feedback, not anonymous. This created a slight paranoia which was at times counter-productive as it meant a lot of extra time spent on some aspects at the expense of others, and a lot of feelings of blame, embarrassment and guilt attached to the feedback experience. The participant suggested that having a surveillance nurse to separate those doing the surveillance from those impacted by the results was extremely useful, likewise the fact that nurses often swab patients without the knowledge of the surgeon (though sometimes they are shouted at as a result). Nevertheless, the

surgeon acknowledged this was probably a good thing. The last major point was that the official position of surveillance nurse empowered this person in challenging and discussing SSI issues in a way that wouldn't be tolerated from a non-specialist.

Main themes: "the process has the power", separation of tasks, empowerment through official roles.

5th April 2018 – Four more interviews down: vascular, tissue viability, general surgery, anaesthetics

The first of these was with the vascular registrar. This was a quiet office although we were interrupted. The quiet environment allowed me to listen more carefully and calmly to the responses. The impact of conducting the GIRFT audit was strikingly clear – the participant gave clear, structured definitions of SSIs. This surgeon pointed out that swabs in vascular surgery are taken on instruction of the surgeon: nurses do not tend to swab autonomously. This has knock-on implications for the QlikView tool. Another point raised here was overcrowding in the ward, and poor practice on ward rounds which sees wounds exposed to the air for up to 4 hours, dressings being changed on certain days rather than when they need to be changed, and dressing supplies being scattered around the ward. An interesting idea here was that referring to guidelines is helpful when challenging others' behaviour.

Main themes: empowerment through guidelines, need for training, need for nursing self-efficacy and autonomy, need to redesign ward environment

The second was with a tissue viability nurse. This was conducted in the café so was more chaotic. This participant did not seem particularly comfortable or expressive throughout the interview and I had trouble getting anything out that was more than basic facts. I ended up asking a lot of leading questions, and using examples which the participant latched onto.

Main themes:

Ideas for next time: might try to ask the participant "what's the best part of your job?" to open the gateway into a more personal and reflective conversation rather than just fact

The third was a surgical registrar. This participant also took part in the GIRFT audit and highlighted that he previously wasn't sure about the definition of an SSI and thinks others should be trained on how to recognise them.

Main themes: training on definitions

The final interview was with an anaesthetic consultant. This participant reinforced the importance of high-quality evidence and guidelines when challenging others. Hierarchy and "discussion" rather than straight

challenge came up again. This participant had had experience of audit and feedback of other outcomes (not SSIs), and found it useful but had not made any significant changes to their practice.

Main themes: use of evidence to support discussions, peer learning, training needed for dosing

8th May 2018 – Another four interviews, and writing up

Microbiology – I have met this participant many times before, and we are on friendly terms. The interview was conducted in his office.

Pharmacist – again, I have met this participant several times before and we are on good terms. We had some useful discussions about the importance of storytelling and patient narratives to add tangibility to data

Obstetrician – this interview was conducted in a room in the library. We were disturbed a few times, but I felt that the flow kept up very well. I felt I had quite a good rapport with this participant.

Plastics consultant – this interview was interrupted several times. I felt that the participant at times was confident in explaining the surveillance setup in the Trust…some of which I know not to be the case. I think this may be partly to do with the participant seeing me as an "outsider" who knew less, and also not wanting to seem out of touch with the workings of the hospital.

Appendix 9 Reflective journal Victor Mariano

July 5 – Recruitment Day

This day I decided to work from St. Mary's Hospital to do recruitment for this study. I have chosen this site, as this was where I used to work as a theatre nurse and trauma research nurse. Thus, I felt it would be easier for me to recruit participants, as I know potential participants as well as the theatre department. In terms of access, it would be easier for me to talk about the study, as I am familiar face to them.

I based myself in my old office as a research nurse and followed my former colleague, who is a research nurse, as she conducted rounds in the ICU and a ward. This provided me the opportunity to talk to other staff members in the wards who are not familiar with me about research. I was able to talk to several nurses in the ICU about this study and provided participant information sheets. I first asked about their experiences with SSI and one particular nurse recounted one's experience. When this nurse agreed to participate, we arranged an interview towards the end of the week on the nurse's day off.

I proceeded to theatres on my own. I have spoken to my former theatre colleagues (across various job roles) about the study. I have provided them with the participant information sheet as well as my personal mobile number. They said that they would get in touch with me. None of those who told me will get in touch me through my mobile contacted me. Someone even said he was unsure because he is going on holidays. However, I saw him the following week. I have not made any follow-ups with them about participating as they see me in theatres and they were aware that I was there to recruit. I took that as a they did not want to participate.

One interesting potential participant I would want to recruit was someone I know that is critical of practices and is confident on placing incident reports (Datix). She was initially interested to participate and understands the value of this type of work. However, she pulled out once she learned that it's going to be audio-recorded. She hesitated as she said the recording could still be used as evidence against her despite the anonymity clause on the participant information sheet / consent form. She suggested that the list of questions or a questionnaire to be sent to her instead, but I said that couldn't be done. This experience showed to me the low awareness of types of research and distrust in the research process.

I approached a consultant surgeon about this study. I explained to him what the study is about and provided him a participant information sheet. At that time, he already said yes and straight away signed the consent form. When I asked for his availability he said he could only do it on Wednesdays in between cases. He offered to be interviewed right at that moment. However, at

that time I haven't done any interviews yet and I felt I would not be prepared enough to be able to get some rich data from a key informant. Also, I'm not confident enough to discuss the SSI semi-automated surveillance. He agreed to be interviewed the following Wednesday. However, I was pleasantly surprised that he signed the consent form straight away and mentioned he'll do anything to help. Probably, he still recognised me as one of his scrub nurses before. I did not introduce myself as such to him as such that day when I approached him.

Upon returning to the office of my former colleagues, I found my other colleague who has a huge social network in hospital. I sought her for any recommendations for ward nurses in surgical units. We proceeded to the surgical ward to find out if the person she was recommending is at work. However, she was not and we just took her email address and I sent the participant information sheet and consent form to her. I have not got any response from her.

As I was working from their office, one of the consultant surgeons who use the office next door passed by the office. I discussed the study and provided the participant information sheet and consent form to this surgeon. This surgeon agreed to be interviewed the following week on a Tuesday when he would be consultant of the week. However, this did not happen as he turned out to be busy from that day with a code red patient.

July 7 – Interview 3 – ICU Nurse

This was my first interview and I was nervous. I reviewed the interview guide we have for the study and I felt that it might be more useful to rearrange the question. The previous interview that I observed with my colleague was done with a surgeon, so I thought maybe taking a different approach in interviewing a nurse would be more beneficial. I consulted with my colleague who was running the study about this approach and I was advised that rearranging the questions is not a problem and I do what I see fit.

I met the participant at lunchtime. We decided to have lunch first together before conducting the interview. I personally do not know the participant before this. However, since we came the same country and we are both nurses (I've also worked in the ICU at the same trust), building rapport with the participant over lunch was easy for me.

Both the participant and I appeared nervous at the start of the interview. Neither of us had any previous experience in qualitative research either as an investigator or participant. However, as environment where we were conducting the interview was private, we were both at ease. During the interview, I noticed that I was more concerned with having an organised flow of the questions, having the right order of the questions and thinking what questions to ask next rather than focusing on the participant's responses. The other thing that I felt that I struggled with was timing when to ask questions and not interrupting the participant. I thought this would be achieved through practice. When I finally gained my composure during the interview, I felt that I was able to probe more into the participant's responses. I felt that my background in working as an ICU nurse facilitated me to ask questions that relate about training and relationship dynamics among professional groups.

At the end of the interview, I realised how else that I could ask some of the questions. For instance, rather than just asking "how comfortable is the participant challenging behaviours in others", I thought it would also be important to ask the participant on their view on the comfort level of their colleagues in challenging the behaviour of others. The response to this question does not only focus on the participant's subjective "comfort level", which may be influenced by her personality, training and experience, but rather this will paint the picture of the culture of her unit or staff group.

July 10 - Interview 4 – Theatre Nurse

In the morning before this interview, I have gone through the recording of participant 3's interview together with my colleague. This activity provided us the opportunity to immerse with the data and identify new lines of questioning for the succeeding interviews. I felt that I am more prepared to conduct my second interview and was quite excited about it.

I met Participant 4 in her office. The participant showed me to their meeting room and that's we were to conduct the interview. The room was quite secluded from the rest of the department. However, at some point during the early part of the interview, someone was peeping at the glass door and mouthing something to her. This has stopped the participant from answering a question mid-sentence as the participant was responding to the person at the door. Despite that, the participant still regained her composure and answered the question properly. Apart from that

incident, the interview went smoothly and I felt that the participant was very candid with her answers. I think the interview environment allowed her to be honest as it was in a very private setting. The participant also mentioned to me off the record that the participant had previous experiences of being an interviewee for qualitative studies conducted by industry. Thus, the participant was quite familiar with the method and understands the value of providing truthful answers. Finally, the participant was also familiar with me, the interviewer, as I worked under the participant's team as a junior theatre nurse. In fact, this came out in the interview where the participant mentioned practices that they have improved and compared it to the time when I was still working with them.

As an interviewer, I felt I was more organised and confident, as this was my second time doing it. It also helped that I was interviewing a former colleague. Unlike the first interview that I conducted, I felt I was more engaged with the conversation. I felt I was probing more the participant. My background working in their department allowed me to come up with more questions. Also, I felt that this background allows her to be candid about her answers rather than giving canned/diplomatic answers as the participant deems that I know what is happening on the shop floor. Towards the end of the interview, I took the opportunity to ask the questions that I've missed asking i.e. antibiotic practices. Finally, I've asked the participant for feedback on my performance as an interviewer, the participant mentioned that it was good that I was digging deep during the interview. After her interview, I also caught up with the more senior theatre coordinator and we discussed about the study and the participant offered to help me with the recruitment for this study

July 11 – Recruitment Day?

Today, I was meant to interview a consultant vascular surgeon. However, due to a code red emergency that came in this morning, the potential participant became very busy in looking after this patient. I decided to just recruit other theatre staff to participate in this study. I bumped into my theatre sister in the hallway and the participant provided me access inside the theatres. I've caught with some former colleagues and was able to arrange an interview with a theatre/anaesthetic nurse. After going through the participant information sheet to her, the participant was already happy to participate and conduct the interview that day. The participant mentioned that the participant's working as anaesthetic nurse and the participant's not really busy at the moment as a long surgery is going on and there's another staff member covering her. However, the participant was suggesting that the interview be conducted in the anaesthetic room. I was uncomfortable about this arrangement. I asked her if our conversation would be audible inside theatre and the participant said "yes". However, the participant said that the participant

would be honest with her answers despite our voices are audible inside theatre, nor if anyone comes through the door in the anaesthetic room. As the participant was explaining this, the participant was already providing me some rich data on the practices in theatres both on the negative and positive sides whilst off the record. This made me optimistic that the details that the participant was providing me in this conversation would surface during the actual interview. Despite that, I explained that it would have be better if it was somewhere private and ideally after the participant's shift. We arranged to have it done the following day after the participant's shift.

July 12, 2017

Postponed Interview – General Surgeon and Recruitment

Today, I was meant to interview a consultant general surgeon. The anaesthetic nurse that I meant to interview at the end of the day was working in the theatre where this consultant surgeon is operating. The participant briefed me on the cases that were on the list that day so that I can plan which of the best time to catch the consultant general surgeon at the staff coffee room for the interview. The anaesthetic nurse offered to text me the moment a case finishes so that I can meet the surgeon at the coffee room. However, their theatre became so busy that day and they moved cases around that list. As the cases were also short, there were not much enough time in between cases to get this surgeon interviewed and be able to provide an uninterrupted interview. As he has signed the consent form, I figured that it would be best to do him in another day.

I caught up with a former colleague during her lunch break and she was checking on me if I get more participants for the study and suggested some people for me to talk to. After I spoken to a few staff members, most of them said no, my former colleague said the probable reasons that they would not like to participate is because it's going to be audio-recorded. Furthermore, my former colleague said that some people are apprehensive on signing consent forms. My former colleague may be right. I've spoken to a theatre support worker who comes from my country (although I don't personally know him before), he said no and said that he doesn't want to get involved in things like this. Probably, they view this kind of research as someone is acting a whistle blower.

Interview 5 – Theatre /Anaesthetic Nurse

At the end of the participant's shift, the participant met me at the staff coffee room and we proceeded to the staff computer room. This room was next to the coffee room. When we came in, the room was empty and all throughout her interview. Participant 5 was the theatre coordinator of the general surgery theatre when I did my rotation in general surgery as a scrub nurse. Thus, both the participant and I are familiar with each other. Despite this, I felt that the participant was giving me textbook answers or appearing very diplomatic in her responses. Often, when I asked hard-hitting questions, the participant tends to pause and make a face. As soon the participant regains composure, the participant provides an answer. I felt that the participant's responses are not as straightforward and possibly not truthful. They may not necessarily reflect reality, as I know it based on my experience working in theatres. In fact, I doubted the participant when the participant said the participant had no experiences of a patient coming back to theatre with a surgical site infection in the participant's 20 plus-year career as a theatre nurse. Towards midway during the interview, the participant has been interrupted by her phone ringing. At this point, the participant said we had to continue another time. I explained to the participant that I'm not sure if that is possible, as I have to consult with my colleague if that's possible. However, the participant provided me with some valuable feedback on how I performed as an interviewer. The participant expressed that I may possibly do not dig deeper because of the nature of the relationship we have. Based on this feedback, I felt that I may not dig deeper when the participant responds with a negative, for example, I don't have any experience with a patient coming back to theatre with SSI. Possibly, it is because I don't want to appear doubting the veracity of the participant's responses. Rather, I have to figure out a way to ask these questions in a more neutral manner.

July 13

Interview 6 – Surgeon (Consultant)

Today I am meeting with a surgeon for an interview of this study after the surgeon's clinic hours. A few days ago, I bumped into this surgeon in theatres and discussed the study. This

surgeon agreed to meet with me on this day after clinic hours. I have worked with this surgeon when this consultant was still a registrar and I was a scrub nurse. The surgeon's level of familiarity with me was as a colleague in theatres and the surgeon was aware that I pursued doing research after I left my former job.

We conducted the interview in the surgeon's clinic. This surgeon's office is tucked away in a corner secluded from clinics of other surgeons. However, it was facing the receptionist desk. The receptionist was still on her desk when he entered the room and after we conducted the consent process. We shut the door but both of us are aware that the receptionist is on her desk, a few metres away from the office.

During the interview I felt that the surgeon was providing diplomatic answers and quite cagey. There were a number of times where he felt uncomfortable about some of the questions, and does not really know how to respond. For example, when I asked about surgical prophylaxis. The surgeon requested for the recorder to be turned off. At that point, I was unfamiliar with the pause setting of my recorder, and just encouraged the participant to proceed. The participant just answered the question regardless, but backed it up this is in coherence with Trust guidelines. Another question was about challenging behaviours by surgical trainees of their more senior colleagues. The surgeon said that does not happen, but when I asked why is that so. It was clear from the participant's facial expression that this made the participant uncomfortable to expound. I could have probed more into it, but I felt it was already too intrusive for the participant. Possibly, my relationship and familiarity with the participant hesitated me to dig deeper. It emerged in this interview that the participant has low awareness about surveillance activities in the elective side of the participant's specialty. This was also the first time for me to discuss the semi-automated surveillance proposal in an interview. Although I felt nervous about discussing this, I thought that this was clear to the participant. The participant also highlighted in this interview the best practices that they have adopted, particularly the dressing clinic. This provided something new to discuss that I was not aware of and it's impact on the reduction of SSIs as well as surveillance at least in trauma patients. I have stopped the interview midway due to a phone call that the surgeon received from another colleague. I marked on my interview guide where we stopped, and then created another audio file as soon as we restarted. After almost an hour of interviewing, we left the clinic and the receptionist was not already on her desk. At some point during the interview, she has left but our door has been closed the entire time. I sought feedback from the participant and the participant felt it was a good project and I discussed more details with the participant regarding the dressing clinic.

The discussion with regard to the dressing clinic sparked an idea for me to recruit the nurse running the dressing clinic. I have asked around the other nurses working in the clinic about details of the nurse running the clinic. Unfortunately, this nurse was not around that day, but they provided

me with an email address. I emailed the nurse about the study and attached the participant information sheet and consent form but I have not gotten any response yet.

Interview 7 – Surgeon (Registrar)

Participant 7 is the first ever participant I've recruited for this study. I used to work with Participant 7 as their research nurse in my previous role and had established a social relationship as well with this participant. After several deferrals of the interview date, I interviewed participant 7 at the registrar's office. When I came in, the participant was with another registrar although the participant was comfortable for the colleague to stay around for the interview. I have not met this colleague before, but as the colleague learned the topic of the study, they started to have a discussion on the current prevalence of SSIs in their speciality in another hospital. This was something that I was looking forward to surface during the interview. This colleague left the room after we have done the consent process. Their office was in a secluded area of the hospital complex and away from the major buildings of the hospital. Thus, it was a private environment.

I went through the general questions with the participant. Some of the questions I felt the participant thought were too basic, as I've noticed he made a face or grunt sounds. For instance, when I asked the participant to clarify patient's personal hygiene as a factor that could influence the acquisition of an SSI. Among all the participants I have interviewed, I was shocked that the participant answered only the surgeons are accountable for SSI prevention. I have tried to dig into the participant's response, but I got as much as I can get. When we talked about SSI rates in the participant's specialty, I felt that he was giving diplomatic answers. I agree that SSI is quite rare in the participant's specialty. I have also expressed this in the conversation with the participant's colleague and the participant present before we started the interview. The participant's colleague expressed that it's not entirely true and the whole conversation of SSI rates in their speciality in another hospital surfaced. I was disappointed though that the details of this conversation did not emerge in our recorded interview. When the participant said that it's low in their specialty, I hesitated to challenge it despite having a privy conversation earlier about the matter in their elective surgeries. I felt that I am uncomfortable challenging "no" or negative answers to questions as I feel it's intrusive, and probably, the nature of our relationship also comes into play. I reckon this is the disadvantage of interviewing people with a certain level of familiarity.

I sought some feedback from participant 7 after the interview. The participant felt that although I probe, he said that it would be difficult for someone to make a surgeon admit anything.

Based on this comment, this confirms my observation about the surgeons that I interviewed were cagey with their answers.

July 14

Part 2 – Interview 5 –Theatre/Anaesthetic Nurse

Today, I again met participant 5 at lunchtime to confirm if the participant was still happy to continue with the interview that was disrupted the other day. The participant said yes we could continue after the shift that day. Beforehand, I have consulted with my colleague about any methodological implications that may have if I continue the interview the other day. To which, I was advised there are no issues. Thus, to prepare for this interview I listened to the participant's recording to reacquaint with myself what has emerged from the data and where we left off. During this process, I was taking down notes and restructuring some questions. Some of the participant's responses that I have doubts with were rephrased in a different manner. Most of the questions from the interview guide were already asked during the initial interview. However, there was a touchy theme that has surfaced in the other interviews that I haven't discussed with her yet.

We again had the interview at the computer room. This time there was one person in the computer room. Both of us do not recognise this person. Despite that we carried on with the interview. I started asking a less sensitive question, "What happens to the patient when they are transferred from theatres?". This type of question made the participant at ease, as it is general and nothing sensitive. When the participant was answering this question, the lady who was with us in the computer room left. I figured out a strategy to ask general neutral question first then slowly move into sensitive topics. I also figured that before asking her sensitive topics directed on the transparency of surgeons, I asked the participant a more general question on transparency on SSI rates for the trust and sought the participant's suggestions on how it is best done. This provided me opportunities to dig deeper on the participant's thoughts whilst making the participant feel at ease and feel that their opinion on the matter is valued. Then, I proceeded asking more sensitive questions like surgeons being transparent about their own individual SSI rates. At the end of the interview, the participant has verbalised to me that I've squeezed the participant with my questions and put the participant on a reflective stance on the issue of transparency of rates even after the interview.

Having revisited some of the questions I asked the participant on the initial interview, the participant's answers remained consistent despite how I rephrased the questions. Some of the participant's previous responses still surfaced in this interview despite I don't directly ask the question about the matter. For instance, the participant was consistent that the participant had not have any experience of a patient coming back to theatre due to an SSI. This made me feel confident that the participant was telling the truth despite I had doubts previously on the accuracy of these responses. I was also pleased that I still had another 20 minutes of interview time on the second part of the interview, which I have not expected to long last any longer as the participant had 30 minutes of interview time the first time and almost covered all questions from the interview guide.

July 17

Interview 8 – Theatre Support Worker

I was meant to interview a theatre support worker after his shift at 5:30 pm. I went to theatres at 5 pm to check if he's around and confirm if he is happy to do the interview. After speaking to one of his colleagues, I was told he was on a short shift today and has already left work. However, this colleague of his who is currently in-charge of the TSSU department was a former colleague of mine. I have discussed the study with this person a week before and provided the participant information sheet. This person verbally said yes to me the previous week, and planned to do the interview after one of this person's shifts over coffee. However, this person was quite unsure of timing of the interview as he was working most days of the week. Today, I took the opportunity to ask if this person was still happy to do it, and the person offered to do it today.

I met the participant outside of the QEQM building after their shift and we decided to go over a coffee shop in Bayswater for the interview. The participant mentioned that it would be more comfortable to have the interview in a secluded area away from people that the participant would most likely know from work.

We conducted the interview at a top floor of a coffee shop with barely any people around. I've restructured the questions from the interview guide and added some pertinent questions for the participant's job role, i.e. the participant's role in storage of sterile instruments and sending off used/dirty instruments after surgery to the facility that does autoclaving of the instruments. English is not the first language of the participant and the participant asked to clarify my questions if the

participant does not understand them properly, either it's because of the level of English or because they are medical jargon. I found the participant at ease in answering questions and could express one's self. The participant was quite familiar with me as we started working in theatres about the same time, and was working in the same theatres for a particular period. This may have helped the participant to be more at ease during the interview. I was pleased that I was able to have 20 minutes of interview time with this participant. Despite me trying to probe more into the participant's answers, there was nothing more else to talk about from the participant's perspective as a theatre support worker (healthcare assistant).

July 18

Interview 9 – A&E Nurse

Participant 9 has just left his job at the A&E a few weeks ago. The participant is now a research nurse. After hearing about this qualitative study, this participant was keen to get involved. At first, I was hesitant involving this person due to the participant's current role as a research nurse for A&E and trauma may not be able to provide any data for this study. However, the participant mentioned that through his experience in our A&E there were quite a number of patients who get readmitted to hospital due to an SSI. Upon reflection, I recalled my interview with the consultant surgeon, wherein the surgeon mentioned about patients going through the GP or directly to A&E when they experience symptoms that may appear as an SSI. I decided that it might be worth interviewing an A&E nurse. As the participant is just fresh from leaving the A&E job and has availability for the interview and has the experience that the participant mentioned, I felt that this is still within the bounds of purposeful sampling for this study.

I have just recently met participant 9. I have not worked with the participant previously so we are not familiar with each other. We know each other through my former colleagues, so the professional/clinical background that the participant knows about me is that I was a trauma research nurse.

We conducted the interview in a small office a few doors away from their main office. The office was empty and in secluded area in the hospital. I briefed the participant that for this study the participant has to take the hat of an A&E nurse so the responses will be based on the participant's experiences working in A&E. I went through the general questions on the interview guide. Most of which the participant struggled to answer due to the limited contact with the same

patients and that information such as SSI rates would be more pertinent in the ward according to the participant's opinion. Thus, I felt that the main focus on my interview was on when patients with SSI gets readmitted to hospital. Questions that are related to how patients perceive SSI, what factors the participant thought could have influence on the acquisition of an SSI based on the accounts of patients, their motivation of seeking treatment, what happens to them when they leave A&E, etc. I have also clarified with the participant the source of patients admitting with an SSI, whether they had the surgery within the trust or elsewhere. This information I felt is important to address. I had 15-minute minutes of interview time with this participant. This was the shortest interview I had conducted. Despite that, I felt that the appropriate questions for this job role have already been exhausted.

Interview 10 - Band 5 Theatre Nurse – Part 1

I first met Participant 10 on the first weeks since the participant started as a theatre nurse in this trust. At that time, I was a trauma research nurse who comes to theatre as part of my role and as well as I did several bank shifts as a scrub nurse during that time. There was no familiarity between participant 10 and I, as we never worked together and neither hung out socially. However, the background that the participant was familiar about me is that I was a scrub nurse in the same department as his and also as a research nurse.

I have bumped into this participant at the staff coffee room the previous week and I briefly talked to him about the study and provided him a participant information sheet. This person verbally agreed to do the study with me. Though this person expressed that this person's English is not good enough and is not really sure what contribution could provide to the study.

We agreed to conduct the interview after the participant's shift today (July 18). Previously, we agreed that it would be done over a drink, so we proceeded to a pub near the hospital. We stayed at the secluded section of the pub. We were at a corner and only one group of customers were also in the same section a few tables across from us. Both of us do not recognise any of the people a few tables away from us, and there was music playing in the background. I felt that this was quite private area to do an interview.

I emphasised to the participant to ask me to clarify questions if the participant does not understand them due to language issues, which the participant actually did during the interview. Also, there were a few times that we had to stop the recorder for breaks for a fog or use of the

toilet. However, before we proceeded doing that I took notes on what the last question was and the participant also requested me to take notes for what the participant wanted to say to remind the participant when the recorder was on.

After conducting several interviews already, I have felt that I have improved in my active listening skills. I tend now more to encourage the participant to speak more. In this case, I provide the participant enough time to think before the participant responds or wait for the participant to clarify the question rather than rephrase it. I realised that the participant translates his responses from his native language to English in the participant's head. There was a time I had to help the participant for an English word, but the participant describes i.e. general infection and I provide the word sepsis. I don't feel that I was influencing his responses rather I'm just providing the English word that the participant sought.

I was quite surprise on how candid this participant's responses to the questions. The participant does not just provide a general answer to the question, but rather backs them up with actual incident as an example. I felt that the participant was using this interview as a venue to air grievances or the participant's difference of opinion on the current practice. It emerged from the interview that the participant was uncomfortable to challenge or convey differences in opinion to other staff members because of the participant's short tenure in the unit and even because the participant is a nurse and it's uncomfortable to do that to surgeons. Despite that the participant wanted to do what's best for the patient in the participant's view, I feel that the participant does not want to engage in an argument and fight a losing battle.

Although participant 10 has not been long in the Trust, the participant had several years experience working in another European country (not the participant's home country) after qualifying as a nurse in the participant's home country. This provided the participant a comparison of practices in theatres across countries. Although his reference to the British practice is only limited to one trust, and likewise the other European country practice is limited to one hospital. Regardless, I feel that this was a helpful comparison and provided rich data that otherwise other interviews did not provide. With this background, this provided the participant more confidence to be critical of clinical practice due to the participant's experience. It may have also helped that the participant is now working in the same unit as the interviewer, as the interview appeared to be more of a conversation with a colleague while the participant shares the participant's views on matters in the workplace.

About 1 hour worth of interview time, we were still about halfway through the questions on the interview guide, and I was running out of memory on the recorder. I took notes on where we were currently at the interview. I liaised with my colleague to seek approval regarding deleting the audio file of my first interview, which we have already transferred in her computer in the office. We

agreed to delete it and this provided us an additional 45 minutes of interview time. Despite this amount of memory, we were not yet finished covering everything else that can be covered on the topic and the participant still carries on talking. The participant and I decided to carry on with the interview the next day after the shift. At this point, the participant had a total of 1 hour and 45 minutes interview time.

July 19

Interview 10 - Theatre Nurse – Part 2

This morning, I transferred the audio files that were saved on my recorder to my colleague's computer. This allowed me to erase the data from my recorder, leaving only the interview that was done the previous evening with participant 10. Prior to meeting participant 10 again, I have listened to all the participant's audio files from the initial interview and took notes where we stopped. I have also noted the last few questions that we still haven't discussed.

We again met after the participant's shift at 5:30 pm and proceeded to the same pub where we met yesterday. We sat at the same spot and there were no other people around that secluded area of the pub. To start the interview, I reinstated the same questions that were asked towards the end of the interview, to set the tone of the interview. The participant verbalised a feeling of exhaustion today and might not be able to respond properly. Several times during the interview the participant asked me to clarify the questions. The participant requested that this be done off the record. I rephrased the question in the simplest way in English. Although I felt that this participant does not have any inhibitions on being candid on one's answers, I utilised the same technique as I did with participant 5's second interview as they have the same questions left unanswered. This technique entailed asking general questions then proceeding to more sensitive questions. As usual, participant 10 was providing the answers candidly. I know that this technique is useful in an interview. In this case, I felt that this technique should be applied in any disrupted interview/continuation interviews. This provided us another 30 minutes of interview time, which brings participant total interview time of 2 hours and 15 minutes. This was the longest interview I've done ever and for this study. I was pleased, as most of the talking was done by the participant, and there was minimal effort for me to make the participant provide this data. All I had to do was

act as a facilitator in making the participant provide his answers and probe more into the participant's responses.

Appendix 10 Consolidated Framework for Implementation Research

I. INTERVENTION CHARACTERISTICS		
A	Intervention Source	Perception of key stakeholders about whether the intervention is externally or internally developed.
B	Evidence Strength & Quality	Stakeholders' perceptions of the quality and validity of evidence supporting the belief that the intervention will have desired outcomes.
C	Relative Advantage	Stakeholders' perception of the advantage of implementing the intervention versus an alternative solution.
D	Adaptability	The degree to which an intervention can be adapted, tailored, refined, or reinvented to meet local needs.
E	Trialability	The ability to test the intervention on a small scale in the organization, and to be able to reverse course (undo implementation) if warranted.
F	Complexity	Perceived difficulty of implementation, reflected by duration, scope, radicalness, disruptiveness, centrality, and intricacy and number of steps required to implement.
G	Design Quality & Packaging	Perceived excellence in how the intervention is bundled, presented, and assembled.
H	Cost	Costs of the intervention and costs associated with implementing the intervention including investment, supply, and opportunity costs.
II. OUTER SETTING		
A	Patient Needs & Resources	The extent to which patient needs, as well as barriers and facilitators to meet those needs, are accurately known and prioritized by the organization.
B	Cosmopolitanism	The degree to which an organization is networked with other external organizations.
C	Peer Pressure	Mimetic or competitive pressure to implement an intervention; typically because most or other key peer or competing organizations have already implemented or are in a bid for a competitive edge.
D	External Policy & Incentives	A broad construct that includes external strategies to spread interventions, including policy and regulations (governmental or other central entity), external mandates, recommendations and guidelines, pay-for-performance, collaboratives, and public or benchmark reporting.
III. INNER SETTING		
A	Structural Characteristics	The social architecture, age, maturity, and size of an organization.
B	Networks & Communications	The nature and quality of webs of social networks and the nature and quality of formal and informal communications within an organization.

C	Culture	Norms, values, and basic assumptions of a given organization.
D	Implementation Climate	The absorptive capacity for change, shared receptivity of involved individuals to an intervention, and the extent to which use of that intervention will be rewarded, supported, and expected within their organization.
1	Tension for Change	The degree to which stakeholders perceive the current situation as intolerable or needing change.
2	Compatibility	The degree of tangible fit between meaning and values attached to the intervention by involved individuals, how those align with individuals' own norms, values, and perceived risks and needs, and how the intervention fits with existing workflows and systems.
3	Relative Priority	Individuals' shared perception of the importance of the implementation within the organization.
4	Organizational Incentives & Rewards	Extrinsic incentives such as goal-sharing awards, performance reviews, promotions, and raises in salary, and less tangible incentives such as increased stature or respect.
5	Goals and Feedback	The degree to which goals are clearly communicated, acted upon, and fed back to staff, and alignment of that feedback with goals.
6	Learning Climate	A climate in which: a) leaders express their own fallibility and need for team members' assistance and input; b) team members feel that they are essential, valued, and knowledgeable partners in the change process; c) individuals feel psychologically safe to try new methods; and d) there is sufficient time and space for reflective thinking and evaluation.
E	Readiness for Implementation	Tangible and immediate indicators of organizational commitment to its decision to implement an intervention.
1	Leadership Engagement	Commitment, involvement, and accountability of leaders and managers with the implementation.
2	Available Resources	The level of resources dedicated for implementation and on-going operations, including money, training, education, physical space, and time.
3	Access to Knowledge & Information	Ease of access to digestible information and knowledge about the intervention and how to incorporate it into work tasks.
IV. CHARACTERISTICS OF INDIVIDUALS		
A	Knowledge & Beliefs about the Intervention	Individuals' attitudes toward and value placed on the intervention as well as familiarity with facts, truths, and principles related to the intervention.
B	Self-efficacy	Individual belief in their own capabilities to execute courses of action to achieve implementation goals.
C	Individual Stage of Change	Characterization of the phase an individual is in, as he or she progresses toward skilled,

		enthusiastic, and sustained use of the intervention.
D	Individual Identification with Organization	A broad construct related to how individuals perceive the organization, and their relationship and degree of commitment with that organization.
E	Other Personal Attributes	A broad construct to include other personal traits such as tolerance of ambiguity, intellectual ability, motivation, values, competence, capacity, and learning style.
V. PROCESS		
A	Planning	The degree to which a scheme or method of behavior and tasks for implementing an intervention are developed in advance, and the quality of those schemes or methods.
B	Engaging	Attracting and involving appropriate individuals in the implementation and use of the intervention through a combined strategy of social marketing, education, role modeling, training, and other similar activities.
1	Opinion Leaders	Individuals in an organization who have formal or informal influence on the attitudes and beliefs of their colleagues with respect to implementing the intervention.
2	Formally Appointed Internal Implementation Leaders	Individuals from within the organization who have been formally appointed with responsibility for implementing an intervention as coordinator, project manager, team leader, or other similar role.
3	Champions	"Individuals who dedicate themselves to supporting, marketing, and 'driving through' an [implementation]" [101] (p. 182), overcoming indifference or resistance that the intervention may provoke in an organization.
4	External Change Agents	Individuals who are affiliated with an outside entity who formally influence or facilitate intervention decisions in a desirable direction.
C	Executing	Carrying out or accomplishing the implementation according to plan.
D	Reflecting & Evaluating	Quantitative and qualitative feedback about the progress and quality of implementation accompanied with regular personal and team debriefing about progress and experience.

Appendix 11 Staff survey

Surveillance of Surgical Site Infections in the Trust

The Trust are looking at ways to improve the coverage of surgical site infection (SSI) surveillance, and we would like your opinion on how best to achieve this. Please complete the survey below, which should take no more than 10 minutes, to ensure your views are heard.

Enter your email address at the end for a chance to win a £50 M&S or John Lewis gift card!

Responses to this survey will be anonymised, aggregated, and reported in a business case, reseach paper or PhD thesis. By completing this survey you are agreeing to the use of your responses in this way. Please contact Giovanni Satta (giovanni.satta@imperial.nhs.uk) if you have any queries.

* 1 Who should do SSI surveillance?

- ○ Individual surgical teams
- ○ Infection prevention & control team
- ○ Specialist SSI nurse
- ○ Specialist pharmacist
- ○ Epidemiology
- ○ Microbiology
- ○ Dedicated multidisciplinary SSI team
- ○ Other (please specify)

* 2 Are SSIs a priority for the surgical team you work with?

- ○ Yes
- ○ No

* 2 Are SSIs a priority for the surgical team you work with?

- ○ Yes
- ○ No

If not, what are your top priorities?

* 3 Does your team have capacity to do SSI surveillance?

- ○ Yes, we can use existing resources
- ○ No, we have no capacity at all
- ○ No, but we could with extra resources and support from the Trust (enter suggestions below)

4 What kind of outputs would you like to see from an SSI surveillance program?

Next

* 5 Please rank what you believe to be the top 5 priorities for surgical site infection surveillance at the Trust, assuming no mandatory requirements.

	1 (Most important)	2	3	4	5
Abdominal hysterectomy	○	○	○	○	○
Appendicectomy	○	○	○	○	○
Bile duct, liver and pancreas	○	○	○	○	○
Breast surgery	○	○	○	○	○
CABG	○	○	○	○	○
Caesarean section	○	○	○	○	○
Cardiac (non-CABG)	○	○	○	○	○
Cholecystectomy	○	○	○	○	○
Cranial Surgery	○	○	○	○	○
Gastric	○	○	○	○	○
Herniorrhaphy	○	○	○	○	○
Hip replacement	○	○	○	○	○
Knee replacement	○	○	○	○	○
Large bowel surgery	○	○	○	○	○
Limb amputation	○	○	○	○	○
Maxillofacial/ENT/Oral	○	○	○	○	○
Neck surgery (e.g. thyroid, tracheal)	○	○	○	○	○
Oesophageal surgery	○	○	○	○	○
Pacemaker surgery	○	○	○	○	○
Prostate surgery	○	○	○	○	○
Reduction of long bone fracture	○	○	○	○	○
Renal surgery/urology	○	○	○	○	○
Repair neck of femur	○	○	○	○	○
Shunt for dialysis	○	○	○	○	○
Small bowel surgery	○	○	○	○	○
Solid organ transplant	○	○	○	○	○
Spinal surgery	○	○	○	○	○
Splenic surgery	○	○	○	○	○
Thoracic surgery	○	○	○	○	○
Vascular surgery	○	○	○	○	○
Ventricular shunt	○	○	○	○	○

Prev Next

6 Do you have any suggestions on how to improve SSI surveillance, or anything else you would like to add?

* 7 Please describe your staff group and/or specialty

e.g. cardiac surgeon, trauma nurse, pharmacist

8 Enter your email address for a chance to win a £50 M&S or John Lewis gift card (optional)

Prev Done

Appendix 12 Staff workshop survey

Survey – please place a tick in the box, and add a comment if further explanation is needed

Statement about the system	Strongly disagree	Disagree	Neither agree nor disagree (please comment)	Agree	Strongly agree	Comment
This system was developed internally						
I am confident this system will be useful						
This is the best solution to problems with SSI surveillance						
The system is adaptable and can be tailored to local needs						
We can always abandon this system if it doesn't work						
This system will be very difficult to implement						
We are tired of trying new interventions						
The interface is user-friendly						
This Trust welcomes new innovations						
We really need to do something about SSI surveillance						
This system won't fit in with our workflow						
There are so many more important things we should be spending time and money on						
The project will have unjustifiable resource implications						
My feedback will be valued by senior managers						
The implementation of this system has been planned in advance						
There are other people who should be involved in implementing this system						
I feel comfortable championing this system						
I am confident we will have plenty of opportunities to give and receive feedback about this system						

Appendix 13 Realist review search strings

Medline and Embase

Theory search:

(((((((("surgical wound infection"[MeSH Terms] OR ("surgical"[All Fields] AND "wound"[All Fields] AND "infection"[All Fields]) OR "surgical wound infection"[All Fields] OR ("surgical"[All Fields] AND "site"[All Fields] AND "infection"[All Fields]) OR "surgical site infection"[All Fields]) OR ssi[All Fields]) OR (((((("post-operative period"[MeSH Terms] OR ("post-operative"[All Fields] AND "period"[All Fields]) OR "post-operative period"[All Fields] OR ("post"[All Fields] AND "operative"[All Fields]) OR "post operative"[All Fields]) OR ("post-operative period"[MeSH Terms] OR ("post-operative"[All Fields] AND "period"[All Fields]) OR "post-operative period"[All Fields] OR "post-operative"[All Fields])) OR ("post-operative period"[MeSH Terms] OR ("post-operative"[All Fields] AND "period"[All Fields]) OR "post-operative period"[All Fields] OR ("post"[All Fields] AND "operative"[All Fields]) OR "post operative"[All Fields])) OR (post[All Fields] AND ("surgical procedures, operative"[MeSH Terms] OR ("surgical"[All Fields] AND "procedures"[All Fields] AND "operative"[All Fields]) OR "operative surgical procedures"[All Fields] OR "surgical"[All Fields]))) OR postsurgical[All Fields]) OR post-surgical[All Fields]) AND ("infection"[MeSH Terms] OR "infection"[All Fields]))) OR (poi[All Fields] OR pwi[All Fields])) AND ((((post[All Fields] AND ("patient discharge"[MeSH Terms] OR ("patient"[All Fields] AND "discharge"[All Fields]) OR "patient discharge"[All Fields] OR "discharge"[All Fields])) OR postdischarge[All Fields]) OR post-discharge[All Fields]) AND ((("epidemiology"[Subheading] OR "epidemiology"[All Fields] OR "surveillance"[All Fields] OR "epidemiology"[MeSH Terms] OR "surveillance"[All Fields]) OR (follow[All Fields] AND up[All Fields])) OR follow-up[All Fields])))))) AND program theory

PDS method search:

(((((("surgical wound infection"[MeSH Terms] OR ("surgical"[All Fields] AND "wound"[All Fields] AND "infection"[All Fields]) OR "surgical wound infection"[All Fields] OR ("surgical"[All Fields] AND "site"[All Fields] AND "infection"[All Fields]) OR "surgical site infection"[All Fields]) OR ssi[All Fields]) OR (((((("post-operative period"[MeSH Terms] OR ("post-operative"[All Fields] AND "period"[All Fields]) OR "post-operative period"[All Fields] OR ("post"[All Fields] AND "operative"[All Fields]) OR "post operative"[All Fields]) OR ("post-operative period"[MeSH Terms] OR ("post-operative"[All Fields] AND "period"[All Fields]) OR "post-operative period"[All Fields] OR "post-operative"[All Fields])) OR ("post-operative period"[MeSH Terms] OR ("post-operative"[All Fields] AND "period"[All Fields]) OR "post-operative period"[All Fields] OR ("post"[All Fields] AND "operative"[All Fields]) OR "post operative"[All Fields])) OR (post[All Fields] AND ("surgical procedures, operative"[MeSH Terms] OR ("surgical"[All Fields] AND

"procedures"[All Fields] AND "operative"[All Fields]) OR "operative surgical procedures"[All Fields] OR "surgical"[All Fields]))) OR postsurgical[All Fields]) OR post-surgical[All Fields]) AND ("infection"[MeSH Terms] OR "infection"[All Fields]))) OR (poi[All Fields] OR pwi[All Fields])) AND ((((post[All Fields] AND ("patient discharge"[MeSH Terms] OR ("patient"[All Fields] AND "discharge"[All Fields]) OR "patient discharge"[All Fields] OR "discharge"[All Fields])) OR postdischarge[All Fields]) OR post-discharge[All Fields]) AND ((("epidemiology"[Subheading] OR "epidemiology"[All Fields] OR "surveillance"[All Fields] OR "epidemiology"[MeSH Terms] OR "surveillance"[All Fields]) OR (follow[All Fields] AND up[All Fields])) OR follow-up[All Fields]))) AND ((((((("cesarean section"[MeSH Terms] OR ("cesarean"[All Fields] AND "section"[All Fields]) OR "cesarean section"[All Fields] OR "c section"[All Fields])) OR ("cesarean section"[MeSH Terms] OR ("cesarean"[All Fields] AND "section"[All Fields]) OR "cesarean section"[All Fields] OR "c section"[All Fields])) OR ("chemical synthesis"[Subheading] OR ("chemical"[All Fields] AND "synthesis"[All Fields]) OR "chemical synthesis"[All Fields] OR "cs"[All Fields])) OR ((("intestines"[MeSH Terms] OR "intestines"[All Fields] OR "bowel"[All Fields]) OR ("colon"[MeSH Terms] OR "colon"[All Fields])) OR colorectal[All Fields])) OR ((((("orthopaedic"[All Fields] OR "orthopedics"[MeSH Terms] OR "orthopedics"[All Fields] OR "orthopedic"[All Fields]) OR ("orthopaedic"[All Fields] OR "orthopedics"[MeSH Terms] OR "orthopedics"[All Fields] OR "orthopedic"[All Fields])) OR ("hip"[MeSH Terms] OR "hip"[All Fields])) OR ("knee"[MeSH Terms] OR "knee"[All Fields] OR "knee joint"[MeSH Terms] OR ("knee"[All Fields] AND "joint"[All Fields]) OR "knee joint"[All Fields])) OR ("femur"[MeSH Terms] OR "femur"[All Fields])) OR ("fractures, bone"[MeSH Terms] OR ("fractures"[All Fields] AND "bone"[All Fields]) OR "bone fractures"[All Fields] OR "fracture"[All Fields])))

Scopus

Theory search:

surgery and (("surgical site infection" OR SSI OR (post?operat* and infection) or (post?surg* and infection) or poi or pwi) and (post?discharge or pds) and (surveillance or epidemio* or follow?up) and program theory

PDS method search:

surgery and (("surgical site infection" OR SSI OR (post?operat* and infection) or (post?surg* and infection) or poi or pwi) and (post?discharge or pds) and (surveillance or epidemio* or follow?up) and ((cesar* or caesar* or c?section or CS) or (bowel or colorectal or colon) or (orthopaedic or orthopedic or hip or knee or (femur and fracture))))

Appendix 14 Data Protection Office advice

REPLY REPLY ALL FORWARD ...

GOMEZ, Sophie (IMPERIAL COLLEGE HEALTHCARE NHS TRUST)
Wed 20/06/2018 10:48

Mark as unread

To: TROUGHTON, Rachael (IMPERIAL COLLEGE HEALTHCARE NHS TRUST);

Cc: **dpo;** NEWLANDS-BENTLEY, Victoria (IMPERIAL COLLEGE HEALTHCARE NHS TRUST); BURRIDGE, Linda (IMPERIAL COLLEGE HEALTHCARE NHS TRUST);

You replied on 20/06/2018 10:50.

Dear Rachael,

Thank you for the clarification that you provided. I have set out the issues that I have identified.

Registration of Project – You have clarified that there is not a registration process for QI projects, therefore I have no further comments on this issue.

Opt-out of contacting – I would recommend that you follow up with the wider ICT department to clarify whether any patients have opted out of receiving correspondence for research or planning purposes.
Contacting patients – We believe that our use of the patient's contact details is permissible in line with new data protection legislation as this is for service improvement purposes. However, I would recommend that it is the member of the clinical team make this contact, as they owe a duty of confidence to the patient which a member of staff external to the clinical team does not. Please follow the link to the pictogram that depicts this (please ignore the reference to research): http://source/cs/groups/intranet/@corporate/@information/documents/document/sid_100112.pdf

I hope that this sets out a resolution for you. Please do not hesitate to get in touch if you have any additional questions.

Kind regards,

Sophie Gomez
Research Information Governance Officer
Deputy Data Protection Officer
ICT Directorate
Imperial College Healthcare NHS Trust

Appendix 15 Focus group discussion guide

Discussion guide

- Welcome and thanks for agreeing to take part
- Introduce self
- Recap on study (already described in participant information leaflet). Briefly, the study aims to find out the best ways of contacting patients to ask whether their surgical wound became infected after they left hospital. It's important to collect this information so hospitals can improve how they prevent infections.
- Recap on aspects of process:
    - The focus group will last approximately 2 hours. I'll ask you some opening questions about how the hospital contacts you. Then I'll show you some explanations developed through my PhD work that I think might explain peoples' behaviour and ask you to consider whether they reflect your experience of being contacted. If at any time during the focus group you do not wish to answer a question, that's okay.
    - You have agreed that I may digitally record our conversation. The recording will be typed out, but everything you say will be anonymous. This means that your name and any names you mention, and any places you mention will be taken out, so that if someone read your interview transcript, they will not be able to identify you or anyone else or any other place you might mention.
    - If, at any stage, you wish to stop the audio recorder, please let me know.
    - Your comments will remain confidential, unless (as discussed and outlined in the consent form) it is possible that you or someone else is at risk, but this will be discussed with you first.
- Introduce ground rules for focus group regarding: role of researcher in guiding discussion but allowing participants to take up the discussion in their own terms; importance of not talking over one another; encouraging people to voice their opinions, including disagreements with other; and maintaining confidentiality outside the group).
- Ask if any questions before we focus group starts?

1. Tell me about a time when the hospital communicated with you
    a. Explore the context eg for what purpose, what sort of information was communicated
    b. How was this done eg letter, email, telephone, text?
    c. In what ways did it work well? In what ways could it have been done better?

2. What are the problems with these? What are the benefits of these methods?

Distribute CMOCs one at a time

3. Look at the explanation in front of you. What do you think about it? How would you change it?

Explore how the context might change with the same mechanism and vice versa
Think/pair/share

4. Of all the explanations, which is the most important to you? Why?

5. Which one is least important? Why?

Provide information about the options available at ICHNT: phone calls, letters, clinic, app, via midwife, automated phone system.

6. Which of these methods would you be most likely to use? Which would you be least likely to use?

Do these fit with the explanations we have been discussing?

7. Is there anything else that you think is important that you haven't yet had a chance to discuss?

1	In a context where hospitals use a variety of methods and formats for the follow-up survey nobody is left out and patients are more likely to respond because patients feel the follow-up is practical and convenient to complete
2	In a context where reminders (in the same or different format) are sent to patients patients are more likely to respond because patients feel prompted to engage with surveillance
3	In a context where hospital staff address the patient by name patients are more likely to respond because the patient feels known or cared for
4	In a context where the format of the follow-up survey allows the patient to interact directly with hospital staff patients are more likely to respond because they feel their experiences are valued
5	In a context where the format of the follow-up survey allows the patient to interact directly with hospital staff patients are more likely to respond because they think they may receive useful advice on their wound

Appendix 16 References for appendices

A1. Public Health England. Protocol for surveillance of surgical site infection [Internet]. 2013 [cited 2016 Apr 20]. Available from: https://www.gov.uk/government/publications/surgical-site-infection-surveillance-service-protocol-procedure-codes-and-user-manual

A2. Public Health England. Protocol for surveillance of surgical site infection - OPCS Operating Procedure Codes Supplement [Internet]. 2011 [cited 2016 Aug 2]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/406932/OPCS_codes_supplement_September_2011_Rev_4_PHE.pdf

A3. Damschroder LJ, Aron DC, Keith RE, Kirsh SR, Alexander JA, Lowery JC. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implementation Science. 2009;4:50.