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How evidence matters in adopting innovative technologies – comparative case studies of 12 English NHS Trust

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How evidence matters in adopting innovative technologies – comparative case studies of 12 English NHS Trusts

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ABSTRACT

Objectives: To understand organisational technology adoption by looking at the different types of innovation knowledge used during the process.

Design: Qualitative, multi-site, comparative case study design.

Setting: One primary care and 11 acute care organisations (trusts) across all health regions in England in the context of infection prevention and control.

Participants and data analysis: 121 semi-structured individual and group interviews with 109 informants, involving clinical and non-clinical staff from all organisational levels and various professional groups. Documentary evidence and field notes were also used. 38 technology adoption processes were analysed using an integrated approach combining inductive and deductive reasoning.

Main findings: Decision makers variably accessed three types of innovation knowledge during the technology adoption process: *'awareness'* (knowledge that an innovation exists), *'principles'* (knowledge about an innovation's functioning principles), and *'how-to'* (knowledge required to use an innovation properly). Centralised (national, government-led) and local sources were used to obtain this knowledge. Decentralised professional networks were preferred sources for all three types of knowledge. Overall, less attention was given to *'how-to'* compared to *'principles'* knowledge at the early stages of the process, which contributed to 12 cases of incomplete implementation or discontinuance after initial adoption. The leadership style and the professional background of key decision makers influenced this asymmetric attention to different types of innovation knowledge.

Conclusions: Potential adopters and change agents often overlooked or undervalued *'how-to'* knowledge. Balancing *'principles'* and *'how-to'* knowledge early in the innovation process enhanced successful technology adoption and implementation by considering efficacy as well as strategic,

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structural and cultural fit with the trust's context. This learning is critical given the policy emphasis for organisations to be innovation-ready.

Word count: 269 (word limit 300 words)

ARTICLE SUMMARY

Article focus • Despite policy support and the development of a dedicated evidence dissemination infrastructure in the NHS, why is technology adoption and implementation still a challenge? • We need to understand better *how* the innovation process unfolds in organisations to build on what we know about individual behaviours. In particular, how the use of different types of knowledge about an innovation impacts decision making.
Key messages • In our study, centralised dissemination of evidence had minimal to moderate impact on organisational innovation decisions. Practice-based, peer-mediated, and local dissemination systems were perceived more relevant. • When *'how-to'* knowledge was undervalued and considered late, important strategic, structural, and cultural elements of the trust's context were overlooked. This had negative implications for technology adoption and implementation. • Professional backgrounds and leadership styles influenced the types of innovation knowledge considered by decision makers. The involvement of diverse professionals in decision making improves the chances of successful implementation through a balanced consideration of the strength of scientific evidence and practical application.

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Strengths and limitations

- The scale of the study, its real time and longitudinal nature provide a rich dataset. Our study is theory driven and comprises multi-site, comparative case studies, which enhance the generalisability of findings beyond the context of the studied trusts.
- We explicitly studied cases of non-adoption and discontinuation after initial adoption to provide important learning, often missing from innovation diffusion research.
- On limitations, we were not able to follow implementation past the end of August 2010 and therefore do not have information on routinised use of the implemented technologies.

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INTRODUCTION

The recent focus by policy makers on quality and efficiency in healthcare[1], highlight the need to harness new healthcare technologies and innovation to improve quality of patient care and health system productivity[2 3]. The uptake and implementation of new technologies in healthcare has often proved challenging and in some cases very slow[4-6]. In the UK the significant 'research to practice' knowledge gap and the suboptimal implementation of new ideas and technologies into clinical practice have been emphasised in several recent policy documents[7-9]. Policy and academic systematic reviews[6 10] consistently show that there remains a poor understanding of the mechanisms and processes that encourage the adoption of new interventions. Specifically, attention to the processes by which organisational members access and use implementation and clinical evidence during decision making is required[9 11 12]. As regards technology adoption in the National Health Service (NHS) a recent systematic review[13] has found that there has been little research in this area.

In the last decade government funded agencies have been created to encourage innovative thinking across the NHS and promote the use of evidence-based innovations; such predominately centralised evidence dissemination structures include the NHS Institute for Innovation and Improvement, the National Institute for Health and Clinical Excellence (NICE) with the launch of the NHS Evidence online portal, and the NHS Technology Adoption Centre, which works to speed-up the adoption of proven technologies by NHS organisations. Despite these initiatives, the challenges of adopting novel technologies in the NHS persist.

Our study addresses this research gap and is well grounded in innovation change and diffusion theories[14-16]. Specifically, our study unpacks the innovation processes in organisations - in contrast to individuals - by investigating in detail the interplay between the types and sources of innovation

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knowledge used. We empirically focus our investigation on infection prevention & control (IPC) as it represents a cross-cutting priority area in healthcare with application to primary and acute care, surgery and medicine alike. While there has been increasing public and policy attention to address healthcare associated infections (Box 1) the uptake and implementation of new technologies in IPC varies and in some cases is slow[17]. This empirical setting, therefore, offers opportunities to generate transferrable lessons.

Box 1 Healthcare associated infections initiatives in the NHS

Healthcare associated infections (HCAIs) are a worldwide problem causing high mortality and morbidity with significant cost implications for health systems.[18-23] Both developing and more developed countries face the challenge[19] and there is intense media and public attention on the issue. In the UK a range of infection prevention and control policies have been introduced to help tackle the problem, including legislation, performance targets, and clinical guidelines. In England the reporting of Meticillin-resistant *Staphylococcus aureus* (MRSA) bloodstream infections and Clostridium *difficile* (C. *difficile*)infections are mandatory and there are national and local targets for reduction as well as national evidence-based guidelines.[24] The development of effective technology interventions to complement good infection control practice is viewed as central to tackling HCAIs and a range of evidence-based innovations have been developed. Government funded programmes, such as the Department of Health 'HCAI Technology Innovation Programme'[17] have been created to fast track the innovation process. Programme work-streams span development to procurement and implementation processes and include: 'Smart Ideas', 'Design Bugs Out', 'Smart Solutions', 'Product Surgeries' and 'Showcase Hospitals', the latter focusing on the in-use value of HCAI technologies. In addition, the Health Protection Agency (HPA) Rapid Review Panel (RRP) was set up in 2004 to review new HCAI-related technologies providing a prompt assessment of new and novel equipment, materials, and other

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products or protocols that may be of value to the NHS to help reduce HCAI rates; recommendation statements about the novel products are given to suppliers and NHS bodies ('Recommendation 1' being the highest, encouraging adoption by the NHS).

METHODS

Design and theoretical approach

This article reports on findings from a larger innovation adoption study in the area of HCAIs commissioned by the Department of Health (DH)[25]. We employed a multiple case study research design to build theory inductively[26] covering the decision making, procurement, and implementation processes by NHS organisations when introducing innovative technologies. We undertook comparative case studies[27] across 12 NHS trusts in England with each trust and technology adoption decisions as units of analysis. Guided by our study's research aims we employed interpretive methods of inquiry which are particularly suited in studies where the task is the description, interpretation, and explanation of a phenomenon rather than estimation of its prevalence.[28]

Damanpour and Schneider[14] suggest that the process of innovation adoption in organisations can be divided into three broad phases of 'pre-adoption', 'adoption decision' and 'post-adoption', also referred to in the literature as 'initiation', 'adoption (decision)', and 'implementation'[15 14 27]. The adoption is viewed as a process in which an organisation analyses the potential benefits and negative aspects of an innovation on the basis of gathered knowledge. During this process three types of innovation knowledge are important in moving potential adopters from 'ignorance' through awareness, attitude formation, evaluation and on to adoption – *"the decision to make full use of the innovation as the best course of action available"*[15]:

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1. Awareness knowledge – the awareness that an innovation exists and knowledge of its key properties.
2. How-to knowledge – the information necessary to use an innovation properly.
3. Principles knowledge – information dealing with the functioning principles underlying how the innovation works.

Sampling and settings

The sample of organisations (NHS trusts) was predefined with one attribute in common as recipients of DH's 'HCAI Technology Innovation Award for outstanding contributions to fighting infections 2009'. The study comprised one primary and 11 acute care trusts, across all 10 Strategic Health Authorities (SHAs) in England. The trusts included in the study sample were diverse in geography, size and type (Table 1).

Table 1 Case study sites characteristics

Trust	Trust type	Number of beds	Population covered (m)	Financial turnover (m)	Number of sites	DIPC profession	Number of technologies adopted
T1	S, PFI	1,269	0.75	£400	Multi-site	Medical Doctor	1
T2	S, F, PFI	754	0.34	£156	Multi-site	Medical Doctor	6
T3	T, U	1,902	1 (S) 3 (T)	£652	Multi-site	Medical Doctor	1
T4	T, U, (PFI)	988	0.5 (S) 1.5 m (T)	£420	Multi-site	Medical Doctor	3
T5	T, U, F, (PFI)	2,068	0.5 (S) 1.7 (T)	£648	Multi-site	Medical Doctor	3
T6	S, PFI	1,095	0.6	£430	Multi-site	Medical Doctor	2
T7	S, F, (PFI)	602	0.35	£200	One site	Medical Doctor	4
T8*	T, U, F	807	0.33 (S) 1.5 (T)	£250	One site	Nurse	3
T9	T, F, (PFI), U	1,150	0.12 (S) 1 m (T)	£440	Multi-site	Nurse	3

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T10	S, (U)	974	0.6	£415	Multi-site	Medical Doctor	4
T11*	T, U, F	802	0.3 (S) 1.5 (T)	£400	Multi-site	Nurse	3
T12*	P / I	76 (I)	0.43	£202 (P) £744 (S)	Multi-site	Nurse	5

P: primary, I: intermediate care, S: secondary, T: tertiary, U: university, F: foundation, PFI: private finance initiative, DIPC: Director of Infection Prevention &Control

** Each of these trusts received £50K as the award was split across the health economy whilst the remainder trusts each received £150K*

Data collection and participants

We collected data from secondary sources to provide a historical dimension to better situate the studied decision making processes. We gathered publicly available NHS trust documents and internal documents provided by the trusts, including the trusts' organisational and IPC team structures, infection control committee meeting minutes, infection control reports, business cases, minutes from board meetings related to the Innovation Award, local press articles, and trust newsletters.

Data from primary sources comprised 121 semi-structured individual and group interviews (July 2009 - August 2010). We conducted 85 individual interviews and group interviews with 36 informants. 12 informants were interviewed more than once. Within each of the trust sites we purposively sampled a diverse range of informants involved in the technology adoption or implementation, reflecting various perspectives, professional and organisational roles. Our participants included clinical and non-clinical managers, members of trusts' executive boards, health professionals - infection control nurses, matrons, infection control doctors, consultants, clinical biochemists, clinical microbiologists, and staff from domestic services, estates and facilities.

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Interviews lasted on average an hour and explored individuals' perceptions, experiences, and views on the technology selection decisions, procurement and implementation processes. In the first visit the ongoing decision making process was captured and in the follow up visits the technology selection outcome and implementation experiences were explored for each trust. Field notes were taken, as well as summary notes from participation in meetings in which the technologies were discussed, and by observing the selected technologies in use. Data collection at each site continued until all aspects of the decision process had been accounted for by a diverse sample of informants. The data collection periods and sample varied by study site, depending on the scale of technology deployment.

Data analysis

We analysed data using an integrated approach[29]. We combined an inductive *"ground up"* development of codes with a deductive organising conceptual framework for the adoption of complex health innovations to generate a *"star-up list"*[29]. This framework has been previously employed to understand multi-level innovation adoption[30]. Data analysis was conducted in parallel to ongoing data collection to feed emerging findings and 'test' these in subsequent interviews. The Qualitative Data Analysis computer software package N-Vivo 8 (QSR International) was used to systematically code the data and assist analysis, especially in cataloguing and linking concepts and codes. In line with recommendations by qualitative methodologists[31-33] authors 1 and 2 independently coded all data. The three authors met to review discrepancies[29], enhancing internal validity[33-35]. Comparative cases were analysed in two stages: first each of the technologies within each trust, producing individual trust case studies; second a comparative analysis across the trusts. Summary tables were used to simultaneously compare several categories and dimensions of the data, helping us to reduce the volume of primary data and to make analytical inferences by comparing and contrasting. Pairs of cases as well as group of cases were compared by listing similarities and differences[26].

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MAIN FINDINGS

The organisational innovation process and outcomes

Of the 38 organisational technology adoption decisions made during the period of the study, 22 technologies were successfully adopted and implemented, whilst 12 were discontinued after initial adoption or only partially implemented (Table 3). There was no clear outcome within the timeframe of the study for four technologies. Our empirical findings suggest that each of the three broad phases (pre-adoption, adoption decision, post-adoption) consisted of sub-stages. Most informants reported that they went through a series of evaluations, choices and actions over time as the adopting trusts principally engaged in a problem solving exercise. These involved: identifying a need in an IPC service area, considering or becoming aware of potentially useful technologies, searching for and evaluating available 'evidence', tentatively accepting, trialling, procuring, renegotiating, rejecting, (continuously) using the technologies considered. The process was dynamic, iterative and not always linear. We found that the majority of technology decisions were led by a perceived need - an area of priority in IPC had been identified by trusts first, and then relevant technologies were sought ('need pull'). A minority of technology adoption decisions were characterised by selecting a technology in the first instance and exploring how this might fit with strategic plans and service needs ('technology push').

Use of innovation knowledge in the process

During the 'adoption decision' stage all trusts carried out systematic pre-adoption evaluations of the evidence related to the technologies prior to committing to procurement, with nine trusts trialling the technologies. Trusts variably accessed and prioritised the three types of knowledge about the technologies. Under *'awareness'* knowledge the trusts considered the range of technologies available to address a particular problem, as well as key features and potential cost implications of such

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technologies. In seeking *'principles'* knowledge the trusts sought primarily evidence of the technologies' technical efficacy based on the scientific principles behind the technology. They assessed the validity of claims made by commercial suppliers. In the *'how-to'* knowledge the trusts sought knowledge about the practical application of the technologies in local healthcare settings. This included users' experience with the technologies, aesthetics, functionality, as well as compatibility with strategic, structural and cultural elements of the trust's context. A more detailed estimation of the short-term and long-term associated costs also constituted *'how-to'* knowledge. In the setting of a healthcare organisation the *'how-to'* knowledge comprised a much broader, multi-dimensional definition compared to a simpler definition when the potential user is an individual[15].

All trusts assessed the *costs.* Those trusts which spent little time in assessing *'how-to'* knowledge omitted important considerations such as long-term and running costs of a given technology. All trusts also made an assessment of the *effectiveness* of the technologies. The definition of *effectiveness* was broader when both *'principles'* and *'how-to'* knowledge were given sufficient attention and this ranged from local opinion including patient perceptions, ease of use by staff, to experimental controlled trials data. The majority of informants from all trusts noted that no particular technology could be solely or directly attributable to reducing HCAIs and impact was attributable to ongoing multifaceted approaches.

Centralised and local dissemination of innovation knowledge

Decision makers used a wide range of *sources* to get information on the three types of innovation knowledge (Table 2). Peer review journals and commercial suppliers were used in all trusts to source *'principles'* knowledge. Supplier information was reported as compact and easy to access for practitioners, however this source was viewed as less credible. Of the government-funded centralised evidence dissemination structures, DH Showcase Hospitals Programme was widely used by trusts for

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obtaining *'awareness'* and *'how-to'* knowledge but none of the trusts used it for *'principles'* knowledge. Local expert advice was preferred to the dedicated central expert panel (RRP) for obtaining *'principles'* knowledge, while guidelines were used by only three trusts. Professional networks consistently featured amongst the top sources for all three types of innovation knowledge. The latter were used to exchange experiences on the use of the same or similar technologies, spreading information horizontally via networks of peers and local experts.

Table 2 Type and sources of innovation knowledge used in the technology adoption process per trust

Types of Innovation Knowledge / **Sources of Innovation Knowledge**	**Awareness Knowledge:** Identify technologies available to specific IPC priority areas& information about the nature of these technologies	**Principles Knowledge:** why and how a technology works in terms of the underlying scientific principles or theory	**'How to' Knowledge:** how to put the technology in use, including issues of compatibility with trust structures / strategy / culture &issues of sustainability
Professional networks / other NHS trusts	**n=11**	**n=7**	**n=10**
Peer review journals	**n=2**	**n=12**	-
Hospitals outside UK	**n=1**	-	-
Commercial Supplier	**n=6**	**n=12**	**n=11**
Previous experience of other technologies	-	-	**n=5**
Previous experience of same/similar technology	**n=6**	-	**n=6**
Showcase Hospitals Pprogramme	**n=7**	-	**n=8**
Rapid Review Panel (RRP1)	**n=7**	**n=1**	-
Expert advice	**n=7**	**n=4**	-
Own research / evaluation trial	-	**n=2**	**n=3**
DH dissemination – conferences, websites	**n=5**	**n=1**	-
Internet	**n=1**	-	-
Guidelines	-	**n=3**	-

n= number of trusts (out of a total population of 12 trusts studied)

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Critical timing of innovation knowledge use

We found that at the earlier stages of the process, *'principles'* knowledge was given more attention overlooking important aspects of *'how-to'* knowledge. When *'how-to'* knowledge was considered late, there were negative implications for the adoption and implementation of the technologies (Table 3). For example, *'how-to'* knowledge was not considered early on in Trust 4 for the ultra violet light air sterilisation units, and consequently the technology was discontinued after adoption. Hidden running costs, such as replacing costly bulbs and filters regularly, as well as the practicality of assembling units on site, were overlooked. Conversely, when *'how-to'* knowledge was considered earlier by decision makers, successful technology adoption and implementation was evident. The 14 technology cases for which *'how-to'* knowledge was first considered during the 'initiation/pre-adoption' stage were all adopted and implemented successfully. The ten technology cases for which *'how-to'* knowledge was first considered during the 'adoption decision' stage, mainly during pre-adoption evaluation trial, resulted in informed organisational decisions to either adopt or reject technologies; and for those technologies adopted led to subsequent successful implementation. For the ten technology cases where *'how-to'* knowledge was first considered during 'implementation', uptake was challenging leading to unsuccessful implementation following initial adoption.

Table 3 The stage when *'how-to'* knowledge was first considered in the process & associated outcome

Pre-adoption / Initiation	Adoption decision	Post-adoption / Implementation
Infection Manager Software (T6)→**Successful adoption & implementation**	Smart flat infection control computer keyboard &mouse (T8) →**Technology modification &subsequent successful implementation**	Hydrogen Peroxide Vapour System (T9)→ **Incomplete implementation**
Urinary Catheter Care Bundle (T1)	Hydrogen Peroxide Vapour	Ultrasonic cleaning tanks (T5)→

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→Successful adoption & implementation	System (T7)→**Implementation trial informed disinvestment**	**Discontinued adoption of the technology**
Endoscopy sinks (T2)→**Successful adoption & implementation**	Ozone Sanitizer Machines (T9) →**Successful adoption & implementation in 1 of the 2 hospital sites / not implemented in 2nd site**	Adenosine triphosphate (ATP)Hygiene Monitoring System (T9)→ **Discontinued adoption of the technology**
Real-time Polymerase Chain Reaction (PCR) for Norovirus testing (T2) →**Successful adoption & implementation**	Antiseptic Body Cleaning Washcloths 2% Chlorhexidine Gluconate (T10, T11)) →**Implementation trial informed disinvestment (T10) / 'controlled & focused' use (T11)**	Ultra Violet (UV) light air sterilisation units (T4)→ **Discontinued adoption of the technology**
Hydrogen Peroxide Vapour System (T12) →**Successful adoption &implementation**	Infection control IT surveillance system (T3)→ **Delayed adoption& very delayed/incomplete implementation**	Faecal management system(T10) → **Discontinued adoption of the technology**
Adenosine triphosphate (ATP) Hygiene Monitoring System (T11, T12)→**Successful adoption & implementation**	Hydrogen Peroxide Vapour System (T6) →**Successful adoption &implementation**	Adenosine triphosphate (ATP) Hygiene Monitoring System (T4)→**Incomplete implementation**
Microbiology testing: mass spectrometry analysis machine (T5) →**Successful adoption & implementation**	Adenosine triphosphate (ATP) Hygiene Monitoring System (T5,T10)→**Evaluation trial informed procurement & successful trust-wide implementation**	Non-chlorine disinfectant(T10)→ **Discontinued adoption of the technology**
Digital Count up posters/boards (T8) →**Successful adoption & implementation**	Hand signage (T2) →**Successful adoption & implementation**	Polymerase Chain Reaction(PCR) for MRSA testing (T2) → **Delayed implementation**
Portable PC Tablets (T6, T8) →**Successful adoption & implementation**		Chlorhexidine Gluconate (CHG) dressing (disk) to prevent Catheter-Related Blood Stream Infections (T4)→**Incomplete implementation**
Individual Patients MRSA Decolonisation Pack (T11)		Ultra Violet (UV) light inspection units (T11)→

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→Successful adoption & implementation	Discontinued adoption of the technology
Single use disposable Blood Pressure Cuffs & Pulse Oximeter Probes (T7)→**Successful adoption & implementation**	
Ultra Violet (UV) light hand inspection kit (T12) →**Successful adoption & implementation**	

NB: Four technologies are excluded in the table as there were no clear outcomes within the timeframe of the study

Looking in more detail at an example where *'how-to'* knowledge was inadequately considered in the early stages of the process is that of ultrasonic cleaning tanks in Trust 5:

"[the technology] was very definitely sold as a replacement for manual cleaning…we embarked in the belief that using the tank would mean that when the equipment came out at the other end and was dried it would be safe to use on the next patient…we didn't feel comfortable [after having tested the tanks for bacteria levels in water after cleaning] and we felt that to make these pieces of equipment safe we would then manually go over them with a disinfectant…and this means additional workload" [Senior IPC Nurse]

Important aspects of structural incompatibility only came to light during implementation, affecting the practical application of the technology. The water in the tanks needed to be replaced after each cleaning session, a long process as the tanks needed to be emptied first, then refilled and water heated overnight. This added to the hospital staff workload. The tanks needed to be hardwired for electricity, which meant no manoeuvrability – the initial plan had been to move the tanks around the hospital rather than shift dirty and bulky items to the tanks. Other health and safety issues were identified during early implementation. The technology though purchased by the trust, resulted in becoming obsolete;

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the tanks were housed by estates in a storage area on the top floor of the hospital and used in a very different way from the original plan.

An example where detailed attention was given to *'how-to'* knowledge during the 'adoption decision' stage informed subsequent purchases of infection control computer keyboards and mice (fully enclosed and flat design enabling quick and thorough cleaning) used with Picture Archiving and Communication Systems (PACS) in clinical areas. In Trust 8 feedback from chest consultants (principal users of the technology) resulted in appropriate procurement of computer devices which were consistent with working practices as well as compliant with infection prevention guidelines:

"Had we not changed the [the newly introduced] flat computer mouse to replace it with one that has got a push scrolling button, the targeted users would not have used it at all; it is highly likely that they would have replaced them with normal computer mouse instead..." [Trust 8]

The influence of professional background and leadership role

We found variation in the priority given to the type of innovation knowledge across professional groups. Consistently across the trusts consultant microbiologists, clinical matrons, and infection control nurses looked at the same technologies differently and came to divergent decisions regarding the value of specific technologies, or gave higher value to different sources and types of evidence. For instance, in T4, T6, T7, T10, T11 the clinical microbiologists valued highly and almost exclusively *'principles'* knowledge to judge the effectiveness and appropriateness of technologies for the trusts. All clinical microbiologists across trusts, looked primarily at peer reviewed published articles for such information. In contrast, clinical matrons preferred more applied information about technology effectiveness and would discount very technical accounts, as the following quote illustrates:

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"You don't want such jargonistic information. You need to make it very simple to say this is how it works. These are the benefits, blah, blah, blah, rather than going to such, you know, higher level of microbiology" [Clinical Matron].

An IPC nurse in the same trust highlighted the importance of combining *'how-to'* and '*principles'* knowledge to assess effectiveness and appropriateness of the technologies:

"You need both evidence from [peer review] papers and the practicality of using the product [in the local context]. It's very important" [IPC Nurse].

Further, our systematic mapping of cases accounting for the type of trust and the types of innovation knowledge prioritised showed that trusts affiliated with universities, comprising research active organisations (T3, T4, T5, T8, T10,T11 – also see Table 1), meticulously searched for and emphasised *'principles'* knowledge that derived from scientific research. This attitude was mirrored across professional groups, though was more pronounced in accounts by respondents from the medical profession. Among this group of trusts, when the key decision maker, namely the Director of Infection Prevention and Control (DIPC), was a nurse by profession (T8 and T11) the careful focus on *'principles'* knowledge' was more balanced by giving adequate attention to *'how-to'* knowledge. By contrast, in the trusts in which the key decision maker (DIPC) was a medical doctor by profession (T3, T4, T5, T10) the *'how-to'* knowledge was given less attention with subsequent adverse impact on adoption and implementation of many of the technologies selected, as illustrated in the case examples in Table 3.

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Linked to this was the leadership role taken by the DIPC which had a bearing in technology adoption decisions. The leadership style adopted by DIPCs varied from 'heads on', technical and highly prescriptive to more discrete, strategic, 'hands off', and facilitating. This was an important theme that mediated the differing use of types of innovation knowledge sought by trusts. For example, the DIPCs in two of the trusts adopted very different leadership roles in the decision making process, partly due to different functional roles within their respective organisations. One of the DIPC's was clear about differentiating his/her role as a manager from his/her professional training as a microbiologist. The DIPC, who was also a Medical Director in the hospital, took the role of a facilitator:

"I'm a microbiologist by background but in this project,...something that I learnt right at the beginning, when I took on this post, is when you actually become a clinical manager or a clinical leader you actually have to drop your knowledge of your own ...because you start interfering... I think that is quite important for clinicians who become either leaders or managers of any sort, that they really have to let the professionals guide and say, this is what we need to do, and the role of the manager or leader is just to facilitate" [DIPC]

In contrast, the second DIPC, who was also a consultant microbiologist but not a Medical Director in the hospital, felt that this management role could be effectively fulfilled only by virtue of one's professional training and specialist knowledge.

The first trust had 100% success in technology adoption and implementation, whilst the second had implementation success rate of 25%. In the first trust, the involvement of a more diverse set of stakeholders/professions in the process provided opportunities to critique both *'principles'* and *'how-to'* knowledge rather than focusing exclusively on one.

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DISCUSSION

Main findings

We found the technology adoption process to be highly dynamic and iterative, comprising a number of sub-stages. Adoption decisions entailed the acquisition and processing of new knowledge primarily by teams or groups who sought to reduce uncertainty about an innovation. Trying to find solutions to problems was the key motivator for sourcing evidence across the cases.

The scientific knowledge on which claims of innovations' effectiveness were based was of greater interest to decision makers in the healthcare organisations studied. Empirical and experiential types of knowing were also widely used to judge the *effectiveness* and *appropriateness* of the technologies in the local setting, but were often assessed later in the process. This late consideration of *'how-to'* knowledge had implications for successful adoption and implementation. In the cases where *'how-to'* knowledge was given least priority during the early stages of 'initiation' and 'adoption decision', issues which should have been picked up when adoption decisions were being made came up at implementation trial and even once trust-wide implementation had begun. This resulted in: (a) increased likelihood of technology rejection or protracted procurement decision at the 'adoption decision' stage, (b) delayed or incomplete implementation, or discontinuance (following initial adoption) during the stage of 'post-adoption / implementation'.

Commercial suppliers and peer review publications were used as often as each other for *'principles'* knowledge whilst noting potential supplier bias. Suppliers responded to preferences for theoretical knowledge of a highly professionalised user group. This is in contrast to individual consumers where marketing, as well as consumer interest is focused on *'awareness'* and *'how-to'* knowledge[15]. Centralised

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(health system) structures were particularly under-used as sources for *'principles'* knowledge and were reported as less accessible and less relevant to the local context. Professional networks were widely used and comprised practice-based, peer-mediated information about the innovations, relevant to the micro-conditions of local settings.

The priority given to the three types of innovation knowledge depended on: (a) type of trust - teaching hospitals or research active organisations prioritised *'principles'* knowledge; (b) professional background of decision makers - members of the medical profession tended to prioritise *'principles'* and often ignored *'how-to'* knowledge, while members of the nursing profession tended to balance the use of *'principles'* and *'how-to'* knowledge; (c) organisational role and leadership style of the key decision maker – the DIPC's leadership approach conditioned the level of involvement of staff outside of the IPC team; where the DIPC had strategic oversight as Medical Director or Director of Nursing, this led to wider involvement.

Strengths and weaknesses discussing important differences in results with other studies

The scale of the study and the real time nature of investigating 38 adoption and implementation processes over a period of 18 months provided a rich dataset. Our study is theory driven and comprises multi-site, comparative case studies which overall enhance the generalisability of findings beyond the context of the specific sites studied[27]. We explicitly studied cases of non-adoption and discontinuation after initial adoption, which are rarely included in innovation diffusion studies. We looked at centralised, organisational, professional and local influences in the process.

On limitations, the predefined sample in our study was not exhaustive by trust type, though sufficiently diverse (Table 1). At the same time, a common barrier to adoption (availability of funding) was

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'controlled for' in this sample, allowing other factors during adoption decision to be explored. We were not able to follow implementation past the end of August 2010 and therefore do not have information on routinised use of the implemented technologies.

Data from all our cases show that acceptance of the knowledge associated with innovative technologies depended on the perceived credibility of the source. Current health policy practice, as outlined in the introduction, is implicitly founded on the notion that health professionals do access primarily centralised sources to acquire knowledge about innovative technologies. Our findings differ, emphasising a more prominent role of local and peer-mediated sources, such as professional associations, local practice trials, experiences of peers and local experts.

Whilst innovation literature in commercial sectors considers the three types of innovation knowledge in technology adoption by individuals[15], the role of these types of knowledge in organisational decisions within the highly professionalised context of a healthcare system is missing. In addition, our study shows *how* the interplay between the types of innovation knowledge at different stages of the process mediates the adoption or implementation outcome and the role of professionals in this interplay. This builds on work by Ferlie and colleagues[5] who looked at the adoption of guidelines in four areas of clinical care and found that there are cognitive, social and epistemic barriers to knowledge flow amongst health professionals. In particular, our findings suggest a differential approach by diverse professional groups in seeking and prioritising *'how-to'* knowledge.

Data from all cases show that *'how-to'* knowledge was important in the innovation process, not only operationally but also strategically, spanning issues of structural and cultural compatibility, and

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sustainability. Our findings suggest a more prominent focus for *'how-to'* knowledge in the future, by both practitioners and researchers[36 37].

Meaning of the study: possible explanations and implications for clinicians and policymakers

Health systems remain to fully exploit patient benefit through sustainable use of evidence-based technologies[38 39]. This study provides actionable insights to address the evidence-practice gap relevant to a range of stakeholders, including operational and senior managers, frontline clinicians, policy makers, academics and the industry. Balancing *'principles'* and *'how-to'* knowledge at the *early* stages of the innovation process will provide decision makers with clinical and financial justification for innovations, as well as practical implementation guidance. Identifying appropriate individuals or developing organisational structures to facilitate this knowledge transfer is critical for informed adoption decisions and successful implementation of innovations. Learning from discontinued adoption or failed implementation of technologies is as important as success stories. Given the patterns of knowledge exchange amongst our respondents, investing in horizontal knowledge exchange to complement 'top down' knowledge transfer is indicated. Appraising the local environment for structural and cultural compatibility of the technologies is essential along with evidence for efficacy and cost-effectiveness, to avoid waste of valuable resources, and potential to cause inadvertent harm from inappropriate implementation.

There are implications here of who is involved in the innovation adoption process and the role played by key decision makers. Since healthcare services are increasingly configured as multi-professional team activities[40] organisational innovation adoption decisions need also to account for local attitudes to evidence of different professional groups. Policy makers need to reconcile the need for central guidance

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and quality standards with locally relevant practice-based evidence to contextualise the research in line with practical needs.

Future research and unanswered questions

To develop an innovation agenda where evidence influences technology adoption there needs to be some agreement as to what constitutes evidence, and how different forms of evidence might be relevant to diverse policy and practice questions. Our data illustrate that scientifically produced research findings were not the only influence on adopters' behaviour with respect to innovative technologies; empirical and experiential forms of knowledge were also widely used. More work is needed to understand how organisational priorities shape the perspective of organisational leaders and other key decision makers. A study in progress funded by NIHR/SDO considers such issues in depth[41].

A number of other questions remain unanswered. Future studies need to account for individual and organisational motivation to source evidence. Also, given that different professionals view different sources and types of evidence differently, how can these differences be reconciled? And who can play the role of 'evidence broker'? The innovation literature describes the effective role of champions – we need to know if these champions are also effective knowledge brokers able to consider all three types of innovation knowledge. Perhaps champions are inherently biased towards their chosen technology, pointing to wider involvement of a multi-disciplinary team. Finally, we need to account for influences of different health system structures (centralised tax based versus disaggregated 'market' systems) and how these shape use of evidence and ultimately, innovation uptake.

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Governance and ethics

Ethical approval was not required for the study under NHS research governance arrangements (letter dated 23 April 2009 by Hammersmith and Queen Charlotte's & Chelsea Research Ethics Committee). The research was classed as service evaluation by the chairman of the Committee. Access to the participating trusts was via DH in the first instance through an introductory letter. The trusts were then approached by a member of our research team. The project lead and IPC teams in each trust further facilitated access to those involved in the decision making, procurement and implementation of the selected technologies. Prior informed consent to join the study was obtained in writing by participating individuals. Author 1 and author 2 conducted the interviews, both experienced qualitative researchers with no prior relationship with the informants. Interviews were guided by a topic guide. All interviews, but one, were audio-recorded. Audio recorded interviews were transcribed verbatim by professional transcribers, and then checked by the researchers for accuracy. Primary data were anonymised and stored securely on password protected computers prior to processing.

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No competing interests

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work.

Details of contributors

YK and RA conceived the idea for the paper, collected and systematically analysed all data. All three authors interpreted the data. YK designed the initial study and drafted the article, RA contributed to study design and all three authors revised it critically for important intellectual content. All three authors approve the content of the manuscript submitted.

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Technology adoption and implementation in organisations – comparative case studies of 12 English NHS Trusts

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Technology adoption and implementation in organisations – comparative case studies of 12 English NHS Trusts

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ABSTRACT

Objectives: To understand organisational technology adoption (initiation, adoption decision, implementation) by looking at the different types of innovation knowledge used during this process.

Design: Qualitative, multi-site, comparative case study design.

Setting: One primary care and 11 acute care organisations (trusts) across all health regions in England in the context of infection prevention and control.

Participants and data analysis: 121 semi-structured individual and group interviews with 109 informants, involving clinical and non-clinical staff from all organisational levels and various professional groups. Documentary evidence and field notes were also used. 38 technology adoption processes were analysed using an integrated approach combining inductive and deductive reasoning.

Main findings: Those involved in the process variably accessed three types of innovation knowledge: *'awareness'* (information that an innovation exists), *'principles'* (information about an innovation's functioning principles), and *'how-to'* (information required to use an innovation properly at individual and organisational levels). Centralised (national, government-led) and local sources were used to obtain this knowledge. Localised professional networks were preferred sources for all three types of knowledge. Professional backgrounds influenced an asymmetric attention to different types of innovation knowledge. When less attention was given to *'how-to'* compared to *'principles'* knowledge at the early stages of the process this contributed to 12 cases of incomplete implementation or discontinuance after initial adoption.

Conclusions: Potential adopters and change agents often overlooked or undervalued *'how-to'* knowledge. Balancing *'principles'* and *'how-to'* knowledge early in the innovation process enhanced successful technology adoption and implementation by considering efficacy as well as strategic,

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structural and cultural fit with the organisation's context. This learning is critical given the policy emphasis for health organisations to be innovation-ready.

Word count: 268 (word limit 300 words)

ARTICLE SUMMARY

Article focus

- Despite policy support and the development of a dedicated evidence dissemination infrastructure in the NHS, why is technology adoption and implementation still a challenge?
- We need to understand better *how* the innovation process unfolds in organisations to build on what we know about individual behaviours. In particular, how the use of different types of knowledge about an innovation impacts its adoption and implementation.

Key messages

- In our study, centralised dissemination of evidence had minimal to moderate impact on organisational innovation adoption decisions. Practice-based, peer-mediated, and local dissemination systems were perceived more relevant.
- In contrast to technology adoption by individuals, organisational adoption required a wider, multi-faceted conceptualisation of *'how-to'* knowledge in line with the more complex dynamics in organisations. When *'how-to'* knowledge was undervalued and considered late, important strategic, structural, and cultural elements of the trust's context were overlooked. This had negative implications for technology adoption and implementation.
- Professional backgrounds of those involved in the process influenced the types of innovation knowledge considered, which had implications for implementation. The involvement of

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diverse professionals in decision making improves the chances of successful implementation through a balanced consideration of the strength of scientific evidence and practical application.

Strengths and limitations

- The scale of the study, its real time and longitudinal nature provide a rich dataset. Our study is theory driven and comprises multi-site, comparative case studies, which enhance the generalisability of findings beyond the context of the studied trusts.
- We explicitly studied cases of non-adoption and discontinuation after initial adoption, to provide important learning often missing from innovation diffusion research.
- On limitations, we were not able to follow implementation past the end of August 2010 and therefore do not have information on routinised use of the implemented technologies.

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INTRODUCTION

The recent focus by policy makers on quality and efficiency in healthcare[1], highlight the need to harness new healthcare technologies and innovation to improve quality of patient care and health system

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productivity[2 3]. The uptake and implementation of new technologies in healthcare has often proved challenging and in some cases very slow[4-6]. In the UK the significant 'research to practice' knowledge gap and the suboptimal implementation of new ideas and technologies into clinical practice have been emphasised in several recent policy documents[7-9]. Policy and academic systematic reviews[6 10] consistently show that there remains a poor understanding of the mechanisms and processes that encourage the adoption of new interventions. Specifically, attention to the processes by which organisational members access and use implementation and clinical evidence during decision making is required[9 11 12]. As regards technology adoption in the National Health Service (NHS) a recent systematic review[13] has found that there has been little research in this area.

In the last decade government funded agencies have been created to encourage innovation uptake and promote the use of evidence-based innovations in the NHS[1 14]; such predominately centralised evidence dissemination structures include the NHS Institute for Innovation and Improvement, the National Institute for Health and Clinical Excellence (NICE) with the launch of the NHS Evidence online portal, and the NHS Technology Adoption Centre, which works to speed-up the adoption of proven technologies by NHS organisations. Despite these initiatives, the challenges of adopting novel technologies in the NHS persist.

Our study addresses this research gap and is well grounded in innovation change and diffusion theories[15-17]. Specifically, our study unpacks the innovation processes in organisations - in contrast to individuals - by investigating in detail the interplay between the types and sources of innovation knowledge used. We empirically focus our investigation on infection prevention & control (IPC) as it represents a cross-cutting priority area in healthcare with application to primary and acute care, surgery and medicine alike. While there has been increasing public and policy attention to address healthcare

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associated infections (Box 1) the uptake and implementation of new technologies in IPC varies and remains slow[18]. This empirical setting, therefore, offers opportunities to generate transferrable lessons.

Box 1 Healthcare associated infections initiatives in the NHS

Healthcare associated infections (HCAIs) are a worldwide problem causing high mortality and morbidity with significant cost implications for health systems.[19-24] Both developing and more developed countries face the challenge[20] and there is intense media and public attention on the issue. In the UK a range of infection prevention and control policies have been introduced to help tackle the problem, including legislation, performance targets, and clinical guidelines. In England the reporting of Meticillin-resistant *Staphylococcus aureus* (MRSA) bloodstream infections and Clostridium *difficile* (C. *difficile*)infections are mandatory and there are national and local targets for reduction as well as national evidence-based guidelines.[25] The development of effective technology interventions to complement good infection control practice is viewed as central to tackling HCAIs and a range of evidence-based innovations have been developed. Government funded programmes, such as the Department of Health 'HCAI Technology Innovation Programme'[18] have been created to fast track the innovation process. Programme work-streams span development to procurement and implementation processes and include: 'Smart Ideas', 'Design Bugs Out', 'Smart Solutions', 'Product Surgeries' and 'Showcase Hospitals', the latter focusing on the in-use value of HCAI technologies. In addition, the Health Protection Agency (HPA) Rapid Review Panel (RRP) was set up in 2004 to review new HCAI-related technologies providing a prompt assessment of new and novel equipment, materials, and other products or protocols that may be of value to the NHS to help reduce HCAI rates; recommendation statements about the novel products are given to suppliers and NHS bodies ('Recommendation 1' being the highest, encouraging adoption by the NHS).

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METHODS

Design and theoretical approach

This article reports on findings from a larger innovation adoption study in the area of HCAIs commissioned by the Department of Health (DH)[26]. We employed a multiple case study research design to build theory inductively[27] covering the decision making, procurement, and implementation processes by NHS organisations when introducing innovative technologies. We undertook comparative case studies[28] across 12 NHS trusts in England with each trust and technology adoption decisions as units of analysis. Consistent with our research aims we employed interpretive methods of inquiry which allows description, interpretation, and explanation of a phenomenon rather than estimation of its prevalence[29].

Damanpour and Schneider[15] suggest that the process of innovation adoption in organisations can be divided into three broad phases of 'pre-adoption', 'adoption decision' and 'post-adoption', also referred to in the literature as 'initiation', 'adoption (decision)', and 'implementation'[16 14 27]. In this article we use the latter terminology. Adoption is viewed as a process in which organisational members analyse the potential benefits and negative aspects of an innovation on the basis of gathered knowledge. During this process three types of innovation knowledge are important in moving potential adopters from 'ignorance' through awareness, attitude formation, evaluation and on to adoption – *"the decision to make full use of the innovation as the best course of action available"*[16]:

1. Awareness knowledge – the awareness that an innovation exists and knowledge of its key properties.
2. How-to knowledge – the information necessary to use an innovation properly.
3. Principles knowledge – information dealing with the functioning principles underlying how the innovation works.

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The above definitions of innovation knowledge may be relatively simple and consistent when applied to technology adoption by individuals, while they become ambiguous when applied to the organisational setting in which the process is complex and contested[13 30]. Evidence is a form of knowledge and in this article comprises empirical, theoretical and experiential ways of knowing[31].

Sampling and settings

The study comprised one primary and 11 acute care organisations (NHS trusts), across all 10 Strategic Health Authorities (SHAs) in England. The trusts included in the study sample were diverse in geography, size and type (Table 1). The sample was predefined with one attribute in common as recipients of DH's 'HCAI Technology Innovation Award for outstanding contributions to fighting infections 2009'. The trusts were nominated by each SHA on the basis of having excelled in either turnaround or 'best in class' concerning infection prevention performance in the fiscal year 2008/9. The trusts were given free reign to use the sum to procure technologies that could help reduce HCAIs (awarded in February 2009).

Table 1 Case study sites characteristics

Trust	Trust type	Number of beds	Population covered (m)	Financial turnover (m)	Number of sites	DIPC profession	Number of technologies adopted
T1	S, PFI	1,269	0.75	£400	Multi-site	Medical Doctor	1
T2	S, F, PFI	754	0.34	£156	Multi-site	Medical Doctor	6
T3	T, U	1,902	1 (S) 3 (T)	£652	Multi-site	Medical Doctor	1
T4	T, U, (PFI)	988	0.5 (S) 1.5 m (T)	£420	Multi-site	Medical Doctor	3
T5	T, U, F, (PFI)	2,068	0.5 (S) 1.7 (T)	£648	Multi-site	Medical Doctor	3
T6	S, PFI	1,095	0.6	£430	Multi-site	Medical Doctor	2
T7	S, F, (PFI)	602	0.35	£200	One site	Medical Doctor	4

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T8*	T, U, F	807	0.33 (S) 1.5 (T)	£250	One site	Nurse	3
T9	T, F, (PFI), U	1,150	0.12 (S) 1 m (T)	£440	Multi-site	Nurse	3
T10	S, (U)	974	0.6	£415	Multi-site	Medical Doctor	4
T11*	T, U, F	802	0.3 (S) 1.5 (T)	£400	Multi-site	Nurse	3
T12*	P / I	76 (I)	0.43	£202 (P) £744 (S)	Multi-site	Nurse	5

P: primary, I: intermediate care, S: secondary, T: tertiary, U: university, F: foundation, PFI: private finance initiative, DIPC: Director of Infection Prevention &Control

** Each of these trusts received £50K as the award was split across the health economy by the respective SHA whilst the remainder trusts each received £150K*

Data collection and participants

We collected data from secondary sources to provide a historical dimension to better situate the studied decision making processes.

Data from primary sources comprised 121 semi-structured individual and group interviews carried out during the 18 months (July 2009 - August 2010). On average this equates to ten, hour-long interviews per trust. Twelve informants were interviewed more than once. Depending on the number and scope of technologies we conducted between two to five visits per trust. Within each of the trust sites we purposively sampled a diverse range of informants involved in the technology adoption or implementation, reflecting various perspectives, professional and organisational roles. Our participants included clinical and non-clinical managers, members of trusts' executive boards, health professionals, staff from estates and facilities and IPC teams comprising: DIPC, deputy DIPC, medical microbiologist, infection doctor, infection control nurses (the most populous group), surveillance staff, decontamination lead. Some IPC teams included a pharmacist or infection control matrons. .

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Interviews explored individuals' perceptions, experiences, and views on the technology selection decisions, procurement and implementation processes. In the first visit the ongoing decision making process was captured and in follow up visits technology selection outcome and implementation experiences were explored. Field notes were taken during observation of technologies in-use and relevant meetings. Observation was used to familiarise with technologies and context, and triangulate interview data. For example in one trust a technology reported in interview accounts as 'fully implemented' was not verified as such during observation visits to implementation wards. A total of 20 hours of observation were completed, on average 30 minutes per technology. Data collection at each site continued until all aspects of the decision process had been accounted for by a diverse sample of informants.

Data analysis

We analysed data using an integrated approach[32]. Development of codes were initially derived from the primary data ('ground-up'), subsequently complemented with an organising conceptual framework for the adoption of complex health innovations [32]. This framework has been previously employed to understand multi-level innovation adoption[33]. Data analysis was conducted in parallel to ongoing data collection to feed emerging findings and 'test' these in subsequent interviews. The Qualitative Data Analysis computer software package N-Vivo 8 (QSR International) was used to systematically code the data and assist analysis, especially in cataloguing and linking concepts and codes. In line with recommendations by qualitative methodologists[34-36] authors 1 and 2 independently coded all data. The three authors met to review discrepancies[32], enhancing internal validity[36-38]. Comparative cases were analysed in two stages: first each of the technologies within each trust, producing individual trust case studies; second a comparative analysis across the trusts. Summary tables were used to reduce the volume of primary data and to make analytical inferences by comparing and contrasting pairs and

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groups of cases[27]. We defined the outcomes of the technology adoption process as follows: 'successful adoption' - the organisational executive decision to make full use of a technology, which results in procurement; 'successful implementation' – the technology is put into use and operationalised.

MAIN FINDINGS

The organisational innovation process and outcomes

Of the 38 organisational technology adoption decisions made during the period of the study, 22 technologies were successfully adopted and implemented, whilst 12 were discontinued after initial adoption or only partially implemented (Table 3). There was no clear outcome within the timeframe of the study for four technologies. The nature of technologies is described in detail elsewhere[26]. A general typology of technologies isolated from context did not provide insights to likelihood of adoption. As illustrated in Table 3 the same technologies (i.e. the Hydrogen Peroxide Vapour System, or the ATP Hygiene Monitoring System) in diverse trusts and at different stages of the innovation process resulted in differential outcomes. Most informants reported that they went through a series of evaluations, choices and actions over time as the adopting trusts principally engaged in a problem solving exercise. The process was dynamic, iterative and not always linear. The IPC team and some wider staff were involved in adoption decisions. Whilst the formal executive decision lay with the DIPCs, they were not always the key decision makers across the cases. The size and professional composition of the IPC teams, and the professional background of the DIPC (Table 1), varied. We found that the majority of technology decisions were led by a perceived need - an area of priority in IPC had been identified by trusts first, and then relevant technologies were sought ('need pull'). A minority of technology adoption decisions were characterised by selecting a technology in the first instance and exploring how this might fit with strategic plans and service needs ('technology push').

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Use of innovation knowledge in the organisational setting

Trusts variably accessed and prioritised the three types of innovation knowledge in the organisational setting, and these comprised a much broader, multi-dimensional definition compared to a simpler definition when the potential user is an individual[16]. Under *'awareness'* knowledge the trusts considered the range of technologies available to address a particular problem, as well as key features and potential cost implications of such technologies. In seeking *'principles'* knowledge the trusts sought primarily evidence of the technologies' technical efficacy based on the scientific principles behind the technology. They assessed the validity of claims made by commercial suppliers. In the *'how-to'* knowledge the trusts sought knowledge about the practical application of the technologies in local healthcare settings with nine trusts trialling the technologies. This included users' experience with the technologies, aesthetics, functionality, as well as compatibility with strategic, structural and cultural elements of the trust's context. A more detailed estimation of the short-term and long-term associated costs also constituted *'how-to'* knowledge. Cost and effectiveness issues permeated the three types of innovation knowledge. The definition of *effectiveness* was broader when both *'principles'* and *'how-to'* knowledge were given sufficient attention and this ranged from local opinion including patient perceptions, ease of use by staff, to experimental controlled trials data. The majority of informants from all trusts noted that no particular technology could be solely or directly attributable to reducing HCAIs and impact was attributable to ongoing multifaceted approaches.

Centralised and local dissemination of innovation knowledge

Those involved in decisions used a wide range of *sources* to get information on the three types of innovation knowledge (Table 2). Peer review journals and commercial suppliers were used in all trusts to source *'principles'* knowledge. Supplier information was reported as compact and easy to access for practitioners, however this source was viewed as less credible. Of the government-funded centralised

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evidence dissemination structures, DH Showcase Hospitals Programme was widely used by trusts for obtaining *'awareness'* and *'how-to'* knowledge but none of the trusts used it for *'principles'* knowledge. Local expert advice was preferred to the dedicated central expert panel (RRP) for obtaining *'principles'* knowledge, while guidelines were used by only three trusts. Professional networks consistently featured amongst the top sources for all three types of innovation knowledge. The latter were used to exchange experiences on the use of the same or similar technologies, spreading information horizontally via networks of peers and local experts.

Table 2 Type and sources of innovation knowledge used in the technology adoption process per trust

Types of Innovation Knowledge / **Sources of Innovation Knowledge**	**Awareness Knowledge:** Identify technologies available to specific IPC priority areas& information about the nature of these technologies	**Principles Knowledge:** why and how a technology works in terms of the underlying scientific principles or theory	**'How to' Knowledge:** how to put the technology in use, including issues of compatibility with trust structures / strategy / culture &issues of sustainability
Professional networks / other NHS trusts	**n=11**	**n=7**	**n=10**
Peer review journals	**n=2**	**n=12**	-
Hospitals outside UK	**n=1**	-	-
Commercial Supplier	**n=6**	**n=12**	**n=11**
Previous experience of other technologies	-	-	**n=5**
Previous experience of same/similar technology	**n=6**	-	**n=6**
Showcase Hospitals Pprogramme	**n=7**	-	**n=8**
Rapid Review Panel (RRP1)	**n=7**	**n=1**	-
Expert advice	**n=7**	**n=4**	-
Own research / evaluation trial	-	**n=2**	**n=3**
DH dissemination – conferences, websites	**n=5**	**n=1**	-
Internet	**n=1**	-	-

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Guidelines	-	**n=3**	-

n= number of trusts (out of a total population of 12 trusts studied)

Critical timing of innovation knowledge use

We found that at the earlier stages of the process, *'principles'* knowledge was given more attention overlooking important aspects of *'how-to'* knowledge. When *'how-to'* knowledge was considered late, there were negative implications for the adoption and implementation of the technologies (Table 3). For example, *'how-to'* knowledge was not considered early on in Trust 4 for the ultra violet light air sterilisation units, and consequently the technology was discontinued after initial adoption. Hidden running costs, such as replacing costly bulbs and filters regularly, as well as the practicality of assembling units on site, were overlooked. Conversely, when *'how-to'* knowledge was considered earlier by decision makers, successful technology adoption and implementation was evident. The 14 technology cases for which *'how-to'* knowledge was first considered during the 'initiation' stage were all adopted and implemented successfully. The ten technology cases for which *'how-to'* knowledge was first considered during the 'adoption decision' stage, mainly during pre-adoption evaluation trial, resulted in informed organisational decisions to either adopt or reject technologies; and for those technologies adopted led to subsequent successful implementation. For the ten technology cases where *'how-to'* knowledge was first considered during 'implementation', uptake was challenging leading to unsuccessful implementation following initial adoption.

Table 3 The stage when *'how-to'* knowledge was first considered in the process & associated outcome

Initiation	Adoption decision	Implementation
Infection Manager Software (T6)→**Successful adoption & implementation**	Smart flat infection control computer keyboard &mouse (T8) →**Technology modification &subsequent successful implementation**	Hydrogen Peroxide Vapour System (T9)→ **Incomplete implementation**

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Urinary Catheter Care Bundle (T1) **→Successful adoption & implementation**	Hydrogen Peroxide Vapour System (T7)**→Implementation trial informed disinvestment**	Ultrasonic cleaning tanks (T5)**→ Discontinued adoption of the technology**
Endoscopy sinks (T2)**→Successful adoption & implementation**	Ozone Sanitizer Machines (T9) **→Successful adoption & implementation in 1 of the 2 hospital sites / not implemented in 2nd site**	Adenosine triphosphate (ATP)Hygiene Monitoring System (T9)**→ Discontinued adoption of the technology**
Real-time Polymerase Chain Reaction (PCR) for Norovirus testing (T2) **→Successful adoption & implementation**	Antiseptic Body Cleaning Washcloths 2% Chlorhexidine Gluconate (T10, T11)) **→Implementation trial informed disinvestment (T10) / 'controlled & focused' use (T11)**	Ultra Violet (UV) light air sterilisation units (T4)**→ Discontinued adoption of the technology**
Hydrogen Peroxide Vapour System (T12) **→Successful adoption &implementation**	Infection control IT surveillance system (T3)**→ Delayed adoption& very delayed/incomplete implementation**	Faecal management system(T10) **→ Discontinued adoption of the technology**
Adenosine triphosphate (ATP) Hygiene Monitoring System (T11, T12)**→Successful adoption & implementation**	Hydrogen Peroxide Vapour System (T6) **→Successful adoption &implementation**	Adenosine triphosphate (ATP) Hygiene Monitoring System (T4)**→Incomplete implementation**
Microbiology testing: mass spectrometry analysis machine (T5) **→Successful adoption & implementation**	Adenosine triphosphate (ATP) Hygiene Monitoring System (T5,T10)**→Evaluation trial informed procurement & successful trust-wide implementation**	Non-chlorine disinfectant(T10)**→ Discontinued adoption of the technology**
Digital Count up posters/boards (T8) **→Successful adoption & implementation**	Hand signage (T2) **→Successful adoption & implementation**	Polymerase Chain Reaction(PCR) for MRSA testing (T2) **→ Delayed implementation**
Portable PC Tablets (T6, T8) **→Successful adoption & implementation**		Chlorhexidine Gluconate (CHG) dressing (disk) to prevent Catheter-Related Blood Stream Infections (T4)**→Incomplete implementation**

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Individual Patients MRSA Decolonisation Pack (T11) **→Successful adoption & implementation**	Ultra Violet (UV) light inspection units (T11)→ **Discontinued adoption of the technology**
Single use disposable Blood Pressure Cuffs & Pulse Oximeter Probes (T7)→**Successful adoption & implementation**	
Ultra Violet (UV) light hand inspection kit (T12) →**Successful adoption & implementation**	

NB: Four technologies are excluded in the table as there were no clear outcomes within the timeframe of the study

Looking in more detail at an example where *'how-to'* knowledge was inadequately considered in the early stages of the process is that of ultrasonic cleaning tanks in Trust 5:

"[the technology] was very definitely sold as a replacement for manual cleaning...we embarked in the belief that using the tank would mean that when the equipment came out at the other end and was dried it would be safe to use on the next patient...we didn't feel comfortable [after having tested the tanks for bacteria levels in water after cleaning] and we felt that to make these pieces of equipment safe we would then manually go over them with a disinfectant...and this means additional workload" [Senior IPC Nurse]

Important aspects of structural incompatibility only came to light during implementation. The water in the tanks needed to be replaced after each cleaning session, refilled and water heated overnight. This added to the hospital staff workload. The tanks needed to be hardwired for electricity, which meant no manoeuvrability – the initial plan had been to move the tanks around the hospital rather than shift dirty and bulky items to the tanks. The technology though purchased by the trust, resulted in becoming

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obsolete; the tanks were housed by estates in a storage area on the top floor of the hospital and used in a very different way from the original plan.

An example where detailed attention was given to *'how-to'* knowledge during the 'adoption decision' stage informed subsequent purchases of infection control computer keyboards and mice (fully enclosed and flat design enabling quick and thorough cleaning) used with Picture Archiving and Communication Systems (PACS) in clinical areas. In Trust 8 feedback from chest consultants (principal users of the technology) resulted in appropriate procurement of computer devices which were consistent with working practices as well as compliant with infection prevention guidelines:

"Had we not changed [the newly introduced] flat computer mouse to replace it with one that has got a push scrolling button, the targeted users would not have used it at all; it is highly likely that they would have replaced them with normal computer mouse instead..." [Trust 8]

The influence of professional background and organisational type

We found variation in the priority given to the type of innovation knowledge across professional groups. Nurse professionals involved in adoption decisions reported taking an approach where careful focus on *'principles'* knowledge' was balanced with adequate attention to *'how-to'* knowledge. Conversely, medical professionals always prioritised *'principles'* knowledge. Consistently across the trusts consultant microbiologists, clinical matrons, and infection control nurses looked at the same technologies differently and came to divergent decisions regarding the value of specific technologies. Specifically in T4, T6, T7, T10, T11 the clinical microbiologists valued almost exclusively *'principles'* knowledge to judge the effectiveness and appropriateness of technologies for the trusts. Clinical microbiologists across trusts, looked primarily at peer reviewed published articles for such information. In contrast, clinical

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matrons preferred more applied information about technology effectiveness and would discount solely technical accounts, as the following quote illustrates:

"You don't want such jargonistic information. You need to make it very simple to say this is how it works. These are the benefits, blah, blah, blah, rather than going to such, you know, higher level of microbiology" [Clinical Matron].

An IPC nurse in the same trust highlighted the importance of combining *'how-to'* and '*principles'* knowledge to assess effectiveness and appropriateness of the technologies:

"You need both evidence from [peer review] papers and the practicality of using the product [in the local context]. It's very important" [IPC Nurse].

Trusts affiliated with universities, comprising research active organisations (T3, T4, T5, T8, T10, T11 – also see Table 1), prioritised and systematically searched for scientifically produced *'principles'* knowledge. This attitude was mirrored across professional groups, though was more pronounced in accounts by respondents from the medical profession.

DISCUSSION

Main findings

We found the technology adoption process to be highly dynamic and iterative. Adoption decisions entailed the acquisition and processing of new knowledge by organisational members who sought to reduce uncertainty about an innovation. Trying to find solutions to problems was the key motivator for sourcing evidence across the cases.

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Scientifically produced *'principles'* knowledge was prioritised by those involved in decisions to judge *effectiveness* of technologies. Empirical and experiential types of knowing were also widely used to judge the *effectiveness* and *appropriateness* of the technologies in the local setting, but were often assessed later in the process. This late consideration of *'how-to'* knowledge had implications for successful adoption and implementation. In the cases where *'how-to'* knowledge was given least priority during the early stages of 'initiation' and 'adoption decision', issues which should have been picked up when adoption decisions were being made came up at implementation trial and even once trust-wide implementation had begun. This resulted in: (a) increased likelihood of technology rejection or protracted procurement decision at the 'adoption decision' stage, (b) delayed or incomplete implementation, or discontinuance (following initial adoption) during the stage of ' implementation'.

Commercial suppliers and peer review publications were used as often as each other for *'principles'* knowledge whilst noting potential supplier bias. Suppliers responded to preferences for theoretical knowledge by a highly professionalised user group. This is in contrast to individual consumers where marketing, as well as consumer interest is focused on *'awareness'* and *'how-to'* knowledge[16]. Centralised (health system) structures were particularly under-used as sources for *'principles'* knowledge and were reported as less accessible and less relevant to the local context. Professional networks were widely used and comprised practice-based, peer-mediated information about the innovations' relevance to the local setting.

The priority given to the three types of innovation knowledge depended on: (a) type of trust - teaching hospitals or research active organisations prioritised *'principles'* knowledge; (b) professional background of those involved in adoption decisions - members of the medical profession tended to prioritise

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'principles' and often ignored *'how-to'* knowledge, while members of the nursing profession tended to balance the use of *'principles'* and *'how-to'* knowledge.

Strengths and weaknesses

The scale of the study and the real time nature of investigating 38 adoption and implementation processes over a period of 18 months provided a rich dataset. Our study is theory driven and comprises multi-site, comparative case studies which overall enhance the generalisability of findings beyond the context of the specific sites studied[28]. We explicitly studied cases of non-adoption and discontinuation after initial adoption, which are rarely included in innovation diffusion studies. We looked at centralised, organisational, professional and local influences in the process.

On limitations, the predefined sample in our study was not exhaustive by trust type, though sufficiently diverse (Table 1). At the same time, a common barrier to adoption (availability of funding) was 'controlled for' in this sample, allowing other factors during adoption decision to be explored. We were not able to follow implementation past the end of August 2010 and therefore do not have information on routinised use of the implemented technologies.

Important differences in results with other studies

Whilst innovation literature in commercial sectors considers the types of innovation knowledge in technology adoption by individuals[16], the role of these types of knowledge in organisational decisions within the highly professionalised context of a healthcare system is missing. The types of trusts, and the professional background of those involved in technology adoption decisions influenced how technologies were adopted and implemented in our study. These factors had bearing on the type of

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innovation knowledge utilised and timing of this knowledge utilisation. These findings build on literature which identifies interactions between the innovation, local actors, leadership, and multi-level contextual factors[13 39 10 40 41] shaping the technology adoption process. Furthermore, our study demonstrates an impact of variable use of knowledge on 'successful' adoption decisions. The role of professional backgrounds in this process builds on work by Ferlie and colleagues[5] who looked at the adoption of guidelines in four areas of clinical care and found that there are cognitive, social and epistemic barriers to knowledge flow amongst health professionals.

Data from all cases show that *'how-to'* knowledge was important in the innovation process, not only operationally but also strategically, spanning issues of structural and cultural compatibility, and sustainability. This broader conceptualisation better aligns the construct with the complex adjustments that are often needed in organisational settings[6 30]. Our findings suggest a more prominent focus for *'how-to'* knowledge in the future, by both practitioners and researchers[42 43].

Implications for clinicians and policymakers

Health systems remain to fully exploit patient benefit through sustainable use of evidence-based technologies[44 45]. Balancing *'principles'* and *'how-to'* knowledge at the *early* stages of the innovation process will provide decision makers with clinical and financial justification for innovations, as well as practical implementation guidance. Learning from discontinued adoption or failed implementation of technologies is as important as success stories.

Data from all our cases show that acceptance of innovation knowledge depended on the perceived credibility of the source. Current health policy practice, as outlined in the introduction, is implicitly founded on the notion that health professionals do access primarily centralised sources to acquire

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knowledge about innovative technologies. Our findings differ, emphasising a more prominent role of local and peer-mediated sources, such as professional associations, local practice trials, experiences of peers and local experts. Given the patterns of knowledge exchange amongst our respondents, investing in horizontal knowledge exchange to complement 'top down' knowledge transfer is indicated. Appraising the local environment for structural and cultural compatibility of the technologies is essential along with evidence for efficacy and cost-effectiveness, to avoid waste of valuable resources, and potential to cause inadvertent harm from inappropriate implementation.

There are implications here of who is involved in the innovation adoption process and the role played by key decision makers. Since healthcare services are increasingly configured as multi-professional team activities[46] organisational innovation adoption decisions need also to account for local attitudes to evidence of different professional groups. Policy makers need to reconcile the need for central guidance and quality standards with locally relevant practice-based evidence to contextualise the research in line with practical needs.

Future research and unanswered questions

More work is needed to understand how organisational priorities shape the perspective of organisational leaders and other key decision makers regards innovation knowledge. In particular, a better understanding of the dynamics in the late stages of the innovation process in organisations (implementation and routinisation) is needed. A study in progress funded by NIHR/SDO considers such issues in depth[47].

A number of other questions remain unanswered. Future studies need to account for individual and organisational motivation to source evidence. Also, given that different professionals view different

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sources and types of evidence differently, how can these differences be reconciled? And who can play the role of 'evidence broker'? Finally, we need to account for wider influences of different health system structures (centralised tax based versus disaggregated 'market' systems) and how these shape use of evidence and ultimately, innovation uptake.

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Governance and ethics

Ethical approval was not required for the study under NHS research governance arrangements (letter dated 23 April 2009 by Hammersmith and Queen Charlotte's & Chelsea Research Ethics Committee). The research was classed as service evaluation by the chairman of the Committee. Access to the participating trusts was via DH in the first instance through an introductory letter. The trusts were then approached by a member of our research team. The project lead and IPC teams in each trust further facilitated access to those involved in the decision making, procurement and implementation of the selected technologies. Prior informed consent to join the study was obtained in writing by participating individuals. Author 1 and author 2 conducted the interviews, both experienced qualitative researchers with no prior relationship with the informants. Interviews were guided by a topic guide. All interviews, but one, were audio-recorded. Audio recorded interviews were transcribed verbatim by professional transcribers, and then checked by the researchers for accuracy. Primary data were anonymised and stored securely on password protected computers prior to processing.

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No competing interests

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work.

Details of contributors

YK and RA conceived the idea for the paper, collected and systematically analysed all data. All three authors interpreted the data. YK designed the initial study and drafted the article, RA contributed to study design and all three authors revised it critically for important intellectual content. All three authors approve the content of the manuscript submitted.

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