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Advancing the digital and computational capabilities of healthcare providers: A qualitative study of a hospital organisation in the NHS

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Abstract

Objective: Healthcare systems require transformation to meet societal challenges and projected health demands. Digital and computational tools and approaches are fundamental to this transformation, and hospitals have a key role to play in their development and implementation. This paper reports on a study with the objective of exploring the challenges encountered by hospital leaders and innovators as they implement a strategy to become a data-driven hospital organisation. In doing so, this paper provides guidance to future leaders and innovators seeking to build computational and digital capabilities in complex clinical settings.

Methods: Interviews were undertaken with 42 participants associated with a large public hospital organisation within England's National Health Service. Using the concept of institutional readiness as an analytical framework, the paper explores participants' perspectives on the organisation's capacity to support the development of, and benefit from, digital and computational approaches.

Results: Participants' accounts reveal a range of specific institutional readiness criteria relating to organisational vision, technical capability, organisational agility, and talent and skills that, when met, enhance the organisations' capacity to support the development and implementation of digital and computational tools. Participant accounts also reveal challenges relating to these criteria, such as unrealistic expectations and the necessary prioritisation of clinical work in resource-constrained settings.

Conclusions: The paper identifies a general set of institutional readiness criteria that can guide future hospital leaders and innovators aiming to improve their organisation's digital and computational capability. The paper also illustrates the challenges of pursuing digital and computational innovation in resource-constrained hospital environments.

Keywords

Electronic health records, implementation, organisational strategy, hospitals, computational medicine

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Introduction

Healthcare systems must undergo transformation to meet anticipated societal challenges and projected health demands in the coming decades. Digital and computational medicine are fundamental to this transformation,[1] and hospitals have a key role to play in the successful implementation of digital and computational tools in healthcare.[2] The comprehensive implementation of such approaches within hospitals, however, is immensely challenging. Hospitals are complex organisations, encompassing multiple clinical specialisms and administrative units with distinct workflows and varying levels of autonomy.[3,4] This, along with

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the general division between clinical and managerial authority, can impede intraorganisational coordination.[5] Large metropolitan hospitals typically have heritage infrastructures and cultures that impede organisational flexibility,[6] and public hospitals in many countries are resource-constrained, hindering their capacity to make strategic investments in infrastructures for research and service improvement. Historically, such organisational factors have hindered hospitals' ability to support the development and implementation of new technologies, including some digital technologies such as electronic health records (EHRs).[7–9]

Major hospital organisations throughout the Organisation for Economic Cooperation and Development have successfully implemented EHRs.[7,10] Currently, there is little guidance for hospital managers and innovators (i.e. people tasked with developing and/or implementing digital systems) on how to build their organisations' capacity to leverage EHR and other health data for operational, clinical, and research gains. Pioneering hospitals can therefore serve as important exemplars, providing insights into factors that enable or constrain the implementation of data-driven healthcare within hospital settings. In this paper, we explore the challenges encountered by senior leaders and innovators within a case study hospital organisation as they implement a strategic vision for a data-driven research hospital. A 'data-driven research hospital' refers to an organisation that leverages digital health and operational data to improve services and support translational medicine.[11] The paper reports on a study that had the objective of exploring the challenges encountered by hospital leaders and innovators as they implement a strategy to become a data-driven hospital organisation. In doing so, this paper provides guidance to future leaders and innovators seeking to build computational and digital capabilities in complex clinical settings. In this paper, we refine the analytical framework of *institutional readiness* (IR) to explore a pioneering organisation's capacity to develop, implement and/or benefit from data-driven approaches. We identify general IR criteria to guide future hospital innovators and senior leaders aiming to improve their organisation's digital and computational capability.

IR refers to an organisation's ability to take advantage of a new technology or system.[12] The premise of IR is that successful innovation involving disruptive technology requires the co-evolution of the technology itself (i.e. advances in technology readiness[13]) and the organisational context in which it will be implemented.[14] IR was initially developed to explore the capacity of clinical sites to implement regenerative medicine (RM) technologies in the UK health system.[12,14,15] Specific IR criteria for enabling the development and implementation of RM technologies were identified by bringing together the first-hand accounts of RM innovators with findings from scholarship on the challenges of health technology implementation.[16–19] The identified IR criteria pertain to four general domains relevant to a variety of disruptive health technologies, including digital and computational technologies and approaches:[20] *organisational vision*, the alignment of the organisation's strategic vision with the technology; *technical capability*, the suitability of the organisations' technological infrastructure for supporting the technology; *organisational agility*, the ability of organisational elements to transform according to challenges and affordances of the technology; and *skills and training*, the capability of staff to support and utilise the technology, and mechanisms enabling staff to acquire this capability.

In this paper, we describe IR criteria for advancing the data-driven research hospital that relate to these four domains. We define IR for advancing the data-driven research hospital as referring to two aspects:

(a) The capacity of the organisation to function as a constructive partner in the development of new data-driven and computational approaches and tools;
(b) The capacity of the organisation to serve as an early adopter of data-driven and computational approaches that could deliver operational gains and clinical benefits.

Using this as a general analytical framework, we explore the accounts of innovators at the case study site to identify criteria related to the domains of organisational strategy, technical capability, organisational agility, and skills and training that influence these two aspects of IR. We also identify several challenges to improving IR which have broader relevance for public hospital organisations.

The case study site is a public hospital organisation within England's National Health Service (NHS). It has recently implemented an integrated EHR system, and via its Biomedical Research Centre (BRC) partnership with a university, has begun implementing a strategic vision for a 'data-driven' research hospital. This reflects the organisation's legacy as a pioneer in medical research and its commitment to serve as a national leader in transformational healthcare innovation within the NHS. The case study is a hospital organisation which manages and administers several affiliated hospitals. It is large and complex, encompassing almost 10,000 staff, and it is navigating a challenging national healthcare context characterised by a huge demand for clinical services and constrained funding.

Methods

Semi-structured interviews were used to explore participants' experiences of and perspectives on organisational initiatives to implement a data-driven research hospital vision. A purposive sampling approach was used to identify potential participants on the basis of their specialist knowledge and expertise.[21] Purposive sampling is highly

appropriate for studies such as this that aim to achieve an in-depth understanding of specific processes or practices that fall within the realm of participants' expertise.[22] Two senior leaders with oversight of research and innovation within the case-study organisation assisted with the identification of specific participants. Fifty-four individuals were identified and approached via email, and 42 agreed to be interviewed, including all individuals identified as 'must-haves' due to their roles as determined by the senior leaders. This included executive and non-executive directors and other senior figures involved in formulating the organisations' digital and computational strategic vision ($n = 5$); medical directors and managing directors with in-depth knowledge of their organisation ($n = 7$); individuals tasked with implementing aspects of the vision, including IT specialists, health informatics specialists, and clinicians with data science expertise, governance specialists and members of the research office ($n = 13$); clinician-researchers and academics involved in developing and testing computational tools ($n = 11$); Senior academic leaders within the university with responsibility for facilitating research collaborations between the two organisations ($n = 2$); and individuals employed at a large software company that had assisted the organisation with aspects of its computational medicine strategy ($n = 2$). Twenty-five of the participants had clinical training (in either medicine or nursing).

Interviews were undertaken by JG during a six-month period from July 2021 to January 2022. JG had no prior relationship with the participants aside from one participant who provided initial access to the case study organisation. He has 10 years of experience in undertaking qualitative interviews in healthcare settings. Due to Covid-19 management protocols, all interviews were undertaken remotely via videoconferencing software and were between 30 min and 62 min in length. During the interviews, participants were encouraged to discuss their experiences and perspectives on activities related to each of the four IR domains, as well as provide more general reflections on the affordances and challenges of computational medicine, and the challenges of current and future healthcare provision. The general structure of the interview guide was informed by the IR analytical framework and thus contained discussion prompts related to the four domains of organisational vision, technical capacity, organisational agility, and talent and skills, which were identified via analysis of existing literature on IR in healthcare contexts. For example, general interview prompts included the following: 'To what extent is the vision to develop digital and computational capacity understood and shared within the organisation?'; 'How have pre-existing technological infrastructures hindered, enabled or shaped the advancing digital and computational capacity within the organisation? What organisational arrangements and collaborations have either facilitated or hindered the building of digital and computational capacity?' The interview guide also included questions about the participant's professional background and expertise, and their general thoughts on the challenges facing public hospitals and opportunities for hospitals to respond to these challenges. These questions helped to situate the discussions about digital and computational medicine within their perceptions about the wider ecosystem of hospitals and healthcare.

All interviews were audio-recorded and transcribed by a third-party transcription service. Thematic analysis was undertaken by JG, aided by NVivo software, following the well-known method described by Braun and Clarke.[23] The thematic analysis was iterative, involving attentiveness to general issues and concerns that relate to IR, as specified in existing literature, while also remaining open to the identification of new, unanticipated themes. This was achieved through the iterative development and application of a coding framework. Initial codes were formulated to capture criteria that hinder, enable, shape the building of computational capacity, relating to each of the four domains of IR (*organisational vision, technical capability, organisational agility, and skills & training*). Additional codes were added and refined during the analysis to capture broader themes (such as those related to general resource constraints) and newly unanticipated themes. All data were coded, and theme saturation was achieved. While all the analysis was undertaken by JG, provisional themes and emerging findings were checked with the two leaders who oversee research and innovation within the case-study organisation. This was undertaken approximately one-third of the way through the data collection period and again at the end of the data-collection period to help ensure the accuracy of the findings.[24]

The project received ethical approval from the NHS Health Research Authority (21/HRA/1407), and governance approval was obtained from the case-study organisation research office. Written informed consent was obtained from all participants, during which participants were informed about the study's objectives and the academic goals of the researcher, JG. All data were deidentified during the transcription stage. Participants were informed of the aims of the study as part of the consent process.

Results

Organisational vision

A strategic vision of the organisation is to become a data-driven research hospital, and hence, building digital and computational capabilities is a strategic priority. Participants were encouraged to reflect on the vision and its impact. Common themes emerged from discussions relating to senior-level support and championing, staff receptiveness and understanding, and operationalisation.

Senior-level support. The organisation's commitment to building computational capability was enthusiastically endorsed by all senior leaders ($n = 13$). A managing director remarked 'It's well championed and well supported, particularly at the board level' (Managing Director 1). This enthusiasm among leaders was attributed to the campaigning of specific senior leaders and a widely shared perception that transformation is necessary to meet future healthcare and research needs. Participants also stated that it reflected the organisation's important role as a pioneer within the NHS. One participant stated 'the hospital board recognises that innovation and transformation is essential… we're positioning ourselves as a leader' (Medical director 1).

Staff receptiveness and understanding. Interviews revealed that the vision aligns with the beliefs and aspirations of staff throughout the organisation, despite uncertainty among some about how the vision directly relates to their roles (see below). Participants expressed the belief that digital approaches have the potential to genuinely benefit patients by improving patient safety and experiences ($n = 40$), bringing about new avenues for research ($n = 38$), and thus enabling staff to fulfil their professional responsibilities and aspirations as clinicians, researchers, and administrators. Participants ($n = 35$) felt that these beliefs were generally shared among the majority of staff within the organisation. Many participants ($n = 17$) attributed this to the recent implementation of the EHR system: '…this huge digital ecosystem in front of you… you know the data is in there to answer the questions' (Technology specialist). The enthusiasm also presented challenges, however. One senior leader noted that it was necessary to correct a mindset that EHRs were not easily exploitable 'goldmines' and that the implementation of EHRs was 'the beginning, not the beginning and end' (Medical director 1). The risk was that staff would fail to appreciate the ongoing investment and work required.

Operationalisation and coordination. Many participants are involved in initiatives aimed at building digital and computational capability. Despite this, there is uncertainty about how these initiatives work together as a coordinated approach. One participant expressed, 'Do I know research is a high priority for [the organisation]? Yes… Do I know what their operational objectives are in the next few years? Haven't a clue…' (EHR manager). Many participants ($n = 28$) felt that such uncertainties were inevitable given the pioneering nature of the endeavour, but that ideally, specific workplans would be formulated to provide greater organisational coordination and to gauge progress.

Participants ($n = 26$) were also concerned that frontline staff act as if the vision had no relevance to their day-to-day work. One senior leader noted that some frontline clinicians mistakenly equate 'research' solely with hypothesis-driven research and not with service evaluation and optimisation: 'People hear about [the data-driven research hospital], they think "oh well, that's for the academics. I'm a jobbing clinician"' (Medical director 4). Such perceptions, and the time constraints of 'jobbing clinicians', have major implications for data quality: 'key information is just not entered (appropriately into EHR) because people don't feel they've got the time to do It or it's not their role' (Medical director 1). The potential consequence of this is poor quality, unstructured data. This organisation has established several initiatives to address this (see below).

Organisational vision criteria for IR. Overall, these accounts suggest that an organisation will have a greater degree of IR when the following criteria are met: (1) a commitment to advancing digital and computational capability is reflected in its strategic vision; (2) the vision accords with the general aspirations and values of staff; (3) the vision has been operationalised into work plans with short- and medium-term goals, and; (4) when the strategy aligns with the day-to-day priorities of frontline staff. Unrealistic expectations, and the necessary prioritisation by frontline clinicians of business-as-usual clinical work, present challenges for IR.

Technical capability

Participants were encouraged to discuss the suitability of existing infrastructures, initiatives to improve infrastructures, and associated organisational barriers and affordances.

Suitability of existing infrastructures. All participants ($n = 42$) were enthusiastic about the recent implementation of an integrated EHR system and its potential to advance digital and computational capabilities. Phrases such as 'key enabler' (Clinician IT specialist 1) and 'game changer' (Medical director 2) were used. Many participants ($n = 29$) were also quick to point out, however, that the EHR system on its own will not bring about data-driven healthcare: 'you don't get a sudden change in your ability to analyse your digital data just by putting [EHR] in place' (Medical director, 1). Participants involved in EHR oversight also noted that a small number of services are reluctant to 'move to [EHR] in full', and are 'still booking patients on spreadsheets', meaning that valuable data is not being collected (EHR manager).

Initiatives to improve infrastructures. Participants ($n = 13$) stated that awareness of EHR limitations had resulted in a substantial investment in a research-enabling data platform. Participants described the platform as a 'sidecar' to the EHR, containing real-time shadow EHR data, but curated for research purposes, enabling data access, and computational

tools to be tested. It was described as a major asset: one participant stated the organisation was 'ahead of the crowd because we've got the platform' (Technology specialist). Participants believed, however, that the organisation's capacity to support imaging data research was not strong. Several participants ($n = 9$) expressed significant frustration at this, due to its expected clinical and research potential. A major reason for this shortfall, several participants stated, is inadequate technical infrastructure. Current IT systems for imaging data were described as 'collapsing' (Health informatics specialist) and insufficient for managing large data sets. Participants throughout the organisation identified this as an issue requiring urgent action.

Standardisation was foregrounded by some participants ($n = 4$) as a major element in building digital and computational capabilities. There had been 'a massive implementation of SNOMED-CT' within the organisation (Health informatics specialist 1), which a senior leader described as 'one of [its] strengths' (Medical director 1).

Technological capability criteria for IR. Participants' accounts of technological capability thus suggest that IR is enhanced when there is (1) widespread and systematic use of an integrated EHRs; (2) an integrated research data platform for EHR and similar health data; (3) integrated IT systems for the collection, storage and use of medical imaging data for research; and (4) adoption of relevant international standards to facilitate interoperability.

Organisational agility

Many participants are involved in intra-organisational committees, groups and workstreams aimed at implementing the data-driven research hospital vision, and hence, these were discussed in detail.

Intra-organisational initiatives. Participants ($n = 25$) felt that the organisation had made beneficial changes to support intra-organisational collaboration. Participants referred to the recently established Digital Directorate that enables board-level oversight of digital and computational initiatives. It also aims to 'bring together the research and the operational aspects' (Medical director, 2) into decision-making. It encompasses groups and committees with representation from organisational units involved in performance and planning, EHR operations, information governance, research support, and a recently formed health research informatics unit. This unit, supported by the BRC, was also described by participants as a major intra-organisational mechanism. Thus far, it has produced the research enabling data platform 'sidecar' (described above) and a new governance process for digital data access (discussed below). As noted above, however, some participants ($n = 17$) felt that there was some uncertainty about how the initiatives of the unit and Digital Directorate worked within a coordinated strategy. One participant remarked 'it's just not clear what people are doing in different bits of the system' (Clinician academic 3). Such uncertainty was generally described as a reflection of the pioneering nature of such initiatives.

New professional roles. Many participants ($n = 22$) described the importance of recently established roles: the Chief Nursing Informatics Officer (CNIO) and Chief Research Information Officer (CRIO) – the former reporting to the Chief Nurse and the Digital Director and the latter to the Digital Director and the Research Director. The benefit of the CRIO, CNIO and also the Chief Technology Officer, as one participant described, is that highly skilled people were 'genuinely moving across all of those sectors and understand[ing] them' (Clinician academic 3). However, several participants with detailed knowledge of the roles ($n = 5$) worried that these and other critical roles could become overburdened with responsibilities and areas of focus, resulting in bottlenecks. One participant stated, 'everything has to flow through [them]…but at the end of the day… [their] bandwidth is limited… it has been a block' (Clinician academic 2).

Tensions between research and clinical priorities. Participants ($n = 38$) also voiced concerns that intra-organisational collaboration could be hindered by a general scarcity of resources and the need to focus on immediate clinical care. One participant stated, 'it's all about resources, and if you can choose…the priority is always care' (Clinician & informatics specialist). It is therefore essential to somehow 'protect the research space' and ensure its 'separation but not isolation' from care (Clinician IT specialist 1). For this reason, the Digital Directorate has been tasked with identifying how to align business-as-usual operations with research while ensuring a protected space for research and innovation.

New governance approach. Participants ($n = 21$) felt that the organisation has demonstrated an ability to support new organisational processes aimed at building computational capability, an example being the recent establishment of a research support platform for data-based research. This includes a 'data concierge' to guide researchers through approval processes, a data access group with cross-organisational representation to assess the suitability of data requests, and a data ethics committee with authorisation to undertake ethical review of data research proposals. Its establishment was motivated by frustration among senior leaders, research-active clinicians, and academics about the difficulty of accessing digital data from the organisation.

Greater organisational change. Many participants ($n = 18$) stated that, in the long term, the successful realisation of a data-driven research hospital would require more

comprehensive changes throughout the organisation, beyond these intra-organisational initiatives. One senior leader stated that it would ultimately require 'everybody working together… it truly is a collective and no single team can do it' (Clinician IT specialist 2). Senior leaders felt that such a collective sense of endeavour is possible, despite the complexity of the organisation. This organisations' response to the COVID-19 pandemic had demonstrated the following: 'people had a single mission', and this had the effect of 'break[ing] down the silos… reducing the bureaucracy' (Clinician IT specialist 2).

Organisational criteria for IR. Overall, participants' accounts suggest that an organisation has a greater degree of IR when it has the following: (1) intra-organisational mechanisms for identifying problems, sharing learnings and coordinating responses; (2) implemented new organisational systems to address known technological, governance and other challenges; and (3) a demonstrated capacity and willingness of staff to adapt to new demands and challenges. Overburdened staff in key intra-organisational roles and the necessity of maintaining business as usual operations in a resource-constrained environment threaten organisational agility.

Talent and skills

Participants discussed the suitability of existing IT expertise within the organisation, opportunities for training and professional development, digital literacy, and the skills required to translate computational approaches into the clinic.

Existing IT expertise and associated challenges. The health research informatics unit was described by participants ($n = 22$) as an important hub of multidisciplinary expertise from the organisation and the university, as demonstrated by its construction of the research data platform. Participants ($n = 11$) also described the importance of the EHR IT team, as its ongoing optimisation of the EHR system is necessary to support the advancement of computational capabilities in the near future. Participants with IT oversight ($n = 13$) roles described two challenges. The first is IT staff retention. Nationally there 'isn't a large pool of pre-trained people' (Medical director 2) and the organisation has recently 'lost between 15 and 20 from our 50-strong configuration team' to other organisations (Medical director 2). Staff had been replaced, but 'it takes a while to get them back up to the same level of capability' (Medical director 2). The second challenge was a lack of capacity to fully optimise the EHR system. Undertaking 'business-as-usual' system maintenance took so much time that there was little capacity for undertaking more innovative refinements. One IT leader described it, 'we are not under-resourced, but are we resourced enough to meet the ambition?… I suspect the answer is no' (EHR manager).

Digital literacy and opportunities for training. Participants ($n = 9$) described the significance of a digital workforce task force (established within the Digital Directorate) for improving digital and computational capability. Specific initiatives include nurturing an EHR 'expert community': a group of around 30 senior clinical EHR experts advising other clinical staff on how to maximise the EHR system. The task force is also focused on improving general digital literacy, so that they can understand 'what is possible through information and why it is important to get data into the system accurately' (Medical director 4). This basic level of literacy is 'not there yet', and hence a digital literacy training programme had been established. One senior leader stated that long-term organisational support for such training is essential: it can take years 'for things to really start motoring' (Medical director 4).

Translational research expertise. Several participants ($n = 5$) described the necessity of what could be defined as translational research expertise. This refers to an understanding of how to translate computational tools into a clinical environment. They stated that it requires a detailed understanding of the tool, and importantly, the context in which it will be used, so that 'you work out what is actually going on… how we translate that into interventions that are going to work' (Clinician academic 3). Participants delineated features of translational research expertise: the capacity to work in interdisciplinary initiatives (academics, clinical staff, administrative staff and patient representatives) and familiarity with research methods that enable close examination of workflows and clinical contexts (e.g. ethnography, interviews, focus groups).

Talent and skills criteria for IR. Based on participants' accounts of talent and skills, an organisation can be described as having a greater level of IR when it has the following criteria: (1) sufficient specialist IT staff to run and optimise core platforms; (2) opportunities for clinical staff to foster and share their computational-relevant competencies; (3) mechanisms to improve the general digital literacy of staff; and (4) expertise in translational research approaches that align promising new computational tools with clinical workflows and priorities.

Collating the institutional readiness criteria for building digital and computational capability

The accounts of senior leaders and innovations engaged in building digital and computational capability within the organisation thus revealed a number of criteria relating to each of the four domains. These are presented in Table 1.

Discussion

The transformation of healthcare will require hospitals to participate in the development and implementation of

Table 1. Institutional readiness (IR) for advancing data-driven healthcare and research within hospital organisations.

Domain	Criteria
Organisational vision	Building digital and computational capability is reflected in the organisation's strategic vision
	The vision is in accordance with the general aspirations and values of staff
	The vision has been operationalised into strategies and work plans with short & medium-term goals and targets
	Strategy aligns with day-to-day priorities of frontline staff
Technical capability	Organisation-wide use of an integrated electronic health record system
	IT infrastructure enables access to and use of EHR data for research
	IT infrastructure enables access to and use of medical imaging data for research
	Adoption and systematic use of international data standards
Organisational agility	Intra-organisational collaboration mechanisms convene relevant expertise to identify problems, coordinate approaches and share learnings
	Establishment of novel organisational systems that address impediments to the development of computational approaches.
	Workplace culture, capability and willingness to adapt to evolving demands and conditions
Talent and skills	Specialised IT expertise to develop, maintain and optimise key data platforms
	Opportunities for clinical staff to develop and leverage their expertise in IT and/or computational approaches
	Mechanisms to improve general digital literacy of staff
	Specialist expertise in translational research approaches that facilitate engagement between clinicians and researchers

digital tools and computational approaches. As hubs of clinical activity, hospitals have the unique potential to generate large quantities of data required to develop and validate digital and computational tools. Additionally, given their critical role in the provision of healthcare and their significant economic operational costs, healthcare systems have much to benefit from the implementation of digital and computational systems within hospitals that can, ideally, reduce their operational costs and improve the precision of interventions. Here we have identified criteria that can sensitise hospital leaders and innovators to the factors that can facilitate the implementation of digital tools and computational approaches.

Our focus is on a hospital organisation's IR for advancing its digital and computational capability, and we have identified IR criteria related to the domains of organisational vision, technical infrastructure, organisational agility, and talent and skills (see Table 1). Many of the criteria identified here align with the findings of recent studies examining the implementation of specific digital or computational tools, such as the importance of a clear implementation strategy, senior-level support, end-user clinician attitudes, interoperable data architectures, and a detailed awareness of clinical contexts.[25–32] This hospital organisation case study approach provides an opportunity to explore the tensions that emerge as complex, resource-constrained hospitals embark on building their general computational capabilities.

The criteria identified reflect the findings from one case study and should not be seen as an exhaustive list: undertaking further case studies and using different methods (e.g. surveys) will generate additional IR criteria. Nevertheless, an awareness of these criteria and associated challenges can assist other senior leaders and innovators to advance digital and computational capability in their organisations.

This case study illustrates, for example, the importance of having a long-term strategic vision for the organisation that explicitly includes a commitment to building digital and computational capabilities. Within the case study organisation, this took the form of the data-driven research hospital vision. Building computational capability thus has

board-level support and is less likely to be sidelined by other priorities. Our findings also illustrate the importance of translating visions into work plans that outline short- and medium-term objectives. As scholarship in healthcare management has noted, such objectives and clear work plans function to focus resources and serve as success indicators to gauge progress.[31,33–34]

The case study illustrates the importance of intra-organisational committees and working groups. The Digital Directorate has been an important means for bringing together clinical, operational, IT, and research support expertise needed to identify and manage specific technological and organisational hurdles. The importance of CRIO and similar roles for advancing digital and computational capability has been described elsewhere.[35–36] Here we see that having joint reporting lines for the CRIO and CNIO supports collaborative linkages across the organisation. The findings also illustrate the need for strategies to prevent valuable boundary-spanning roles from becoming overburdened. Overall, the intra-organisational committees, working groups and roles have enabled some organisational agility, as demonstrated by the creation of new organisational systems (e.g. the data research platform) to address identified challenges.

The challenges presented by variable levels of digital literacy among staff and poor IT staff retention are well-known.[29,37–39] The case study suggests that building and maintaining general data literacy should be approached as both an immediate priority and a long-term endeavour. Hospitals should also enhance and clarify their value proposition as a workplace for IT staff to improve retention. In order to foster a reservoir of clinicians with computational-relevant expertise (such as EHR optimisation, health informatics/bioinformatics, machine learning & AI), organisations should consider establishing expert clinical communities and establishing training routes such as clinical data research fellowships. The case study also highlights the importance of fostering translational research expertise, among clinicians and academics, such as expertise in qualitative methods to obtain an in-depth understanding of clinical contexts. The importance of such expertise and qualitative methods for bridging the 'bench to bedside' has been noted in other areas of translational medicine.[40]

The criteria identified here also reaffirm the importance of clear intra-organisational communication for meeting strategic goals.[31,34,41] Any organisational strategy to build computational capability needs to be clearly communicated in a manner that conveys coherence and coordination to facilitate a widespread sense of collective endeavour. Targeted communication can also raise awareness among frontline staff that their day-to-day work, particularly their engagement with EHR systems, contributes to the operationalisation of the data-driven research hospital.

This exploration of IR has also identified tensions that will likely have relevance for many organisations with similar visions. The promise of the data-driven research hospital is that digital tools will enable better integration between 'business-as-usual' clinical services and operational improvement and research. The reality, however, is a tension between providing care in a context of highly constrained resources, and the need to enhance operational and research-enabling infrastructures and systems. As with many public healthcare systems, the NHS is beset by ongoing staff shortages and funding constraints, with many hospital organisations running at a deficit.[42] Any resourcing to enhance operational or research infrastructures – such as the establishment of boundary-spanning roles or a community of clinical experts – could be swallowed up by 'business-as-usual' activities. A strategy aimed at building digital and computational capabilities will need to identify ways of keeping research-enabling and operational-enhancing resources protected from severally stressed clinical services. Another tension relates to unrealistic expectations among staff regarding the impact of EHRs. In the case study hospital, some staff including senior leaders failed to recognise the considerable investment needed to realise the vision. The hype surrounding digital and computational medicine is well-known,[43–45] and the risk is that it could undermine the advancement of digital and computational capacity as resources are directed elsewhere.

The establishment of a data-driven research hospital innovation champion is one way in which resourcing for building computational capability could be protected. Such roles have been advocated by commentators to accelerate high-impact innovation in the NHS more generally.[46] Unlike other senior leaders with remits that include (and whose focus could easily be subsumed by) business-as-usual operations, the innovation champion's sole or primary leadership role would be to spearhead the implementation of the strategic vision. The role would function to provide coordination across various digital and computational initiatives described in general terms here and to strengthen collaborations with external academic and industry partners. It would therefore need to be a role with a sufficient level authority to engage with senior leaders across the various directorates and units of the organisation.

In conclusion, this paper presents the findings of a qualitative exploration of a hospital organisation's initiatives to advance its computational capability. Using IR as an analytical framework, we have identified IR criteria related to organisational vision, technological capability, organisational agility, and skills and training that bear on an organisation's capacity to function as a partner in the development of computational tools and approaches, as well as an early adopter of computational tools and approaches. We have illustrated the tensions that arise as busy, resource-constrained healthcare providers struggle to maintain business-as-usual clinical services while also investing in operational-enhancing and research-enabling initiatives.

Awareness of the IR criteria and tensions outlined here can guide other organisations in implementing and developing their own strategies for advancing computational medicine.

Limitations of the study

The findings of this study emerged from interviews with a particular group of purposively-sampled professionals, many of whom are deeply involved in the initiatives and activities aimed at building computational capability within one organisation. Hence, the findings presented here regarding the suitability of technical, organisational, governance and other systems to support the building of computational capability are based on the perspectives of participants who have a professional interest in advancing computational and digital systems. Future research on IR criteria for digital and computational medicine should include a wider array of organisational case study sites, and also a wider array of participants, including frontline health professionals who are not directly involved in overseeing or administering digital innovation activities.

Data availability statement: The data that support the findings of this study are available from Monash University, Melbourne, but restrictions apply to the availability of these data. The data for this study are interview transcripts, and in alignment with common practice relating to qualitative studies of this type, transcripts are not publicly available, as full transcripts may enable the identity of participants to be inferred.

Author contributions: JG, DH, and NMN designed the study that forms the basis of this article. JG devised the conceptual ideas and undertook the data collection. JG wrote the article with input from all authors.

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