Defining the enablers and barriers to the implementation of large-scale healthcare related mobile technology: a qualitative case study in a tertiary hospital setting

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Abstract

Background: The successful implementation of clinical smartphone applications in hospital settings requires close collaboration with industry partners. A large-scale hospital-wide implementation of a clinical mobile application for healthcare professionals developed in partnership with Google Health and academic partners was deployed on a Bring Your Own Device (BYOD) basis using mobile device management (MDM) at our UK academic hospital. As this was the first large-scale implementation of this type of innovation in the UK health system, important insights and lessons learned from the deployment may be useful to other organisations considering implementing similar technology in partnership with commercial companies.

Objective: The aims of this study were to define the key enablers and barriers, and to propose a ‘roadmap’ for the implementation of a hospital-wide clinical mobile application developed in collaboration with an industry partner as a data processor and an academic partner for independent evaluation.

Methods: Semi-structured interviews were conducted with high-level stakeholders from industry, academia and healthcare providers who had instrumental roles in the implementation of the application at our hospital. The interviews explored participant’s views on the enablers and barriers to the implementation process. Interviews were analysed using a broadly deductive approach to thematic analysis.

Results: In total, 14 participants were interviewed. Key enablers identified were the establishment of a steering committee with high-level clinical involvement, well-defined roles and responsibilities between partners, effective communication strategies with end-users, safe information governance precautions and increased patient engagement and transparency. Barriers identified were the lack of dedicated resources for mobile change at our hospital, risk aversion, unclear strategy and regulation, and the implications of BYOD and MDM policies. The key lessons learned from the deployment process are highlighted and a roadmap for the implementation of large-scale clinical mobile applications in hospital settings is proposed.

Conclusions: Despite partnering with one of the world’s biggest technology companies, the cultural and technological change required for mobile working and implementation in healthcare was found to be a significant challenge. With an increasing requirement for healthcare organisations to partner with industry for advanced mobile technologies, the lessons learned from our implementation can influence how other healthcare organisations undertake similar mobile change and improve the chances of successful widespread mobile transformation.

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Abstract

Background
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Conclusions
Despite partnering with one of the world’s biggest technology companies, the cultural and technological change required for mobile working and implementation in healthcare was found to be a significant challenge. With an increasing requirement for healthcare organisations to partner with industry for advanced mobile technologies, the lessons learned from our implementation can influence how other healthcare organisations undertake similar mobile change and improve the chances of successful widespread mobile transformation.
Introduction

The implementation of mobile technologies into hospital workflows have the potential to significantly improve patient safety, transform healthcare delivery and positively impact patient outcomes.[1] Although there is widespread agreement about the importance and potential benefits of mobile technologies to tackle critical challenges in healthcare, successful implementation of this emerging technology into clinical settings has proved to be challenging.[2-4] In the National Health Service (NHS), the deployment of hospital-wide clinical mobile applications in secondary care is still uncommon despite the ubiquity of smartphone ownership amongst healthcare professionals (HCPs).[5, 6] HCPs continue to use their own smartphones in hospitals for daily clinical tasks including communication amongst teams, accessing clinical applications (apps) such as decision support aids or medical calculators, and for educational purposes.[7-10] Whilst medical apps are freely available to download from ‘App Stores’, there has been limited deployment of hospital-wide clinical mobile apps for HCPs in the NHS.

Streams (Google Health, London, UK) is a multi-functional smartphone application displaying a range of patient clinical information that has been implemented on a ‘bring your own device’ (BYOD) basis at our hospital (Imperial College Healthcare NHS Trust (ICHNT)). Streams was iteratively developed by a multidisciplinary team of researchers, clinicians and developers in a tripartite partnership with DeepMind Health / Google Health[11] and Imperial College London. This partnership was initiated as part of ICHNT’s goals to be one of the most digitally mature organisations in the NHS and one of 16 Global Digital Exemplar (GDE) providers in the UK.

The ambition was to process and display routinely collected clinical results onto clinician’s own smartphone devices through integration with the hospital’s existing information systems and the electronic health records (EHR) (Cerner (Cerner Corporation, Kansas City, USA)). Streams was developed for use on iOS devices only as it had been demonstrated that 75.6% of doctors and 58.4% of nurses at our institution used an iOS device.[5] Streams was registered with the Medicines and Healthcare Products Regulatory Agency (MHRA) as a Class I, non-measuring, non-sterile medical device under the EU Medical Device Directive (1993). The implementation of the Streams app at our hospital began in early 2019 with a small pilot group of clinicians. Further development of the app and instigation of mobile device management (MDM) software ensued before widespread deployment commenced in January 2020 with the app available to all HCPs across each hospital site.
within the organisation.

Before Streams was implemented at our hospital, a limited version of the app had been deployed in a focused capacity at another London-based hospital network (Trust) to aid HCPs in the detection and management of acute kidney injury.[12] This deployment attracted significant public and media interest due to an investigation by the Information Commissioner’s Office (ICO) into the nature of data processing between the Trust and the industry partner.[13-15] In a separate initiative that learnt from these well publicised issues, a wide-scale implementation of the Streams app was undertaken at our hospital. To the best of our knowledge, this was the first large-scale hospital-wide deployment of a BYOD clinical smartphone application using mobile device management (MDM) technology in the NHS. As such, the implementation process has delivered important insights into the opportunities and challenges of delivering this type of innovation to the NHS and health systems more widely.

In light of previous experiences, the difficulties encountered and the ‘lessons learnt’ from this deployment may be generalisable and applicable to other healthcare organisations that are considering working with industry partners as data processors to deploy similar mobile technology and academic partners to independently evaluate these interventions. Therefore, the aim of this study was to characterise the key enablers and barriers, and to propose a ‘roadmap’ for the implementation of a hospital-wide clinical mobile application developed in collaboration with an industry partner as a data processor and an academic partner for independent evaluation.

Methods

Design

Semi-structured interviews were conducted individually with study participants at a single time point. An in-depth literature review was undertaken to identify implementation and change management frameworks applicable to digital health interventions. These findings fed into the creation of a structured topic guide which drew heavily from the “Digital Change in Health and Social Care” document published by The King’s Fund in 2018.[16] This seminal report highlights five key areas to consider when undertaking digital change implementation in healthcare: leadership and management, user engagement, information governance, partnerships, and resourcing and skills. These areas formed the domains upon which the enablers and barriers were characterised upon.
Participants and sample size

Participants were purposively recruited,[17] following a key informant strategy,[18] to ensure that a well-informed, representative sample of staff members were obtained from all participating stakeholders who were involved in the implementation of the Streams app. These were predominantly members of the Streams Steering Group (SSG) which consists of academics, clinicians, and technicians from ICHNT, Institute of Global Health Innovation at Imperial College London (ICL) and Google Health (GH).

The total number of individuals who were involved in the implementation process was small, which unavoidably restricted the number of interviewees. The sample size was guided by repeated assessments of the emerging data, and in line with international consensus guidance and previously published work.[19, 20] Whilst the sample was necessarily heterogeneous to ensure sampling of all the various roles in the steering committee, the wider research team agreed that the dataset was adequate for the stated objectives to be met.[21] In total, sixteen members of the steering committee were invited to participate in the study through email, with fourteen members consenting to be interviewed. All three participating organisations were adequately represented. Each participant was interviewed once. The mean duration of each interview was 35.53 minutes (SD 12.36 mins), and in total 497 minutes of audio recordings were transcribed for analysis.

Data Collection and Analysis

All interviews were conducted online with the participants alone over Microsoft Teams video-conferencing software (Microsoft Corporation, Redmond, WA, USA). An audio recording was made of the interviews which were then transcribed verbatim. All interviews were conducted by a single male researcher (RA) who is a practising medical doctor and conducted the study as part of a wider research project. The interviewer took field notes during the interview which were used to adapt the interview guide depending on the verbal responses given.

A broadly deductive approach to data analysis was employed,[22] with the topic guide adapted, as noted, from the King’s Fund “Digital Change in Health and Social Care”[16] document which formed the basis of an initial pre-defined coding framework and thus a consistent focus for interpretation. The analysis was conducted by two independent researchers (RA and SV). After
familiarisation with the data, an iterative process of coding and indexing was adopted to ensure that important aspects of the data were not missed from the pre-defined coding framework. A working analytical framework was developed and applied to the coding of all transcripts. The coded data was then charted to emerging themes which were then summarised into the framework matrix. All data was coded, indexed and charted using NVivo for Mac v.12 (QSR International, Melbourne, Australia).

**Ethical Considerations**

Ethical approval was granted for this study by the Joint Research Compliance Office (JRCO) at Imperial College London under the Science Engineering Technology Research Ethics Committee (SETREC) process (Reference: 20IC5854). Informed consent was taken from all participants. All data was de-identified for the purposes of analysis with each individual interview identified by an alphanumeric code. Participants are only acknowledged by their organisation to avoid the identification of specific participants.

**Results**

The reported enablers and barriers to the implementation of Streams at ICHNT are described across the five key themes in successful digital change management. \[16\] The development of overarching themes and sub-themes are summarised in Table 1 and Figure 1.

| Leadership and management | Enablers | Barriers |
|---------------------------|----------|---------|
|                           | • Steering Group  <br> • Clinical involvement at leadership level  <br> • Motivation and champions for change | • Shifting prioritisation  <br> • Unclear strategy and roadmap  <br> • Risk aversion |
| User Engagement | • Communication and engagement with end-users  <br> • Testing and feedback | • Adoption challenge  <br> • Not device agnostic  <br> • Functionality and iterative development  <br> • Covid-19 |
| Information Governance | • Data processing and information sharing  <br> • Data protection and security  <br> • Patient engagement and transparency | • Difficulties in data extraction  <br> • BYOD policy and MDM  <br> • Regulation |
| Partnerships | • Collaborative working groups  <br> • Defined roles and responsibilities | • Siloed working  <br> • Partnership model |
| responsibilities | Resourcing and skills | • Dedicated project manager | • Personnel | • Investment | • Expertise | • Training and support |

**Leadership and management**

The involvement of senior leadership within the implementation process helped with decision making, highlighted the importance of the project within the organisation and helped to motivate other key stakeholders in the process. Amongst the enablers identified was the establishment of the SSG consisting of key stakeholders and leaders from all three organisations including the Chief Clinical Information Officer (CCIO), Caldicott Guardian, and Medical Director from the Trust, UK Lead and Project Managers from Google Health and the Chief Scientific Advisor at the university partner. The SSG met every 6 weeks with an over-arching remit to manage the project with decision making by consensus. Clinical leaders were also recruited to the SSG and were able to act as champions for change amongst clinical teams:

“I think the steering committee overall worked well. It had sort of senior people from both parties that met on a regular basis. I think it was important that there was that senior buy in […] the senior people from both parties regularly engaged, despite busy schedules.” (Participant 13, GH)

“There’s a lot of clinical involvement and I think that ends with a product that is, at its core, clinically safe and has clinical utility.” (Participant 7 GH)

Barriers identified at a leadership level included shifting prioritisation of the project competing with a myriad of other IT projects ongoing at the hospital which affected the amount of dedicated resource allocated:

“I think because Streams was not a key clinical system […] you would not expect streams to be prioritized over other key clinical systems, obviously.” (Participant 13 GH)

An unclear strategic framework for deployment, risk aversion and extensive due diligence caused by the alliance with the high-profile industry partner were also identified as barriers:
“What there wasn’t was almost that strategic framework within which to sit it, and I think we were both to blame for that, and actually possibly had either side pushed the other one a bit harder on that, that would have helped, but I think we were both a bit amateur on that front.” (Participant 1 ICHNT)

User Engagement

Multiple strategies were trialled in an attempt to engage end-users to participate in the implementation process. Enablers identified were the broad range of communication and promotional activities utilised to drive uptake including attendance at routine clinical meetings and inductions, regular emails from various sources and visual media placed around the hospital. Involving clinicians with testing and feedback sessions at an early stage of the change process also helped:

“So on the whole that was good, the amount of feedback that we got back. And it helped iterate the product.”

(Participant 14 GH)

Barriers identified were the adoption challenge where the system was opt-in and was not integral to any clinical workflows. This was partially due to the limited functionality of the app when first deployed and slow iterative improvements and updates during the development cycle. Moreover, the app was solely available on iOS devices and therefore the potential user base was restricted:

“I think ultimately the user base is driven by the utility of the product. If the product is super useful and provides value, then people will use it. Any limitation in the number of downloads, in my mind, always reflects back to the core value offering of the product.” (Participant 7 ICHNT)

“I think also, in many cases, I think a lot of clinical users can be quite tech averse. And maybe that’s from previous experience through your existing systems they’re currently having to use. So there can be that barrier around, this is just going to have to be another thing that I’m going to have to use and it's almost coming at it from a “you need to show me the value before I actively engage in helping use this, I don’t want it to be another burden on my clinical time.” (Participant 12 GH)

Information Governance

Collaborating with industry partners as data processors raised information governance issues during
this implementation process. Extra governance and precautions were required due to the public interest and scrutiny in the partnership, with proactive engagement with external bodies such as the Information Commissioner’s Office (ICO), National Data Guardian and organisational legal teams:

“We had to jump through more hoops, and we had to be a little bit more careful, because normally we’d have a process where we can sign off on systems and suppliers in a fairly straightforward manner. We tend to only engage with the ICO and National Data Guardian if we think there’s a major problem.” (Participant 8 ICHNT)

Respondents commented that data protection and security aspects were handled well especially during the migration of the data centre to a cloud platform, despite the significant delays it caused to the implementation process:

“I think it’s the rigour of the processes that we put in place around our information governance and I think we do have a very strong information governance capability within the organisation. I think it’s been working collectively through that, but inevitably these things take time, don’t they?” (Participant 6 IHCNT)

Comprehensive patient engagement was also identified as an enabler:

“We need just to make sure that we were on board with the right messaging and we were engaging with all of the right partners, in addition to the public. We went out to the public in a number of different ways just to make sure we were transparent and in good faith, and really clear on the intent.” (Participant 9 ICHNT)

Difficulties in data extraction and assessing data quality from the EHR and the regulatory burden were noted to be barriers with effects of delaying the implementation process. This involved extensive engagement over many months with a large number of clinical, technical and legal stakeholders at the Trust to review data processing agreements and assess the quality, accuracy and safety of data being processed:

“I think there was probably maybe slight frustrations on both sides [with regards to delays], but I think there was also recognition that we need to get this completely right, and it was much better to be delayed […] than go fast and have another cycle.” (Participant 2 GH)

Furthermore, issues with BYOD policies and a change in plan midway through the development cycle to require an MDM solution for extra security was also noted to have delayed the
Partnerships

Mutually reinforcing partnerships can help organisations with digital change. The working practises between the partners were frequently commented on by respondents. Enablers identified were the technical, implementation, user engagement and clinical collaborative working groups that convened weekly and were established to oversee specific aspects of the project.

“We've had a formal governance arrangement in place, which has built into it a series of meetings for different groups. We've got a Streams steering group that has met every six weeks. We've had a technical working group that has met fortnightly. We've had a programme management weekly meeting, and we've had very well-defined attendees and good regular attendance from the right people for those meetings. That has got us into quite a good cycle of good communication for particular areas.” (Participant 5 ICHNT)

Well defined roles and responsibilities between partners were also established. The technical expertise of Google Health team members was utilised to develop and implement the app. Respondents felt that this was not something that the Trust would be capable of doing unilaterally:

“I think most health systems and NHS organisations are, 'We should go out and partner with start-ups and established companies,' and I think that's the right approach.” (Participant 2 GH)

The established link and connections between the Trust and the University was used to engage academic experts to the implementation process. This enabled rigorous continuous evaluation and benefits realisation of the app:

“The university, particularly in this setting, were clinician scientists who have a feel for both the clinical practice and also the research.” (Participant 11 ICL)

Barriers were identified as occasional siloed working practises amongst partners causing delays in the implementation and making the partnership model feel like a traditional supplier-client model.
rather than the development partnership that was envisaged:

*If you want a development partner, you have to work in a much more integrated, collaborative manner, and they don't do that at the moment. They go away with an idea. They say they've done a lot of thinking, and this is what they're planning to do, [...] We need to be a development partner.* (Participant 8 ICHNT)

**Resourcing and skills**

The ability of an organisation to support mobile transformation is dependent on the resources and skills involved in the project. The presence of a dedicated full-time project manager to oversee day-to-day running of the deployment was a key enabler in this process:

> “I think what really helped was appointing a project manager at the Trust whose principal responsibility was to bring all the different competing teams at the Trust together, and act as a single point of contact and project manage it.” (Participant 3 ICL)

> “I really feel like the project management at Imperial is very good and it’s often not the organisation or the project management that’s lacking, it’s just it takes a long time because there isn’t enough resource to actually do some of the work that the project manager is organising.” (Participant 7 GH)

However, respondents noted that the project manager was the only dedicated resource at the Trust and therefore a major barrier was the lack of personnel, investment, expertise, training and support to help with the implementation process:

> “I think if we’d have more resource we could have moved more quickly and we might have realised more of the original scope. I think it’s been resource-constrained” (Participant 6 ICHNT)

**Lessons Learned**

The implementation of mobile technology and working with commercial partners in NHS organisations has been a significant challenge. The key lessons learned from this process are described in addition to a proposed roadmap for the implementation of clinical mobile technology developed with commercial partners at scale. These are illustrated with temporal relationships in *Figure 2.*
Leadership and management

- **Clarify the ‘problem to solve’**
  
  Be specific about the clinical problem that needs solving and assess at an early stage whether this problem can be ameliorated by mobile technology. This will help to create a shared vision across the organisation.

- **Make the system a priority**
  
  Create a sense of urgency in the organisation by making the deployment a priority amongst the leadership and end-users.

- **Steering committee with senior key stakeholders and clinical involvement**
  
  Establish a board level steering committee comprising of high-level key stakeholders to guide the implementation. They should act as a decision making body and build consensus around the strategic vision. This should include clinical leaders such as the CCIO and deputy CCIO’s which will help to engage other clinicians and aid with dissemination.

- **Clear roadmap and strategy**
  
  Implementation strategies need to be tailored to organisational circumstances and should be well planned, allowing room for flexibility in timelines.

- **Embed programme into existing organisational structures**
  
  Ensure that mobile change is implemented as a key part of the organisation’s digital transformation, rather than as an isolated project and that it is interoperable with other systems already in place.

User Engagement

- **Choose a system that is fit for clinical practice and focused on end-users**
  
  The system being deployed needs to be usable and effective for clinicians. It should fit into existing clinical workflows to improve quality of care or efficiency. The value of the system should be demonstrated to clinicians to warrant adoption.

- **Make system universal**
  
  Choose a system that can be universally adopted. It should be device /operating software agnostic and offer functionality that will be useful to multiple clinical user groups.

- **Involve end-users in the change process**
  
  Give end-users a sense of ownership over the change process and involve them in the iterative development of the product. A clinical user group should be established as a forum to discuss new features and contribute to user acceptance testing and local champions should be enlisted. A variety of communication strategies to engage with end-users to promote the system and ensure adoption
should also be used. The strategy should be linked with wider Trust communications to help distribution of promotional material.

- Continuous feedback to evaluate and inform iterative development

It is essential to capture user feedback about the system and respond in a timely manner. An agile, rapid turnaround should be targeted for iterative development to demonstrate to end-users that their feedback is being regarded.

**Information governance**

- Proactive engagement with governance and regulatory organisations

If required, pro-active engagement with the ICO and other regulatory bodies is recommended to ensure that all data processing, data security and regulatory guidance is adhered to. Data processing, particularly if undertaken by industry partners should be transparent and within legal boundaries.

- Consider BYOD and MDM policies at early stage

BYOD and MDM policies should be formulated to ensure security and privacy with widespread mobile implementation. If MDM is chosen, investment for the software will need to be considered. Tackling staff perceptions and attitudes towards MDM on personal devices will also need to be explored further before MDM is widely accepted.

- Identity and certification

The product should be embedded into the digital ecosystem at the NHS organisation. The system should be made secure by utilising existing active directories for account creation and role-based access permissions.

- Patient engagement

Be open and transparent with patient and public groups about the nature of the partnership and data processing and security aspects.

**Relationship between partners**

- Collaborative working groups with defined escalation pathways

Clinical and technical workstreams with defined roles and responsibilities should be established. These working groups should have defined terms of reference and clear escalation paths.

- Frequent communication between partners at all levels

Frequent and effective communication channels between partners should be established to instil a ‘one-team’ culture.
• Decide on ‘partnership’ model or ‘procurement’ model
Appraise the nature of the partnership with the commercial supplier and decide whether a customisable system or an ‘off-the-shelf’ system is required.

• Partner with academic institutions to perform formal evaluation
Pre-existing links with academic institutions should be utilised for continuous independent evaluation and benefits realisation.

Resourcing and skills
• Dedicated project manager to drive through vision and acting as key point of call
Appoint a dedicated project manager who focuses on all activities related to clinical implementation. They should act as the key point of call to liaise with all stakeholders to help overcome any barriers.

• Dedicated clinical implementation and technical teams
Ensure that resource is available for dedicated clinical implementation and technical teams within the NHS organisation to support the implementation process.

• Investment in personnel and expertise
Investments should be made for specialist expertise that may be required, personnel to aid implementation, training of staff and on-going support.

Discussion
Principal findings
This study sought to (1) identify the enablers and barriers to widespread implementation of mobile technology in an NHS Trust and (2) to formulate an implementation roadmap from the experiences and perspectives of those leading and heavily involved with the change management process. In doing so, key enablers and barriers and the implementation roadmap were mapped onto five overarching themes that encompassed all of the crucial aspects of the digital change management process: leadership and management, user engagement, information governance, partnerships and resources and skills.[16]

We identified that despite the implementation occurring in a Global Digital Exemplar (GDE) NHS Trust with world-class IT infrastructure,[23] in partnership with one of the world’s biggest technology companies and with strong support from an array of key stakeholders, the cultural and
technological change required for mobile working and implementation in healthcare was a significant challenge. Widespread deployment of the mobile app was pursued at our organisation; however multiple barriers and hurdles were encountered along the process. These barriers were acknowledged to have either contributed to delays in the implementation or decreased the adoption of the app amongst end-users. The key barriers identified were:

- **Delays to implementation**: shifting prioritisation, risk aversion, instigation of MDM policies and investment for software, problems with data quality and data extraction from the EHR, limited resources at the Trust and the migration of data storage to a cloud-based platform.

- **Decreased adoption**: limited functionality of the app that did not integrate into clinical workflows and was not clinically useful for large proportions of the workforce, the tardiness of iterative development and responding to feedback, and the fact that the app was not device agnostic.

By considering the experiences and perspectives of key stakeholders of overcoming the aforementioned barriers, together with the enablers that were recognised to be present within the partnership, we have proposed a novel implementation roadmap for mobile technology deployment at scale. This roadmap highlights the key lessons learned which may act as a blueprint for multi-stakeholder scoping processes at healthcare organisations considering mobile transformation. This may help to avoid some of the commonly encountered pitfalls and improve the likelihood of successful implementation of mobile technology.

This study also identified and exposed some of the difficulties NHS organisations may encounter if working with industry partners for digital change. With regards to Streams at ICHNT, added transparency about the partnership was required due to the media scrutiny and public interest.[24] This high-profile partnership led to some risk-aversion on behalf of the NHS organisation, however the implementation of the General Data Protection Regulations (GDPR) and proactive engagement with regulators provided a secure backdrop for data processing. Furthermore, the relationship between the Trust and the industry partner was recognised as a development partnership rather than a supplier-customer partnership.[25] With this type of partnership being relatively novel and all partners having different ways of working, it is perhaps inevitable that frustrations were noted about the levels of collaborative working and the alignment of goals between the partners.

Although mobile change shares much similarity with digital change, it comes with its own unique
challenges.[26, 27] In this study, whilst many of the barriers can also be applied to digital change, additional mobile-specific barriers were identified such as the adoption challenge, and privacy and security concerns related to HCPs using their own smartphones for clinical use. Long-held beliefs about the appropriateness of mobile phones in hospital settings may be a further barrier.[28, 29] This is particularly relevant with the prospect of HCPs using their personal smartphones for clinical use on a BYOD basis. This strategy can blur the lines between professional and personal use of smartphones, potentially creating conflicts that could arise related to their use on the wards or when off-site.[30] Furthermore, BYOD raises governance, information security and patient confidentiality issues[27] which must be addressed. MDM software can be a solution to these concerns due to their ability to enforce security policies and secure devices,[31] however implications such as the loss of control and privacy felt by staff, and the financial investment required by the organisation with this system may not be universally acceptable. Other options including ‘hardening’ the security of the app through features such as two factor authentication and geolocation could be considered if MDM is not appropriate.[32] Overcoming these barriers is important to ensure widespread acceptability of mobile devices in clinical settings and requires increased awareness amongst both HCPs and patients as to the benefits of these technologies.

Whilst the cultural barriers may take further time and resource to overcome, there does now appear to be extensive and widespread progress in overcoming the technical and information governance barriers to mobile change identified in our study. The introduction of GDPR in Europe has defined the legal framework around data processing, and guidance from NHSX[30] and the MHRA[33] has defined the current regulatory framework. The new EU Medical Device Regulation, to be implemented in 2021, will re-define the regulatory framework with more stringent and specific protocols for various types of medical device software and mobile apps.[34] A mobile technology investment toolkit was also recently published by NHS Digital which provided practical tools and resources for IT leads to deploy mobile technology.[35] Furthermore, the difficulties encountered in our study with data extraction, sharing and interoperability will be alleviated with increased utilisation of Fast Healthcare Interoperability Resources (FHIR) (a new international standard for healthcare data formats and elements).[36]

With increasing digital technology being introduced into the healthcare space and the potential introduction of advanced data-driven technologies, it is inevitable that NHS organisations will need to continue to work with commercial and industry partners to develop and implement interventions.
This is now accepted and the NHS relies on numerous strategic partnerships to improve outcomes and deliver its ambitions in all fields.[37] These partnerships need to transparent and comply with legal, regulatory and ethical boundaries[38] to ensure that the partnership is acceptable to patients and that they can trust it. However, the approach of technology companies in the health sector can be challenging as successful methods that have be used in other industries may not be appropriate in the regulated and necessarily risk-averse healthcare space. Maximising new partnerships with technology companies require the development of innovative interventions, the agile deployment of solutions in clinical environments, and ongoing evaluation and iterative development to improve the product.[39] Whilst more traditional medical device companies are limited in the speed of introducing products to market due to the time taken for design, safety testing, manufacturing and efficacy trials, technology companies may lack these restraints and lean towards rapid iteration and updates to evolve and improve products. This can create opposing views on the balance between careful evaluation and thorough evidence-based principles versus rapid technology development and fast product cycles that need to be addressed.[40] Tension with other partners such as academic institutions may also ensue as comprehensive evaluations of a novel intervention inevitably take time and added cost which must be accounted for in the product roadmaps of commercial companies.

**Limitations**
The study was limited to a single NHS hospital and the implementation of a single clinical mobile application. Whilst this inevitably will influence the perspectives of the interviewees and many of the findings will be related to local contextual factors, we believe that the broad sample of key stakeholders interviewed and robust qualitative analysis identified issues that are generalisable to the implementation of other mobile technologies in hospital settings. The sample size and heterogeneity of participants was unavoidable due to the limited number of key stakeholders and members of the SSG suitable for inclusion in the study. However, purposeful sampling was used to ensure that a representative cross-section of the SSG were included in the study. Furthermore, we accept that there will be a bias with members of the SSG reviewing its own role in the implementation process. Viewpoints of end-users of the application were not explored to compare and provide a “top-to-bottom” view of the mobile change management process. Lastly differences across different healthcare settings, hospitals and departments were also not explored in this study.
Conclusion

The implementation of mobile technology in healthcare and working with commercial partners has been a significant and complex challenge for NHS Trusts. With the requirement of more industry partnerships for advanced mobile technologies in the future, the findings of this study should influence how other organisations undertake similar mobile transformation and improve the probability of successful implementation and widespread adoption. By overcoming the cultural and technological barriers identified and by observing the proposed roadmap, future deployments of mobile health technology in healthcare settings could be facilitated and have a greater chance of success.

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Conflicts of interest

AD is Chair of the Health Security initiative at Flagship Pioneering UK Ltd.

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Figure 1 – Thematic map for semi-structured interviews demonstrating developed sub-themes and overarching core themes
Figure 2 - Proposed roadmap for large-scale hospital-wide mobile implementation
Supplementary Files
Figures
Thematic map for semi-structured interviews demonstrating developed sub-themes and overarching core themes.
Proposed roadmap for large-scale hospital-wide mobile implementation.
CONSORT (or other) checklists
COREQ checklist.
URL: http://asset.jmir.pub/assets/a9e4f4618d1b43f868b2af80e2a5ab9f.pdf