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Abstract

Problem Direct application of digital health technologies from high-income settings to low-and-middle-income countries may be inappropriate due to challenges around data availability, implementation and regulation. Hence different approaches are needed.

Approach Within the Viet Nam ICU Translational Applications Laboratory project, we are developing since 2018 a wearable device for individual patient monitoring and a clinical assessment tool to improve dengue disease management. Working closely with local staff at the Hospital for Tropical Diseases, Ho Chi Minh City, we developed and tested a prototype of the wearable device. We obtained perspective of design and use of the sensor from patients. To develop the assessment tool, we used existing research data sets, mapped workflows and clinical priorities, interviewed stakeholders and held workshops with hospital staff.

Local setting In Viet Nam, a lower middle-income country, the health-care system is in the nascent stage of implementing digital health technologies.

Relevant change Based on patient feedback we are altering the design of wearable sensor to increase comfort. We built the user interface of the assessment tool based on the workshop attendees selected core functionalities. The interface was subsequently tested for usability in an iterative manner by the clinical staff members.
Lessons learnt The development and implementation of digital health technology need an interoperable and appropriate plan for data management including collection, sharing and integration. Engagements and implementation studies should be conceptualized and conducted alongside the digital health technology development. The priorities of end-users and understanding context and regulatory landscape are crucial for success.

Introduction

Artificial intelligence and digital health technologies are improving clinical services and are facilitating the decentralization of health care. Within low- and middle-income countries, opportunities in applying these innovations are rapidly becoming realized for diagnostics, patient monitoring and aiding clinical decision-making. However, significant barriers to implementation remain, including data sharing and individual rights to privacy, algorithmic bias, end-user interpretability and accountability. To date, research addressing these barriers has mainly been conducted in high-income settings and direct application of these findings to low- and middle-income health-care settings is often inappropriate, given significant differences in context and resource availability.

Here, we share our experience in conducting multidisciplinary research for the development and implementation of digital health technologies in Viet Nam. We outline challenges encountered and describe specific findings around real-world implementation. Our approaches and methods are applicable to similar settings and provide insights on design considerations from a low-and-middle-income country perspective.

Local setting

In Viet Nam, a lower middle-income country, opportunities exist to apply artificial intelligence and digital health technologies to improve health outcomes, especially for many infectious diseases, which exert significant burdens on the health-care system. The Vietnamese health-care system is in the nascent stage of implementing digital health technologies. For example, electronic medical records are being introduced for routine clinical use. In contrast with high-income settings where electronic medical records data is routinely generated, availability of such data in our setting is limited. While information on heterogeneity between health-care settings exists, care pathways, strategic health system priorities, infrastructure and capacity for individual settings remain poorly characterized, hampering the estimation of resources required and the development of an implementation plan of new digital health technologies.
Approach

The Viet Nam ICU Translational Applications Laboratory (VITAL) project, funded by the Wellcome Trust, started in 2018. The project aims to reduce morbidity and mortality from infectious diseases by using innovative technology and clinical approaches to improve the management of critical care. This multidisciplinary project is a collaboration between the Hospital for Tropical Diseases and Oxford University Clinical Research Unit in Ho Chi Minh City, Imperial College London, University of Oxford and other partners. The implementation site is the 550-beds public Hospital for Tropical Diseases, which is a referral centre for infectious diseases for the south of Viet Nam.

As a part of the project, we have been conducting research and implementation studies to investigate the role and utility of novel digital health technologies for improving the management of dengue, a major public health issue in Viet Nam. Our work includes the development of a novel wearable and an artificial intelligence-driven electronic clinical decision support system, namely D-SCAPE (dengue severity classification and prediction wearable) and D-CAT (dengue clinical assessment tool), respectively.

In collaboration with engineers at Imperial College London, we developed a wearable prototype measuring physiological parameters relevant for dengue. We tested the prototype on 50 dengue patients admitted to the implementation hospital and we explored patients’ perspective of design and use of the sensor. We also collected physiological data from 250 hospitalized dengue patients with different severity grades using a commercial wearable named SmartCare (SmartCare Analytics, Oxford, England) to develop artificial intelligence models for dengue physiological monitoring.

The development of the assessment tool consisted of training and testing artificial intelligence models alongside implementation work, which included landscape exploration, user interface design and stakeholder usability testing. To develop the artificial intelligence predictive algorithms, we used existing research data sets, including pooled data from 8000 Vietnamese patients collected over 19 years. Concurrently, we conducted a multistage qualitative study to better understand existing health-care pathways and the possible impact of the interventions on these pathways. First, we mapped workflow and clinical priorities in our setting to characterize differences in management between patient cohorts which could affect deployment.
organized 10 in-person interviews and two workshops with hospital staff who directly care for dengue patients to explore their perspectives towards dengue and their needs and desired functionalities of tools for improving disease management. We used the information obtained to guide the system frontend design. Finally, we conducted 50 separate observations of 15 clinicians to evaluate the usability of the assessment tool.

We engaged with hospital stakeholders during the project’s conceptualization phase as well as throughout the project operation. We also actively attended digital health technology workshops to engage with governmental authorities and policy-makers including the Vietnamese health ministry.

**Relevant changes**

We are working on refining the designs of the digital health technologies in our project. Based on patient feedback we are altering the wearable sensor to increase comfort. After the participants of the workshop had selected the core functionalities of the assessment tool, we built the user interface, which subsequently was tested for usability in an iterative manner by the clinical staff members.

**Lessons learnt**

**Data**

Despite of the potential use of artificial intelligence models developed from pooled data, we found seasonality and disease prevalence affected our model performance. These findings highlight the need for continuous data collection methods to sustain model performance for dengue tools. As the data availability and quality issues hindered the application of automated pipelines for data collection, pre-processing and sharing in our project, we emphasize the importance of strengthening the capacity for electronic medical records transition and interoperability. We are therefore facilitating the upgrade of current hospital electronic medical records to comply the HL7 Fast Healthcare Interoperability Resources, an international industry standard, which will facilitate health data exchange across different systems.

Furthermore, we acknowledged the use of large secondary data set for model development could introduce hidden biases that are difficult to detect and account for in our models. While patient diversity and large cohort size from pooled data were beneficial in
providing a representative sample over time, the narrow scope and homogenous nature of research data can adversely affect the downstream generalizability and real-world performance of artificial intelligence models.\textsuperscript{9} We are therefore continuing to refine our models using data from our prospective ongoing studies to validate the clinical utility and generalizability, and to reduce biases. Furthermore, population groups underrepresented or excluded in research data represent significant challenges to address health inequity.\textsuperscript{10} Therefore, continuous real-world evaluation is needed to ensure clinical utility and improve the performance through continuous learning.

\textbf{Implementation}

New digital health technologies need to be sustainable, pragmatic, interoperable and aligned with existing health-care processes,\textsuperscript{11} as well as solving real-life problems that matter to the population. To ensure that the project fulfilled these points, we discussed with stakeholders before the implementation and conducted several activities throughout the development of the digital health technologies. Interviews with individual health-care workers around decision-making processes during the development revealed insights about its usability of the clinical decision support systems, and the need to balance clinical usefulness and digital complexity of the tool. Clinician highlighted that digital health technologies should not significantly alter existing pathways in terms of data entry and patient flow.\textsuperscript{7} As process mapping revealed different patient flow between adult and paediatric patients, the implementation of the assessment tool should thus have flexibility according to age of the patient.\textsuperscript{7} Data entry to two electronic systems (hospital electronic medical record and the assessment tool) would discourage uptake of the new tool in clinical practice. We therefore recommend developers of digital health technologies to consider strategies for system integration into existing electronic medical records to maximize uptake and sustainability. Furthermore, to increase long-term uptake, we asked about patients’ perceptions towards the wearable sensor and we learnt that the patients and their relatives expressed concerns that its use would reduce interactions with health-care workers. Although digital literacy and the role of technology in many low-and-middle-income country settings are increasing at a significant pace, better understanding of attitudes towards digital health technologies is needed. An implementation research approach is therefore crucial in any digital health technology project, and should ideally run alongside development of the technology to better guide the iterative development and delivery.
During the project we had difficulties in recruiting local artificial intelligence researchers, hence local research capacity needs to be boosted through collaboration with local academic institutions as well as investment in higher education. Another important and complex challenge to the viability of many digital health technology projects in low-resourced settings is the migration of digital practitioners to high-income settings.

**Regulation**

Recent released policies focusing on enhancing electronic medical records interoperability, picture archiving and systems to support communications between health-care bodies,\(^{12}\) provide an opportunity to develop digital health technologies within our setting. These policies facilitate the digital transformation, by increasing data availability and interoperability between systems. We engaged with governmental authorities and policy-makers, including the health ministry, early on in our project to better understand the priorities and infrastructure investment. We found that policy-makers were receptive to our experience and supported plans on future roll-out.

Artificial intelligence-enhanced applications in health care can only create impact providing they exist within a legal and regulatory framework. Understanding these environments is important in facilitating collaboration and safeguard users.\(^4\) In Viet Nam, we have found that the availability of local guidelines supporting development of novel digital health technologies is limited. Adapting existing guidance on artificial intelligence developed in high-income settings can provide important insights,\(^{13,14}\) although all stakeholders involved need to be cognizant of the relevance and direct applicability of these guidance. Given the fast pace of digital health technology development in Viet Nam, it is important to have a formal, iterative process led at the national level, to capture local needs and develop necessary regulations.\(^{12}\) At the same time, heterogeneity between individual health-care settings requires that sufficient support and expertise are available for local bodies (such as research ethics committees) for evaluation of novel digital health technologies.

The project is still ongoing and the next steps in our dengue work package are to refine the design of wearable sensor based on feedbacks from patients, validate the artificial intelligence models embedded in the assessment tool and further explore potential pathways for regulatory submission.
The lessons learnt (Box 1) from our project, as well as the challenges and potential solutions in applying digital health technologies (Table 1) in Viet Nam could be useful for other settings in low- and middle-income countries. We suggest that challenges specific to low- and middle-income countries need to be explicitly considered and often require a different approach than replicating or extrapolating the solutions from the high-income countries. Application of artificial intelligence and digital health technologies requires development of digital infrastructure, placing local health-care workers and stakeholders at the centre of the implementation process and co-development of regulatory frameworks across different relevant bodies.

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**Competing interests:**

None declared.

**References**


Box 1. Summary of main lessons learnt

• An interoperable and appropriate plan for data management including collection, sharing and integration is important.

• Engagements and implementation studies should be conceptualized and conducted alongside the digital health technology development.

• The priorities of end-users and understanding context and regulatory landscape are crucial for success.
Table 1. **Challenges and potential solutions in applying digital health technologies, lessons from Viet Nam**

<table>
<thead>
<tr>
<th>Challenges, by stage</th>
<th>Potential solutions</th>
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<tbody>
<tr>
<td><strong>Data and development</strong></td>
<td>• Strengthening capacity for data collection and ensuring system interoperability</td>
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<tr>
<td>• Limited data availability for model</td>
<td>• Multidisciplinary collaboration (clinical, data science, information technology)</td>
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<tr>
<td>development</td>
<td>for development work, support local workforce development and retention, specific</td>
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<tr>
<td>• Ensuring representative data is</td>
<td>focus on addressing model bias</td>
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<td>available and model fairness</td>
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<tr>
<td><strong>Implementation</strong></td>
<td>• Co-design of interventions with focus on integration and minimising disruption to</td>
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<tr>
<td>• Difficulties to integrate digital</td>
<td>workflow.</td>
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<tr>
<td>health technologies in existing health-</td>
<td>• Better understanding of health care context through methods including process</td>
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<tr>
<td>care systems</td>
<td>mapping and human-centred design</td>
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<tr>
<td>• Enhancing uptake and behaviour change</td>
<td>• Interventions targeting digital literacy and engagement with relevant communities.</td>
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<td>• Addressing concerns of end-users and</td>
<td>Involve local institutions and policy-makers during public engagement</td>
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<td>bodies regarding familiarity of using</td>
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<tr>
<td>digital health technologies in local</td>
<td></td>
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<tr>
<td>settings</td>
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<tr>
<td><strong>Legal and regulatory framework</strong></td>
<td>• Initial adoption of existing guidelines while collaborating with stakeholders to</td>
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<tr>
<td>• Lack of artificial intelligence</td>
<td>continuously re-evaluate their relevance to local setting</td>
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<tr>
<td>governance capability and local expertise</td>
<td>• Adoption of flexible frameworks and early engagement in intellectual property to</td>
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<tr>
<td>• Limited experience with intellectual</td>
<td>ensure clear understanding of rights between stakeholders</td>
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<tr>
<td>property</td>
<td>• Sharing experiences with regulatory bodies and using research findings to inform</td>
</tr>
<tr>
<td>• Varying digital ecosystem maturity</td>
<td>and co-develop policies relevant to the setting</td>
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