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Towards Equitable and Resilient Digital Primary Care Systems: An International Comparison and Insight for Moving Forward

IMIA Primary Care Informatics Working Group

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Summary

Objective: While the COVID-19 pandemic provided a global stimulus for digital health capacity, its development has often been inequitable, short-term in planning, and lacking in health system coherence. Inclusive digital health and the development of resilient health systems are broad outcomes that require a systematic approach to achieving them. This paper from the IMIA Primary Care Informatics Working Group (WG) provides necessary first steps for the design of a digital primary care system that can support system equity and resilience.

Methods: We report on digital capability and growth in maturity in four key areas: (1) Vaccination/Prevention, (2) Disease management, (3) Surveillance, and (4) Pandemic preparedness for Australia, Canada, and the United Kingdom (data from England). Our comparison looks at seasonal influenza management prior to COVID-19 (2019-20) compared to COVID-19 (winter 2020 onwards).

Results: All three countries showed growth in digital maturity from the 2019-20 management of influenza to the 2020-21 year and the management of the COVID-19 pandemic. However, the degree of progress was sporadic and uneven and has led to issues of system inequity across populations.

Conclusion: The opportunity to use the lessons learned from COVID-19 should not be wasted. A digital health infrastructure is not enough on its own to drive health system transformation and to achieve desired outcomes such as system equity and resilience. We must define specific measures to track the growth of digital maturity, including standardized and fit-for-context data that is shared accurately across the health and socioeconomic sectors.

Keywords

Primary care, digital health, maturity, health systems, COVID-19

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1 Introduction

Much has been written about how the COVID-19 was the push needed for digital health expansion at a global level [1, 2]. Digital health models emerged that offer promise for more robust health delivery systems going forward. However, we also know that health systems are learning health systems and our goal must be to develop a health system that is sustainable in the long term and not to simply to develop tools or approaches to manage COVID-19. To that end, we know that the digital response to COVID-19 has also generated unintended consequences, including equity issues and uneven access to healthcare services [3-5]. To develop health delivery systems that are equitable for everyone we need to focus on the entire spectrum of system components and not just the technology aspect.

Digital health maturity refers to the structured way that behaviors, structures, and processes are aligned to reliably achieve desired outcomes from the use of digital health [6]. Digital health maturity models enable us to monitor and track the progress of digital health solutions over time so that we can create positive health outcomes while mitigating any unintended consequences. The COVID-19 pandemic and its resultant public health measures and social restrictions (including periods of local and national lockdown) led to a global acceleration in the uptake of digital care delivery models. Virtual care tools such as telehealth enabled

core micro level tasks like home monitoring, virtual health assessments, medication review, education and support for patients and families and coordination between family doctors [7-8]. At a macro level, digital health tools and methods effectively supported essential tasks like disease surveillance and contact tracing [9].

While digital health solutions were essential in supporting regional, national and global responses to COVID-19, the benefit from these solutions were not shared equally across all populations. Negative unintended consequences (UICs) including inequity issues and uneven transition of some tasks to digital format were commonplace [10-12]. UICs often occur during and post health information technology (HIT) implementation [13, 14]. However, we cannot focus on technology as a direct cause of UICs and instead need to assess the respective contributions and of social, policy and organisational factors and their myriad interactions [15-17]. Designing health systems that are resilient and equitable for all citizens is not a one-time task but rather an ongoing one that requires a learning health system approach [18]. A digital health maturity lens enables systems design that considers how digital health capabilities and competencies are developed over time as a precursor to building a resilient and equitable health system.

Relevant to primary care was that the pandemic-mediated move to virtual care did not benefit all citizens equally but rather certain communities such as those with socioeconomic risk factors were underserved by comparison and suffered more adverse outcomes overall [19-20]. Similarly, uneven development of digital tools and capacity created adverse outcomes because of partial or underdeveloped virtual care models [21]. Our global desire to develop a digital primary care system cannot only focus on technology but rather must provide a systematic approach for the design of a resilient and equitable primary care system [22]. Digital health interventions can worsen existing health system inequities [23]. This trend was observed during COVID-19 where digital inequities led to poor health outcomes [24]. Other system factors including social, political, and human resource factors must be co-designed with the technology used to support healthcare transformation [15]. While the configuration and design of resilient and equitable health systems is a universal goal, we need to make sustained incremental progress to get to this goal. Gathering evidence on how digital health tools are adopted and implemented into primary care delivery over time is an essential first step to achieving our overall goal [25].

This paper from the IMIA Primary Care Informatics Working Group (WG) provides necessary first steps for the design of a digital primary care system that can support system equity and resilience. We use the concept of digital maturity to study the growth of primary care informatics during the COVID-19 pandemic. We look at digital health capacity in primary care in three countries (Australia, Canada, England) before and during the COVID-19 pandemic to understand how digital healthcare has evolved and how we can continue to build resilient and equitable primary care systems. We then use our analysis to offer a set of recommendations for developing digital primary care capacity to support resilient and equitable primary care delivery.

2 Methods

We based our study on a digital health maturity conceptual framework, comparing maturity in the influenza and COVID-19 domains. The WG consensus was to report digital capability and growth in digital maturity in four key areas: (1) Vaccination/Prevention, (2) Disease management, (3) Surveillance, and (4) Pandemic preparedness. We review each of those categories across four foundational aspects of digital health maturity: essential IT infrastructure, essential digital tools, readiness of information sharing and readiness of health system/enabling environment, drawing upon a digital health maturity framework [6]. Our data sources for the work came from a variety of publications, reports, government documents and websites in the three countries.

Our first level of analysis looks at each of the four digital maturity categories for seasonal influenza management prior to COVID-19 (2019-20). We then carry out the same analysis for the digital health capacity that emerged during COVID-19 (winter 2020 onwards), with an emphasis on the differences between influenza and COVID-19. We provide a synopsis of each country followed by a discussion that provides global comparison across the three countries.

3 Results

Our results are first presented at a country level with data tables for Australia, Canada, and the United Kingdom (data from England). We then provide a synopsis for each country followed by an integrated discussion.

3.1 Australia

Table 1 describes Digital Health Maturity Foundations by Prevention/Vaccination, Disease Mx, Surveillance & Pandemic preparedness for Australia with a comparison between influenza in 2019-20 and the COVID-19 pandemic (winter 2020 and beyond).

Australia Synopsis

Australia has a national digital health strategy, released in 2017, that is focused on development of digital health capability and integration within the health system, to support the availability, exchange and quality of health information, and its subsequent use to support innovative models of care. (https://conversation.digitalhealth.gov.au/australias-national-digital-health-strategy). A key element is a national online, personally-controlled, shared health summary, called My Health Record (mHR) [26]. Australian GP data repositories include POLAR [27] and MedicineInsight [28]. The Australian Sentinel Practices Research Network (ASPREN) is a network of sentinel general practitioners and nurse practitioners who report de-identified information on Influenza like illness and other conditions seen in general practice (https://aspren.dmac.adelaide.edu.au/).

The Australian National Framework for Communicable Disease Control (https://www1.health.gov.au/internet/main/publishing.nsf/Content/ohp-nat-frame-communic-disease-control.htm)

Table 1 Digital Health Maturity Foundations by Prevention/Vaccination, Disease Mx, Surveillance & Pandemic preparedness for Seasonal Influenza and COVID-19 in Australia.

Seasonal Influenza (pre COVID)				
Response category	**Essential IT Infrastructure**	**Essential Digital Tools**	**Readiness of Information Sharing**	**Readiness of Health System/Enabling environment**
Vaccination / Prevention	▪ National broadband network is robust and reliable, ensuring connectivity of primary care vaccination sites (GPs & pharmacies); ▪ Inequitable access and affordability a problem with rurality and disadvantaged groups.	Unique ID system: ▪ Individual health Identifier (IHI) – linked to the Medicare number (which is not necessarily unique); ▪ A national system of identifying individual practitioners (HPI-I) and the organisations they deliver care from (HPI-O); ▪ A national program of secure key certificates for transferring information.	Two national platforms: ▪ Australian Immunisation register (Compulsory use) ▪ MyHealth Record. Subnational platforms ▪ ASPREN Flu vaccine effectiveness data combined with hospital ED data to publish annual estimate (exc 2020, 2021); ▪ SAFESIG – monitoring of vaccine adverse events; ▪ AusVaxxSafety: https://ausvaxsafety.org.au/	▪ Regulations for cybersecurity and various DH challenges exist at both Federal and State levels. ▪ All federal and state MOHs have training programs; ▪ The Australian Digital Health Agency (ADHA) is coordinating DH related training programs nationally; ▪ No completely inclusive enterprise-wide architecture or platform at state or federal levels or between levels of care.
Disease management	National Broadband Network	Telemonitoring apps for NCDs (pre-mainstreaming for spread and scale). Not as many apps for ID monitoring.	My Health Record as well as local eHR solutions in general practice. (eHR use less common in community health or hospital sectors)	National vertical NCD programs and disease registries
Surveillance		ASPREN surveillance of pathology testing (uses LOINC)	State influenza surveillance programs are combined into fortnightly Australian Influenza Surveillance Report through the NISS.	Two sentinel systems : ▪ Flutracking, online syndromic survey & vaccination status; ▪ National Health Call Centre Network. ▪ Social media monitoring e.g. EpiWatch: https://www.epiwatch.org/
Pandemic Preparedness	NA	A number of untested COVID-prompted tools which may not be fit for purpose and sustained into the long term.	▪ National Influenza Surveillance Committee (NISC); ▪ National Interoperable Notifiable Diseases Surveillance System (NINDSS); ▪ ASPREN; ▪ FluCAN Healthdirect; ▪ Flutracking; ▪ WHO Collaborating Centre for Reference and Research on Influenza; ▪ Sentinel laboratory surveillance; ▪ State & Territory health surveillance reports.	Australian National Pandemic plan for influenza https://www1.health.gov.au/internet/main/publishing.nsf/Content/ohp-ahmppi.htm State level plans are available here: https://knowledge.aidr.org.au/resources/pandemic-plans/ CREID – Centre of Research Excellence in Emerging Infectious Diseases – Getting new technologies into public health practice
COVID-19				
Response category	**Essential IT Infrastructure**	**Essential Digital Tools**	**Readiness of Information Sharing**	**Readiness of Health System/Enabling environment**
Vaccination/ Prevention	National broadband network to ensure connectivity of vaccination sites – General Practices and pharmacies	Standardisation of nomenclature National reporting framework (with associated digital tools) to report vaccination status to AIR regardless of site	Two national platforms: ▪ Australian Immunisation register; ▪ MyHealth Record. Developed a national 'covidsafe app' that was a failure. PHN reporting platforms (e.g. POLAR, PEN) Standard reporting platform for funded GP respiratory clinics	State-commonwealth "disconnect & chaos" initially and still recovering "politically". National COVID-19 vaccination training program National response summarised here: https://www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert/government-response-to-the-covid-19-outbreak

Table 1 continued Digital Health Maturity Foundations by Prevention/Vaccination, Disease Mx, Surveillance & Pandemic preparedness for Seasonal Influenza and COVID-19 in Australia.

COVID-19				
Response category	**Essential IT Infrastructure**	**Essential Digital Tools**	**Readiness of Information Sharing**	**Readiness of Health System/ Enabling environment**
Disease management		▪ Development and deployment of ePrescribing; ▪ ePOE and requests (Path / Imaging); ▪ No nationally coordinated or endorsed EHR or telehealth tools; ▪ Prototype apps to support Hospital-in-the-Home programs available, developed de novo or repurposed existing home telemonitoring apps. Unclear about prototyping and evaluation.	Health Pathways for COVID-19 – PHN and LHD/LHN sponsored systems. However, the Federal-State divide is a challenge, though not as acute as the "detect and track" aspects State based ICUs do share data and clinical information. There is a national network for clinical trials) A national evidence based approach: https://covid19evidence.net.au	▪ National telehealth funding ▪ National appointment booking system ▪ National Call Centre to triage people with symptoms, provide advice and direct them to appropriate health services; ▪ Nationwide network of respiratory clinics based in the community to complement state- and territory-run fever clinics; ▪ Online infection prevention and control training for all care workers; ▪ Safeguard the health remote Aboriginal and Torres Strait Islander communities; ▪ Consistent messaging to primary care workforce.
Surveillance	IoT/ICT infrastructure to support monitoring of social media for early warning e.g, EpiWatch	▪ ASPREN ▪ PHN based tools e.g. POLAR https://polargp.org.au/polar-phn/) and PENCS https://www.pencs.com.au/	State based reporting systems merged into a national framework (National Interoperable Notifiable Diseases Surveillance System (NINDSS)).	There is now a national guideline for COVID-19 https://www1.health.gov.au/internet/main/publishing.nsf/Content/cdna-song-novel-coronavirus.htm
Pandemic Preparedness	▪ "Check in" apps; ▪ QR codes.	Various apps with no coordinated R&D program – private contractors with little transparency of the commissioning process.	Little interoperability (data and services) across the federal-state divide The NINDSS is a platform that underpinned the pandemic response. However, information sharing is in one direction: state to federal!	Four NHMRC funded Centres of Research Excellence (CRE): ▪ APPRISE https://www.apprise.org.au/ ▪ HOT NORTH – Improving Health Outcomes in the Tropical North – R&D to mitigate infectious tropical disease threats; ▪ PRISM2 – Policy Relevant Infectious disease Simulation and Mathematical Modelling http://prism.edu.au/; ▪ ISER – Integrated Systems for Epidemic Response – Systems research in biosecurity and epidemic response https://iser.med.unsw.edu.au/

is a foundation of the Australian Health Sector Emergency Response Plan for Novel Coronavirus (the COVID-19 Plan), which guides the Australian health sector response. (https://www.health.gov.au/resources/publications/australian-health-sector-emergency-response-plan-for-novel-coronavirus-covid-19). The Australian Technical Advisory Group on Immunisation (ATAGI) advises the Minister for Health on the National Immunisation Program (NIP) and other immunisation issues (https://www.health.gov.au/committees-and-groups/australian-technical-advisory-group-on-immunisation-atagi#members).

There was limited flu in Australia during 2020, which dropped away rapidly in March 2020 with virtually no flu about in 2021. POLAR showed an increase in influenza testing, as part of opportunistic testing for multiple viruses, with little positive identification of influenza. Eventually, GPs were advised to cease test requests for influenza as there just wasn't any. Little swabs were done in general practice because of financial losses from shutdown of practices for two weeks if a positive case was detected in the practice. POLAR data showed that over half the participating general practices in NSW and Victoria assessed symptomatic patients by telephone, variations on the car park consultation or through dedicated GP respiratory clinics established as part of the COVID-19 response. PPEs were provided to general practices via Primary Health Networks (PHN). However, the success varied according to variable quality of PHNs and supply chain. COVID vaccination was initially undertaken in Federal and state vaccination hubs and workplace. When general practice started in May 2021, they could only provide Vaxzevia (AstraZeneca). The AstraZeneca-Pfizer competition and an overly cautious ATAGI led to a lack of public confidence in Vaxzevia and people waited for emergency purchases of the Pfizer

vaccine to come about. GP vaccination rapidly became, with the state hubs, the main sources of vaccination. Interpretation of GP vaccination data requires an understanding of these developments.

The essential DH foundations are at various levels of maturity. The Internet Communication and Technology (ICT) and Internet of things (IoT) infrastructure are robust and reliable, but the issue of access and inequity is an issue especially from the rural and other disadvantaged patient and citizen perspectives. Similarly, primary care and general practice varied in their investments and maturity in their digital infrastructure. Government initiatives and funding for "telehealth" helped to a certain extent but reinforced existing strengths with the telephone rather than encouraged more video consultations.

A range of digital tools were available for use by patients and providers especially for telehealth and home telemonitoring in NCD contexts [29]. The AusVaxxSafety (https://ausvaxsafety.org.au/) program is an example of Pre-COVID vaccine safety monitoring. Many tools, including home telemonitoring apps were repurposed for use as standalones or as part of a COVID-19 response system to support community-based management of NCDs with or without COVID infections. Many funded COVID-specific initiatives failed amid controversial governance and funding arrangements by governments. The major question here is whether COVID-prompted development of new digital tools is fit for purpose and sustainable, highlighting the need for systematic evidence-based evaluation [30].

The National Interoperable Notifiable Diseases Surveillance System (NINDSS) is an example of health information sharing, but only in one direction (state to national). The transmission of data may be synchronous in some way in terms of acknowledging successful receipt and upload. The NSW Notifiable Conditions Information Management System (NCIMS) was significantly altered to accommodate the extra information collected for the surveillance of COVID-19, including every reportable COVID test. Surveillance information collected is largely guided by the national guideline (https://www1.health.gov.au/internet/main/publishing.nsf/Content/cdna-song-novel-coronavirus.htm). However, while the NCIMS captured every reportable COVID test, only aggregate counts were shared with the national department, not notifications. Also, daily reporting on notifiable diseases is usually a state responsibility, so the NINDSS would have required significant investment to achieve that for national COVID-19 daily reporting. Daily reporting was available to some PHNs, but not all. Weekly national surveillance meetings are held to discuss data field definitions and alignment across jurisdictions. The mandated use of the Australian Immunisation Registry (AIR) for COVID vaccinations also helped the ongoing national response.

Post-pandemic, the mHR can potentially enhance information sharing in the management of "long COVID" and monitoring of vaccination and vaccine safety. This requires good documentation culture and good health information sharing across the continuum of care and health services. The enabling environment evolved quickly, including appropriate regulations and policies as well as capacity building programs in R&D and training of health professionals and citizens. However, the quality improvement environment is less well defined despite a few Centres for Research Excellence funded for COVID-related topics.

3.2 Canada

Table 2 describes Digital Health Maturity Foundations by Prevention/Vaccination, Disease Mx, Surveillance & Pandemic preparedness for Canada with a comparison between influenza in 2019-20 and the COVID-19 pandemic (winter 2020 and beyond).

Canada Synopsis

Canada showed an acceleration of digital tools in response to the COVID-19 pandemic. A study from the Canadian Institute of Health Information (CIHI) showed marked increase in the delivery of virtual care by physicians between February and November 2020 (https://www.cihi.ca/en/health-workforce-in-canada-highlights-of-the-impact-of-covid-19/increase-in-virtual-care-services) in a study of five provinces. Micro level digital tools for ePrescribing, COVID-19 exposure and contract tracing, uploading of vaccination records, and remote monitoring apps were developed. Macro level digital tools that provided general information on symptoms of COVID-19 and public health guidelines were also common. However, Canada also had some challenges in its response to the pandemic. Many of the digital tools were pilot projects that have not been formally evaluated to assess the value and impact of their sustained use. The rapid jump to virtual care delivery also lacked the necessary training to effectively transition patients and providers to virtual care [10, 31].

A system level challenge in Canada was that while many jurisdictions had been developing virtual care tools such as telehealth systems prior to the pandemic, they had not anticipated the rapid uptake of virtual care due to the pandemic [10]. This resulted in short term issues such as a lack of consensus on privacy and other regulatory issues, as well as more substantial system issues such as a lack of access to timely data and inequitable access to broadband internet [32]. Essential IT infrastructure did not change between influenza management in 2019-20 and the onset of COVID-19 in winter 2020. While widespread broadband internet access is available in urban areas, rural areas may lack needed technical infrastructure for a digitally driven pandemic response. With respect to availability of broadband internet, equity issues related to affordability, insufficient digital literacy, and socioeconomic issues persisted in the response to COVID-19. Further, inequity issues related to digital health became worse, or at least had greater impact during the COVID-19 pandemic due to the closure or reduction of face-to-face care delivery during public health measures such as lockdowns.

The Canadian health system response to the COVID-19 pandemic also exacerbated existing system issues. One example is the digital divide. Racial and ethnic minorities and those impacted by social determinants of health issues had worse health and social outcomes than other population groups [19]. This issue was not caused by the pandemic per se but rather was an example of how digital health can manifest inequity and other system issues. The solution moving forward to is address system issues such as health and digital literacy and equity prior to a pandemic.

Table 2 Digital Health Maturity Foundations by Prevention/Vaccination, Disease Mx, Surveillance & Pandemic preparedness for Canada

Seasonal Influenza (pre COVID)				
Response category	**Essential IT Infrastructure**	**Essential Digital Tools**	**Readiness of Information Sharing**	**Readiness of Health System/Enabling environment**
Vaccination / Prevention	▪ Multiple national and regional providers enable broadband network to ensure connectivity of vaccination sites – General Practices and pharmacies; ▪ Access in rural areas can be problematic; ▪ Affordability a problem as is digital health literacy in some groups (e.g., elderly)	▪ Provincial and territorial implementation of healthcare services has a variety of tools for managing illness such as influenza; ▪ The Canadian Primary Care Sentinel Surveillance Network https://cpcssn.ca/ is a national network with partner nodes at the Provincial level; ▪ Individual provinces or territories have dedicated influenza resources – e.g. https://www2.gov.bc.ca/gov/content/health/about-bc-s-health-care-system/office-of-the-provincial-health-officer/current-health-topics/influenza-information	Information sharing is challenging within a province and more challenging across provinces	▪ Federal and Provincial health systems are not well configured to respond effectively to health system crises such as a global disease outbreak; ▪ A lack of a national information sharing architecture greatly hinders health system response and resilience
Disease management	Infrastructure largely dependent on individual settings such as EMRs in GP offices or hospitals	▪ A variety of digital health tools such as telehealth exist; ▪ Influenza vaccination can be booked online such as in individual pharmacies	Some provinces have provincial health record systems that enable viewing of data such as lab, prescriptions, and vaccination records – Alberta is one example: https://myhealth.alberta.ca/	A lack of real time programs hinders progress and response is very reactive rather than proactive
Surveillance	Varies across provinces and territories	▪ Federal level has 'FluWatch' national surveillance system – https://www.canada.ca/en/public-health/services/publications/diseases-conditions/fluwatch/2019-2020/annual-report.html#about ▪ Many provinces and territories have regional specific flu surveillance systems ▪ Sentinel Practitioner Surveillance Network https://www.publichealthontario.ca/en/health-topics/immunization/spsn provides reporting such as influenza vaccination effectiveness	Federal surveillance system is fed by data from the provinces and territories	Disconnect across the various surveillance initiatives prevents timely response to events
Pandemic Preparedness	Relied on existing infrastructure IT infrastructure	Unknown how existing influenza or telehealth tools scale up to support other outbreaks	▪ Information sharing exists with a mixture of proactive and reactive/ real time information; ▪ Contextual fit of information to patient and public health needs remains a key challenge.	Canadian Pandemic Influenza Preparedness (CPIP) Task Group developed a pandemic plan https://www.canada.ca/en/public-health/services/reports-publications/canada-communicable-disease-report-ccdr/monthly-issue/2018-44/ccdr-volume-44-1-january-4-2018/canadas-pandemic-plan.html

Table 2 continued Digital Health Maturity Foundations by Prevention/Vaccination, Disease Mx, Surveillance & Pandemic preparedness for Canada

COVID-19				
Response category	**Essential IT Infrastructure**	**Essential Digital Tools**	**Readiness of Information Sharing**	**Readiness of Health System/ Enabling environment**
Vaccination/ Prevention	Same dispersed landscape of broadband connectivity as for influenza. Equity issues with IT access relating to geographic location and socioeconomic status were amplified, as were issues related to digital health literacy	▪ Provinces and territories all developed COVID-19 resources ▪ Federal government created a one stop resource page for provincial or territorial digital resources https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/symptoms/provincial-territorial-resources-covid-19.html#a1	Vaccine procurement was done federally while vaccine management and distribution were at the provincial level	▪ The federal-provincial chasm led to inconsistent criteria for access by age-groups and for boosters; ▪ Plan for vaccine distribution did not exist and implementation varied across provinces and territories.
Disease Management	Relied on existing infrastructure and availability of internet and Bluetooth access to support digital tools	▪ Billing codes developed across all provinces to facilitate delivery of digital health; ▪ Increases in virtual care delivery was seen across several provinces https://www.cihi.ca/en/health-workforce-in-canada-highlights-of-the-impact-of-covid-19/increase-in-virtual-care-services; ▪ No nationally coordinated or endorsed EHR or telehealth tools but rather done in a piecemeal approach	Border restrictions at a national level were established and digital tools such as Arrive-Can that enabled uploading of quarantine https://www.canada.ca/en/public-health/services/diseases/coronavirus-disease-covid-19/arrivecan.html plans, vaccination records etc.	▪ No national strategy existed for managing core tasks as part of pandemic response. Essential needs like virtual care and how to bill for it had to be designed in real-time [10]; ▪ Once lockdowns and other restrictions began to lift, there was no real direction on what the balance of face-to-face vs virtual care should be going forward
Surveillance	A variety of tools were developed at federal, provincial, and territorial levels to track COVID-19. Daily reporting of COVID-19 cases and deaths was standard across the country	The federal government developed COVID Alert to notify people of potential exposure before symptoms developed https://www.canada.ca/en/public-health/services/diseases/coronavirus-disease-covid-19/covid-alert.html	▪ Not all provinces supported the federal app, creating data sharing issues. Alberta developed its own tracing app https://www.alberta.ca/ab-trace-together.aspx ▪ Statistics Canada at Federal level offers data driven reports of many outcomes of COVID-19 https://www.statcan.gc.ca/en/covid19	Widespread surveillance was not well configured ahead of time, but Federal and provincial/territorial health systems did quickly develop testing and reporting systems. Sustainable contact tracing remains a challenge.
Pandemic Preparedness	Limited planning on needed IT infrastructure and the digital tools needed to manage a pandemic.	Various apps or digital exist at provincial, territorial and federal levels but very little coordination between sectors. Scale up of existing tools is a challenge.	Lack of overarching data sharing plan and means of analysing data and cycling back new information to inform policy development and program delivery has been a significant challenge to a systematic pandemic response.	Overall, the Canadian health system was not ready to manage the COVID-19 pandemic from a digital health and health data perspective.

Canada certainly had some health system successes in managing the COVID-19 pandemic. The increased development and dissemination of digital health capacity such as virtual care delivery is one example. However, we have also had some failures related to digital health deployment and scale of digital health tools. We must ensure that we use the pandemic as a learning experience to continue to push the needle on digital health maturity.

The overarching challenge that Canada must overcome is a lack of system level pandemic planning that would drive core tasks such as data access and sharing, design and scale up of digital tools, consumer engagement and training, and monitoring of desired system outcomes such as equitable access to services. We also need to recognize that structural elements such as IT infrastructure will not on their own bring about desired system change. System structures must be complemented with the system behaviors that are needed to achieve meaningful progress towards a resilient and equitable Canadian health system.

3.3 United Kingdom (Data from England)

Table 3 describes Digital Health Maturity Foundations by Prevention/Vaccination, Disease Mx, Surveillance & Pandemic preparedness for England with a comparison between influenza in 2019-20 and the COVID-19 pandemic (winter 2020 and beyond).

UK (England) Synopsis

The NHS Long Term Plan [33] plainly states its intention to develop the digital maturity of the nation's healthcare ecosystem to achieve its ambitions for a coherent, paperless, and futureproofed NHS. Its flagship policies of disease prevention and care that is joined-up, personalised and increasingly community-based will only be accomplished through a robust digital infrastructure.

The UK government has a strong digital track-record to leverage, however, most notably regarding disease surveillance and response. The government has invested significant resource into sentinel networks, for example, and these have been tested and refined through several public health emergencies over the decades – most notably over the course of the COVID-19 pandemic and the concurrent circulation of seasonal illness. The unique centrality and consistency of the English healthcare system also lends itself well to executing these digital goals: here researchers, healthcare workers and civil servants alike can benefit from features including the NHS Number, NHS Staff ID and standardised SNOMED disease codification that collectively ensure data is rich, linkable, interoperable, and universally understandable. Furthermore, though sometimes accused of being labyrinthine, the centralised structure of the NHS means that the systems and standards that underpin healthcare provision are universal; they do not vary across localities as much as nations that bestow jurisdiction over both at the state-level.

In terms of digital maturity, England began the COVID-19 pandemic in a relatively strong position. However, several underlying factors have undermined the full digital-enablement of the NHS and its pandemic preparedness and response. Firstly, health data in general is tremendously complex and, even when presented via digital record and reinforced by robust disease surveillance, the signal it generates is still affected by the noise created by data incompleteness and inconsistency. Secondly, even though data linkage via unique patient or carer identifiers is easier than it might have been made otherwise, it has been unrealistic to expect clinicians to take on the bureaucratic burden of digitising their notes at the point of care and data is often lost to paper record as a result. Thirdly, a patient's vaccination history is often incomplete – especially for those performed annually, such as inoculation against seasonal influenza.

The extent to which the national government fully and effectively utilised whatever digital advantage they possessed during the COVID-19 pandemic has been debatable. There are several digitally enabled milestones and achievements to celebrate here, however, most notably the unprecedented coverage of testing and tracing mechanisms and the speed of vaccine discovery and roll-out. That said, there are still some criticisms that warrant discussion.

While the UK government's commitment to taking a digitally-enabled response to the pandemic was commendable, doing so through a mesh of public-private partnerships and emergency commissioning led to runaway expenditure; the full costs of which will not be known for some time and will likely hang heavy on the budget going forward. This over-reliance of private firms and consultants to meet the demands of the pandemic also often undermined previous due diligence measures, transparency standards, privacy regulations and even led to security breaches. The lack of coherence between the offerings that did emerge also often only served to exacerbate pressures on the NHS. Expensive mistakes were made – NHS Test & Trace will likely struggle to justify its current £37 billion price tag [34] – and the new systems and products that were instituted during the pandemic often forced many healthcare workers to return to paper-based working styles when they encountered digital teething problems. Furthermore, the unfortunate timing between the pandemic and the exit of the UK from the European Union demonstrated how vulnerable the functioning of the NHS was – both online and offline – to under-staffing and supply chain disruptions. All this has amounted to a major erosion of public trust, exemplified by the growing calls for an independent inquiry into COVID-19 related expenditure.

Finally, it remains to be seen whether the UK government will effectively repurpose the digital infrastructure, products and services that have emerged from the pandemic. There is a real opportunity for these to be absorbed into disease surveillance and pandemic preparedness efforts going forwards. Parallels could be made here to global cities' efforts to effectively re-engineer Olympic stadiums after the games have come to an end; considerable thought must be put in to ensure these developments do not become 'white elephants' – underused or obsolete constructions that only become cost burdens for the cities they call home. The digital infrastructure and maturity gains seen over the course of the pandemic – as arguably hit and miss as they have been – are just as liable to becoming white elephants unless considerable thought and care is put into their preservation and repurposing. For example, plans are currently underway to decommission the impressive Test and Trace network of case identification and contact tracing; it will be vital to think through how to pivot at least some of what has been created into early warning systems rather than dismantling this investment in its entirety.

A potential candidate for absorbing this pandemic infrastructure includes England's influenza surveillance and vaccine effectiveness sentinel network, the Oxford-Royal College of General Practitioners (RCGP) Research and Surveillance Centre (RSC) [35]. This nationally representative network of 1,900 general practices – a subset of which conduct virology and serological surveillance – could greatly benefit from the increased capabilities and capacity that infrastructure stood up for COVID-19 surveillance could provide. Here, virology and vaccine recording is still individually entered via different computerised record or test request systems; the more advanced IT systems created to combat COVID-19 would rapidly enhance the digital maturity of this network.

Table 3 Digital Health Maturity Foundations by Prevention/Vaccination, Disease Mx, Surveillance & Pandemic preparedness for England.

Seasonal Influenza (pre COVID)				
Response category	**Essential IT Infrastructure**	**Essential Digital Tools**	**Readiness of Information Sharing**	**Readiness of Health System/Enabling environment**
Vaccination / Prevention	▪ Communication infrastructure – for vaccination centres, primary care sites and community pharmacies; ▪ Supply chain disruptions ▪ Internet First Policy access to patient records, health data and diagnostic tools and health and care IT systems, services and applications granted online.	▪ Increased investment in wearable devices ▪ Unique NHS number – facilitates data linkage ▪ NHS App - a 'front door' to provide general medical advice, check symptoms and connect individuals with healthcare professionals via video and telephone consultations ▪ NHS Foundry – data collection, processing and visualisation platform	▪ GP Connect – allows authorised clinical staff to share and view GP practice clinical information and data between IT systems ▪ Summary Care Record - Test results flowing into GP records e.g. EMIS Health's Keystone product ▪ GP2GP – allows patients' EHRs to be transferred securely and directly between old and new practices ▪ Getting it right first time (GIRFT) – in-depth review of services to prevent replication of errors	▪ HoC Public Accounts Committee concerns over upcoming plans to develop IT infrastructure ▪ Exploring Virtual Ward approaches – building out care in the community ▪ What Good Looks Like - Support for Digital Transformation of integrated care systems ▪ The Health and Care Bill – promoting integration between health and social care services and simplified procedures for 3rd party suppliers ▪ Improvement Capability Building and Delivery Team ▪ Estates and Technology Transformation Fund ▪ Internet First Policy ▪ Public Cloud First Policy – Cloud solutions prioritised above non-Cloud based alternatives ▪ Digitally-enabled integrated health models – integrated GPs and dataflow as standard ▪ Developing 'Total Triage' models of care – online consultations as standard
Disease management	▪ Supply chain disruptions ▪ Internet First Policy	▪ Increased investment in wearable devices ▪ Electronic Prescription ▪ Unique NHS number ▪ Unique NHS Staff ID/ Electronic Staff Record ▪ Standardised codification via SNOMED CT ▪ Technology Enabled Care Services (TECS) - range of telemedicine platforms now available ▪ NHS Foundry ▪ e-Referral ▪ Secure Email (NHSmail) - is the national secure collaboration service for health and social care in England ▪ NHS Login – provides patients with a simple and secure point of access to multiple digital health and care services	▪ GP Connect ▪ Summary Care Record ▪ CareConnect Open APIs – support delivery of care by opening up data held across clinical care settings ▪ NHS Spine/ Spine Mini Service – digital central point allowing exchange of information across local and national NHS IT systems ▪ Child Protection Information Sharing System (CP-IS) – connects health and social care datasets ▪ GP2GP ▪ Future NHS – facilitating share of best practice between health service providers ▪ Getting it right first time (GIRFT) ▪ Care Identity Service – Permits or denies individuals' access to clinical data	▪ HoC Public Accounts Committee concerns over upcoming plans to develop IT infrastructure ▪ Exploring Virtual Ward approaches ▪ What Good Looks Like ▪ The Health and Care Bill ▪ Technology Reference Data Uptake Distribution/ Message Implementation Manual for third-party suppliers to navigate working within the NHS ▪ Improvement Capability Building and Delivery Team ▪ Estates and Technology Transformation Fund ▪ Internet First Policy ▪ Public Cloud First Policy – ▪ Digitally-enabled integrated health models ▪ Developing 'Total Triage' models of care
Surveillance	▪ Supply chain disruptions ▪ Internet First Policy	▪ Increased investment in wearable devices ▪ Unique NHS number ▪ NHS Foundry ▪ NHS Identity Guidelines – guidelines for representing the NHS brand even when products/services are supplied by third party suppliers	▪ GP Connect ▪ Summary Care Record ▪ National Flu and COVID-19 surveillance reports ▪ CareConnect Open APIs ▪ NHS Spine/ Spine Mini Service ▪ Child Protection Information Sharing System (CP-IS) ▪ GP2GP	▪ HoC Public Accounts Committee concerns over upcoming plans to develop IT infrastructure ▪ The Health and Care Bill ▪ Technology Reference Data Uptake Distribution/ Message Implementation Manual ▪ Estates and Technology Transformation Fund ▪ Internet First Policy ▪ Public Cloud First Policy ▪ Digitally-enabled integrated health models ▪ Developing 'Total Triage' models of care

Table 3 continued Digital Health Maturity Foundations by Prevention/Vaccination, Disease Mx, Surveillance & Pandemic preparedness for England.

Seasonal Influenza (pre COVID)				
Response category	**Essential IT Infrastructure**	**Essential Digital Tools**	**Readiness of Information Sharing**	**Readiness of Health System/Enabling environment**
Pandemic Preparedness	▪ Communication infrastructure ▪ Supply chain disruptions	▪ SNOMED CT ▪ Digital Maturity Self-Assessment resource to enable health care providers to appraise how well they are utilising digital technology ▪ NHS Identity Guidelines	▪ GP Connect ▪ National Flu and COVID-19 surveillance reports ▪ CareConnect Open APIs ▪ NHS Spine/ Spine Mini Service ▪ Spine OpenTest environment – testing environment for developing healthcare applications	▪ HoC Public Accounts Committee concerns over upcoming plans to develop IT infrastructure ▪ What Good Looks Like ▪ The Health and Care Bill ▪ Internet First Policy ▪ Public Cloud First Policy ▪ Digitally-enabled integrated health models ▪ Developing 'Total Triage' models of care
COVID-19				
Vaccination/ Prevention	▪ Communication infrastructure ▪ Supply chain disruptions ▪ Internet First ▪ ICT Infrastructure underpinning NHS Test & Trace - facilitated expansion from 1000s/ day to 100,000s/day ▪ NHS Test & Trace efficacy (and associated costs) questioned	▪ Increased investment in wearable devices – rise in remote clinical monitoring Unique NHS number ▪ NHS App – also provides vaccination record ▪ NHS Foundry ▪ Social media-based disinformation – NHSX partnering with major firms to combat health disinformation	▪ GP Connect ▪ Summary Care Record ▪ GP2GP ▪ Getting it right first time (GIRFT) ▪ NHS COVID Data Store - holds personal data representing aspects of individual patient's access to health services ▪ Electronic notifications from pharmacy to GP systems - securely shares information about urgent supply of medicines and pharmacy administered COVID vaccinations with GP practices ▪ New dataflow to monitor variants of interests – linking test results from reflex assays to UKHSA's national register for notifiable diseases and supporting public health experts ▪ COVID-19 Vaccine Surveillance Reports - Granular data available on vaccine uptake and performance – can be differentiated by brand/batch ▪ National Immunisation Management System - Centralised management of COVID immunisation	▪ HoC Public Accounts Committee concerns over upcoming plans to develop IT infrastructure ▪ Exploring Virtual Ward approaches – ▪ What Good Looks Like ▪ The Health and Care Bill ▪ Improvement Capability Building and Delivery Team ▪ Estates and Technology Transformation Fund ▪ Internet First Policy ▪ Public Cloud First Policy – ▪ Digitally-enabled integrated health models ▪ Developing 'Total Triage' models of care ▪ Additional funding for Clinical Commissioning Groups and Primary Care Networks to support network costs associated with additional SMS messages.
Disease Management	▪ Supply chain disruptions ▪ Internet First Policy ▪ ICT Infrastructure underpinning NHS Test & Trace - facilitated expansion from 1000s/ day to 100,000s/day ▪ NHS Test & Trace efficacy (and associated costs) questioned	▪ Increased investment in wearable devices – rise in remote clinical monitoring ▪ Electronic Prescription ▪ Unique NHS number ▪ Unique NHS Staff ID/ Electronic Staff Record ▪ SNOMED CT ▪ Technology Enabled Care Services (TECS) ▪ NHS Foundry ▪ e-Referral ▪ Secure Email (NHSmail) ▪ NHS Login	▪ GP Connect ▪ Summary Care Record ▪ CareConnect Open APIs ▪ NHS Spine/ Spine Mini Service ▪ Child Protection Information Sharing System (CP-IS) ▪ GP2GP ▪ Future NHS ▪ Getting it right first time (GIRFT) ▪ Care Identity Service ▪ NHS COVID Data Store ▪ NHS Pathways COVID Triage Dashboards ▪ Electronic notifications from pharmacy to GP systems – securely shares information about urgent supply of medicines and pharmacy administered COVID vaccinations with GP Practices	▪ HoC Public Accounts Committee concerns over upcoming plans to develop IT infrastructure ▪ Exploring Virtual Ward approaches – ▪ What Good Looks Like ▪ The Health and Care Bill ▪ Technology Reference Data Uptake Distribution/ Message Implementation Manual ▪ Improvement Capability Building and Delivery Team ▪ Estates and Technology Transformation Fund ▪ Internet First Policy ▪ Public Cloud First Policy – ▪ Digitally-enabled integrated health models ▪ Developing 'Total Triage' models of care ▪ Remote services during pandemic - precedence set for successful pivot to remote services

Table 3 continued Digital Health Maturity Foundations by Prevention/Vaccination, Disease Mx, Surveillance & Pandemic preparedness for England.

COVID-19				
Response category	**Essential IT Infrastructure**	**Essential Digital Tools**	**Readiness of Information Sharing**	**Readiness of Health System/Enabling environment**
Disease Management (continued)			▪ Facilitating data share – Information Commissioner decreed that for the public interest, appropriate and lawful data sharing must take priority over data protection concerns during the pandemic ▪ COVID-19 Vaccine Surveillance Reports ▪ NHS Test & Trace dataflow incorporating patient, primary care and broader surveillance networks/ health researchers.	▪ Data Shares Lives Strategy – making appropriate data sharing the norm across adult social care and public health and to create the necessary legal, technical and regulatory frameworks to appropriately facilitate this process. ▪ Oxford COVID-19 Government Response Tracker (OxCGRT) ▪ Additional funding
Surveillance	▪ Supply chain disruptions ▪ Internet First Policy	▪ Increased investment in wearable devices ▪ Unique NHS number ▪ NHS Foundry ▪ NHS Identity Guidelines	▪ GP Connect ▪ Summary Care Record ▪ National Flu and COVID-19 surveillance reports ▪ CareConnect Open APIs ▪ NHS Spine/ Spine Mini Service ▪ Child Protection Information Sharing System (CP-IS) ▪ GP2GP ▪ National Data Opt-Out Exemption – applied during pandemic to override opt-out clause for use of personal data ▪ Facilitating data share ▪ New dataflow to monitor variants of interests ▪ RCGP-RSC surveillance centre ▪ RCGP-RSC COVID-19 Sampling Scheme – including virology and serology ▪ COVID-19 Vaccine Surveillance Reports ▪ NHS Test & Trace dataflow ▪ National Immunisation Management System - Centralised management of COVID immunisation	▪ HoC Public Accounts Committee concerns over upcoming plans to develop IT infrastructure ▪ The Health and Care Bill ▪ Estates and Technology Transformation Fund ▪ Internet First Policy ▪ Public Cloud First Policy – ▪ Digitally-enabled integrated health models ▪ Developing 'Total Triage' models of care ▪ Data Shares Lives Strategy ▪ Oxford COVID-19 Government Response Tracker (OxCGRT) ▪ Coronavirus spending monitoring database – Office for Budget Responsibility scrutinising spending to ensure sustainability
Pandemic Preparedness	▪ Communication infrastructure ▪ Supply chain disruptions	▪ SNOMED CT ▪ Digital Maturity Self-Assessment ▪ NHS Identity Guidelines	▪ GP Connect ▪ National Flu and COVID-19 surveillance reports ▪ CareConnect Open APIs ▪ NHS Spine/ Spine Mini Service ▪ Spine OpenTest environment ▪ National Data Opt-Out Exemption ▪ Facilitating data share ▪ New dataflow to monitor variants of interests ▪ RCGP-RSC surveillance centre ▪ RCGP-RSC COVID-19 Sampling Scheme	▪ HoC Public Accounts Committee concerns over upcoming plans to develop IT infrastructure ▪ What Good Looks Like ▪ The Health and Care Bill ▪ Internet First Policy ▪ Public Cloud First Policy ▪ Digitally-enabled integrated health models ▪ Developing 'Total Triage' models of care ▪ Data Shares Lives Strategy ▪ Oxford COVID-19 Government Response Tracker (OxCGRT)

4 Discussion

The preliminary analysis showed significant growth across micro, meso and macro levels with respect to information analysis and dissemination, coordination across care delivery centres and agents, and tracking and monitoring of group level interventions such as vaccinations. Common across all three countries (Australia, Canada, and England) was significant growth in micro level tools that could push information such as COVID-19 test results or reduce the risk of exposure directly to people. That was changed from 2019-20 influenza level monitoring that put the onus on individuals to monitor outbreaks and manage possible exposures.

All three countries showed growth in digital maturity from the 2019-20 year and management of influenza to the 2020-21 year and the management of the COVID-19 pandemic. However, while progress in digital maturity was seen, the degree of progress was sporadic and uneven. A plethora of digital tools were developed to support COVID-19 tasks related to care delivery/monitoring and surveillance, but these offerings were hindered by their incoherence with one another and the ways in which they often only duplicated pre-existing efforts and added unnecessary levels of complexity to monitoring and treating patients. Work that was done to advance the digital health maturity of nations during the pandemic often appeared ad hoc, lacking systems thinking, and without robust monitoring and evaluation mechanisms to ensure responsible spending and outcomes that would best serve both the general public and specific populations in need. This was not helped by the presence of non-competitive tendering processes during the pandemic. Some countries with strong track-records for disease surveillance and supporting digital infrastructure did not use their natural advantage to the best of their ability during the COVID-19 pandemic and instead opted for 'from scratch' investments. England is a notable example here; its government has been accused of fiscal irresponsibility enough to warrant a public enquiry. It remains to be seen how many other countries will also have to justify their pandemic-related expenditures to their tax-paying public in this way. The digital health maturity comparison we provided is important as it is not enough to simply have a digital health infrastructure but rather, we need to have specific measures to track the growth of digital maturity, including fit-for-purpose data shared accurately across the health and socioeconomic sectors.

Contract tracing was also a digital phenomenon that evolved greatly from influenza to COVID-19. Influenza tracking pre-COVID-19 was often based on population level maps where individuals would have to track outbreaks and monitor their own exposure. While all three countries saw a marked uptake in digital capacity, concerns were raised about the ad-hoc nature of how digital capacity developed. Common across all three countries was a previously described phenomenon that the development of new technologies and innovations occurred faster than the policy that is needed to guide their evolution [36]. Privacy and security issues as well as uncertainty and challenges about data access and sharing were common and impacted effective pandemic response.

Going forward, determining which digital tools provide value and should be kept and which tools need to be redesigned or eliminated is an essential task. This requires a re-invigorated evidence-based approach to integrated primary care informatics and its evaluation to gain public confidence and trust in digital health across primary and other health sectors. We cannot assume that equity and positive health and social outcomes for all will automatically be enabled by health IT. Instead, we need to design for purpose to achieve desired system outcomes.

The opportunity to use the investment in and lessons learned from COVID-19 should not be wasted. Future pandemic planning should focus on enhancing the surveillance systems for influenza and other notifiable infectious diseases that currently exist with an explicit focus to improve digital health maturity and the quality of surveillance enabled by existing systems. As the socio-technical maturity and associated traits such as dependability, resilience, and agility of digital health systems improves, so will the ability to deal not only with an epidemic/pandemic but also the monitoring and management of long-term sequelae such as "long covid" and other chronic diseases. Perhaps a transparent approach emphasising mutual trust and reciprocity will then facilitate international digital health diplomacy [37] to achieve a treaty to underpin a truly global and equitable response to future pandemics that "leaves no one behind" [38].

5 Conclusion

While the COVID-19 pandemic provided a global stimulus for digital health capacity, its development has often been inequitable, short-term in planning, and lacking in overall health system coherence. Inclusive digital health and the development of resilient health systems are broad outcomes that require a systems approach to achieve them. This paper from the IMIA Primary Care Informatics Working Group provided an international comparison of digital maturity from influenza in 2019-20 to COVID-19 in 2020 and beyond. Our analysis and discussion provide direction for the design of digital primary care systems as part of enabling system equity and resilience.

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