BMC Health Services Research

RESEARCH Open Access

Innovation bundles and platforms – a qualitative analysis of health system responses to the COVID-19 pandemic

Hania Rahimi-Ardabili[1], Farah Magrabi[1], Brenton Sanderson[1,2], Thilo Schuler[1,3] and Enrico Coiera[1*]

Abstract

Background Health systems underwent substantial changes to respond to COVID-19. Learning from the successes and failures of health system COVID-19 responses may help us understand how future health service responses can be designed to be both effective and sustainable. This study aims to identify the role that innovation played in crafting health service responses during the COVID-19 pandemic.

Methods Semi-structured interviews were conducted online, exploring 19 health professionals' experiences in responding to COVID-19 in a large State health system in Australia. The data were collected from April to September 2022 and analysed utilising constant comparative analysis. The degree of innovation in health service responses was assessed by comparing them to pre-pandemic services using 5 categories adopted from the IMPISCO (Investigators, Methods, Population, Intervention, Setting, Comparators and Outcomes) framework, which classifies interventional fidelity as: 1/ Identical: No differences are found between health services; 2/ Substitution with alternatives that perform the same function, 3/ In-class replacement with elements that delivers roughly the same functionality, 4/ Augmentation with new functions, 5/ Creation of new elements. Services were decomposed into bundles and fidelity labels were assigned to individual bundle elements.

Results New services were typically created by reconfiguring existing ones rather than being created de novo. The presence of pre-existing infrastructure (foundational technologies) was seen as critical in mounting fast health service responses. Absence of infrastructure was associated with delays and impaired system responses.

Conclusions The need to reconfigure rapidly and use infrastructure to support this suggests we reconceive health services as a platform (a general-purpose service upon which other elements can be added for specific functions), where a common core service (such as a primary care practice) can be extended by adding specialised functions using mediators which facilitate the connection (such as virtual service capabilities). Innovation can be costly and time consuming in crises, and during the COVID-19 pandemic, innovations were typically patched together from pre-existing services. The notion of platforms seems a promising way to prepare the health system for future shocks.

Keywords Health services, Resilience, COVID-19, Innovation, Platform technology

*Correspondence:
Enrico Coiera
enrico.coiera@mq.edu.au
[1]Centre for Health Informatics, Australian Institute of Health Innovation, Macquarie University, Sydney, NSW 2109, Australia
[2]Department of Anaesthesia and Perioperative Medicine, Westmead Hospital, Sydney, NSW, Australia
[3]Department of Radiation Oncology, Northern Sydney Cancer Centre, Royal North Shore Hospital, Sydney, NSW, Australia

Background

The COVID-19 pandemic challenged health systems worldwide, and many were overwhelmed early on by the rapidly spreading novel coronavirus [1]. The toll of COVID-19 on health systems globally is measured in lost or impaired lives [2], exhausted clinicians [3], degraded services, and delayed care for many patients [4, 5]. Globally, economies are still experiencing the aftershocks of the financial and societal costs of this event. Yet it is likely that health systems will face many more such crises over the next decades, some driven by mass climate change-triggered events [6], including future pandemics.

Given the cost of the COVID-19 crisis response, and the high likelihood of multiple future health system shocks, we must ask whether it is possible to sustain effective future care delivery in the middle of so much turbulence [6]. Can we learn anything from the successes and failures of the COVID-19 response to understand how we might design future health services that are quickly reconfigurable, effective and sustainable?

We know that health systems worldwide rapidly responded to COVID-19 and that this response influenced everything from planning through to procurement and care delivery [7, 8]. New services, processes and tools had to be created, either by repurposing existing resources, or from scratch [9, 10]. For example, hospitals repurposed existing clinics and wards to manage COVID-19 surges, and developed ways to deal with unexpected patient volumes that saturated existing services such as intensive care units (ICUs) [11, 12].

Such innovation is a driver of health system change, but it often requires extraordinary effort, can be expensive, and has a high rate of failure at any point from planning to implementation [13]. The pandemic, especially in the first months, was characterised by rapid responses, some of which succeeded (e.g. mRNA vaccines) and many which failed (e.g. COVID-19 contact tracing apps [14]).

Innovation in healthcare has been defined as any 'new concept, idea, service, process, or product aimed at improving treatment, diagnosis, education, outreach, prevention and research, and with the long-term goals of improving quality, safety, outcomes, efficiency and costs' [15]. The process of diffusion of innovations through the health system has been the classic focus for innovation scholarship, based on Rogers' pioneering theoretical work [16]. Innovation diffusion research typically focusses on identifying and circumventing barriers to change, sometimes using implementation science frameworks such as the Promoting Action on Research Implementation in Health Service framework (PARIHS) model [17]. In COVID-19, research has focussed mainly on evaluating the benefits of specific innovations like virtual care [7, 18]. However, there has been little focus on the creative process that produces such innovations [19], and especially not in the context of crises. One innovation strategy explored in the context of COVID-19 is repurposing, which is the reuse of existing methods, technologies and services in a new context. Some work has explored how consumers invent workarounds by sometimes repurposing existing digital tools [20] and drug repurposing during the pandemic has also been examined [21]. In this study, using first-hand stories of health professionals, we aimed to examine the following research questions:

- How are innovations created during a crisis?
- What types of innovation work best in crisis situations?
- Are there general strategies that can be reused in future crisis?

Our overarching goal was to identify potential approaches to rapidly reconfiguring health service during future crises.

Methods

Design

A qualitative analysis of semi-structured interviews was undertaken to explore healthcare workers' lived experiences in either developing or using COVID-19 pandemic response services. The manuscript meets the COREQ (Consolidated Criteria for Reporting Qualitative Research) guidelines [22] (Additional file 1).

Participants and setting

Participants were approached based upon their seniority, professional role, and the setting they worked in, to include a wide range of perspectives. Health professionals who had been involved in the pandemic response in New South Wales (NSW) were eligible for interview. They included medical specialists (e.g. respiratory physicians), nurses and midwives, general practitioners (GPs), allied health workers (e.g. physiotherapists working in ICUs), health service executives and administrative staff, and paramedics. Participants came from a diverse range of health system settings, including hospitals, public health organisations, laboratories, and public and private services in NSW, Australia. A systematic review of 14 qualitative studies of healthcare workers' experience with pandemics reported that the studies required 15 participants on average to reach data saturation [23], and so we anticipated 20 participants would provide sufficiently rich data for qualitative analysis. A purposive convenience sampling approach was taken [24]. Researchers first identified potential candidates for interviews that were conveniently accessible and selected respondents who were most likely to yield appropriate and useful information [25]. The research team (E.C., B.S., T.S., F.M.) identified potential participants from their health system networks and then snowballed the sample by asking these individuals for referrals to additional potential participants. Identified individuals did not have any preexisting relationship with the interviewer (H.R.-A.) who invited them by email. For snowballing, participants were asked to forward the study invitation email to others who might be interested. Transcripts were deidentified by H.R.-A. before sharing them with the other core analysis team (E.C., F.M).

NSW is an Australian state with over eight million people. It includes about 9,600 full-time equivalent GPs [26] and 2000 registered pharmacies [27] governed by the federal government [28]. NSW Health is the public health system provider for the state and includes NSW Ambulance, Health Pathology, eHealth NSW, Health Protection (public health legislation and surveillance), and Local health districts (LHDs) [29]. LHDs encompass hospitals, home hospitals, hospital pharmacies, aged health and disabilities, mental health, aboriginal health, drug health, and public health including immunisation [30]. During 2020-21, NSW had a total of 228 public hospitals and 210 private hospitals [31], and over 150 pathology collection centres [32].

Participants in this study were from general practices and community pharmacies, as well as NSW Health including NSW Ambulance, Health Pathology (including COVID-19 testing centres), eHealth NSW, hospitals, hospital pharmacies, and immunisation services.

Ethics and consent

Ethics approval was obtained from the Macquarie University Ethics Committee prior to commencing the study (ID: 11187). Participants provided written consent prior to data collection.

Data collection

Data were collected between April and September 2022. One-on-one interviews were conducted online using the Zoom videoconference platform, with each session lasting an average of 51 min (range: 27–73 min). One of the research team (H.R-A.) with experience in qualitative interviews was responsible for conducting the interviews. Interviews were recorded with permission and an AI-based transcription tool (rev.com) was used. A subset of four transcripts were checked for accuracy (H.R-A.). Data collection and analysis were concurrent. Emerging themes and the IMPISCO (Investigators, Methods, Population, Intervention, Setting, Comparators and Outcomes) framework [33] were adapted after an initial data analysis and shaped subsequent interview questions and recruitment.

After the interviewer introduced herself and reasons for conducting the research (identifying potential approaches for a crisis ready health system) participants were asked about the specific health service responses that they were involved with and what they did differently to their pre COVID-19 practices (see Additional file 2 for the interview guide). For our purposes, health services were any activity undertaken to manage health, illness or disability.

Data analysis

Data were analysed using constant comparative analysis [34]. Two early transcripts were coded line-by-line to identify concepts and themes (by H.R-A.). Data were then categorised using an initial set of codes (open coding). To ensure generalisability, these early codes were discussed and refined with a second analyst (E.C.). The codes were further refined and extended during the process by comparing similar categories across participants. An axial coding approach was taken, looking at connections between categories in terms of causation, strategies, consequences, context, and related conditions [34]. This process continued until all transcripts were coded. Finally, selective coding was employed to integrate the findings into a theoretical framework. Both inductive and deductive approaches were utilised for coding and conceptualising the themes and frameworks. Inductive methods were employed to identify themes and concepts directly from the data, while deductive reasoning was applied to analyse data using existing frameworks within the literature. The frameworks served as structures for understanding the data.

Data coding was supported by QRS International NVivo® 12 Software. Visualisation of code connections, codes and data was undertaken using Microsoft Excel. Some codes were grouped into more general constructs, and others specialised into several distinct codes. H.R-A. created memos of each transcript, including key quotes, cross-indexed back to the transcripts, and documented all process changes in methodological decisions and analysis in an audit trail. Three participants were selected to provide feedback on initial analyses.

Reflexivity

Authors (E.C., B.S., T.S.) have a clinical background (MD) and two are currently in clinical practice (B.S., T.S.; males). All authors are experienced health system researchers, with prior experience in qualitative research. E.C. (PhD, male), F.M. (PhD, female) and H.R-A. (PhD, female) were academic researchers at the time of the study. E.C. developed the IMPISCO framework utilised for the analysis of the current study.

To address reflexivity [35], collaborative strategies were employed, including creating a research team with diverse backgrounds and perspectives, and triangulation methods during data analysis to reduce individual biases.

Further, feedback was sought from researchers external to the investigator team with expertise in health systems for analysis and interpretation.

Analytic framework

We analysed data to identify health service responses made in response to challenges presented by the pandemic and described the role of the innovation process, but did not undertake detailed analyses of the extent and distribution of the innovations.

Various theories were explored to describe the process of innovation, including SAMR (Substitution, Augmentation, Modification and Redefinition) [36], Healthcare Sustainability theories [37] and the IMPISCO framework [33]. SAMR, which describes how existing functions are changed to meet new demands, considers every function as a singular independent unit. However, within health systems, individual services will likely serve multiple functions, and depend upon other service elements. Given its richer typology and suitability to describe health intervention complexities, we elected to adopt the IMPISCO framework.

The *IMPISCO* framework assesses the degree of fidelity between potentially complex health service interventions in heterogenous settings [33]. Based on the research replication literature, IMPISCO classifies interventional fidelity as:

- Identical: No differences are found between health services.
- Substitutable: Although different in some way, a new service element is a plausible replacement for an existing element, in that it can be substituted with the expectation of achieving similar performance.
- In-class (conceptual reuse): The service element is drawn from the same conceptual class as the original process or tool (e.g., replacing one appointment booking system with another) with similar core functionality. Similar performance is not guaranteed.
- Augmentation: An existing service has components added to support tasks beyond the current capability.
- Creation: New elements in one health service cannot be directly compared to those in another.

Each health system response identified from the interviews was independently assigned an IMPISCO fidelity class by two researchers (H. R-A. and E.C.) and codes were discussed until a consensus was reached. One challenge that quickly emerged was the highly contextual nature of fidelity. For example, the use of personal protective equipment (PPE) might be standard practice in a pre-pandemic infectious disease ward, also making it a standard practice during the pandemic. However, use of PPE was novel for all patients and carers in community-based clinics or primary care settings. To resolve this challenge and capture the context of innovation, we introduce the notion of a *service bundle*, which we define as the set of components (processes or technologies) assembled to deliver a defined service [38].

Bundle components each perform a discreet *service task* within a larger service. *Tasks* may contain sub-tasks. Tasks may have dependencies on other tasks, e.g. one is dependent on the prior completion of another. Fidelity classes were then assigned to each task element within the context of their bundle (Fig. 1). For a primary care

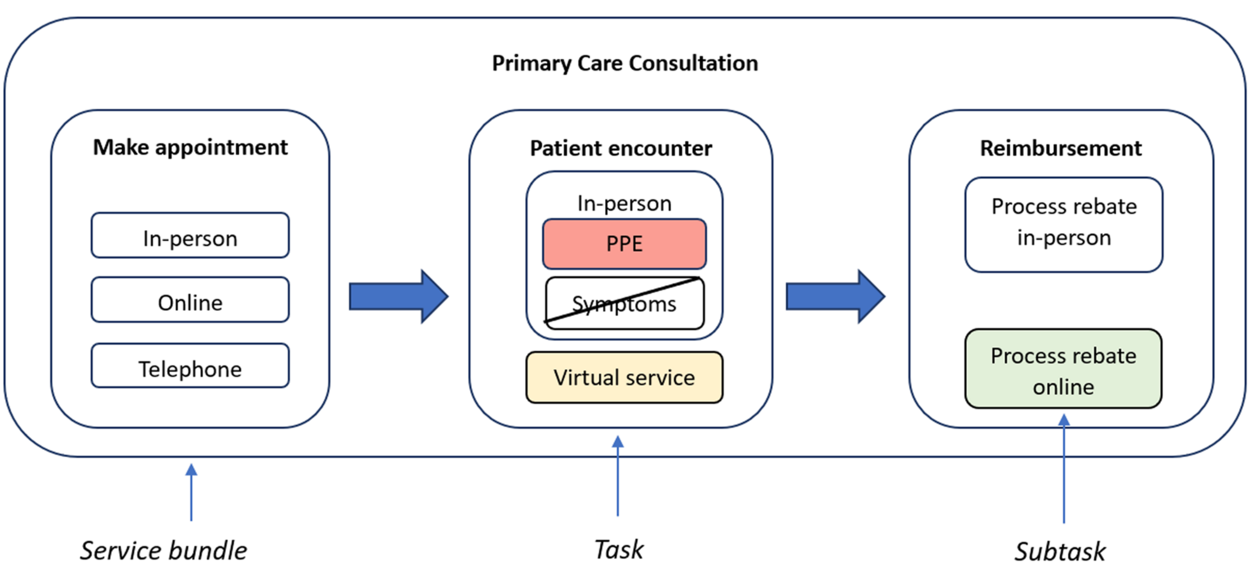

Fig. 1 A primary care service bundle during COVID-19. Legend: Green - new element is a direct substitution for an existing element. Orange - in-class alternative that provides similar but not identical performance. Red - new element needed to address a new need. Crossed – deleted element

Table 1 Participants demographics ($n = 19$)

		n (%)
Role/Profession	Specialist (e.g. emergency physician)	3(16%)
	Nurse and midwife	3 (16%)
	General practitioner	3 (16%)
	Pharmacist	2 (10%)
	Pathologist	2 (10%)
	Digital health implementation manager	2 (10%)
	Allied health worker working in ICU	2 (10%)
	Paramedic	1 (5%)
	Clerical officer	1 (5%)
Sex	Male	7 (37%)
	Female	12 (63%)
Career stage	1–5 y experience	4 (21%)
	5–10 y experience	4 (21%)
	> 10y experience	12 (58%)

consultation bundle, the addition of virtual services during COVID-19 as an alternative to in-person encounters would be classified as *in-class*, as it offers the same general functionality as other tasks in its bundle context. An online option to receive reimbursement for the virtual encounter would, however be a direct *substitute* for an in-person rebate process, as the same financial function is performed. The need for doctors and patients to wear PPE like masks during an in-person consult is an *augmentation*, as it is an additional task added because of a new service requirement. Deleted elements are a further source of variation. For example, pre-pandemic patients with respiratory symptoms were not prevented from visiting their primary care physician, but patients with symptoms were often excluded during the pandemic and referred to specialist respiratory clinics or hospital emergency departments.

Results

Participant characteristics

Of 28 invited health professionals, 19 participated in our study coming from a variety of health professions and health system settings (see Table 1).

Assessing the innovation required to respond to problems

Two case studies illustrate the way existing service bundles were modified to meet the demands of the pandemic.

Case study 1 – the community medication bundle

Some community pharmacies changed the way they dispensed medications during COVID-19, especially during lockdown periods (Fig. 2). Traditionally patients needed to bring a printed prescription and physically attend a pharmacy to pick up their medications, but the pandemic service was modified to also allow the use of electronic prescriptions (E-scripts), online reimbursement and home delivery of medications:

- Home delivery: *"[We] did do [home] deliveries [to isolated patients], before our pharmacy didn't do deliveries for medications" [Pharmacist – 17].*
- Electronic prescriptions: *"... e-script now after COVID it's fully reimbursed" [Pharmacist – 17].*

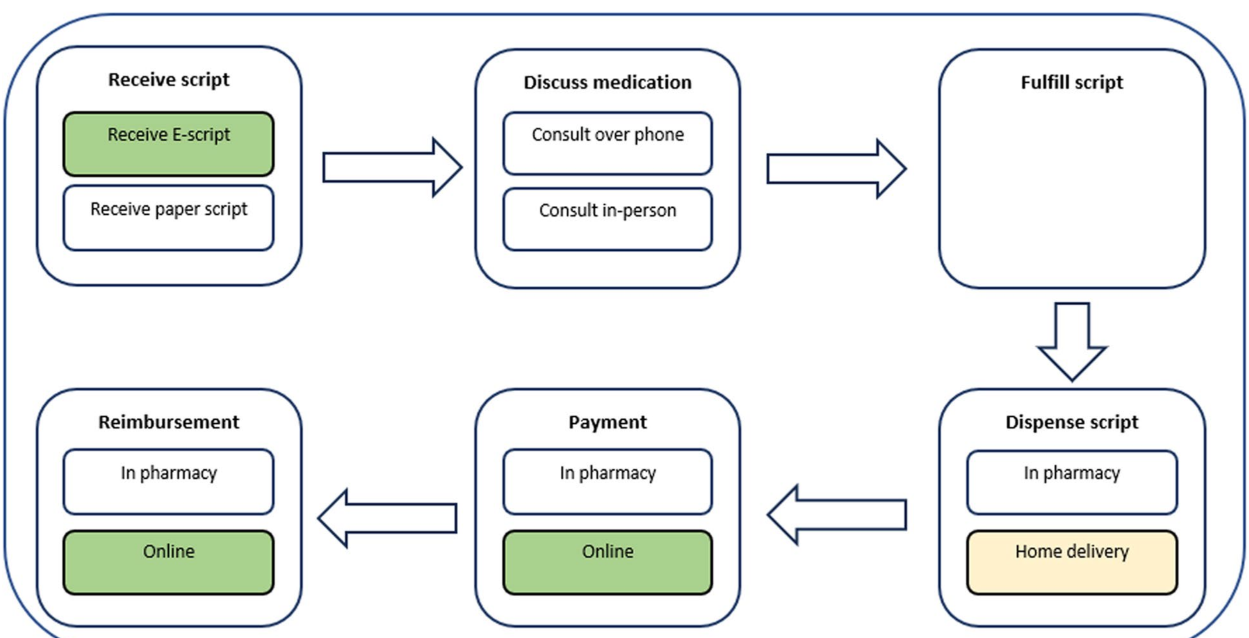

Fig. 2 Dispensing medicine from a community pharmacy during COVID-19. Legend: Green - new element is a direct substitution for an existing element. Orange - in-class alternative that provides similar but not identical performance

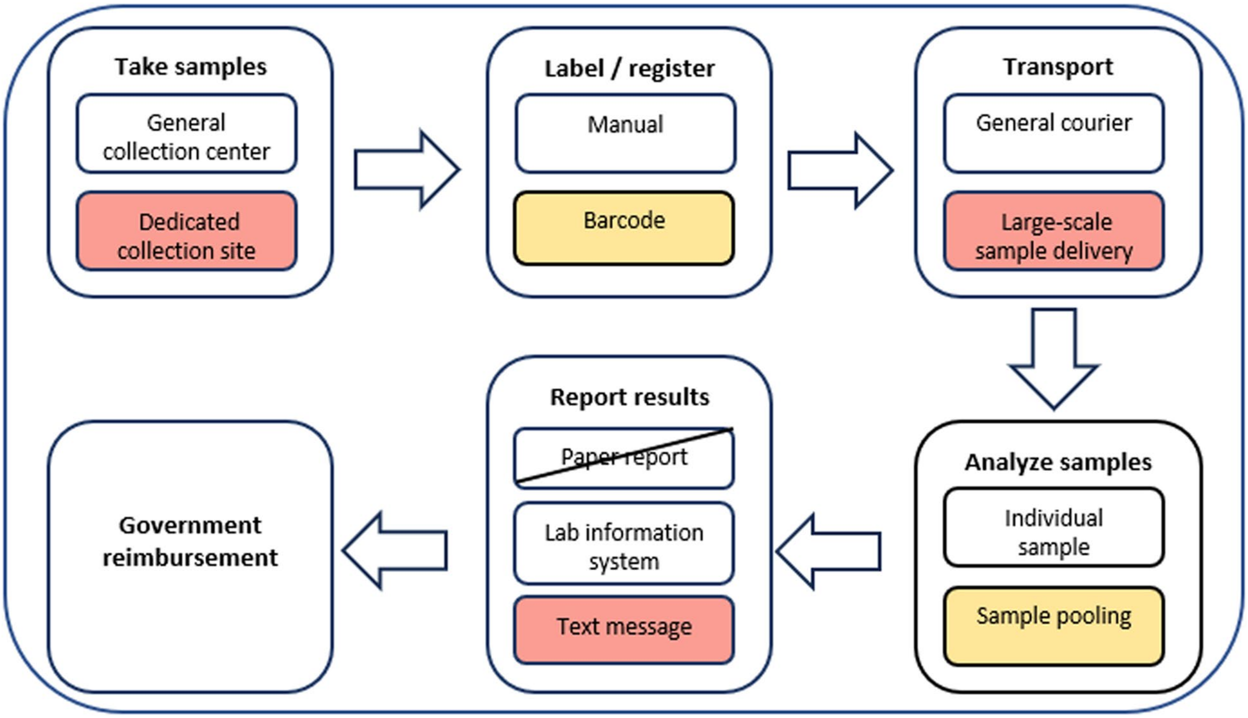

Fig. 3 The COVID-19 community pathology service bundle. Legend: Orange - in-class alternative that provides similar but not identical performance. Red - new element needed to address a new need. Crossed – deleted element

Digital elements such as the use of e-scripts and online reimbursement provided direct substitutions for pre-existing methods with the expectation of identical outcomes. Home delivery of medications was seen as an "in class" substitution as it replaced physical attendance at a pharmacy but might see outcome differences such as delays in fulfilment, and requirement for someone to be able to receive the medications at home.

Case study 2 –the community COVID-19 PCR bundle

Pre-pandemic, community pathology services collected a wide variety of specimen types for many different assays from collection centres. The COVID-19 pandemic generated a need to handle high volumes of samples for Polymerase Chain Reaction (PCR) testing, at facilities with the capacity to minimise the risk of transmission. Drive-in mass testing centres within repurposed existing buildings or newly erected temporary structures were a notable and early feature of the response. Finding solutions that supported high volumes of samples and rapid turnaround times from test to communicated result was critical, as individuals were dependent on receiving results to come out of or enter isolation, undertake travel, or return to work (including clinical services). As a result, routine pathology services offered by laboratories were re-engineered e.g by pooling individual samples and testing them 'en bloc' (see [39] for a description of this strategy).

Our respondents identified some of the unique aspects of mass community testing (Fig. 3):

- Mass COVID-19 PCR sample collection hubs: "*the local health district had set up outside collection clinics, the drive through clinics [Pathology workflow manager – 28].*";
- Automated PCR sample data entry: *"private pathologies were using barcode(s) for sample registration, so samples were registered before they even hit their laboratory [Pathology workflow manager – 28].*";
- Modified laboratory equipment maintenance: "*they put specific staff onto doing these quarterly services [Pathology lab manager – 26].*";
- Delivering high sample volumes: "*So the nurses and the doctors that were running collection clinics eventually send us the samples, bags of hundreds of swabs [Pathology workflow manager – 28].*";
- PCR testing with pooled samples: "*laboratories [started] pooling patient samples together, which is not an unknown practice [Pathology lab manager – 26].*";
- Results sent via text: "*So once the results were in our laboratory information system, that would automatically connect to a text messaging system [Pathology workflow manager – 28].*"

Infrastructure

Across the interviews, health system infrastructure was repeatedly discussed, most often in relation to the creation of virtual care or IT services. This infrastructure (generic enabling technologies, systems and services) included software and hardware such as cameras and wi-fi, a pre-existing pool of trained staff, and functioning exemplars of models of care such as pre-existing virtual services.

Several respondents identified the critical role of infrastructure in successfully mounting a health service response to the pandemic:

- *"I think a big challenge is not having the right infrastructure foundational pieces, to enable quick responses to these sort of crisis situations [Digital health implementation manager – 02]."*
- *"Initially we didn't have the infrastructure. We didn't have … webcams and headsets and all that sort of stuff needed to facilitate [virtual] care [Primary care GP – 03]."*
- *"…the other thing [with] the implementation or infrastructure [is] having the right people to implement these sorts of things … you need to have access to on-site support [Digital health implementation manager – 02]."*

This lack of preparedness for virtual services was possibly foreseeable:

> *"a lot of these things could have been established earlier years before … but it took a pandemic, for us to really push it forward, and so, in the first few months we were scrambling… I would have liked to have seen every outpatient clinic had already options for virtual care delivery before the pandemic [so that] these models of care already set up and people knew how to implement them, because what we found was that most of the State didn't. [There were a] very few pockets where they were already doing virtual care and they were very advanced in it [Digital health implementation manager – 02]."*

This absence of pre-existing infrastructure meant that developing new services took time whilst the crisis required immediate responses:

- *"It took about three to four months to actually be able to bring people on, so all that kind of setup, you're establishing a program from scratch with no prior … structure around it or material or anything like that [Digital health implementation manager – 02]."*
- *"We weren't really set up to [implement virtual services]. I think a big challenge is not having the right infrastructure foundational pieces, to enable quick responses to these sort of crisis situations, we had to build it all from scratch and deliver at the same time… we've been trying to build the ship while we sail", "Without the pandemic … it would have taken six to 12 months, just to do the planning and then probably five years to implement. We had all of that in like less than 12 months [Digital health implementation manager – 02]."*

Despite prior evidence for the value of virtual models of care [40, 41], respondents indicated such models were rare in practice and clinical staff had a steep learning curve:

- *"It became a lot of virtual. So at this point it was very new to everyone. All we had around was telephones and the basic tools to provide updates because we were so used to people coming in [ICU occupational therapist– 21]."*
- *"I don't think anyone foresaw that there would be … such a strong reliance on technology to deliver care." [Primary care GP – 03]."*

The lack of supporting infrastructure meant that quickly assembled virtual services were imperfect:

- *"Because we don't have digital a truly integrated digital health care system we had lots of problems … you see a patient virtually but then you have to … organize a scan for them. You might need to send them forms [or] a prescription [but] the public hospital outpatient setting is not geared up doing secure messaging [Primary care GP – 03]."*
- *"we were finding very basic challenges to implement virtual models of care, a lot of them just didn't have the right technology like laptops, not knowing how to use video conferencing platforms [Digital health implementation manager – 02]".*

Discussion

Faced with the challenges of responding to COVID-19, new services or service configurations were urgently required during the pandemic's early years. We sought to understand the creation of these new services using the lens of innovation – what was new and what was the process for bringing it into service? If we can understand how effective these processes of service innovation were, we may be in a position to mount better responses with future health system crises.

To characterise the degree of innovation required for these changes, we compared new services with any related pre-existing ones, using a measure of fidelity. During analysis, two things became clear. Firstly, the notion of innovation is highly contextual. Virtual services may be routine for some services but can represent a significant innovation for others. Secondly, entirely new services such as COVID-19 tracing apps were rare. In general, novel services were created by rapidly reconfiguring pre-existing ones. The significance of context in health services responses has also been previously emphasised [17].

Seeing health services as a bundle of connected elements helps describe how pre-existing services are reconfigured and contextualises innovation within the bundle. Pre-existing bundle elements could be substituted with alternatives to perform the same function (e.g. a paper script with an e-script), replaced with an element that delivers roughly the same functionality (e.g. face to face consultation with video consultation) or augmented to add in new functions (e.g. adding in the use of PPE to an emergency hospital clinic to allow it to continue to function during the pandemic). Health service innovation clearly requires organizational change, and in this study, we did not tease apart these two issues. The strategies adopted by organisations to support innovations during crisis are worthy of separate examination in future work.

Platforms

Some health services were subject to multiple innovations. Primary care clinics for example, were reconfigured into vaccination clinics, and became virtual care providers. Infectious disease laboratories reconfigured their services to enable community drive-in mass testing centres, and to provide very fast turnaround data updates to public health authorities.

Respondents described how pre-existing infrastructure, whether in the form of technology, process or people, made a substantial difference in their ability to mount timely and effective responses. Even if new services using such infrastructure were imperfect and required local workarounds, they could be made to work in the crisis.

This ability to repurpose a service in multiple ways suggests that we can see innovations as a combination of re-using a core service configuration, and specialised extensions of that core to perform specific functions. This is very similar to the notion of a platform technology, which provides a common general-purpose foundation upon which other elements can be added for specific functions. Smartphones are a platform upon which can be placed multiple different apps and sensors [42]. Platform trials answer multiple questions by using a shared control arm [43]. mRNA technologies provide a common platform for vaccine and drug design [44]. While the notion of digital and business platforms have some currency in healthcare [45, 46], could we not also begin to see some health services as a platform?

This perspective may allow us to redesign health services in a way that maximises the capacity of health system to flexibly respond to unexpected shocks and challenges. For a health service to be a platform, we would need to modularise its design into (Fig. 4):

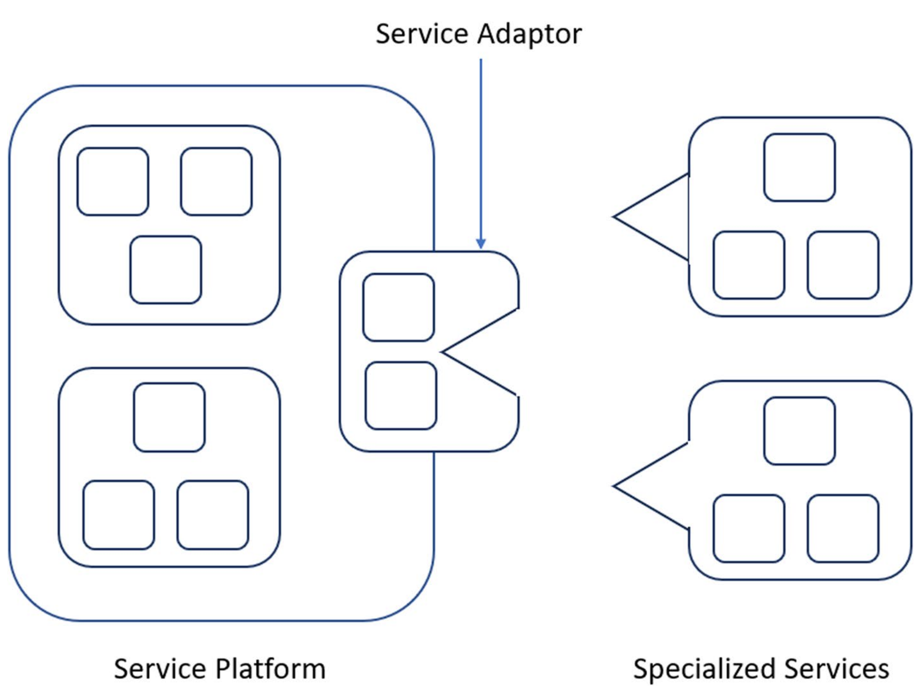

Fig. 4 Modularising health service design into core platforms and adaptors may allow for more rapid delivery of specialized services

- A *platform,* which is a service bundle that provides the functionality required for expected core purposes and is general enough to support a variety of more specialised services. For example, a primary care platform would include the core capability of providing consultations between a primary care physician and patients.
- *Service adaptors*, which facilitate extending the platform with additional services. For example, the capability to offer virtual care services enables a wide variety of clinical, public health and administrative uses. So called 'digital front doors' are also an example of a service adaptor, by providing a single place online where a clinical service can expose multiple capabilities to the public.
- *Specialized services,* which take advantage of the services provided by platforms, reducing the need to duplicate these generic services and focus on their own more unique aspects.

Modularity in service should minimise cost and waste (by avoiding creation of service elements that are infrequently used) and maximise the ability to respond quickly and at scale (by having pre-prepared infrastructure in the form of platforms and known methods to extend them through service adaptors).

This structuring of services as platforms implies a degree of commonality of design. If all primary care services in a region are reconfigured as platforms, the process can be seen as a form of standardization. Deciding how much one actually needs to standardize is, however a nuanced question [47]. We can only standardise for what we can expect and must improvise for what we cannot. For the truly unexpected, non-standard responses may be needed, and the most flexible mediator services we have are our health service staff. Respondents made clear that it was often health service staff inventing patches and workarounds that held a new bundle of service elements together.

Testing the idea of health services as a platform will require a systematic examination of how infrastructure has performed during times of rapid change or crisis across a wide range of settings, to test the generalisability of this mid-level hypothesis. The role of health consumers in self-management [20] and health service staff [48] as adaptors has already been much explored in areas such as the creation of workarounds and analysis of workforce capability to support innovation. Ultimately, prospective studies would be needed to measure any benefits of service platforms compared to other approaches.

Technologically enabled virtual services may prove to be a rich area for study, given that information technology elements already exhibit a platform architecture. In parallel, when new health services are being designed, it should be possible to evaluate the impact of exploiting a platform architecture on aspects such as cost, flexibility, workforce, and service performance outcomes.

Limitations

The results reported here provide critical insights into processes, but may not be broadly representative because of low sample sizes and the potential for participant recruitment selection biases (due to the use of convenience and purposive sampling) [24]. We anticipated achieving theoretical saturation with 20 participants but did not. This may be due to the richness of innovations during COVID-19 or the diverse selection of participants [49, 50]. Failure to saturate suggests that interviewing other subjects would likely identify new examples and issues which might alter the present analysis. With over 50% of our participants having more than 10 years of experience, this may have introduced a seniority bias. However, these subjects were the most able to provide a perspective on systemic and policy-level challenges. Participants reported on their experiences during the COVID-19 epidemic in one large state of Australia, and so the results may not generalise to all other settings, which have different health services, resources and populations. Different nations also had very different experiences during COVID-19, for example in terms of public health measures undertaken, access to vaccines, lockdowns, government policy, and virus impacts on the health of the population.

Conclusions

Innovations are an integral part of health system responses in times of crises, and the COVID-19 response demonstrated just how quickly such innovations could be patched together, often from pre-existing services. While effective to a point, the human and resource costs are huge. Consequently, this approach to innovation is not likely sustainable in the face of the multiple crises we are likely to experience with future climate and pandemic events. Formalising the innovation strategies described in this study around the notion of platforms, and reconfigurable innovation bundles seems a very promising strategy to prepare health system for future shocks and deserves close attention.

Abbreviations

ICU	Intensive care unit
IMPISCO	Investigators, methods, population, intervention, comparators and outcomes
PCR	Polymerase Chain Reaction
PPE	Personal protective equipment

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12913-024-11672-y.

Additional file 1. COREQ checklist.

Additional file 2. Interview guide questions.

Acknowledgements
The authors thank K-lynn Smith and Yvonne Zurynski for their valuable feedback on the manuscript.

Authors' contributions
E.C., B.S., T.S. and F.M. conceptualised the study. H.R.-A. developed the study protocol and collected data, E.C. and H.R.-A analyzed the data. E.C. proposed the bundle and platform concepts. E.C. and H.R.-A. prepared the original draft, and all authors contributed to the final drafts of the manuscript.

Funding
The project was conducted with funding from the National Health and Medical Research Council: Partnership Centre for Health System Sustainability; and Centre of Research Excellence in Digital Health (APP1134919).

Availability of data and materials
The datasets generated and analysed during the current study are not publicly available because consent was not obtained from study participants for data to be made public but are available from the corresponding author on reasonable request subject to approval from the Macquarie University Ethics Committee.

Declarations

Ethics approval and consent to participate
Ethics approval was obtained from the Macquarie University Ethics Committee prior to commencing the study (ID: 11187). All participants provided written informed consent prior to data collection.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 31 October 2023 / Accepted: 27 September 2024
Published online: 04 October 2024

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