Integrated Management Systems (IMS) to Support and Sustain Quality One Health Services: International Lessons from the COVID-19 Pandemic by the IMIA Primary Care Working Group

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Summary

Objectives: One Health considers human, animal and environment health as a continuum. The COVID-19 pandemic started with the leap of a virus from animals to humans. Integrated management systems (IMS) should provide a coherent management framework, to meet reporting requirements and support care delivery. We report IMS deployment during, and retention post the COVID-19 pandemic, and exemplar One Health use cases.

Methods: Six volunteer members of the International Medical Association's (IMIA) Primary Care Working Group provided data about any IMS and One Health use to support the COVID-19 pandemic initiatives. We explored how IMS were: (1) Integrated with organisational strategy; (2) Utilised standardised processes, and (3) Met reporting requirements, including public health. Selected contributors provided Unified Modelling Language (UML) use case diagram for a One Health exemplar.

Results: There was weak evidence of synergy between IMS and health system strategy to the COVID-19 pandemic. However, there were rapid pragmatic responses to COVID-19, not citing IMS. All health systems implemented IMS to link COVID test results, vaccine uptake and outcomes, particularly mortality and to provide patients access to test results and vaccination certification. Neither proportion of gross domestic product alone, nor vaccine uptake determined outcome. One Health exemplars demonstrated that animal, human and environmental specialists could collaborate.

Conclusions: IMS use improved the pandemic response. However, IMS use was pragmatic rather than utilising an international standard, with some of their benefits lost post-pandemic. Health systems should incorporate IMS that enables One Health approaches as part of their post COVID-19 pandemic preparedness.

Keywords

Primary care, Electronic Health Records, Integrated Advanced Information Management Systems, One Health, Public Health

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1 Introduction

One Health is defined by the World Health Organisation (WHO) as: "An integrated, unifying approach to balance and optimize the health of people, animals, and the environment. This is particularly important to prevent, predict, detect, and respond to global health threats such as the COVID-19 pandemic"[1]. The WHO, along with the European Centre for Disease Control (ECDC) and the Centre for Disease Control (CDC) in the USA also stress the importance of the work being cross sectoral. The key professions that need to be involved in One Health programmes are (1) health care including public health; (2) veterinarian; and (3) environmental scientists[2, 3]. One Health has been more fully defined as a transdisciplinary and trans-sectoral, and views animals especially wildlife, humans, and their shared settings or environment as linked and affected by the socioeconomic interest of humans and other external pressures such as changes in ecosystems and land use, intensification of agriculture, urbanisation, and international travel and trade [4].

ECDC states that after COVID-19, gastroenteritis due to campylobacter and salmonella are the next most common [5]. However, since that report, avian flu has emerged as another potential infection that requires a One Health approach. Whilst transmission of avian flu to humans is rare, there is a small chance of mutation to a pandemic strain. A recent editorial in the Medical Journal of

Australia called for Australia to set up its own national centre for disease control, to deliver One Health; the paper stressed the need for integration [6-8].

Integrated management systems (IMS) should provide a coherent approach to management and be aligned with organisational strategy delivery [9]. They should include standardised management systems (e.g., International Standards Organisation (ISO) 9000 family) [10, 11], support working within legal and regulatory constraints, meet reporting requirements including those needed for public health, and support care delivery.

We carried out this study to report how IMS are being provided or maintained post COVID-19, from the perspective supporting One Health.

2 Methods

Volunteer members of the International Medical Association's (IMIA) Primary Care Working Group completed a data collection form about the extent to which IMS exist within their health system to support One Health initiatives, with particular reference to COVID-19.

Data were specifically collected about IMS using a Donabedian approach of exploring structures, processes and outcomes [12], relevant to that country's national response to the COVID-19 pandemic. The components were (1) Structural evaluation required an assessment of the extent to which, if at all, IMS was integrated with health system organisational strategy. This could be a pre-, during or post-pandemic strategy. (2) Process evaluation focussed on two areas: (2a) Use of standardised IMS processes to meet legal and regulatory constraints, ISO 9000 family being probably the best described and most used; and (2b) Meeting reporting requirements, particularly for public health. (3) Outcome evaluation was measured using the quintuple goals of health systems [13]. (3a) Patient experience – focussed on waiting list data or e-access information. (3b) Population health – we reported WHO life expectancy and any reports of rates of COVID mortality using ECDC or the international John Hopkins University COVID reports [14]. (3c) Cost control – we stated the proportion of Gross Domestic Product (GDP) spent on health care using Organisation for Economic Co-operation and Development (OECD) data [15], and an overview comment about vaccine uptake and testing. (3d) Maintaining the health care team – COVID service delivery comments. (3e) Equity – to report any disparities seen over the COVID-19 pandemic. We allowed 150-175 words per contributor across all sections and up to six references.

Additionally, contributors were requested to create a Unified Modelling Language (UML) use case diagram for a specific One Health example, from their health system. UML use case diagrams capture the interaction between the actors (people) and with the system, thereby capturing its functionality. The key actors we asked modellers to prioritise are the medical, veterinarian, and environmental actors providing health care, veterinary care and public health, and those involved in the environment and ecosystem.

3 Results

3.1 Overview

We report the results from the countries who provided data (Tables 1-3), then two exemplar UML use cases of One Health initiatives (Figure 2 and Figure 3). We had six volunteer countries provide data from an informatics perspective (Tables 1-3). These were Australia (Table 1), Canada (Table 1), Chile (Table 2), England (Table 2), Norway (Table 3) and Peru (Table 3). We selected two use cases: Avian influenza (the most suggested) and flavivirus mosquito transmitted diseases (which includes yellow fever, dengue, Japanese encephalitis, and West Nile and Zika virus disease), and Hendra virus (HeV). We selected the latter to be the exemplar use case given its unusual transmission by fruit bats.

3.2 Country Reports

Australian, Chilean, Norwegian and Peruvian data are national. Canadian data was from Ontario, as health services are run by province. Although England (56 million) is approximately 85% of the UK (65 million population), the devolved nations, Scotland, Wales, and Northern Ireland have their own health systems; though they did collaborate and conduct pooled analyses [16].

All countries or regions had some IMS and intention for this to be structurally integrated with their health system organisational strategy. Australia did not identify any formal IMS process, Figure 1 shows the Ontario IMS version 2, which predates the pandemic. Chile adopted a pragmatic, but highly successful approach. Only Norway has comprehensively introduced such a process into practice. England used a data vault system to link together key data, this may be continued longer term [17]. Norway had the most integrated IMS system.

With the exception of Norway there was little adoption of standard IMS processes, though most countries had standardisation of clinical data recording, improved data sharing and integrated working. These enabled largely effective reporting of disease, vaccination, and its effectiveness.

Patients were generally provided ready access to testing, vaccination, and vaccination certificates. Proportion of GDP invested in health care varied from 3.1% Peru, then 9.3% (Chile) through to 11.7% (Canada). There was only a small difference in life expectancy, Australia has the longest at 82.3 years, with Peru the shortest 77.23 years. Neither size of GDP spent on health care or life expectancy appeared to predict vaccine uptake or mortality, except for Peru, which had a low proportion of GDP spend on health care and a high mortality, though good vaccine coverage. Chile had the best uptake of vaccines, and one of the lowest COVID-19 mortality, with Norway and Canada also having very low mortality. There was recognition of, but national differences in the way that disparities were being addressed. However, all countries aspired to achieve the quintuple aims.

Pragmatism largely drove national or regional response to the pandemic, with these changes often stood down at the end of the pandemic period. However, the scope and functionality of disease surveillance systems were extended. There were only very limited moves towards a One Health response.

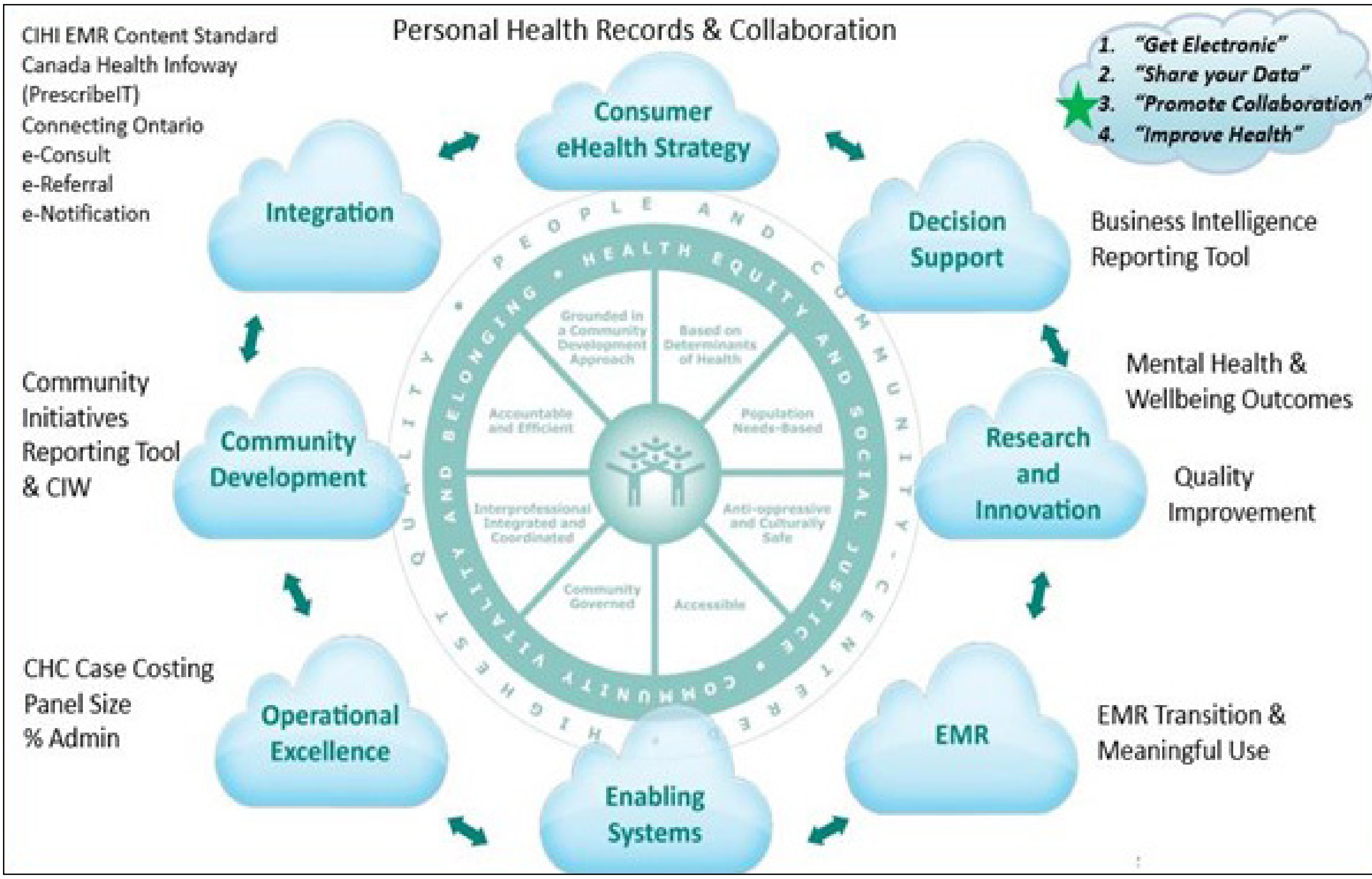

Fig. 1 This figure is obtained from Reference 19, which is available from: https://www.allianceon.org/sites/ default/files/documents/Information%20Management%20Strategy%20v2%202015-2020.docx. CIHI=Canadian Institute for Health Information; EMR=Electronic Medical Record; CIW=Canadian Index of Wellbeing; CHC=Community Health Centres.

3.3 Unified Modelling Language (UML) One Health Use Cases

We present UML diagrams (Figure 2 and Figure 3) which set out how human health, veterinarian, and environmental health agencies need to be involved in delivering a One Health programme. We present avian influenza and Hendra virus (HeV) infections in humans as exemplars.

3.3.1 Response to Avian Influenza in the UK

The UK implemented a One Health response to the avian influenza (AI) outbreak, led by the Department for Environment, Food and Rural Affairs (DEFRA). DEFRA is the lead government department for the management of AI incidents and outbreaks in poultry and wild birds and is the policy lead for outbreaks in England. The DEFRA minister is involved in strategic decision making during an incident, working closely with the UK Chief Veterinary Officer (UK CVO) and senior officials. DEFRA may chair Cabinet Office Briefing Room (COBR) meetings and provide briefing to the Environment, Food and Rural Affairs (EFRA) select committee to ensure that strategic advice is translated into practical instructions to those carrying out the operational response (Figure 2) [62].

DEFRA leads on the management of AI incidents and outbreaks in poultry and wild birds, with Health Protection Teams (HPTs) responsible for leading the local public health response to these incidents, working in close collaboration with the Animal and Plant Health Agency (APHA) [63]. The health response is delivered jointly with the local authority (LA), local NHS and with support from UKHSA colleagues regionally and nationally [64].

AI incidents requiring follow up of exposed humans are led locally by the HPT, unless escalated to an enhanced national response as defined in the National Incident and Emergency Response Plan [65].

3.3.2 Hendra Virus (HeV) Outbreaks Controlled Using a One Health Approach

The 1994 outbreak of HeV in horses laid the foundation for a One Health approach in Australia [66, 67]. The HeV outbreak caused significant damage to the animal and public health over the subsequent years. Various

Table 1 Summary results table analysis of any formal IMS use – Australia and Canada.

IMS	Australia	Canada - Ontario
(1) Structures		
Integrated with organisational strategy	Australia's COVID-19 Primary Care integrated response is being dismantled. However, the National Antimicrobial Resistance Strategy emphasizes 'Integrated Surveillance' [18].	Canadian health care is provided at province level, these data are for Ontario, which has an IMS [19]. However, there are moves towards pan-Canadian health data strategy (Figure 1) [20].
(2) Processes		
Standardised IMS processes	ICD-10 currently used in public health collections and SNOMED CT in EMR. Australia holds some national health data collections [21]. There is no national common data model although a metamodel exists.	There is no national standardisation of primary care data [22]. Though IMS development is part of organisational strategy.
Meeting reporting requirements including public health	Public health legislations are harmonised with international health regulations. Models for a National One Health surveillance are being considered [23].	Provision of regional public health data and dashboard, which in turn contributed to the Canadian national public health information management system. Data enabled research on uptake [24] and effectiveness [25].
(3) Outcomes		
Patient experience	Community-oriented education program including multilingual awareness campaigns for culturally and linguistically diverse (CALD) communities.	Public can book vaccination directly, or walk-in to clinics, download certification, all data on provincial database.
Population health	WHO life expectancy 83.2 years. 17,712 COVID deaths, 0.0069% of population.	WHO healthy life expectancy 82.8 years. High vaccine uptake 0.9% mortality [26].
Value / cost effective	10.2% GDP spent on health care. 86.6% one dose, 84.3% fully vaccinated.	11.7% GDP spent on health care. 80.6% population coverage at least one dose.
Maintains health & care workforce	The public health measures are being maintained for health workers.	Shift to remote consulting, shortage of PCR testing in Omicron phase [27].
Ensure equity	Multilingual awareness campaigns with translations for CALD communities.	25% fewer homeless people had a 1st, and 34% fewer a 2nd vaccine [28].
Actionable informatics that can influence policy	Public health data collections should include disease surveillance [29], routine primary care [30], prescribing [31], and clinical quality data [32].	Good regional data, but lack of national data limits scope to see the impact of national non-pharmaceutical interventions.

Table 2 Summary results table analysis of any formal IMS use – Chile and England.

IMS	Chile	England
(1) Structures		
Integrated with organisational strategy	Chile has a mix of public (FONASA www.fonasa.cl/sites/fonasa/inicio) and private healthcare (ISAPRE - http://www.isapre.cl/home). Pre-pandemic, scope for improved care coordination [33].	"Data Saves Lives" new post-pandemic policy document, recognises need for IMS. Stresses the need for accessible data for research and care [34]. Not all NHS information strategies have been a success [35].
(2) Processes		
Standardised IMS processes	Existing framework for collaboration [36]. Pragmatic collaboration: (1) Government, (2) Universities conducing trials, (3) Vaccination infrastructure, (4) Primary care vaccine administration (5) Electronic vaccine registry [37,38]. A new open-access COVID vaccination platform was created. Active engagement in vaccine research [39].	The National Health Service (NHS) inevitably has standardisation, national data collections etc., but following nationally unique approaches (e.g., UK SNOMED). Some once-off processes such as COVID-19 vaccine data and clinic management may not continue. Previous NHS division into "commissioner and provider" with enforced competition associated weaker IMS [40].
Meeting reporting requirements including public health	National Immunization Program from 1978. Chilean Law on Transparency and Access to Public Information Adopted (Dec. 2008).	Legislation allows reporting for public health purposes; this was widened in the COVID-19 pandemic.
(3) Outcomes		
Patient experience	Fear and the promise of a quick "solution" could explain the Chilean high willingness of being vaccinated.	Generally good, but access targets are challenging, with >7million people awaiting elective treatment, post pandemic.
Population health	WHO life expectancy 79.4 years. Very high vaccine uptake. Vaccine mortality 0.04%.	WHO healthy life expectancy 81.4 years. Excess COVID-19 mortality age related especially care homes prior to vaccine rollout, overall mortality 5%.

Table 2 continued Summary results table analysis of any formal IMS use – Chile and England.

IMS	Chile	England
(3) Outcomes		
Value / cost effective	9.3% GDP spend on health. Vaccine uptake of 92.4% (one dose) and 61.8% (four doses).	9.7% GDP spend on health care (OECD), COVID-19 vaccine uptake (88% population one, 77% two doses).
Maintains health & care workforce	6,000 health professionals including dentists and midwives available to vaccinate.	PPE slow, then priority vaccination for health and care workers. More remote consultations [41].
Ensure equity	The goal was population coverage with priority to high-risk groups.	Non-white ethnicity and lower socioeconomic status were associated with lower vaccine uptake and worse outcomes from COVID-19[42].
Actionable informatics that can influence policy	Daily updated open access data. Including identification and focussed interventions of locations with lower vaccination rates.	Larger sentinel networks sampling all year round [43]. Improved speed of access to national databases and faster analysis and feedback [44].

Table 3 Summary results table analysis of any formal IMS use – Norway & Peru.

IMS	Norway	Peru
(1) Structures		
Integrated with organisational strategy	In 2012, Norway aimed to establish a "One inhabitant one patient record"; this is still being implemented in One Health regions.	A fragmented health system, including public tax financed system, public social insurance system, armed forces and police system and private facilities.
(2) Processes		
Standardised IMS processes	Highly digitalised health care, with most inter organisational communications digital; with a core digital record [47]. The scope of the service can be seen at: https://www.helsenorge.no/en/ This includes COVID vaccination status integrated across regions and nationally	Ministry of Health (MoH) standardised formularies to collect data during care procedures: triage, sample collection, epidemiological investigation, clinical follow-up, and hospital care. Currently standards include ICD-10 and Current Procedural Terminology (CPT). However, some shortcomings noted [48].
Meets reporting requirements including public health	Norwegian Institute of Public Health (NIPH), have access to data are innovating in acute respiratory disease surveillance [49].	Legal to share data for public health purposes. For COVID-19, an Integrated System (SISCOVID) integrates clinical, lab and surveillance across public and private settings [50].
(3) Outcomes		
Patient experience	Patient-accessible records have been implemented nationally and are considered by patients to be useful [51].	Care challenges [52], however, examples from tuberculosis and cancer using technology to improve patient experience [53,54].
Population health	WHO healthy life expectancy 82.8 years. High testing, and lowest COVID-19 mortality rate (0.5%), ECDC data.	WHO health life expectancy 77.2 years. Peru had a high, possibly the highest, excess COVID-19 mortality [55-57].
Value / cost effective	10.1% GDP spent on health care (OECD), extensive; high vaccine uptake 91.5%	3.16% GCP on health care, (133 ICU beds nationwide, by May 2020, there were 2,024 [58]. Good vaccine uptake 93% one dose.
Maintains health & care workforce	A shift to more remote consultations.	Health workers were the first group vaccinated.
Ensure equity	Migrants had lower vaccination rates (79.9% vs. 91.1%) [59].	Some focused reporting[55,60,61] but no recording of ethnicity.
Actionable informatics that can influence policy	A truly national system providing data to inform policy.	Improving of routine information systems, including open data portals. https://datusabiertos.gob.pe

stakeholders from different organisations came together for the first time to discuss the potential hosts of the virus. Fruit bats of the *Pteropodidae* family, (*Pteropus* genus) have been identified as natural hosts of the virus [68, 69].

Subsequently, the Queensland Animal Research Institute and the CSIRO Australian Animal Health Laboratory isolated HeV and reproduced the disease in humans and animals. The response to HeV outbreak used a One Health approach (Figure 3) presented as a UML use case diagram. The response highlighted the significance of effective communications between various stakeholders overcoming the bureaucratic and political challenges.

During this HeV outbreak, the communication and interaction between public and veterinary health authorities was increased [65, 67]. Social science, medical, veterinary, biosecurity and humanities researchers were also included in designing an integrated response in collaboration with the Australian government [66]. Efforts are currently underway to establish an Australian National One Health surveillance system that emphasises an integrated approach [23], and which prioritises proactive engagement of providers and community stakeholders. For general practice, this includes revised prescribing guidelines, screening, and timely reporting [70]. Australia is also developing community, multilingual awareness campaigns with translations for culturally and linguistically diverse (CALD) communities.

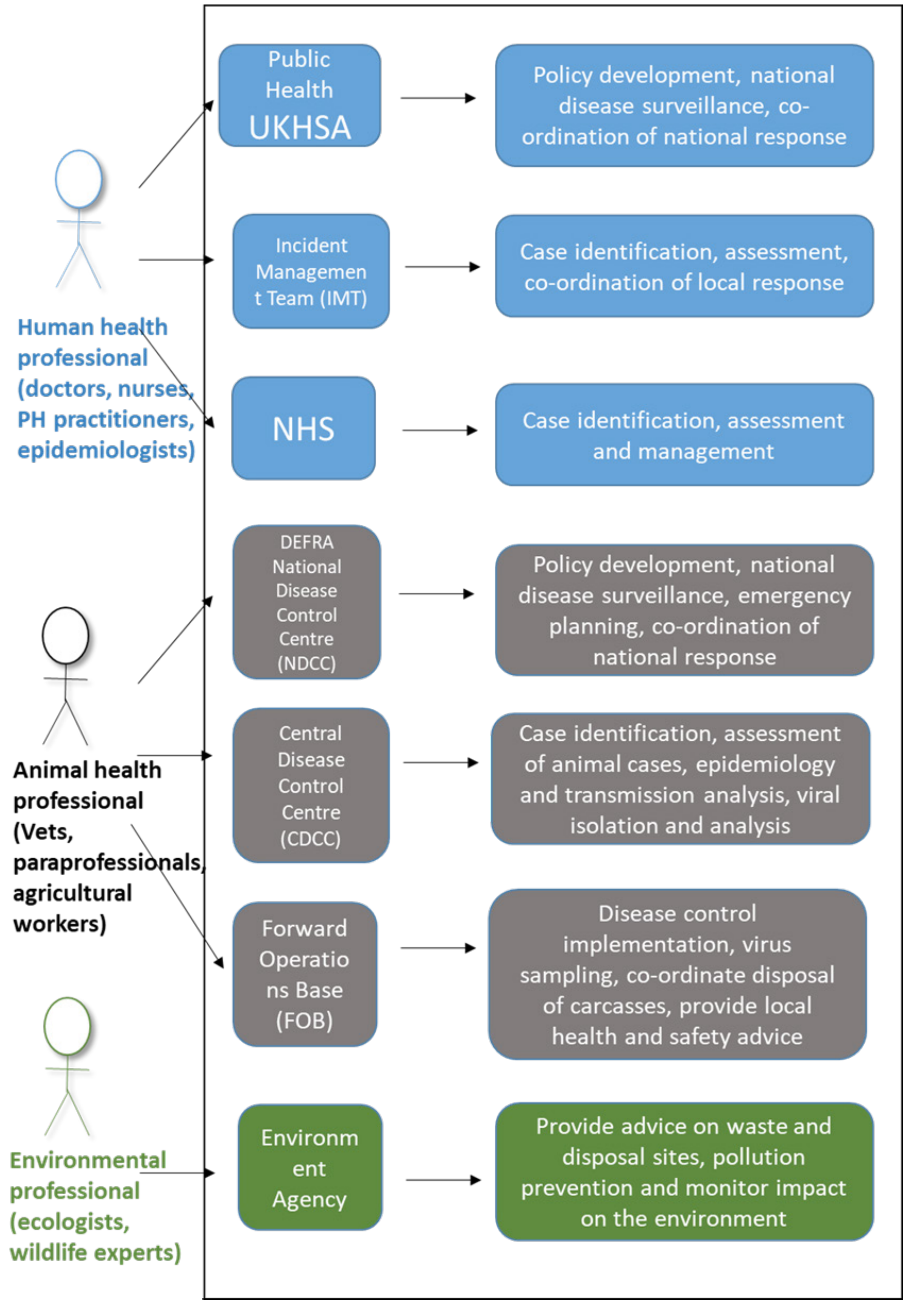

Fig. 2 Use case illustrating the UK One Health response to Avian flu. The use case is presented as a UML diagram showing the interaction of the actors in human health, animal health and environmental health practitioners with this system.

4 Discussion

We found that only one country, Norway, had advanced IMS, well integrated into their health system strategy. Other countries relied on one-off systems and pragmatism in supporting their COVID-19 response. Norway, who had the most established national IMS achieved the triad of comprehensive testing and other measures to reduce spread, good vaccination coverage, and a low mortality from COVID-19. Other countries did well but had to innovate and be pragmatic.

The pragmatic responses to COVID-19 were largely driven within the medical community, with very little evidence of a One Health response. The key elements of the response seen were: (1) Disease testing and measures to reduce spread, (2) Supporting rapid vaccine development, and (3) Vaccination programmes. Testing, rapid implementation of vaccination, and integrated and comprehensive health systems are needed to protect populations from diseases such as the COVID-19 pandemic.

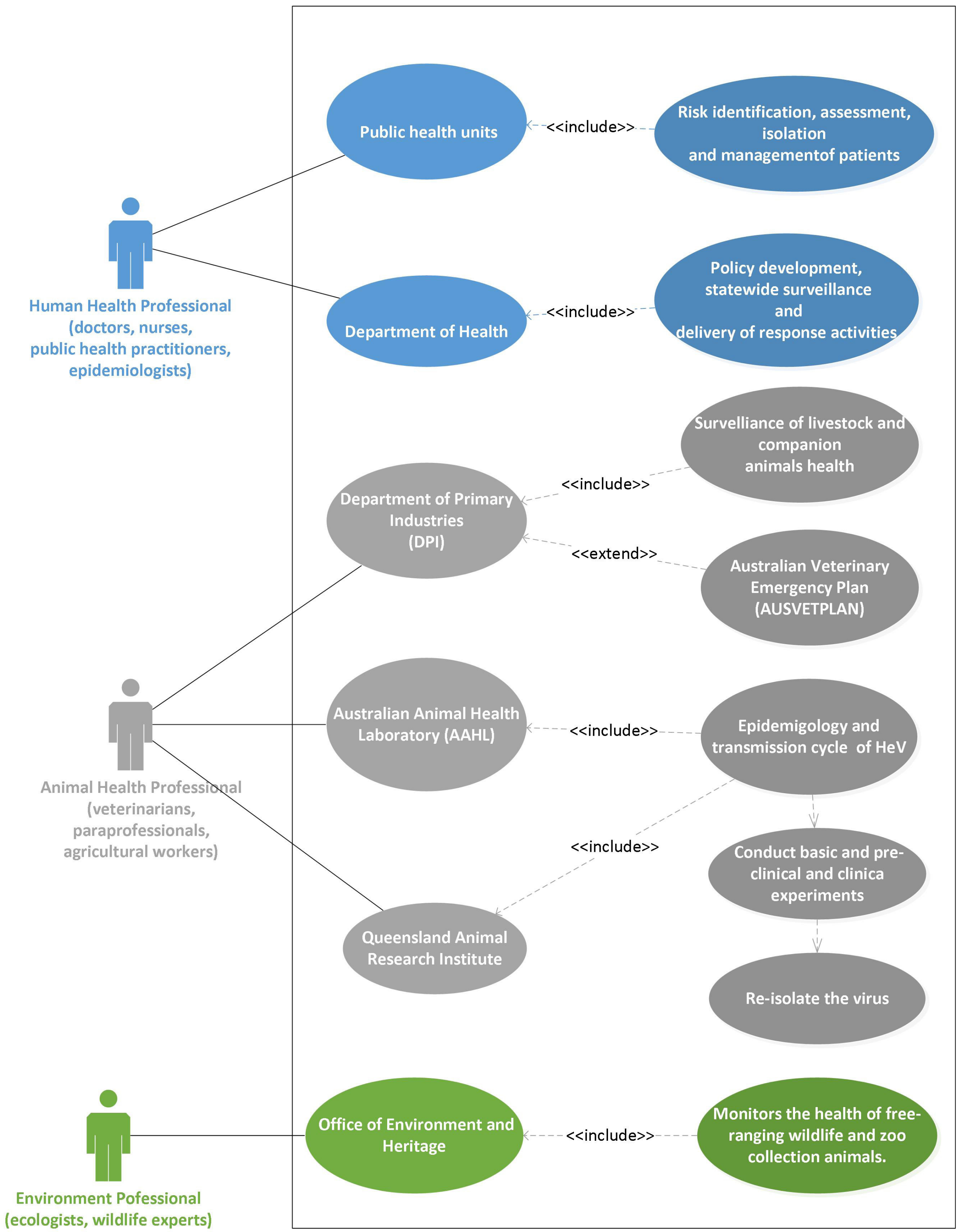

Fig. 3 Use case illustrating the Australian One Health response to Hendra virus (HeV). The use case is presented as a UML diagram showing the interaction of the actors in human health, animal health and environmental health practitioners with this system.

Whilst some benefits from better data sharing and better IMS have been stepped back from, others have persisted. For example, the changes included a shift to remote consultation which has persisted [71, 72].

Whilst we saw little evidence of a One Health approach to the COVID-19 pandemic, countries could readily identify within their health systems use cases where this approach was used. The avian flu response in the UK and the response to the Hendra virus in Australia shows the potential for a One Health response. A One Health approach, and systems that integrate animal, human and environmental health should be part of national and regional preparation for any future pandemic. Such approaches may have enabled a more rapid identification of and control of the process that led on to the COVID-19 pandemic.

There are calls for a One Health approach for influenza surveillance, given the potential for zoonotic viruses to interact and lead to the creation of new variants, particularly of influenza A [73]. Whilst the epidemiology of avian influenza is well described [74]. it is a type of flu that has caused fatal infections [75]. The same applies to Hendra, where it is thought that changing of the environment in which animals, in this case bats, live can cause spill over and new disease variants [76]. Most importantly, it is possible that there may be One Health lessons to learn from the start of the COVID-19 pandemic [77, 78].

The IMS is central to One Digital Health (ODH), a proposal to design, develop and implement a broad transdisciplinary and trans-sectoral digital platform to diagnose and manage sociotechnical challenges at the human-animal-environment interface. The ODH framework includes education, environment, human and veterinary healthcare, the healthcare industry and citizen engagement. The complexity of this horizontal interdisciplinary and intersectoral integration will increase as the micro-meso-macro vertical integration levels are applied to the technologies, data, and services being designed, developed, managed, governed, and sustained across the intersectoral enterprise-wide platform required for One Digital Health. Practically, enterprise architects and informaticians will also have to deal with a complex "analogue-digital" hybrid phase during the transition to a broader One Digital Health paradigm and platform [79].

The strength of this contribution was the range of countries contributing and range of health systems involved - north and south America, Europe, and Australia. Its limitation is that the volunteer authors appear to have come from systems that have largely run successful approaches to introducing vaccination and controlling severe outcomes from COVID.

5 Conclusions

The wide range of responses to the COVID-19 pandemic we describe all depended on improved IMS to draw together the necessary data. Nearly all the countries and regions who contributed to this study used a pragmatic approach to establish comprehensive IMS, rather than adoption of national standards. These IMS linked data about testing and other preventive measures, vaccination uptake and health outcomes. It is likely that the countries with the most effectively deployed IMS achieve the better outcomes. However, as our sample was limited to six nations, albeit with the best and worse COVID-19 related mortalities, our conclusions should be treated with caution. However, successful IMS need to span human, animal, and environmental services if they are to be effective in epidemics and pandemics. Health service strategies for future pandemic responses should include a One Health response, operationalised through an IMS that spans animal, human and environmental health are most likely to be successful in minimising the effect of any future pandemic.

Conflict of Interest Statement

Uy Hoang has undertaken consultation work for Janssen and Sanofi.

Simon de Lusignan has had grants, through his universities for vaccine related research from AstraZenaca, GSK, Sanofi, Seqirus, MSD, Takeda.

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