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Rapid response to crisis: Health system lessons from the active period of COVID-19

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ABSTRACT

Background: This paper outlines the need for a health systems approach and rapid response strategy for gathering information necessary for policy decisions during pandemics and similar crises. It suggests a new framework for assessing the phases of the pandemic.

Method: The paper draws its information and conclusions from a rapid synthesis and translation process (RSTP) of a series of webinars and online discussions from the Pandemic-Mental Health International Network (Pan-MHIN) - policy experts from across 16 locations in Australia, Denmark, Italy, Spain, Taiwan, the UK and the USA. While the initial focus of this research was on mental health, COVID-19 has raised much broader issues and questions for health planners.

Results: We identified gaps affecting the capacity to respond effectively and quickly, including in relation to system indicators, the inadequacy of the prior classification of the phases of the pandemic, the absences of a healthcare ecosystem approach, and the quick shift to digital technologies. The strengths and weaknesses of COVID-19 responses across different systems, services, sites and countries been identified and compared, including both low and high impacted areas.

Conclusions: There is an urgent need for managerial epidemiology based on healthcare ecosystem research encompassing multidisciplinary teams, visualization tools and decision analytics for rapid response. Policy and healthcare context played a key role in the response to COVID-19. Its severity, the containment measures and the societal response varied greatly across sites and countries. Understanding this variation is vital to assess the impact of COVID-19 in specific areas such as ageing or mental health.

Introduction

COVID-19 has imposed a rapid and disruptive transformation of the world healthcare systems [1]. This change can reinforce aspects of healthcare provision, such as telemedicine and acute care, while seriously compromising others, particularly those characterised by complexity with relative low returns involving health and social sectors, such as chronic care for disabilities, the elderly, drug and alcohol, and mental health.

Similarly, the scientific knowledge-base on COVID-19 is expanding very quickly. Traditionally, this growing knowledge-base has been organised using scoping and systematic reviews revised by experts following the standards of evidence-based healthcare [2]. But this pandemic is not a normal situation. Traditional research methods, supported by evidence-based medicine, have proven inadequate to respond to the urgent questions COVID-19 has posed to decision makers [3]. A communicable disease like COVID-19 epitomises the complexity of healthcare, highlighting the importance of shifting from a traditional evidence-based approach to an *evidence-informed* framework. Evidence-informed planning acknowledges that policymaking is inherently political. Research evidence is just one influence on decision making. Scientific evidence often must compete with beliefs, personal interests, political

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considerations, traditions and culture, experience, and financial realities [4].

Existing processes involving rapid synthesis for evidence informed policy [5] have been unable to inform decision making during the first phases of the COVID-19 crisis for several reasons, including: the speed of actions to be taken; the lack of time to conduct 'traditional' cohort studies or trials; the high degree of uncertainty caused by the pandemic; the breadth, velocity and complexity of its spread; significant geographical variation; the failure of standard prediction models; and the huge variability in the nature and timing of containment measures. We need for another way to quickly develop deeper understanding about COVID-19, its health implications, and how best to develop appropriate policy responses now and for future crises.

Finally, bridging and knowledge transfer across different sectors and areas of knowledge may play vital role in organisational learning and in reducing uncertainty on this highly complex crisis. In this regard the genesis of this work being from mental health may make it especially valuable for several reasons.

First mental health has traditionally involved cross-sectoral care involving health and social care, education, employment, housing and justice. This "whole of system" approach helps to understand, for example, patients and professional flows between general hospitals and ageing care. Second, complexity has led to novel approaches to systems analytics in mental healthcare, including managerial epidemiology (epidemiology addressing the concerns of management and planning), healthcare ecosystem approach with a key focus on service provision and capacity and context, and use of knowledge discovery from data combining expert knowledge and modelling of routine data [6]. Third, these techniques have been used in mental health planning and this experience can guide broader application.

The Interactive Systems Framework (ISF) for Dissemination and Implementation presents an overall framework for translating knowledge into action. It uses the Rapid Synthesis and Translation Process (RSTP), allowing public agencies to expedite the transfer of research knowledge to practitioners and policy makers. The RSTP combines domain expert knowledge together with rapid reviews to inform action planning in real world conditions [7], and has been used to guide policy and planning in complex behavioural problems in the US such as violence, child maltreatment and drug and alcohol.

However, even the RSTP requires amendments to guide decision making in this accelerated environment. A critical component of the RSTP is the availability of a reference framework to collect, order and analyse existing information and the available expert knowledge, both formal and tacit, that must be incorporated to the knowledge base under conditions of uncertainty. This expert knowledge is critical to generate key assumptions when quantitative knowledge is missing, or to select the most meaningful information for designing scenarios, or for predictive and forecasting modelling. The availability of models and workable frameworks, as well as a clear definition of the goals, drivers and values of a system, is critical for dynamic systems analysis [8]. This is important for finding the 'best-fit' explanation to current and emerging evidence, and the best set of predictions of new events relating them. These models and frameworks can also stabilise quick recommendations drawing on abductive reasoning or means-end inferences, for practical solutions when deductive approaches are not sufficient, as under COVID-19 conditions. How scientific knowledge is framed was largely ignored until very recently but this is changing now, recognising complexity in health systems research [9].

While the ISF and RSTP provide a solution to the problems associated with traditional planning approaches, a reference framework is critical to inform decision making. A framework of health systems suitable for assessing the COVID-19 pandemic does not exist.

This paper draws its information and conclusions from a rapid synthesis and translation process (RSTP) of a series of webinars and online discussions from the Pandemic-Mental Health International Network (Pan-MHIN) - mental health and policy experts across the World. It uses the expert knowledge in mental health management and practice to identify the core elements comprising a new and more effective framework for health planning at times of crisis, such as now.

Method

This paper describes how an international panel of senior planners and service leaders adapted digital conferencing and the RSTP [7] to transfer and acquire rapid knowledge on COVID-19.

This network gave these experts a forum to provide formal account of their real-world experience managing mental health care in different local scenarios across the world during the COVID-19 pandemic (see Acknowledgements for full list of members).

The Pan-MHIN participated in the webinar series "The Global Impact of COVID-19 on Mental Health" (March-April 2020) [10]. This series was designed to obtain rapid appraisal of experiences related to COVID-19 across 16 locations in seven countries: Australia, Denmark, Italy, Spain, Taiwan, the UK and the USA. Pan-MHIN members shared how they were coping with the active period of the COVID-19 outbreak in real time. Each webinar provided updated information on the evolving situation, drawing on Australian and international pandemic dashboards and repositories, including the World Health Organisation's (WHO) [11], the European Centre for Disease Prevention and Control [12] and the US Centre for Disease Control and Prevention [13]. The meetings also drew on a purposive searching of the published literature and key technical reports.

As stated earlier, the initial focus of the network was mental health. The multi-dimensional and non-linear complexity associated with mental health exemplifies the importance of bridging and knowledge transfer across sectors and disciplines [6]. It became clear the issues discussed by the network had implications for health care broadly.

Results

It is necessary to recalibrate the general aspects of COVID-19 (epidemiological, societal and political) before moving onto its consequences for health planning and policy.

The rapid knowledge acquisition process undertaken by the Pan-MHIN suggests five key domains necessary to derive a robust and useful framework:

- Phases/stages of the Pandemic
- Health System Indicators
- The Healthcare Ecosystem/Glocal Approach
- Digital Technologies
- International Comparisons and Evolution of the Pandemic

Applying these domains as a framework permits evaluation of the strengths and weaknesses of different systems and services across the world in their response to COVID-19.

Phases of the pandemic

Overall, the literature on pandemics before 2020 did not provide a usable matrix to organise and understand the emerging information on COVID-19, impeding international comparisons and preventing effective knowledge transfer across settings. For example, the reference book on mental health and pandemics, although relevant in many aspects, assumed that epidemiological reporting and modelling provided the information necessary to frame the response to COVID-19:

> *"Pandemic outbreaks…have predictable epidemiological models that allow limited, but valuable, time for prognostication, planning, and preparation as the pandemic approaches and progresses"* [14].

While this author concluded that general health information was both available and reliable, we found that this pandemic has shown the contrary. The WHO defines six phases of guidance for pandemic risk management [15], describing different periods in the evolution of pandemics and relating them to specific recommendations on planning, monitoring, communications, actions to reduce the spread of the disease, and sustaining continuity of health care. The Centers for Disease Control and Prevention (CDC) have developed the Pandemic Intervals Framework (PIF) [16] which also defines six intervals to frame interventions and policies. However, these intervals were put in place for tracking the phases of an influenza pandemic, informed by a century of aggregated knowledge on its characteristics. However, COVID-19 has shown critical differences with previous flu pandemics. For example, the extension of the contagion phase during the incubation period, the large proportion of asymptomatic and minor symptom cases, the role of superspreaders, and the lack of availability and/or accuracy of testing during the acceleration and continuation of the pandemics in most of the countries.

Available definitions of pandemic phases failed to provide a good understanding of the depth, extent and complexity of the impact of COVID-19 locally, nationally or worldwide. Alternatives have been suggested [17] but they may be too complicated or difficult to adapt to this pandemic in order to drive rapid, informed planning. Most existing definitions also focus largely on health and fail to adequately describe the broader societal impact of pandemics, thus missing critical information for understanding the longer-term socio-economic consequences of COVID-19.

The 16 selected sites clearly showed major differences in the evolution and control of COVID-19, that did not fit the phases of a pandemics established by the international reference organisations (Table 1). During March and April 2020 some sites were preparing for the acceleration phase of the pandemic (e.g. Australia). Others managed to pause or slow the active outbreak (Denmark) while others faced explosive expansion (Italy, Spain, UK, US). A number of sites were declining or never reached a significant outbreak and the focus was turning to recovery (Taiwan and partially Australia). The challenges posed by each phase varied and a material impact on health system management. The capacity to clearly assess these phase variations was hampered by competing or overlapping definitions and the application of inconsistent typologies.

In order to better understand the impact of COVID-19 on health planning and to create some consistency, we framed the evolution of the pandemic in five major phases as follows:

1. Preparation – the regulations in place and actions taken before declaration of the first case
   - 1.2. Initiation - the regulations in place and actions taken before declaration of the first 1000 cases
   - 2.2. Suspension – the situation in which accumulated cases remain below 1000 after two months – in other words some measure of control has been asserted over the outbreak
3. Acceleration – the course of the pandemic, regulations in place and actions taken between case 1000 and the peak of the curve of declared cases. This phase includes when the acceleration slows, or there is underlying community continuation or control.
4. Deceleration – the course, regulations in place and actions taken after stable decrease in the curve of declared cases (tentatively below one standard deviation of the pandemic's peak in the jurisdiction).
5. Recovery - regulations in place and actions taken one month after reaching zero declared cases, including preparedness for a second wave.

Under this classification system, the 'active' period covers all parts of the acceleration and deceleration phases. This classification is shown in Table 1, aligned against some of the existing international pandemic phase frameworks. The data shown in Tables 2 and 3 indicates that there are several types of acceleration according to the speed of growth in the number of declared cases- very mild, mild, moderate, and explosive. This paper does not provide a workable definition of deceleration, which will require further work.

Health system indicators

A major problem revealed during the pandemic is the appalling level of uncertainty regarding key indicators for estimating numbers nationally and worldwide particularly during the acceleration and deceleration phases of the pandemic [18,19]. The only certainty is that the official numbers of most indicators relevant for planning in most countries constitute little more than rough estimations, with high variability in the calculation methods and reporting. Leaving aside issues about defining pandemic 'phases', apparently simple data such as the number and rates of cases, deaths, tests performed, population infected, and contagion rates have shown striking inconsistencies. The reproduction number (R0) is a key indicator of the pandemic spread as it describes the intensity of the infectious disease outbreak. After 6 months of the outbreak the R0 value oscillates between 1.3 and 7.7, a range wider than any other recent pandemic [20].

Inconsistent, poor-quality and uncertain data have made planning more difficult worldwide since the onset of the infection in China. As an example, declared cases in Spain were 227,436 on 13 May 2020 while a diagnostic test survey estimated that 5% of the population was infected by that time (2.4 million people) [21]. As of 4 August 2020, declared deaths due to COVID-19 in Spain had reached 28,498 while the excess mortality for this period (mortality above what would be expected based on the non-crisis mortality rate in the population of interest during the same period), was approximately 44,000, suggesting a 30% underestimation in the number of deaths related to the COVID-19 outbreak [22]. Strikingly, this has been justified by the uncertainty of the cause of death in the excess of seasonal mortality confounding "death caused by the infection" with "death caused by the pandemic". This does not happen in the evaluation of other human and environmental crises. Disasters like earthquakes, flooding or heat waves use mortality attributable to the crisis, either direct or indirect. The Assessment of Crisis and Mortality Communications and the Information Environment of Hurricane Maria in Puerto Rico in 2017 provides an example on current controversies and approaches to this topic [23]. In any case deaths of declared cases may cause a gross underestimation of the societal impact of the pandemic. The disease control office at the Spanish Ministry of Health reported different figures to the European Centre for Disease Prevention and Control, WHO and Organisation for Economic Cooperation and Development (OECD) in the last week of May 2020.

Unreliable excess mortality data during the COVID-19 active period has been reported in the European region (ranging from 10.6% in Portugal to 98.8% in Italy) [24]. The information has been more reliable in countries in countries where the pandemic has impacted less: Australia, Denmark and Taiwan

Table 1
Stages of the COVID-19 Pandemic. A new basic framework for international comparison.

CDC Intervals	National epidemics (Definition)	International (pandemics) WHO Phases	Pan-MHIN Stages	Definition (for catchment areas over 1 million pop.)
1. Investigation interval	A new type of virus is identified and investigated—in animals or humans anywhere in the world—that is thought to have implications for human health.	1.A virus in animals has caused no known infections in humans.	1.Preparation	Regulation and Actions taken before the first declared case in the country (or defined catchment area)
2. Recognition interval	Increased cases, or clusters of cases, are identified, along with an increased potential for person-to-person transmission	2.An animal flu virus has caused infection in humans.	2. Initiation/ suspension	Evolution of epidemics, regulation and actions taken between case 1 and case 1000 of the first wave. If the accumulated cases have remained below this figure after two months stage 2 is considered in “suspension”
3.Initiation interval	Cases of the virus are confirmed with both efficient and sustained person-to-person transmission	3.Sporadic cases or small clusters of disease occur in humans. Human-to-human transmission, if any, is insufficient to cause community-level outbreaks.	3. Active	Evolution of epidemics, regulation and actions taken after case 1000.
4. Acceleration Interval	The new virus infects susceptible people. Public health officials may take measures such as closing schools, encouraging social distancing, and offering antivirals or vaccines—if available.	4.The risk for a pandemic is greatly increased but not certain.	3.1. Acceleration/ slowed	Evolution of epidemics, regulation and actions taken before case 10,000. If the accumulated cases have remained stable below this figure after two months stage 3.1 is considered “slowed”.
		5.Spread of disease between humans is occurring in more than one country of one WHO region.	3.2. Continuation	Evolution of epidemics, regulation and actions taken after case 10,000. The coding of the continuation phase is measured according to the number of declare cases (letters) followed be the number of peaks, and the number of outbreaks (numbers) (*). The staging of the severity is established adapting a Fibonacci sequence: Mild: below 20,000 Moderate: 20,000–80,000 Severe: 80,000–210,000 Very severe: over 210,000
		6.Community-level outbreaks are in at least one additional country in a different WHO region from phase 5. A global pandemic is under way.	3.3. Deceleration	Evolution of epidemics, regulation and actions taken after reducing declared cases below 10,000 over the last two months
5. Deceleration interval	There is a consistently decreasing rate of cases in the United States.	7. Post-peak period Pandemic disease levels in most countries with adequate surveillance will have dropped below peak observed levels. The post-peak period signifies that pandemic activity appears to be decreasing; however, it is uncertain if additional waves will occur and countries will need to be prepared for a second wave.	3.4. Controlled	Evolution of epidemics, regulation and actions taken after reducing declared cases below 1000 over the last two months
6. Preparation interval	Even after the pandemic has subsided, public health officials continue to monitor the virus and brace for another wave of illness.	The disease activity will have returned to levels normally seen for seasonal influenza. It is expected that the pandemic virus will behave as a seasonal influenza A virus. At this stage, it is important to maintain surveillance and update pandemic preparedness and response plans accordingly. An intensive phase of recovery and evaluation may be required	4. Recovery (preparation for a second wave)	Regulation and actions two months after reaching zero declared cases. In fact evidence arising from COVID-19 experience suggests this stage should refer back to stage 1, in terms of preparation for a second wave.

The healthcare ecosystem/glocal approach

Pan-MHIN sites recorded and reported the evolving complexity of their situations in relation to COVID-19 and the need for a whole of system approach to response planning. This approach involves applying systems thinking to better understand public health challenges and identifying desirable collective actions. This kind of approach has been adopted for health planning in both Scotland [25] and the Basque Country in Spain [26]. It uses healthcare ecosystem methods to analyse, monitor and guide decision making. Health ecosystems refer to the totality of the circumstances that relate to a given health phenomenon in a defined environment. These characteristics comprise the general, natural and social (built and human) capital [27]. A population health ecosystem includes four main domains: the places and communities in which we live; the wider determinants of health (for example the social and demographic characteristics of the environment); our health behaviours and lifestyles; and integrated health care provision at

Table 2
Evolution of the COVID-19 pandemic in the seven countries analysed in this study (as at 15 August 2020).

Country	Pop. (Million)	Date Case 1	Date Death 1	Date Case 1000	Date Death 1000	Response delay (1)	Total declared cases June 7	Total declared cases Aug15	Total declared deaths June 7	Total declared deaths Aug15	Stage (evolution) Aug15
Australia	25.4	Jan.25	March 1	March 20	-	71/55	6980	19,862	102	375	Active Continuation Mild
Denmark	5.8	Feb.27	March 14	March 18	-	49/15	10,667	14,306	587	621	Active Continuation Mild
Taiwan	24	Jan.21	Feb.16	-	-	−9 /0	443	482	7	7	Initiation suspended
Italy	60.3	Jan.29	Feb. 21	March 3	March 28	55 / 31	221,216	252,809	33,846	35,234	Active Continuation Very Severe
Spain	46.7	Jan.31	March 3	March 10	April 2	60 / 38	227,436	342,813	27,135	28,426	Active Continuation Very Severe
UK	66.5	Jan.31	March 6	March 14	March 26	71 / 50	286,000	316,367	40,542	41,357	Active Continuation Very Severe
USA (2)	328.2	Jan.20	Feb. 29	March 14	March 25	64/ 53	1980,000	5,3 million	112,000	168,446	Active Continuation Very Severe

(1) Response delay since the declaration of emergency or main contention measures: Number of days since a) the onset of the pandemic (starting on the date of the announcement of the genome of COVID-19 on 9 January 2020), and b) since the first case declared in every country (32).
(2) The public health emergency was declared on January 21, but the national emergency was not declared until March 13.

the different levels of the ecosystem. The healthcare ecosystem and the complexity of dynamic systems approaches provide a better framework for informing policy during disruptive events, such as COVID-19. They reinforce the centrality of international comparison for organisational learning while highlighting the uniqueness of national, state and local processes of prioritisation, planning and monitoring. Local meaning and tailoring are central to dynamic systems planning. International comparisons and comparative effectiveness facilitate transfer and learning from global experiences to local contexts. This has been defined as the "Glocal" perspective in decision analytics in healthcare. Healthcare ecosystems research incorporates and translates knowledge from diverse disciplines, such as systems engineering, business intelligence, economics and financing. Service ecosystem models in environmental sciences have spurred the incorporation of spatial analysis using Geographic Information Systems, visualisation tools, and advanced modelling and scenarios for policy and action planning [27,28].

Building scenarios and advanced modelling is critical to understand the course of the pandemic; for planning and allocating healthcare supply including Personal Protective Equipment (PPE), testing kits, ventilators and capacity of the healthcare system; and to guide effective control measures, financing and overall policy. However the traditional mechanistic and predictive epidemiological models of pandemics such as SIS (Susceptible, Infectious, Susceptible), SIR (Susceptible, Infectious, Recovered) and their derivatives, have failed to provide adequate information to guide policy [29,30] and this problem is not only attributable to the lack of accuracy of available data. This has given rise to sophisticated models that incorporate different scenarios related to the spread of the disease (e.g. role of superspreaders, asymptomatic cases and impact of containment measures), impact of testing, linkage to the overall capacity of healthcare and its workforce, as well as other relevant local information and spatial analytics (e.g. identification and tracking of hot-spots and local outbreaks).

New complex mathematical models have played an increasing role during the COVID-19 active period. Health systems engineering has attracted increasing attention for planning in all the countries analysed [30,31]. An unexpected consequence of the increased interest in modelling is the extensive use of simplified summaries and graphs. The Imperial College London model, released in March 2020, played a key role in stimulating consideration of, and comparsion between, the containment measures being adopted by different nations [32,33].

One of the major consequences of COVID-19 has been the full adoption of information technologies in every sphere of human life, encouraging a new digital framework for community engagement, participatory action and also to accelerate collaborative research using new tools [34]. COVID-19 has deeply transformed the access, supply and utilisation of healthcare through widespread implementation of information technologies [35,36].

The webinar series confirmed how clinician-patient communication moved quickly to telemedicine during March and April 2020 [37]. But it has been haphazard, unregulated and opportunistic. New on-line services, while often popular with both service providers and users, have been typically implemented without agreed standards, systematic monitoring or evaluation and without a well-developed ethical framework, a problem debated prior to COVID-19 [38].

Real-time dashboards have become a routine tool for checking and assessing the evolution of the pandemic. Information sharing platforms and repositories have emerged as relevant tools for exchange of knowledge [34]. In addition, monitoring apps have played a key role in the successful control of the pandemic in Taiwan [39] and have been rapidly adopted by other countries like Australia. However, our capacity to properly understand this massive change is hampered. There is no workable taxonomy of

Table 3
Severity and response to the COVID-19 active stage in selected regions and countries.

Target Areas	Population (millions)	Preparation Phase (preparedness)	Initiation Phase Response	Active Phase Response	Active Phase Type	Control measures (impact on social capital)	Planning supported by evidence
Madrid (Spain)	6.6	None	None	Late	Continuation Moderate (explosive)	SD+ Total Lockdown	Low
Barcelona (Spain)	7.5	None	None	Late	Continuation Moderate (explosive)	SD+ Total Lockdown	Low
Canary Islands (Spain)	2.1	None	Medium	Early	Acceleration (slowed)	SD+ Total Lockdown	Medium
Friuli-Venezia-Giulia (Italy)	1.2	None	Medium	On time	Acceleration (slowed)	SD+ Total Lockdown	Partly
Florence (Tuscany, Italy)	3.8	None	None	Late	Continuation Mild	SD+ Total Lockdown	Partly
London (UK)	8.9	None	None	Late	Continuation Moderate (explosive)	SD+ Lockdown	Low
Central Region Denmark	5.8 (Denmark)	Some	Medium high	Early	Continuation Mild	SD+ Lockdown	Mostly
New York City (NY, US)	19.5	None	None	Late	Continuation Very severe (explosive)	SD+ Lockdown	Partly
Boston (MA, US)	6.8	None	Medium	On time	Continuation Severe (explosive)	SD+ Lockdown	Partly
Canberra (ACT, Australia)	0.4	Some	High	Early	Initiation suspended	SD+Lockdown	High
New South Wales (Australia)	7.5	Some	Medium high	Early	Acceleration	SD+Lockdown	Mostly
Queensland	5.0	Some	High	Early	Acceleration (slowed)	SD+Lockdown	Mostly
South Australia	1.7	Some	High	Early	Initiation suspended	SD+Lockdown	Mostly
Victoria (Australia)	6.4	Some	Medium high	Early	Continuation (mild)	SD+ Lockdown	Mostly
Western Australia	2.6	Some	High	Early	Initiation suspended	SD+Lockdown	Mostly
Taiwan	24	High	Very high	Very early response	Initiation suspended	SD+Monitoring cases and quarantine	High

Verbal and semaphore (*) analogues are only indicative to facilitate quick appraisal and broad comparison.
(SD = social distancing).

eHealth tools [40]. There is also no consensus on its evaluation [41] nor on the description of local and national eHealth ecosystems [42]. These components are urgently needed to better understand the impact of digitalisation arising from COVID-19.

International comparisons and evolution of the pandemic

A brief comparative appraisal of the evolution of COVID-19 in the selected countries is shown in Table 2. The spread of cases has been uneven across countries and regions. Taiwan was the only country examined here that prepared for the pandemic, implementing measures well before the first declared case. Taiwan's first control and containment measures were implemented nine days before the COVID-19 pandemic was declared in China, by a national independent authority. Taiwan's policy measures during the preparatory and early active period involved strict control of international travel, targeted quarantine and follow-up of risky and declared cases both digitally and by case managers. The use of big data analytics, new technology, and proactive testing played a key role in avoiding an acceleration during the active period [43]. This facilitated control of the pandemic without strict confinement or lockdown, despite its proximity to China and the early detection of the first declared case (January 21) (Table 2).

This rapid response and high reliance on technology has been a common characteristic of many countries that have successfully managed COVID-19 such as Israel, Singapore and Korea, but none to the extent of Taiwan. The Pan-MHIN identified several factors driving successful containment including rapid response; an integrated health care system with universal access; strong primary care; and planning and action based on organisational learning from previous pandemics.

In other countries not quickly overwhelmed by COVID-19, like Denmark and Australia, more time meant opportunity for better organisation. Denmark identified an early lack of supply of PPE, but this was met by a quick response and rapid deployment of containment measures, supported by a strong health system, and a culture of trust and adherence to official sources of advice. Even in countries that avoided an acceleration phase, regional differences appeared. In Australia almost half of all COVID-19 cases in April and May were in one state. Later outbreaks in July and August have been in one other state. There were significant jurisdictional differences in policy and control measures adopted across Australian states, such as the number of people at gatherings. In contrast with Taiwan and Denmark, the state of national emergency in Australia was declared relatively late in relation to the date of the first declared case and the first death due to confirmed COVID-19 (Table 2). Also, in Australia, schools remained open after the Chief Medical Officer stated that there was no evidence of child transmission, while declared cases in children and adolescent were above 300 in Italy and in Spain.

None of the lesser-impacted countries reached 1000 declared deaths during the active period. This simple indicator of acceleration allowed a practical distinction across the countries analysed in this study irrespective of their size. Paradoxically, the comparatively small impact of COVID-19 in these low-impact countries left services underwhelmed with a sense of a 'phoney war' [44], characterised by vacant beds, empty emergency rooms and wards and closed services.

The situation was completely different in countries that suffered an acceleration of the pandemic. The countries hardest hit by COVID-19 were faced with "explosive" exponential growth in cases over a short period and reached a saturation level in their health system's capacity in hot-spot cities. Spain had 525 declared cases of COVID-19 on 7 March 2020, almost 150,000 thirty days later and over 200,000 after 60 days (Table 2). The Hospital Princesa in Madrid has 500 beds, but its capacity was increased to 600 beds during the active period, all of them occupied by COVID-19 cases at the peak of the acceleration phase, with a significant number of health staff infected. The US had 88 cases at the start of March but 177,000 cases a month later. The extent to which the jurisdictions capitalised on or squandered the time they had to prepare is controversial [45].

Disparities across areas and countries with a high incidence also appeared though given this virus was novel, this was not unexpected. The rate of deaths was significantly higher in Italy, Spain, US, UK and Belgium, than in Germany [46]. The rate of declared cases in health workers in Spain was the highest in the world in May 2020. The low demand for care for other conditions was also reported in countries suffering an explosive active period. Even in these highly affected countries, major regional and local differences were identified during the active period. For example, the situation was quite different in the Friuli Venezia Giulia (FVG) region in comparison to neighbouring Lombardy, and between Madrid and Barcelona compared to the Canary Islands, where the epidemic was controlled despite reporting the first declared case in Spain. Even in hotspots in the same country, different perceptions on severity, policy and containment were reported, for example, between Boston and New York.

This unevenness poses significant planning and resource allocation dilemmas for health policy and planning. It has affected the response and determined if services coped or were overwhelmed. The acute healthcare system nearly collapsed at the peak of the acceleration phase in hospitals in Madrid, Barcelona and London. This highlights the importance of considering the heterogeneity of the local population (including behavioural differences) and health systems.

Based on the narratives from the webinars and local-national COVID-19 indicators, we have provided a global estimate of the severity and the response to the pandemic in every one of the target regions using semaphore visual and verbal analogues for a broad comparative description shown in Table 3.

Discussion

COVID-19 has given new impetus to the study of epidemiology. However, a key lesson is the need for a broader application of the concept within a whole of system context. More specifically, there is a need for a managerial epidemiology geared to not just map the uneven contours of the virus as it spreads within and across nations, but designed to help address the practical and logistical issues which manifest [47,48]. This would to help decision makers determine which specific resources, human and other, need to be working where. To date, epidemiological data has been applied narrowly, for example to estimate the date at which demand for intensive care beds might outstrip supply [49].

This more robust approach to a managerial epidemiology would pick up on relevant work by the WHO which has indicated several key logistical pillars underpinning this kind managerial epidemiology, including:

- massive upscaling of testing, tracking and tracing
- enhanced hygiene measures such as masque wearing, frequent handwashing and deep cleaning
- continuous enforcement of some physical distancing policies, banning large gatherings, encouraging people to work from home.

A further issue identified by the Pan-MHIN is the significance of closing borders. In Australia, this does not just mean national points of entry, but also borders between constituent states and territories. Logistical concerns are broad, including managing the health response, in terms of workforce, equipment, medical products, tracking teams etc.; market logistics such as food supply to locked-down areas, managing panic buying; population movements; and the flow of goods between nations and regions. An effective and holistic approach to managerial epidemiology would consider the breadth of these issues and plan accordingly.

The Pan-MHIN identified, during the early active period, key ingredients which had emerged in successful management of health care in the context of COVID-19, and that were confirmed by subsequent reports by experts and national and international organisations [6]. The Network noted that it seemed easier to plan, organise and deliver health care through the COVID-19 crisis in those countries with access to universal public health care rather than those without. In the US for example, many people needing help lacked appropriate insurance coverage. Systemic planning for pandemic response was made more difficult due to complicated funder and provider arrangements.

The Network also noted the greater robustness of systems exhibiting higher levels of integration between primary, community and tertiary elements of health care. Given the massive reduction in access to health care overall, particularly hospital- based acute and outpatient care, those services with significant community health infrastructure are better placed to respond to an event such as COVID-19. Those countries with more independent governance and management of the pandemic seemed to perform better and offered higher levels of confidence than those where decision making was more guided by politics.

Data accuracy and availability was another source of disparity across countries. The US reported how fractured service arrangements are mirrored by a lack of data integration, limiting both the sources and quality of information available to guide decision makers, who were often forced to rely on tardy billing information as a prime source of information about COVID-19 help-seeking.

Places that already enjoyed strong connectivity of e-health and medication records were better positioned to understand client needs throughout pandemic, conduct public health surveillance and provide early warning. But there are big differences between countries in their capacity to take advantage of the opportunities e-health provides [50].

Another lesson confirms the importance of the healthcare ecosystem approach to evidence informed planning [27]. COVID-19 has shown the importance of a whole system framework, considering both global aspects and the importance of local experiences as well as the need to adapt general recommendation to local circumstances. The dramatic impact on nursing homes and other social housing services indicates that the care system goes far beyond acute wards, intensive care units and the number of ventilators. A deep knowledge of the whole system is fundamental for planning. This includes employment, education, social care, housing, justice and defence. The 'whole society approach' also suggests that new forms of social connection should be developed and enhanced as part of a collective effort to tackle the social problems thrown up by COVID-19 [51].

Author contributions

Professor Salvador-Carulla and Dr Rosenberg were responsible for drafting this paper. Adj Assoc Professor Mendoza and Dr Tabatabaei-Jafari helped determine the content, contributed to the text and edited the draft. All the network members (Pan-MHIN) contributed to the final version.

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