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Empowering quality data – the gordian knot of bringing real innovation into healthcare system

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Abstract

Objectives: The introduction of Personalised Medicine (PM) into healthcare systems could benefit from a clearer understanding of the distinct national and regional frameworks around the world. Recent engagement by international regulators on maximising the use of real-world evidence (RWE) has highlighted the scope for improving the exploitation of the treasure-trove of health data that is currently largely neglected in many countries. The European Alliance for Personalised Medicine (EAPM) led an international study aimed at identifying the current status of conditions.

Methods: A literature review examined how far such frameworks exist, with a view to identifying conducive factors – and crucial gaps. This extensive review of key factors across 22 countries and 5 regions revealed a wide variety of attitudes, approaches, provisions and conditions, and permitted the construction of a comprehensive overview of the current status of PM. Based on seven key pillars

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identified from the literature review and expert panels, the data was quantified, and on the basis of further analysis, an index was developed to allow comparison country by country and region by region.

Results: The results show that United States of America is leading according to overall outcome whereas Kenya scored the least in the overall outcome.

Conclusions: Still, common approaches exist that could help accelerate take-up of opportunities even in the less prosperous parts of the world.

Keywords: cancer; empowerment; health data; infrastructure; personalized medicine; policy framework; public trust; real world evidence.

Introduction

Personalized medicine (PM) can deliver benefits for the citizens through public health initiatives that promote disease prevention, prediction of risk, and promotion of healthy lifestyles, with innovative medical interventions tailored to the specific needs of individual patients, providing better treatment, preventing adverse reactions and fostering a more efficient and cost-effective healthcare system (HCS). But health care systems are not always ready to respond to the opportunities. The disruptive nature of personalized care challenges the traditional patterns of thinking in this domain.

At the end of July 2022, the International Coalition of Medicines Regulatory Authorities (ICMRA) issued a statement [1] on international collaboration to enable real-world evidence (RWE) for regulatory decision-making. This unprecedented step marked yet another recognition of the accelerating readiness to take seriously the potential of health data – specifically real-world data (RWD) and RWE, after years of hesitation and even suspicion among many regulators and healthcare campaigners about their value. The statement, drawn up by the representatives of some 40 countries around the world, as well as of the World Health Organisation (WHO), endorsed the role that RWD and RWE have in supporting the different stages of development and use of medicines, and also noted how the role of health data is evolving rapidly.

The ICMRA initiative was led by European Medicines Agency (EMA), Food and Drug Administration (FDA) and Health Canada, organisations where the move towards more effective use of the wealth of health data has already been underway for some years [2]. These are countries where, predominantly, conditions ranging from infrastructure to legislation are being systematically explored and gradually improved. Notably in Europe, diplomats and officials are now fine-tuning the European health data space proposed by the European commission in May 2022 [3, 4] and the outcomes envisaged include better diagnosis and treatments, improved patient safety and continuity of care, greater healthcare efficiency, and enhanced opportunities for research and innovation [5]. However, taking full advantage of the opportunities is still very much work in progress, even in the wealthiest nations. And conditions for making best use of health data are still less conducive in many other parts of the world. The opportunities are there for the taking – and ICMRA itself has underlined many of them in its July statement [1]. The lessons that are still being learnt in the more prosperous countries can now serve to provide some short-cuts that could assist implementation in other countries and regions – offering them a chance of a more rapid catch-up.

The opportunities

Better health care, more efficient health systems and a healthier population are mainly influenced by more efficient collection, processing and use of data – on the health status of individual patients, the incidence of disease and the costs of care [6]. The technologies for acquiring data are advancing all the time, notably with the capacity for precision profiling through molecular diagnostics. The consequence is to deliver both individual and societal benefit [7]. Health data is a repository of potential value that can be realised to deliver benefits to society. Technology has opened up massive opportunities by generating data that is increasingly available and increasingly useful, in regulatory processes such as marketing authorization, early access schemes, and pharmacovigilance, in Health Technology Assessment (HTA) decision making, in academic research, and in healthcare management and financing [8, 9]. It is huge opportunity for enabling better use of the vast amounts of health data that are currently neglected – which could mean improved access for citizens to their own data, and also improved access for researchers and public health authorities to large-scale data sets for secondary use. RWE is of benefit for patients, clinicians, payers, and regulatory decision-makers [10–12].

It also represents another opportunity as a precedent for more effective policymaking on health: it holds out the prospect of creating a more sensitive governance approach that is evidence-based and responsive to real need, instead of a rigid legislative approach allowing little scope for innovation. Capturing transferrable and reliable RWE that can be used by regulators or for HTA decision-making might lead to

potential health outcome benefits and cost savings to inform resource allocation and fast-tracked regulatory and coverage decisions [9]. The development of innovative healthcare products and services both generates and requires hitherto unimagined quantities of reliable RWE, and many regulatory bodies have increased the value they place on it [13].

The conditions

The benefits of health data can be fully realised only if systems are in place for their national – and international – exploitation [14]. Big data poses questions about how to use new data superhighways to meet the needs of patients, researchers, regulators, HCPs and industry [15–18]. Progress will require both the public and private health sectors to adopt a more sophisticated approach to dialogue, in a genuine spirit of co-creation. There are continuing challenges in making use of such data – ranging from heterogeneous data sources and different levels of data quality to the various governance models that apply to data sharing and access from country to country [19]. There is a need for trust; trust by the public and patients of the health system, trust by health system actors in the reliability of each partner in health data use, and trust by citizens in the use of data [20–23]. Challenges include data integrity, quality, and security, lack of skilled personnel to analyse the large volume of data, lack of confidence in observational research, and issues of trust between users and data holders. There is also a need for complex collaboration of parties as diverse as industry, academia, hospitals, government, and payers [9].

Homogenization of different levels of data quality and accuracy, as well as integration of data fragments from different sources are some of the current key challenges in collecting and maintaining large public data sets with consistent and reliable information. In order to show the current value of such large data sets, it is necessary to include the challenging process of converting big data into valuable insights that can be limited due to small number of cases, class imbalance and non-uniform misclassification in current AI models [17]. The risks associated with the tensions of data collection in the laboratory vs. natural conditions have resulted in solutions disconnected from practical applications when working with real scenarios, resulting in poor performance due to the use of unreliable data [24]. And in the same way that the innovative approaches of precision medicine require evolution in methodologies of clinical trials, RWE also has to evolve. There are some ethical, regulatory, and legal issues related to achieving broad patient consent and data sharing. Consensus guidelines are needed to standardise the methodology of RWE-based studies and best practices for data sharing according to data-protection regulations [25–27]. At present, only few journals provide specific recommendations for authors to follow when conducting, reporting, or submitting manuscripts on RWE studies. Making raw data and bioinformatics pipelines for clinical genomics tests accessible to researchers would facilitate re-analysis of data and cross-test comparisons. Moreover, it is important to build infrastructure that brings data together and that invests in future analyses [28].

Citizens are key stakeholders in the entire process, given that their data is at the heart of the exercise. Individuals who choose to share private information about their health should be able to control their own information [29]. Patients and the public must benefit from advances in health research with the help of data protection regulations that will create an appropriate legal framework. This legal framework should aim to establish an appropriate balance between enabling the safe and protected use of personal data in health research and the rights and interests of individuals [30].

In order to grasp the nature and scale of the challenges across a wider geography, European Alliance for Personalised Medicine (EAPM) convened a series of expert panels featuring stakeholders from healthcare, academia, industry and patient organisations from Latin America, Asia, Africa and Australia in May 2022 to sketch some illustrative national and regional profiles, backed up by an extensive literature search. The findings are unsurprising: there is wide variation in capacity and ambition to make use of health data in general and RWD/RWE in particular, most frequently related to issues of underlying prosperity and stability, and to the degree of organisation of health care. However, out of this overview, it is possible to discern some common themes both in relation to obstacles and to approaches to overcome them. A proper framework is needed to empower the scientific enterprise that can realize this potential. The study was conducted, by EAPM, to explore what factors are the most crucial to ensure that health systems are resilient enough to not only handle shocks like a global pandemic but also respond to those underlying forces that are shaping healthcare needs, and particularly for cancer patients, where PM has already begun to transform care prospects. A policy framework to bring personalized medicine into healthcare systems is still not in place everywhere, leaving significant gaps in the approach to issues such as governance, finance, reimbursement, infrastructure, interdisciplinary cooperation, awareness, privacy, collaboration, technology and resilience.

Materials and methods

European Alliance for Personalised Medicine (EAPM) organised series of expert panels in May, 2022 where different stakeholders from healthcare, industry, patient organisations and academia were gathered. The experts were from Asia, Africa, South America and Australia (Table 1). The goal was to explore what are the new options and possibilities to improve health data on the global level which would have a positive impact on personalized medical care. This was complemented with the extensive literature search which provided valuable background for discussions. In order to broaden the views and better understand the barriers and factors necessary for the improvement of PM, EAPM additionally conducted a study to identify the current status of conditions. The PM landscape in oncology was researched globally in the literature, identifying key barriers & enablers for adoption & implementation, which were categorized into seven pillars (Figure 1). As a result of experts brainstorming and a systematic literature review from scientific articles, Governance, Reimbursement, Infrastructure, Adoption and Awareness, Privacy and Cyber Security, Collaborations and Health Technology & Processes were identified as the key factors or pillars. 857 articles were reviewed, yielding 213 relevant articles relating to 22 countries across 5 regions. The research revealed 68 measures based on the seven pillars. The qualitative data was manually converted into quantitative data for easier analysis, and graphical representation and correlation analysis were used to evaluate the current landscape of PM adoption on the basis of selected key areas.

Table 1: Number and characterization of experts involved in the series of expert panels.

Characteristic	Number (%)
Total number of experts	48 (100%)
Sex	
Total	48 (100%)
Female	27 (56%)
Male	21 (44%)
Area of expertise	
Clinician/medical oncologist	16 (33%)
Regulatory official	11 (23%)
Patient representative	8 (17%)
Researcher/geneticist	13 (27%)
Regions	
Africa	17 (35.5%)
Asia	17 (35.5%)
Latin America	10 (21%)
Middle East	4 (8%)

Data analysis

Spearman rank correlation analysis: Spearman rank correlation is a non-parametric test that is used to measure the degree of association between two variables. The Spearman rank correlation test does not carry any assumptions about the distribution of the data and is the appropriate correlation analysis when the variables are measured on a scale that is at least ordinal [31]. Cohen's standard may be used to evaluate the correlation coefficient to determine the strength of the relationship, or the effect size. Correlation coefficients between 0.10 and 0.29 represent a small association, coefficients between 0.30 and 0.49 represent a medium association, and coefficients of 0.50 and above represent a large association or relationship. The "*" sign indicates the correlation coefficient value is statistically significant at 0.05 significance level, which implies that there is a significant association or relation between dependent and independent variables. Through correlation, the index makes possible the attribution of specific factors to performance in specific areas of PM development and implementation, here presented by pillar.

Pillar-1: governance: Independent measures such as uniform testing parameters, national PM priority, PM in national cancer plans, etc. show weak but positive correlation to Multidisciplinary guidelines which is the dependent measure. It implies that if all the factors such as uniform testing parameters, national PM priority, PM in national cancer plans, etc. are enforced and defined then the multidisciplinary guidelines may or may not be observed due to the fact that the

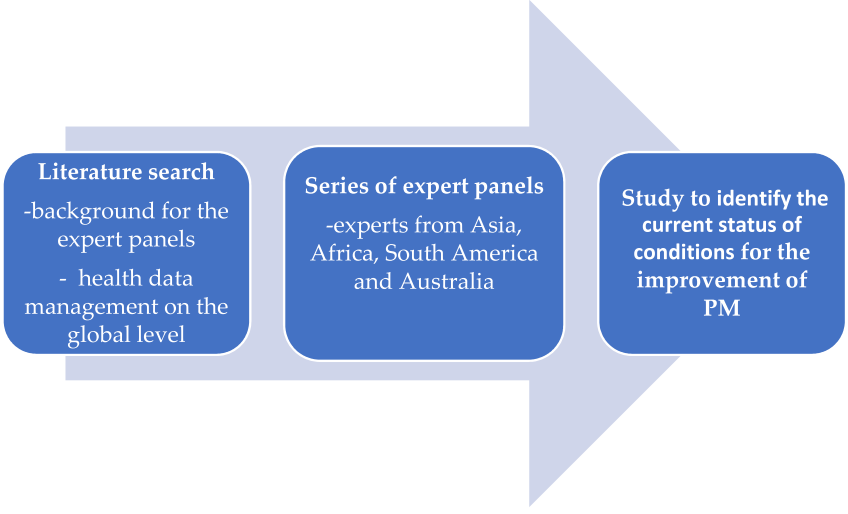

Figure 1: Three steps conducted in the research strategy.

Table 2: Correlation table of governance.

Key area	Dependent variable	Independent variable	Roh (corr. coefficient)
Governance	Funding	Governmental aid	0.6224*
	Government support	Government support (incorporation of biomarkers in diagnostic test)	0.4863*
	External support: funding	Clinical trial methodology	0.4370*
		National PM priority	0.5164*
		Health expenditure per capita	0.5307*
		Governmental aid	0.4468*
		Preferability/priority of biomarker test	0.5684*
		Government support (incorporation of biomarkers in diagnostic test)	0.7062*
		R&D expenditure	0.4692*
	Clinical trial methodology	Uniform testing parameters	0.5164*
		PM in national cancer plans	0.8429*
		General PM policies	0.8429*
		Clear funding mechanism	0.4370*
		Government support (incorporation of biomarkers in diagnostic test)	0.4874*
	Multidisciplinary guidelines	Drug development guidelines	1.0000*
		Clear funding mechanism	0.5610*
		Health expenditure per capita	0.4702*
		Multidisciplinary legal guidelines	1.0000*
		Preferability/priority of biomarker test	0.4512*
		Government support (incorporation of biomarkers in diagnostic test)	0.4392*
		R&D expenditure	0.4360*
		Governance	1.0000*
	Uniform testing parameters	National PM priority	0.5003*
		PM in national cancer plans	0.4353*
		General PM policies	0.4353*
		Clear funding mechanism	0.7483*
		Health expenditure per capita	0.4748*
		Preferability/priority of biomarker test	0.5739*
		Government support (incorporation of biomarkers in diagnostic test)	0.6449*
		R&D expenditure	0.6043*

correlations are weak (Table 2). In the USA, multidisciplinary guidelines are in place and implemented so all the other guidelines are also in place and implemented. Moreover, funding policies by the government to cover treatment expenditure and availability of grants to conduct R&D are also high [32, 33]. However, in South Korea, PM is not considered in national cancer plans and some general PM policies are not in place although the multidisciplinary guidelines are in place and implemented. Other independent measures are in place and implemented as well as funding policies by the government to cover treatment expenditure and availability of grants to conduct R&D are also high [34–38]. Similarly, other dependent and independent variable can be explained.

Pillar-2: reimbursement: Reimbursement for medicine and medical devices is significantly correlated to reimbursement policy implementation in positive direction which implies that if implementation of the reimbursement policies exists the reimbursement for medicine and medical devices is high and vice-versa (Table 3). In Brazil, reimbursement policies exist so the reimbursement for medicine and medical devices is high [39]. In India, the implementation of the reimbursement policies related to PM doesn't exist so the reimbursement for medicine and medical devices is low. Reimbursement for medicine and medical devices is negatively correlated to treatment delay due to financial barriers but the correlation is weak, so if the reimbursement policies for medicine and medical devices exist then the treatment delay due to the financial barrier will reduce [40, 41]. In Japan, reimbursement for medicine and medical devices is high but the

Table 3: Correlation table of reimbursement.

Key area	Dependent variable	Independent variable	Roh
Reimbursement	Reimbursement of medicines (existing reimbursement policies for medicines and medical devices)	Reimbursement policy (implementation of reimbursement policy and availability of recently updated policy regarding PM)	0.4878*
	Treatment delay	Reimbursement policy (existing reimbursement policies for medicines and medical devices)	−0.8370*

unmet treatment due to financial barriers is low [42], while in Germany the reimbursement for medicine and medical devices is high and the unmet treatment due to financial barriers is also high [43]. However, in Mexico, reimbursement for medicine and medical devices is low so the unmet treatment due to financial barriers is high [44].

Pillar-3: infrastructure: Data infrastructure and availability of infrastructure is significantly correlated in positive direction to building new infrastructure for easy access to PM, sharing and incorporation of electronic medical records (EMRs) in the health care system, Availability of biobanks, and infrastructure availability. This implies that if the country has better Data infrastructure, then the building of new infrastructure for easy access to PM, sharing and incorporation of EMR in the healthcare system, Availability of biobanks, and infrastructure availability will also be higher and better (Table 4). For e.g., in Japan, Data infrastructure and availability of infrastructure can be witnessed at its best, so the construction of new infrastructure is high for easy access to PM, incorporation of EMR in the healthcare system is high, the biobank is available either regional or national, and very good infrastructure access is available for the R&D of PM [45, 46]. Whereas in Saudi Arabia, though the incorporation of EMR in healthcare system is high, the Data infrastructure and availability of infrastructure cannot be considered good. The construction of new infrastructure is low for easy access to PM, the biobank is not available, and infrastructure is not so well developed for the R&D of PM [47].

Pillar-4: adoption and awareness: In this pillar, Education and training and Availability of PM and Outreach initiatives are the dependent measures which act as a major factor in influencing the adoption and awareness in targeted countries and simultaneously, the independent measures which are Familiarity, Utilization, Level of access, awareness, course of action, education program, psychosocial needs and palliative care. The dependent and independent measures are significantly correlated in the positive direction which implies that if there is higher availability of Familiarity, Utilization, Level of access, awareness, course of action, education program, psychosocial needs and palliative care, then the Education and training, Availability and Outreach initiatives will also be high and other way around (Table 5). For e.g., South Korea, availability of Education and training, Availability and Outreach initiatives is high so the Familiarity, Utilization, Level of access, awareness, course of action, education program, psychosocial needs and palliative care is high and provided [35–38]. Whereas, in South Africa, availability of Education and training, Availability and Outreach initiatives is low so the Familiarity, Utilization, Level of access, awareness, course of action, education program, psychosocial needs and palliative care is low and not provided [48–55].

Pillar-5: privacy and cyber security: Independent variables such as patient privacy guidelines/law or Data management have major impact on Patient Trust, Data management, Secured Environment which are the major factors which influences the adoption of PM in the healthcare system and are considered as the dependent variables. Data management and Availability of Patient Privacy Law/guidelines shows the weak positive correlation which implies that if data are managed better, then the mechanism to protect patients' data will be better and vice-versa (Table 6). For e.g. In Peru, Patient privacy law is available due to the availability of professionals for data management. Whereas in Brazil, the availability of professionals for data management is high but the patient privacy law is not available [56–60]. However, in China, Patient privacy law is not available since the availability of professionals for data management is also low [61–65].

Pillar-6: collaborations: In this pillar, all the independent measures such as Cross Border, Cross-disciplinary and Stakeholder Involvement are positively correlated to dependent measures such as Collaborative Decision Making, R&D Collaborations which implies that if cross-border, cross disciplinary, and stakeholder involvement are available then collaborations in decision making and cross-disciplinary are evident and available and vice-versa (Table 7). For e.g., in the USA, the collaborations and involvement of stakeholders in decision making are evident and available since the cross disciplinary collaborations and data sharing are observed [66, 67].

Pillar-7: health technology and processes: Individual Test Evaluation is the independent measures which influence Companion Diagnostics (CDx), Clinical Decision Support (CDS), Diagnostic Test (EFGR) and

Table 4: Correlation table of infrastructure.

Key area	Dependent variable	Independent variable	Roh
Infrastructure	Reshaping infrastructure	Data infrastructure	0.7654*
		Biobanks infrastructure	0.6472*
		Organisation infrastructure	0.8458*
		Infrastructure (availability of required infrastructure)	0.7807*
		Infrastructure (availability of proper infrastructure to conduct R&D)	0.5592*
	Data infrastructure	Biobanks infrastructure	0.5370*
		Organisation infrastructure	0.9475*
		Infrastructure (availability of proper infrastructure to conduct R&D)	0.5294*
	Biobanks infrastructure	Organisation infrastructure	0.6091*
		Infrastructure (availability of required infrastructure)	0.5711*
		Infrastructure (availability of proper infrastructure to conduct R&D)	0.6516*
	Organisation infrastructure	Infrastructure (availability of required infrastructure)	0.9650*
		Infrastructure (availability of proper infrastructure to conduct R&D)	0.5994*
	Infrastructure	Infrastructure (availability of required infrastructure)	0.5286*

Table 5: Correlation table of adoption and awareness.

Key area	Dependent variable	Independent variable	Roh (corr. coefficient)
Adoption and awareness	Education & training	Familiarity	0.6539*
		Availability	0.6342*
		Utilisation	0.6661*
		Awareness	0.6539*
		Education programme	0.9846*
		Outreach initiatives	0.8570*
	Familiarity	Availability	0.8013*
		Utilisation	0.7650*
		Level of access	0.6980*
		Awareness	1.0000*
		Education programme	0.6354*
	Availability	Utilisation	0.9417*
		Level of access	0.8520*
		Awareness	0.8013*
		Education programme	0.6382*
		Outreach initiatives	0.6964*
		Palliative care	0.5429*
	Utilisation	Level of access	0.8365*
		Awareness	0.7650*
		Education programme	0.6587*
		Outreach initiatives	0.6514*
		Palliative care	0.5400*
	Level of access	Awareness	0.6980*
		Course of action for awareness	0.6858*
		Outreach initiatives	0.8208*
	Awareness	Course of action for awareness	0.6354*
		Outreach initiatives	0.6175*
	Education programme	Outreach initiatives	0.8482*
	Psychosocial needs	Palliative care	0.4356*

Table 6: Correlation table of privacy and cyber security.

Key area	Dependent variable	Independent variable	Roh (corr. coefficient)
Privacy and cyber security	Data management	Secured environment	0.4573*
		Data accessibility	0.4842*
		Cyber security law	0.4573*
	Secured environment	Cyber security law	1.0000*

Table 7: Correlation table of collaboration.

Key area	Dependent variable	Independent variable	Roh
Collaborations	Collaborative decision making	Stakeholder involvement	1.0000*
	Cross-disciplinary	Cross border	0.5492*
	R&D collaborations international		0.5492*
	Data sharing	Cross-disciplinary	0.4530*
	R&D collaborations international		1.0000*
	R&D collaborations international	Data sharing	0.4530*

Genetic Counselling either in positive or negative direction. Individual test evaluation shows weak correlation with Clinical Decision Support and Involvement of patients for making better treatment related decisions. There is a significant correlation between Individual test evaluation with availability and integration of biomarkers in diagnostic tests in positive direction which implies if Individual test evaluation is high then Clinical Decision Support and Involvement of patients for making better treatment-related decisions may or may not be observed high. Nevertheless, the availability and integration of biomarkers in diagnostic tests will be evidentiary high and vice-versa (Table 8). For e.g., In Japan, Individual test evaluation is high, so Clinical Decision Support and Involvement of patients for making better treatment-related decisions is high. Also, the availability and integration of biomarkers in diagnostic tests is high [43–46, 61–65]. Whereas, in France, Individual test evaluation is high, but Clinical Decision Support and Involvement of patients for making better treatment related decisions is low, however availability and integration of biomarkers in diagnostic tests remains high [43].

Results

In the first part are presented results from the conducted study which shows scores yielded from the review of literature which were further analysed based on Percentage Score Comparison and Score Comparison. Percentage

Table 8: Correlation table of health technology and processes.

Key area	Dependent variable	Independent variable	Roh
Health technology and processes	Companion diagnostics (CDx)	Diagnostic test (EFGR)	−0.5222*
	Diagnostic test (EFGR)	Individual test evaluation	0.4529*

of the scores were used to compare the targeted countries (Germany, France, Italy, UK, Spain, USA, Canada, Mexico, Chile, Peru, Brazil, Argentina, India, China, Japan, South Korea, Australia, South Africa, Israel, Qatar, Kenya and Saudi Arabia) and sum of total of the scores were used to compare the regions (Europe, North America, Latin America, Middle East Asia, Asia). In the second part are data and inputs gained at the expert panels organised by EAPM and also from literature search, where current status in health data management, among different global regions, was discussed.

Percentage score comparison, by country

Brazil ranks highest (80%) in terms of collaborations within Latin America due to the presence of Molecular Tumor Boards supporting decision making. In terms of governance all countries within Latin America range between 46 and 56% indicating availability or implementation of policies and guidance are lacking. Mexico lies close to 70% in terms of reimbursement due to several factors such as level of trust, timeline for Health Technology Assessment and approval. Brazil and Argentina lie very close (65%) in terms of good infrastructure. Yet, level of access and availability of education and training remain very low for all especially for Mexico (25%) [68–72]. South Korea, Japan and Australia are the leaders in terms of governance, adoption and awareness and primary cyber security. This indicates availability of education, its implementation in the form of guidelines, and policies and level of trust for data handling and security. China outperforms other countries in Asia with better collaboration systems promoting efficient decision-making, but ranks lowest in terms of health technology and processes due to lack of trust in drug development processes and diagnostics techniques [62, 73–81]. France ranks highest (~87%) for availability of funding mechanisms and governmental support along with adoption and awareness indicating availability of proper education supporting adoption of PM. Reimbursement scenario remains around 60% for all European Union countries with Germany ahead (~70%) due to existing policies. Germany also boasts the best infrastructure indicating up to date availability of data handling systems [82–101]. The United States of America ranks higher than Canada in terms of governance, reimbursement, infrastructure, adoption and awareness, primary and cyber security, collaboration, health technology and processes, displaying excellent supporting factors for successful implementation of Personalised Medicine [102–110]. Saudi Arabia, Qatar and Israel rank above others in terms of data storage privacy, its management and handling. Israel and Qatar range between 60 and 80% in terms of governance, reimbursement, infrastructure and collaborations. Kenya on the other hand ranks lowest due to lack of government support and funding and due to lack of cross collaborations [111–121] (Figure 2).

Score comparison, by region

Asia has the highest average score in terms of governance (~47) followed by Europe (~45), due to major supporting factors such as availability of policy frameworks for implementation of PM, governmental support in the form of funding, national plans and guidelines. The average score for reimbursement still remains very low for all regions, with Europe and North America the best two regions. Major underlying factors include lack of trust in the effectiveness of the PM and uncertainty in the duration of its approval. North America ranks highest in terms of infrastructure, adoption, awareness and health technology and processes due to excellent availability of data handling and storage facilities, and level of access and trust in PM diagnostics such as CDx. Privacy and cyber security and collaborations still remain a challenge for successful implementation of PM due to lack of trust based on ethical reasoning and transparency of data handling, along with risk factors that accompany data handling, data sharing and cross-border collaboration [62, 68–81, 102–110] (Figure 3).

The current status

There are currently insufficient externally governed standards to guarantee the necessary accuracy and reliability of techniques, and data quality is often inadequate. Data must not only be accurate to advance personalised healthcare solutions. It must be possible to share the data, and to do this efficiently and securely [122]. Currently, integrated information systems exist rarely at a country level to permit the secure collection, management, and sharing of patient data [6]. And at global level, there are still fewer. Lack of data storage infrastructure, inefficient health data management, shortage of trained healthcare professionals, low healthcare budgets, and poor service integration hamper progress [123]. At present the databases generated by clinical trials often remain closed, and their content is often uneven in terms of quality and scope of data, and traceability, with lack of longitudinal follow-up data [124]. Limited availability of equipment often makes it difficult to deploy innovative technology that depends on an appropriate information technology. There is a widespread lack of clear policies and

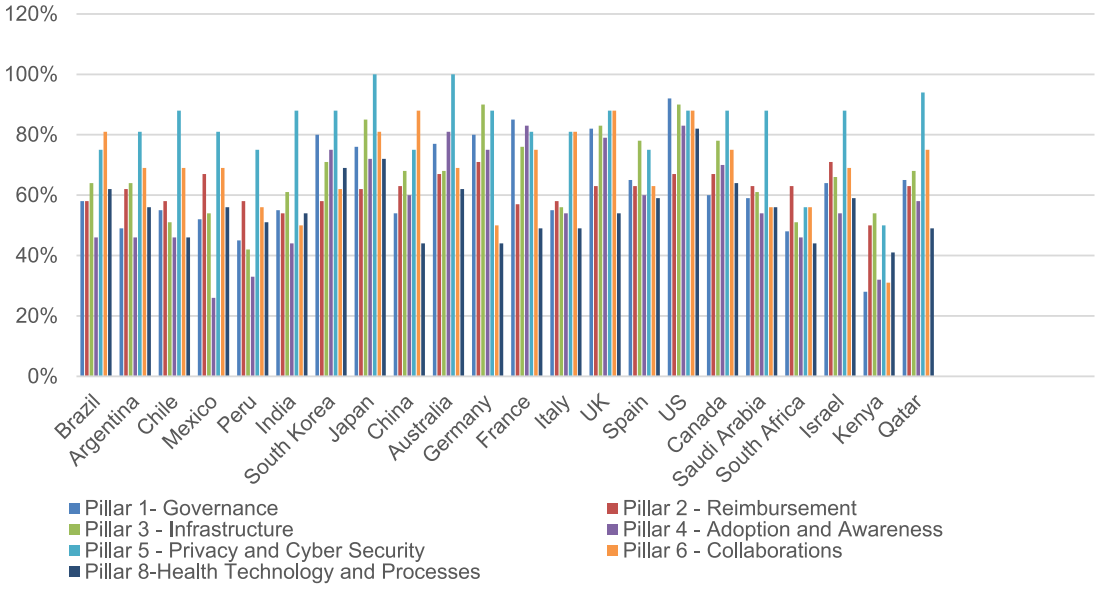

Figure 2: Percentage score comparison of the targeted countries based on each pillar.

procedures on RWD access and protection, and data anonymization and linkage to protect patient confidentiality is uneven. Trust and engagement with science and health is often not strong. Overall, the uptake of RWE is often low. Different perspectives regarding RWE and data management across different global regions are presented in the next chapters which is result of expert panels and literature search.

Latin America (LATAM) perspective

Research on sensing solutions and natural user interfaces has been underway for more than a decade in LATAM, linked to pilot-testing of pervasive care, but the uptake of RWE is still low, and largely restricted to safety or pharmacovigilance and economic questions [125]. At present use of RWE by regulators is mainly for pharmacovigilance purposes (Argentina's National Administration of Drugs, Food and Medical Technology legislation requires "corrective procedures" and Chile's National Drug Regulations Agency's builds "safety profiles" for authorized drugs), while payers and producers focus on economic and effectiveness RWE to support price and coverage negotiations in Argentina, Colombia, and Chile [9].

There are significant gaps. Poor data quality, unclear understanding of RWE applications, and lack of clear policies and procedures on RWD access and protection are some of the frequent barriers faced in the collection and use of RWD, and there is a need to continue in-depth explorations to achieve a better understanding of the landscape of RWE/RWD [125]. Although Brazil generates a large amount of digital health data within key national health datasets, access to RWE is limited by a lack of interoperability between diverse regional and organizational systems, and the country lags behind

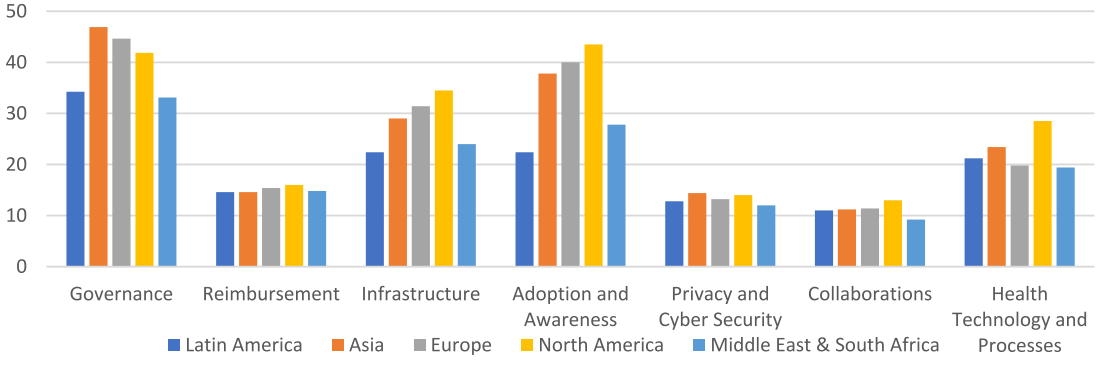

Figure 3: Region-wise comparison based on each pillar.

OECD countries in data availability, reporting, governance and integration [24, 126, 127]. In Chile, connectivity is lacking between 1,400 connected health facilities and 1,000 remote medical facilities and many of its healthcare systems are not easily interoperable, so healthcare providers are deprived of fast and easy access to medical records [128]. Challenges in Mexico relate to healthcare system fragmentation, high cost of hospitals and private insurance and a need for technical capabilities [129, 130]. For Colombia some of the issues are: inadequate implementation of a healthcare model based on diagnostics, promotion and prevention, administrative inefficiencies, changes in population demographics and epidemiology. Data anonymization and linkage to protect patient confidentiality is uneven: Colombian regulators, for instance, did not put any barrier in that matter, which raises privacy issues [131]. Moreover, due to limited equipment in health clinics and hospitals in LATAM, it is difficult to implement innovative technology, which largely depends on appropriate information technology. Infrastructure and architecture are needed to be able to use embedded sensors and innovative technology. Digital health solutions in Latin America are not sufficiently developed to address the diverse health needs of citizens in that region, as they are often reduced to "one size fits all" so that health services adapted to the special needs and capabilities of patients are largely neglected. However, evidence-based health policy design is on the rise, representing a promising perspective for the expanded use of RWE in the region [9].

Asia perspective

In Asia, China, Japan and India are generating most of the existing data and a lot of clinical trials are conducted there. Some of the general challenges, in Asia, are insufficient financial and human capacity, ethical and regulatory systems, lack of research environment, and operational issues. This presents a related challenge of under-representation of Asian population in pivotal Randomized controlled trials (RCTs), with consequent neglect of the biological variations in different genetic makeups between Caucasians and Asians. Frameworks are currently limited or lacking for using RWD and RWE, with consequent impact on take-up. The China Real World Data and Studies Alliance (ChinaREAL) has issued guidance on design of observational studies and on development of research databases and patient registries, and on analysis of RWD, and the Chinese National Medical Products Administration has issued guidance on the use of RWE for drug development and assessment for pilot testing. Secondary databases in China display variations in data quality, unclear data usage mechanism, and lack of longitudinal follow-up data, and clear regulations related to patient privacy protection are lacking [132]. In India, data is managed, stored and accessed in inconsistent ways across different government entities, impacting the efficacy of data-driven governance and impeding the emergence of an innovative ecosystem of data science, analytics and AI. A data management office is projected, with responsibility for framing a national data governance framework policy. But RW studies also face some specific challenges, including clinical practice patterns and varying interest from physicians, since the follow up of patients is strongly influenced by affordability, so there is little routine assessment of effectiveness and safety endpoints. Demand for RWE studies is low from insurance agencies, patients' groups, or regulators, leaving many studies in the hands of pharma companies and private hospitals, risking bias. Some investigator-initiated observational studies or disease registries describe prevalence and disease characteristics, but often have limited details on patients' profile, comorbidities, treatments, natural history of disease, and long-term outcomes. Digital healthcare in Japan is very advanced, with almost every Japanese hospital uses electronic invoicing, and recent liberalisation has paved the way for businesses to make use of data resources [133]. RWD and RWE are employed in reimbursement decisions [132]. In the Philippines, a "Health Agenda for 2016 to 2022" urges rapid steps to improve the quality and scope of data collection, recording, analysis and application [134]. However, the health management information system of the Department of Health could not keep pace with the rapid advancement in information technology. The health management information system remains fragmented, and most of those are developed or are being developed independently in the different hospitals and health care institutions. Ways to utilize health information for evidence-based decision-making is being acknowledged. The constraints on RWD availability are due to multiple factors including resource-intensive nature of data collection, management and analysis. RWD quality and integrity could be compromised by lack of data standardization, data security breaches, and limited data governance. RWE policy and applications have been proactively addressed. Although, mostly these are limited to pharmaceutical companies being required to conduct post-marketing studies on all marketed drugs. Data from the post-marketing studies are observational evidence to examine the safety, tolerability, and effectiveness of a drug in more diverse populations than the populations seen in RCTs. It is envisioned that digital healthcare in the Philippines will improve in line with the goals of the Philippine Health Agenda.

Africa perspective

Lack of data generation, data harmonization, data storage infrastructure, inefficient health data management, shortage of trained healthcare professionals, low healthcare budgets, and poor service integration are general factors inhibiting the realisation of the full potential of data in Africa. The application of data and RWE to Africa's healthcare delivery system remains unused, closing off the avenue that efficient generation, analysis, and utilization of data could provide to closing equality gaps between different target populations [123]. Throughout the continent, there is low trust and engagement in science and healthcare, and almost a third of people do not trust hospitals and health clinics. Trust in doctors and nurses is also weak. A quarter of people have little trust in scientists. Participation in data management issues is low [135]. Although there are few isolated good examples of participatory data governance in African countries such as Tunisia, Kenya and South Africa, there is a lot more to be done especially on leveraging public awareness for more public participation. South Africa and Tunisia have a relatively well-developed data protection law in its legislative machinery to restrict the collection, processing and sharing of personal information. In South Africa, the so-called POPI ACT was enforced from July 2021 [136] while in Tunisia, Tunisian Regulatory and Data protection body (INPDP) is still not yet fully in force [137]. Factors limiting public awareness and participation in data governance include lack of strategic direction by policymakers, limited understanding of stakeholders' responsibilities, low data and digital literacy levels, negative public perception of public policy development, low evidence-based research, and slow-paced regional leadership on data governance issues. Concerning fact is that data stewardship might bring to transferring even more data into the hands of private sector interests rather than utilizing it for the public good. In order to succeed in building data infrastructure African countries, need to tackle challenges such as lack of technical skills, weak regulatory frameworks and political manipulation but also issues of lack of transparency and data trust [138, 139].

Global situation

In addition to the recent ICMRA initiative, ICH is working on "General principles for planning and designing pharmacoepidemiologic studies using RWD to assess drug safety" [140]. There are options for creating natural and intuitive forms of interaction and innovative devices that facilitate data collection and analysis of large data sets in natural settings. Some of the challenges are related to the research of new input and output mechanisms through customized wearable and sensor devices, the use of natural user interfaces to measure new gestural interactions and techniques for indirect inference of health data. However, throughout the world, achievements in seizing opportunities outweigh current deficiencies in the necessary contextual arrangements.

Diverse conditions

US, UK, France, Germany and South Korea are leading in terms of governance in the emergence of PM, with guidelines and policies increasingly in place, backed up by national PM plans or related investment. Some Middle East and Latin American countries lag behind because implementation of PM policies and guidelines is limited [34–38]. Low or slow reimbursement arrangements impede PM adoption in South Africa, Kenya and several regions of LATAM, leaving patients of limited means with unmet needs for treatment. UK ranks high in Europe and Israel in the Middle East due to implementation of policy frameworks designed to promote PM, along with benefiting from a single agency for HTA and reimbursement to minimize delays and inconsistencies in decisions. The US and other EU countries also rank well due to high implementation of reimbursement policies within relevant organisations. The major factor behind poor reimbursement remains low or no implementation of appropriate guidelines [40–44]. In terms of infrastructure, US, Japan, France, UK and Canada are leading because of effective provision for R&D. Peru, South Africa, Argentina, Mexico and Kenya are at the bottom of the table, with more attention required to fulfil the infrastructure requirements and to gain access to biobanks [45–47]. France, US, China, UK and Germany excelled in the terms of adoption and awareness, benefiting from web-based and social media tools that improve health and digital literacy, cooperation between health experts and patient advocates through case studies, seminars, education (with clinical geneticists developing successful local medical genetics graduate training programs), training and exchanges and other initiatives involving PM and healthcare system change (Such as All of Us in the US, French Genomic Medicine 2025, or the 100,000 genome project in the UK). In contrast, Latin America, India, Asia and some countries from the Middle East ranked low due to the lack of awareness among the general public and patients, and limited funding and education facilities [48–55]. Key factors in enabling the adoption of PM include availability of laws on patient privacy and cyber security, along with ethical and social research guidelines as preconditions to any

research. Lack of awareness regarding the law among patients, lack of implementation, or outdated regulation act as barriers to the adoption of PM. Many countries are doing well in terms of privacy and security, but some lag behind [56–60]. Involvement of scientists and clinicians from various organisations across different countries is important for R&D on PM. Regulators, researchers, oncologist and pathologists collaborate effectively for policy making, and in research and development processes such as availability of survey results. Sharing data in a secure environment facilitates the adoption of PM, but there is still a lack of involvement of stakeholders such as payers and public health experts. Strict data protection laws can act as a barrier (as in Germany) [66, 67]. South Korea, Japan and Australia from Asia and North America are leading in terms of health technology and processes, where companion diagnostics (CDx), clinical decision support plans and drug development guidelines improve treatment quality and efficiency. Kenya, South Africa, China and Chile lag behind due to barriers such as lengthy delays in delivering test results, test quality and reliability, insufficient funding for tests, and absence of laws and schemes to promote preventive treatment [43, 45, 46, 61–65] (Figures 2, 3). Lack of implementation of guidelines and policies acts as a barrier to PM, and the consequence is a delay in drug development, clinical trials and approvals – leaving patients and citizens less well cared for than they could be and should be. Personal health care is happening, but to make it happen more widely, more evenly and more rapidly, there should be an overall strategy for personal health care, whether developed by government, consumer advocacy groups, academics researchers or even by the providers.

Discussion

The previous studies have shown that the European Union has increasingly engaged with PM since the subject featured in conclusions reached by EU leaders in 2016. The EU has been a key player in the emergence of the International Conference on PM, and is promoting collaboration among member states on infrastructure, technology and specialized care. PM features directly or indirectly in much of the EU's legislative framework, and the trend is likely to be reinforced by the impending update of its rules on pharmaceuticals and on rare diseases, as well as plans for coordination on cancer and on HTA. Attention to screening is however still rather limited, and progress in every field is heavily dependent on the willingness of member states to support initiatives [82–101]. In the US, cancer care is seen as driven by precision medicine based on the use of biomarkers and covering the full care continuum from prediagnosis and diagnosis to treatment and throughout the entire spectrum. In Canada, by contrast, the size of the country and the uneven population distribution present some regional challenges to access to care, with frustrating inequities and disparities resulting largely from reimbursement provision [101–110]. In Brazil, governments have displayed commitment to financing and supporting cancer registration, the expansion of electronic medical record reporting, and an increase in passive data collection. Mexico is faced with challenges in advancing genomic medicine including financial and human resources, and the lack of sufficient networking and collaboration in specialised medicine [71, 72]. Across the Gulf states comprehensive genomic profiling is increasingly available. There is good regional cooperation, despite wide differences in organisation and funding arrangements from country to country, and GCC countries consolidate purchasing agreements for medications. Israel boasts very advanced provision for genomics in medicine with wide availability and access to testing. Wider reimbursement of healthcare generally is also in prospect. Comprehensive patient data is available with good coverage of electronic health records. A strong regulatory and policy environment imposes strict management requirements on hospitals and attempts are now underway to incorporate PM into routine practice and to speed cancer pathways from diagnosis to treatment. Another challenge is to assure equal access treatment across the country's increasingly multicultural society [121]. Data privacy and data security are a priority concern of government in Australia, and EHR use and sharing is under development. Patient expectations are high, with wide awareness of the potential of next generation data, with increasing prospects for interoperability solutions to enable data sharing and tailored personalized health experiences. Patient organisations are ambitious and engaged, with growing provision for promoting self-care. Some innovative diagnostic tests for primary care are now being reimbursed. But there are unaddressed gaps in collaboration across health services, and very uneven provision for chronic disease. National medicines policy and health technology assessment are currently under strategic review, but performance in key policy areas is not regularly evaluated. In South Korea cancer treatment costs are relatively low, but so is spending, and here new technology is lacking. The need is felt for expansion of coverage of public health services. In India, there is no national framework for PM, and huge disparities in care across the country, not just geographically but in extremes of wealth and poverty, between cities and rural regions, and in terms of digital literacy. The fragmented health system suffers from low investment and limited access

to technology, as well as complex bureaucracy. But cybersecurity is good. Awareness of PM needs developing with physicians, payers and policymakers, but the process is at an early stage [45, 46, 61–65, 73–81]. The use of big data offers not just better care for the sick, but better preventive health for all, more informed responses to population-level health threats, and more efficient use of healthcare resources. What is needed now to turn vision into reality is a clearer understanding among policymaker and decision-takers about what is at stake: about the gains that can be made with the right actions, and equally about the opportunities that might be squandered with the wrong ones. At a time when access to health has never had such priority, and when incoherencies in healthcare planning risk overwhelming public spending, it is the correct moment for a candid assessment of the options available. The health data and information system infrastructure require a detailed audit. When collecting and using high-quality health data for research purposes, it is crucial to build citizens' trust through transparent and clear communication about how their health data will be stored, accessed and (re)used, together with sufficient safeguards that would prevent health data from misuse or leakage. In order to achieve harmonization at the regional level regarding data access and related issues, it is necessary to create a regional framework for data management [141–143]. A central authority must manage health information systems to ensure interoperability and quality guidelines. Legal and standard practice frameworks are needed for anonymizing and linking data that protect patients' rights to confidentiality. The monitoring of transparency and reproducibility of results must be regulated in order to ensure sustainable and mutually beneficial cooperation models. Allocation of information technology resources, training, electronic databases, and storage facilities are needed by public health facilities to ensure the portability of routine data collection and patient traceability throughout the continuum of health care delivery. Policy changes can have a positive influence (and by the same token, can also have negative implications). The EU EHDS concept is not a model, but does raise some principles that could be seen as fundamental to best practice – notably in helping patients to access a real continuum of care when they move between different elements of the healthcare system, and in allowing researchers, innovators and policymakers to access secondary health data in a uniform manner [4, 144, 145]. Covid-19 too offers valuable experience in prompting regulators to establish or reinforce collaborations allowing efficient sharing of data and experience, to allow rapid development of vaccines, therapeutics and diagnostics. With the use of genome sequencing, scientists around the world can identify, assess risks and track emerging variants, which is essential for an effective response. At the end of July 2022, the World Health Organization defined monkeypox as an urgent public health threat at the international level, and the Director General of the World Health Organization's Euroregion, which covers the 53 countries in Europe and Central Asia where this epidemic first appeared and was concentrated, called for maximum cooperation, including surveillance and contact tracing [146]. The European Medicines Agency has also responded to the new challenge of monkeypox by expanding its responsibilities to provide scientific advice, coordinate independent monitoring studies of drugs intended for use against monkeypox and advise on clinical trial protocols [147]. The importance of data sharing and RWE is highlighted in this way by real-world experience. ICMRA offers its own range of specific suggestions. Among its leading recommendations are harmonisation of RWD and RWE terminologies, to create common operational definitions relating to RCTs and observational studies. It also urges convergence on RWD and RWE guidance and best practice, including common principles for RWD quality, metadata to enable characterisation and discoverability of RWD, agreement on suitable scenarios where RWE may contribute to regulatory decision-making, building on existing use-cases, and templates for study protocols/reports that can be used in multiple regulatory jurisdictions [1].

Preparedness triggered by either Covid-19, monkeypox or the threat of AMR – encourages proposals to strengthen international regulatory cooperation on RWE where expert groups are involved in specific topics of interest established to respond to emerging health threats. It is also important to collaborate on governance and processes to enable the efficient conduct of RWD-based studies from different regions in order to address important public health challenges. ICMRA also states the importance of establishing transparency in defining common principles and practices for the systematic registration of pre-specified study protocols and study results in publicly accessible registries. It should be encouraged, by regulatory bodies, to publish study results in peer-reviewed open-source journals. ICMRA has committed itself to working on collaboration to overcome the obstacles to the use of RWE for regulatory decision-making, and its statement set out a series of opportunities it sees to address common challenges "in the interests of patient health and innovation." "Close collaboration between regulators across the world can help address these challenges," it says, suggesting it can itself play an important role by catalyzing increased cooperation. And it foresees this regulatory collaboration on RWD and RWE taken forward through bodies such as ICH, international standardisation bodies, and clusters of interested regulators [1].

Conclusions

Capturing transferrable and reliable RWE that can be used by regulators or for HTA decision-making offers health outcome benefits and cost savings. Experience with exploiting health data in more prosperous countries can help inform implementation in other countries and regions and provide some short-cuts, even offering them a chance of a more rapid catch-up. The factors influencing effective use of health data have been identified under broad headings relating to issues such as governance, reimbursement, infrastructure, adoption and awareness, privacy and cyber security provisions, collaboration, and availability of health technology and processes. The performance of countries and regions around the world demonstrate wide variability in these factors, which correlates with the capacity to benefit from health data. Lack of agreed standards on accuracy, reliability and quality of data, low or slow reimbursement arrangements, limited systematic cooperation among stakeholders, lack of awareness among the general public and patients, and limited funding and education facilities. More prosperous developed countries consistently feature among leaders in data use, often with guidelines and policies backed up by national PM plans or related investment. They have more generous provision for R&D or access to biobanks, they enjoy speedier turnround of tests results, their health and digital literacy levels are higher, and they have developed functioning regulation of patient privacy and cyber security. Access to companion diagnostics, clinical decision support plans and drug development guidelines also improve treatment quality and efficiency. Lack of implementation of guidelines and policies acts as a barrier to PM, and the consequence is a delay in drug development, clinical trials and approvals – leaving patients and citizens less well cared for than they could be and should be. Personal health care is happening, but to make it happen more widely, more evenly and more rapidly, there should be an overall strategy for personal health care, whether developed by government, consumer advocacy groups, academics researchers or even by the providers. 20 years ago, even advanced countries were nowhere, either in technology or policy terms, in data exploitation. Now developed countries have started to recognise the potential and some are making policy and administrative changes. Less prosperous countries could benefit as much – perhaps more – from an analogous shift, and there is the chance of doing so in a much shorter time period, with concomitantly much more substantial positive benefits. This is a chance to seize since the potential benefits make the effort worthwhile.

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References

1. ICMRA. ICMRA statement on international collaboration to enable real-world evidence (RWE) for regulatory decision-making; 2022. Available from: https://www.icmra.info/drupal/sites/default/files/2022-07/icmra_statement_on_rwe.pdf [Accessed 25 Jul 2022].
2. ICMRA. A draft policy paper for ICMRA pharmacovigilance project; 2016. Available from: https://icmra.info/drupal/sites/default/files/2018-02/ICMRA%20PhV%20Big%20Data%20SubWG%20Policy%20Paper.pdf.
3. European Commission. European health data space; 2022. Available from: https://health.ec.europa.eu/ehealth-digital-health-and-care/european-health-data-space_en [Accessed 25 Jul 2022].
4. Jauregui AE. Overview of the European health data space (EHDS): goals and current challenges. Eur J Publ Health 2021;31:ckab164.123. https://doi.org/10.1093/eurpub/ckab164.123.
5. Shabani M. Will the European Health Data Space change data sharing rules? Science 2022;375:1357–9.
6. Dash S, Shakyawar SK, Sharma M, Kaushik S. Big data in healthcare: management, analysis and future prospects. J Big Data 2019;6:54.
7. Gwinn M, MacCannell DR, Khabbaz RF. Integrating advanced molecular technologies into public health. J Clin Microbiol 2017;55:703–14.
8. Burns L, Le RN, Kalesnik-Orszulak R, Christian J, Hukkelhoven M, Rockhold F, et al. Real-world evidence for regulatory decision-making: guidance from around the world. Clin Therapeut 2022;44:420–37.

9. Justo N, Espinoza MA, Ratto B, Nicholson M, Rosselli D, Ovcinnikova O, et al. Real-world evidence in healthcare decision making: global trends and case studies from Latin America. Value Heal 2019;22:739–49.
10. Hampson G, Towse A, Dreitlein WB, Henshall C, Pearson SD. Real-world evidence for coverage decisions: opportunities and challenges. J Comp Eff Res 2018;7:1133–43.
11. Brixner D, Biskupiak J, Oderda G, Burgoyne D, Malone DC, Arondekar B, et al. Payer perceptions of the use of real-world evidence in oncology-based decision making. J Manag Care Spec Pharm 2021;27:1096–105.
12. Burcu M, Dreyer NA, Franklin JM, Blum MD, Critchlow CW, Perfetto EM, et al. Real-world evidence to support regulatory decision-making for medicines: considerations for external control arms. Pharmacoepidemiol Drug Saf 2020;29:1228–35.
13. Frappe E. Liquid biopsy technology – changing the paradigm in clinical diagnostics and IVD regulatory approaches; 2021. Available from: https://www.iqvia.com/blogs/2021/04/liquid-biopsy-technology-changing-the-paradigm-in-clinical-diagnostics-and-ivd-regulatory-approaches.
14. Germann S, Jasper U. Realising the benefits of data driven digitalisation without ignoring the risks: health data governance for health and human rights. MHealth 2020;6:34.
15. Batko K, Ślęzak A. The use of big data analytics in healthcare. J Big Data 2022;9:3.
16. Huang BE, Mulyasasmita W, Rajagopal G. The path from big data to precision medicine. Expert Rev Precis Med Drug Dev 2016;1:129–43.
17. Hulsen T, Jamuar SS, Moody AR, Karnes JH, Varga O, Hedensted S, et al. From big data to precision medicine. Front Med 2019;6:34.
18. Shahbaz M, Gao C, Zhai LL, Shahzad F, Hu Y. Investigating the adoption of big data analytics in healthcare: the moderating role of resistance to change. J Big Data 2019;6:6.
19. Brizmohun N. Global regulators join hands to boost RWE use in decision-making; 2022. Available from: https://pink.pharmaintelligence.informa.com/PS146768/Global-Regulators-Join-Hands-To-Boost-RWE-Use-In-Decision-Making.
20. Holland S, Cawthra J, Schloemer T, Schröder-Bäck P. Trust and the acquisition and use of public health information. Health Care Anal 2022;30:1–17.
21. Ostherr K, Borodina S, Bracken RC, Lotterman C, Storer E, Williams B. Trust and privacy in the context of user-generated health data. Big Data Soc 2017;4:1–11.
22. Peek N, Rodrigues PP. Three controversies in health data science. Int J Data Sci Anal 2018;6:261–9.
23. Zhao D, Zha H, Cleary PD. Understanding the determinants of public trust in the health care system in China: an analysis of a cross-sectional survey. J Health Serv Res Pol 2019;24:135581961879911.
24. Tentori M, Ziviani A, Muchaluat-Saade DC, Favela J. Digital healthcare in Latin America: the case of Brazil and Mexico. Commun ACM 2020;63:72–7.
25. Horgan D, Borisch B, Cattaneo I, Caulfield M, Chiti A, Chomienne C, et al. Factors affecting citizen trust and public engagement relating to the generation and use of real-world evidence in healthcare. Int J Environ Res Publ Health 2022;19:1674.
26. Li M, Chen S, Lai Y, Liang Z, Wang J, Shi J, et al. Integrating real-world evidence in the regulatory decision-making process: a systematic analysis of experiences in the US, EU, and China using a logic model. Front Med 2021;8:669509.
27. Monga N, Garside J, Quigley J, O'Rourke J, O'Donovan P, Padhiar A, et al. Review of real-world evidence to assess the burden of illness of mantle cell lymphoma. Value Healh 2017;20:A469.
28. Mateo J, Steuten L, Aftimos P, André F, Davies M, Garralda E, et al. Delivering precision oncology to patients with cancer. Nat Med 2022;28:658–65.
29. Janssen M, Brous P, Estevez E, Barbosa LS, Janowski T. Data governance: organizing data for trustworthy artificial intelligence. Govern Inf Q 2020;37:101493.
30. Horgan D, Borisch B, Richer E, Bernini C, Kalra D, Lawler M, et al. Propelling health care into the twenties. Biomed Hub 2020;5:1–53.
31. Aerd statistics. Spearman's rank-order correlation using SPSS statistics; 2022. Available from: https://statistics.laerd.com/spss-tutorials/spearmans-rank-order-correlation-using-spss-statistics.php#:~:text=The%20Spearman%20rank%2Dorder%20correlation,letter%20%CF%81%2C%20pronounced%20rho) [Accessed 16 Aug 2022].
32. Cavazzoni P. FDA takes steps to provide clarity on developing new drug product in the age of individualize medicine; 2021. Available from: https://www.fda.gov/news-events/press-announcements/fda-takes-steps-provide-clarity-developing-new-drug-products-age-individualized-medicine [Accessed 16 Aug 2022].
33. WHO. WHO, WIPO, WTO to hold technical symposium on response, preparedness to future pandemics; 2022. Available from: https://www.who.int/news/item/10-11-2022-who–wipo–wto-to-hold-technical-symposium-on-response–preparedness-to-future-pandemics.
34. OECD. Reviews of public health: Korea: a healthier tomorrow; 2022. Available from: https://www.oecd-ilibrary.org/sites/3b1ee34f-en/index.html?itemId=/content/component/3b1ee34f-en [Accessed 16 Aug 2022].
35. Dayton L. How South Korea made itself a global innovation leader. Nature 2020;581:S54–6.
36. Cho HN, Shin SY, Hwangbo B, Chang YJ. Views on precision medicine among health professionals in Korea: a mixed methods study. Yonsei Med J 2020;61:192–7.
37. Son KB. Understanding the adoption of new drugs decided by several stakeholders in the South Korean market: a non-parametric event history analysis. Health Econ Rev 2018;8:34.
38. Kim H, Kim SY, Joly Y. South Korea: in the midst of a privacy reform centered on data sharing. Hum Genet 2018;137:627–35.
39. Abicalaffe A, Schafer J. Opportunities and challenges of value-based health care: how Brazil can learn from U.S. Ex-Perience. J Manag Care Spec Pharm 2020;26:1172–5.
40. LEK. Structuring unstructured medical device reimbursement in India; 2021. Available from: https://www.lek.com/insights/ei/structuring-unstructured-medical-device-reimbursement-india.
41. LEK. Unlocking the opportunities for companion diagnostics in Asia-pacific; 2019. Available from: https://www.lek.com/insights/ei/unlocking-opportunities-companion-diagnostics-asia-pacific.
42. Ebi H, Bando H. Precision oncology and the universal health coverage system in Japan. JCO Precis Oncol 2019;3:1–12.
43. IQN Path / ECPC / EFPIA. Unlocking the potential of precision medicine in Europe; 2021. Available from: https://ecpc.org/wp-content/uploads/2021/02/unlocking-the-potential-of-precision-medicine-in-europe-FULL-REPORT.pdf [Accessed 16 Aug 2022].
44. Ortiz I, Luna A. Regulatory, pricing and reimbursement; 2018. Available from: https://pharmaboardroom.com/legal-articles/regulatory-pricing-and-reimbursement-mexico/ [Accessed 16 Aug 2022].
45. Xi K. Precision medicine in Asia: more regional cooperationed needed; 2020. Available from: https://pharmaboardroom.com/articles/precision-medicine-in-asia-regional-cooperation/ [Accessed 16 Aug 2022].
46. Statista. Share of hospitals in Japan that implemented electronic medical records (EMR) as of October 2019; 2022. Available from: https://www.statista.com/statistics/1121012/japan-share-hospitals-electronic-health-record/ [Accessed 16 Aug 2022].
47. Saffer QA, Faith TA, Alshehri A, Mohammed RA, Homidi SA, Hamza MM, et al. The capacity of primary health care facilities in

Saudi Arabia: infrastructure, services, drug availability, and human resources. BMC Health Serv Res 2021;21:365.
48. Brivik T. Who owns your health records in South Africa? 2015. Available from: https://www.hcsmsa.co.za/healthdatalaw/ [Accessed 16 Aug 2022].
49. Fasseeh A, Karam R, Jameleddine M, George M, Kristensen FB, Al-Rabayah AA, et al. Implementation of health technology assessment in the Middle East and North Africa: comparison between the current and preferred status. Front Pharmacol 2020;11:15.
50. Katurura MC, Cilliers L. Electronic health record system in the public health care sector of South Africa: a systematic literature review. Afr J Prim Health Care Fam Med 2018;10:1–8.
51. Market Data Forecast. Middle East & Africa companion diagnostics market research report – segmented by indi-cation, by technology & by country (KSA, UAE, Israel, rest of GCC countries, South Africa, Ethiopia, Kenya, Egypt, Sudan, rest of MEA) – industry analysis on size, share, trends, COVID-19 impact & growth forecast (2021 to 2026); 2021. Available from: https://www.marketdataforecast.com/market-reports/mea-companion-diagnostics-market.
52. Giles J. Privacy and data protection in healthcare in South Africa; 2021. Available from: https://www.michalsons.com/blog/privacy-in-healthcare/8637 [Accessed 16 Aug 2022].
53. Mulder N. Development to enable precision medicine in Africa. Futur Med 2017;14:467–70.
54. USC Schaeffer. Health technology assessment for the U.S. healthcare system; 2020. Available from: https://healthpolicy.usc.edu/research/health-technology-assessment-for-the-u-s-healthcare-system/.
55. Smit M. Regulatory, pricing and reimbursement; 2018. Available from: https://pharmaboardroom.com/legal-articles/regulatory-pricing-and-reimbursement-south-africa/ [Accessed 16 Aug 2022].
56. Kielstra P. Cancer control, access and inequality in Latin America a tale of light and shadow; 2017. Available from: http://www.alatro.org/images/archivos/Cancer-control-access-LatinAmerica.pdf [Accessed 16 Aug 2022].
57. GHI Team. Electronic medical records growing in Latin America; 2017. Available from: https://globalhealthintelligence.com/ghi-analysis/electronic-medical-records-growing-in-latin-america/ [Accessed 16 Aug 2022].
58. Grimaldo AAT. Personalised healthcare in Latin America-universalizing the promise of innovation; 2020. Available from: https://www.researchgate.net/publication/346061802_Personalised_Healthcare_in_Latin_America-_Universalising_the_promise_of_innovation.
59. Market Data Forecast. Latin America companion diagnostics market research report – segmented by indication, by technology & by country (Mexico, Brazil, Argentina, Chile and rest of Latin America) – industry analysis, size, share, growth, trends, forecast (2021 to 2026); 2022. Available from: https://www.marketdataforecast.com/market-reports/mea-companion-diagnostics-market [Accessed 16 Aug 2022].
60. Rosselli D, Lazo CQ, Csanadi M, Castilla EMR, Gonzalez NC, Valdes J, et al. HTA implementation in Latin American countries: comparison of current and preferred status. Sci Dir 2017;14:20–7.
61. Chong HY, Allotey PA, Chaiyakunapruk N. Current landscape of personalized medicine adoption and implementation in Southeast Asia. BMC Med Genom 2018;11:94.
62. Liu J, Wu EQ, Ahn J, Kamae I, Xie J, Yang H. The development of health technology assessment in Asia: current status and future trends. Sci Dir 2020;21:39–44.
63. Iqvia. Accelerating patient access to precision oncology in Asia-pacific; 2021. Available from: https://www.iqvia.com/-/media/iqvia/pdfs/asia-pacific/white-papers/accelerating-patient-access-to-precision-oncology-in-asia-pacific.pdf.
64. PharmaBoardRoom. Precision medicine in Asia: more regional cooperation needed; 2020. Available from: https://pharmaboardroom.com/articles/precision-medicine-in-asia-regional-cooperation/.
65. Hou T, Le Deu F, Shao Y, Tian J. Managing China's growing oncology burden; 2020. Available from: https://www.mckinsey.com/industries/life-sciences/our-insights/managing-chinas-growing-oncology-burden [Accessed 16 Aug 2022].
66. Pennell NA, Arcila ME, Gandara DR, West H. Biomarker testing for patients with advanced non–small cell lung cancer: real-world issues and tough choices. Am Soc Clin Oncol Educ Book 2019;39:531–42.
67. Chitale A. Precision medicine and its impact on the global therapeutic landscape; 2019. Available from: https://pharmaboardroom.com/articles/precision-medicine-and-its-impact-on-the-global-therapeutic-landscape/ [Accessed 16 Aug 2022].
68. Strasser-Weippl K, Chavarri-Guerra Y, Villarreal-Garza C, Bychkovsky BL, Debiasi M, Liedke PE, et al. Progress and remaining challenges for cancer control in Latin America and the Caribbean. Lancet Oncol 2015;16:1405–38.
69. Guerrero C. Cancer preparedness in Latin America. The need to build on recent progress; 2019. Available from: https://worldcancerinitiative.economist.com/pdf/Roche-cancer-preparedness-in-latin-america/CANCER%20PREPAREDNESS%20IN%20LATAM.pdf [Accessed 16 Aug 2022].
70. Torres-Grimaldo AA. Personalised healthcare in Latin America universalizing the promise of innovation; 2020. Available from: https://www.researchgate.net/publication/346061802_Personalised_Healthcare_in_Latin_America-_Universalising_the_promise_of_innovation [Accessed 16 Aug 2022].
71. Staff reporter. City of hope supporting precision oncology education efforts at Brazilian hospital; 2021. Available from: https://www.precisiononcologynews.com/business-news/city-hope-supporting-precision-oncology-education-efforts-brazilian-hospital#.YS5iu81R2M9 [Accessed 16 Aug 2022].
72. Export.gov. Healthcare resource guide: Chile; 2019. Available from: https://2016.export.gov/industry/health/healthcareresourceguide/eg_main_108572.asp [Accessed 16 Aug 2022].
73. Xu J, Gao X, Sorwar G, Croll P. Implementation of E-health record systems in Australia. Int Tech Manag Rev 2013;3:92–104.
74. Express News Service. Experts call for patients to access cancer treatment without delay despite Covid pandemic; 2020. Available from: https://indianexpress.com/article/cities/pune/experts-call-for-patients-to-access-cancer-treatment-without-delay-despite-covid-pandemic-7099910/ [Accessed 16 Aug 2022].
75. Misra SC, Bisui S, Singh A. A study on the role of trust factor in adopting personalised medicine. Tay Franc Onl 2020;39:771–87.
76. Lee SS, Salole E. Medical device reimbursement coverage and pricing rules in Korea: current practice and issues with access to innovation. Value Health 2014;17:476–81.
77. Kwon S. Patients can now access their health records online, but they may not understand them; 2021. Available from: https://www.latimes.com/science/story/2021-05-17/patients-can-access-health-data-online-on-demand-confusion [Accessed 16 Aug 2022].
78. Komine K, Shirota H. Interinstitutional collaboration for molecular tumor Boards. Gan to kagaku ryoho 2019;46:626–9.
79. Kim H, Byrnes J, Goodall S. Health technology assessment in Australia: the pharmaceutical benefits advisory com-mittee and medical services advisory committee. PubMed 2021;24:6–11.

80. Patrone J. Spanish government allocates €25M for precision and genomic medicine, data science; 2020. Available from: https://www.genomeweb.com/research-funding/spanish-government-allocates-25m-precision-and-genomic-medicine-data-science#.YRpQ2s1R2M9 [Accessed 16 Aug 2022].
81. Badwaik R. Precision medicine: emerging trends in cancer therapy. J Clin Diagn Res 2019;13:FE01–4.
82. Biobanking. 10 largest biobanks in the world; 2021. Available from: https://www.biobanking.com/10-largest-biobanks-in-the-world/ [Accessed 16 Aug 2022].
83. Burnel P. The introduction of electronic medical records in France: more progress during the second attempt. Health Pol 2018;122:937–40.
84. CancerNet. Financial resources; 2021. Available from: https://www.cancer.net/navigating-cancer-care/financial-considerations/financial-resources [Accessed 16 Aug 2022].
85. Chambers and Partners. Artificial intelligence 2022; 2022. Available from: https://practiceguides.chambers.com/practice-guides/comparison/861/9017/14155-14157-14159-14162-14165-14169-14172-14174-14180-14184-14186-14188-14190-14192 [Accessed 16 Aug 2022].
86. Ciampi M, Esposito A, Guarasci R, Pietro GD. Towards interoperability of EHR systems: the case of Italy. ICT4AWE 2016;1:133–8.
87. Canadian Institutes of Health Research. Funding decisions database; 2022. Available from: https://webapps.cihr-irsc.gc.ca/decisions/p/main.html?lang=en#fq={!tag=allText}acallText%3A201906ENP&sort=namesort%20asc&start=0&rows=20 [Accessed 16 Aug 2022].
88. Diez IDT, Gonzalez S, Coronado ML. EHR systems in the Spanish public health national system: the lack of in-teroperability between primary and specialty care. PubMed 2013;37:9914.
89. Ecipe Working Paper. Restrictions on cross-border data flows: a taxonomy; 2017. Available from: https://ecipe.org/wp-content/uploads/2017/11/Restrictions-on-cross-border-data-flows-a-taxonomy-final1.pdf.
90. Fundación Instituto Roche. Proposal of recommendations for a personalised precision medicine national strategy; 2017. Available from: https://www.institutoroche.es/static/pdfs/Propuesta_de_Recomendaciones_MPP_INGLES.pdf.
91. Garrido P, Aldaz A, Vera R, Calleja MA, Álava ED, Martín M, et al. Proposal for the creation of a national strategy for precision medicine in cancer: a position statement of SEOM, SEAP, and SEFH. Clin Transl Oncol 2018;20:443–7.
92. Xifin. How will reimbursement be managed in the era of precision medicine and value-based care? 2019. Available from: https://www.xifin.com/resources/blog/201903/how-will-reimbursement-be-managed-era-precision-medicine-and-value-based-care.
93. Grand View Research. Oncology companion diagnostic market size, share & trends analysis report by product & service, by technology (IHC, NGS), by disease type (breast cancer, leukemia), by end-use, by region, and segment forecasts, 2020 – 2027; 2020. Available from: https://www.grandviewresearch.com/industry-analysis/oncology-companion-diagnostics-market.
94. Hartman HE, Sun Y, Devasia TP. Integrated survival estimates for cancer treatment delay among adults with cancer during the COVID-19 pandemic. JAMA Oncol 2020;6:1881–9.
95. ICLG. Data protection laws and regulations; 2022. Available from: https://iclg.com/practice-areas/data-protection-laws-and-regulations/spain [Accessed 16 Aug 2022].
96. Lexology. Germany prepares new law for patient data protection and increased digitalization in healthcare and for “data donations” for research purposes; 2020. Available from: https://www.lexology.com/library/detail.aspx?g=e042656c-5c9c-4b11-a9c0-97cd1ca18d7e.
97. The Commonwealth Fund. What is the status of electronic health records? 2020. Available from: https://www.commonwealthfund.org/international-health-policy-center/system-features/what-status-electronic-health-records [Accessed 16 Aug 2022].
98. HumanApi. The current state of electronic health record (EHR) dana access; 2022. Available from: https://www.humanapi.co/health-data-innovation-blog/the-current-state-of-ehr-data-access.
99. Healthcare Industry BW. EHR and PHR: digital records in the German healthcare system; 2019. Available from: https://www.gesundheitsindustrie-bw.de/en/article/news/ehr-and-phr-digital-records-in-the-german-healthcare-system.
100. Pinsent Masons. GDPR guidance issued for health bodies in Spain; 2019. Available from: https://www.pinsentmasons.com/out-law/analysis/gdpr-guidance-issued-for-health-bodies-in-spain.
101. PMF. Innovation in Italy; 2020. Available from: https://www.pmf-research.eu/en/innovation-in-italy-in-2020/ [Accessed 16 Aug 2022].
102. Coos A. Data protection in Canada: all you need to know about PIPEDA; 2019. Available from: https://www.endpointprotector.com/blog/data-protection-in-canada-pipeda/.
103. Canadian Breast Cancer Network. Living with Breast Cancer; 2022. Available from: https://www.cbcn.ca/en/Facing_Financial_Issues [Accessed 16 Aug 2022].
104. Cancer Council Wa. How we protect your data; 2022. Available from: https://cancerwa.asn.au/news/how-we-protect-your-data/ [Accessed 16 Aug 2022].
105. CancerNet. Cancer in my community: Providing free access to cancer care in Saudi Arabia; 2020. Available from: https://www.cancer.net/blog/2020-09/cancer-my-community-providing-free-access-cancer-care-saudi-arabia [Accessed 16 Aug 2022].
106. Cardoso F, Wilking N, Bernardini R, Biganzoli L, Espin J, Miikkulainen K. A multi-stakeholder approach in optimizing patients’ needs in the benefit assessment process of new metastatic breast cancer treatments. Science Direct 2020;52:78–87.
107. FDA. FDA takes steps to provide clarity on developing new drug products in the age of individualized medicine; 2021. Available from: https://www.fda.gov/news-events/press-announcements/fda-takes-steps-provide-clarity-developing-new-drug-products-age-individualized-medicine.
108. Kichko K, Marschall P, Flessa S. Personalized medicine in the U.S. and Germany: awareness, acceptance, use and preconditions for the wide implementation into the medical standard. J Personalized Med 2016;6:15.
109. Leonard K. White house details ‘precision medicine’ initiative; 2015. Available from: https://www.usnews.com/news/articles/2015/01/30/white-house-details-precision-medicine-initiative [Accessed 16 Aug 2022].
110. WHO. The global healthobservatory; 2022. Available from: https://www.who.int/data/gho/publications/world-health-statistics [Accessed 16 Aug 2022].
111. Almuammar A. Primary health care factors associated with late presentation of cancer in Saudi Arabia. J Radiother Pract 2019;19:71–5.
112. Barasa LKM, Greene S, Abinya NAO, Wheeler SB, Skinner A, Bennett AVA. Review of Kenya’s cancer policies to improve access to cancer testing and treatment in the country. BioMedCentral 2020;18:2.
113. Barasa LKM, Greene S, Abinya NAO, Wheeler SB, Skinner A, Bennett AV. Improving access to cancer testing and treatment in Kenya. J Glo Onc 2017;4:1–8.
114. PNO. Innovation funding trends for personalized medicine; 2017. Available from: https://www.pnoconsultants.com/wp-content/uploads/2017/09/Epaper-Personalized-Medicine-by-PNO.pdf.

115. Brich S, Alsayed T, Ansari A, Malik EH, Herod J. 465 Delays in treatment in gynaecology oncology patients in Qatar seeking management overseas. Int J Gynecol Cancer 2020;30:A192.
116. Dewik NIA, Qoronfleh MW. Genomics and precision medicine: molecular diagnostics innovations shaping the future of healthcare in Qatar. Adv Public Health 2019;2019:1–11.
117. Elmagd MA, Assisi M, Schulten HJ, Dallol A, Pushparaj PN, Ahmed F, et al. Individualized medicine enabled by genomics in Saudi Arabia. BMC Med Genom 2015;8(1 Suppl):S3.
118. Elsayed O. Data protection in the kingdom of Saudi Arabia: a primer; 2013. Available from: https://www.globalprivacyblog.com/privacy/data-protection-in-the-kingdom-of-saudi-arabia-a-primer/
119. Fosci M, Loffreda L, Chamberlain A, Naidoo N. Assessing the needs of the research system in Kenya. Report for the SRIA programme; 2019. Available from: https://assets.publishing.service.gov.uk/media/5ef4acb5d3bf7f7145b21a22/NA_report_Kenya__Dec_2019_Heart_.pdf [Accessed 17 Aug 2022].
120. Global Giving. Medical emergency cancer fund for Kenya; 2022. Available from: https://www.globalgiving.org/projects/medical-emergency-cancer-fund-for-kenya/ [Accessed 17 Aug 2022].
121. Hasanain RA, Vallmuur K, Clark M. Electronic medical record systems in Saudi Arabia: knowledge and preferences of healthcare professionals; 2015. Available from: https://www.jhidc.org/index.php/jhidc/article/view/135.
122. Hulsen T. Sharing is caring—data sharing initiatives in healthcare. Int J Environ Res Publ Health 2020;17:3046.
123. Ewumi O. How can big data, RWD, and RWE upgrade healthcare in Africa? 2021. Available from: https://www.the-yuan.com/89/How-Can-Big-Data-RWD-and-RWE-Upgrade-Healthcare-in-Africa.html.
124. Inan OT, Tenaerts P, Prindiville SA, Reynolds HR, Dizon DS, Cooper-Arnold K, et al. Digitizing clinical trials. NPJ Digit Med 2020;3:101.
125. Costa L, Hincapie AL, Gilardino R, Tang B, Julian G, Soares CS, et al. PNS118 real world evidence (RWE) use in Latin America healthcare decision making: an stakeholder survey analysis; 2021. Available from: https://www.ispor.org/docs/default-source/intl2021/pdfispor-ipostersessions--an-amuze-interactive-system-pdf.pdf?sfvrsn=aec9d922_0.
126. Alves D, Yamada DB, Bernardi FA, Carvalho I, Colombo Filho ME, Neiva MB, et al. Mapping, infrastructure, and data analysis for the Brazilian network of rare diseases: protocol for the RARASnet observational cohort study. JMIR Res Protoc 2021;10:e24826.
127. OECD. Health data infrastructure and information system in Brazil; 2021. Available from: https://www.oecd-ilibrary.org/sites/b601203f-en/index.html?itemId=/content/component/b601203f-en.
128. Lopez SM. Transforming Chile's health sector with connectivity; 2017. Available from: https://www.blog.google/topics/google-cloud/transforming-chiles-health-sector-connectivity/.
129. Diaz A, Ortiz Munoz I. Digital health 2022-Mexico; 2021. Available from: https://www.mondaq.com/mexico/healthcare/1169098/digital-health-2022.
130. Ho C. MS26.02 translation of clinical data to real world – North America. J Thorac Oncol 2018;13:S296–7.
131. Rodriguez-Ferrand G. Colombia: law creating interoperable electronic health records system enacted. The Library of Congress; 2020. Available from: https://www.loc.gov/item/global-legal-monitor/2020-03-09/colombia-law-creating-interoperable-electronic-health-records-system-enacted.
132. Lou J, Kc S, Toh KY, Dabak S, Adler A, Ahn J, et al. Real-world data for health technology assessment for reimbursement decisions in Asia: current landscape and a way forward. Int J Technol Assess Health Care 2020;36:474–80.
133. Böttinger E. Big health data, big health opportunities; 2019. Available from: https://hpi.de/fileadmin/hpi/Forschung/Publikationen/HealthReport_Japan_Boettinger.pdf.
134. Cabral EI. The philippine health agenda for 2016 to 2022. Philippine J Intern Med 2016;54:1–11.
135. World Economic Forum. Why the most important tool in healthcare is trust; 2019. Available from: https://www.weforum.org/agenda/2019/08/important-tool-in-healthcare-is-trust-vaccines-africa/.
136. Cookiebot. POPIA – South Africa's protection of personal information act | enforcement update July; 2021. Available from: https://www.cookiebot.com/en/popia/.
137. Council of Europe. Instance nationale de protection des données à caractère personnel (INPDP); 2022. Available from: https://www.coe.int/fr/web/tunis/inpdp [Accessed 25 Jul 2022].
138. Adeniran A. Developing an effective data governance framework to deliver African digital potentials; 2022. Available from: https://www.brookings.edu/blog/africa-in-focus/2022/03/21/developing-an-effective-data-governance-framework-to-deliver-african-digital-potentials/ [Accessed 25 Jul 2022].
139. Osakwe S, Adeniran A. Strengthening data governance in Africa; 2021. Available from: https://cseaafrica.org/wp-content/uploads/2021/08/Strengthening-Regional-Data-Governance-in-Africa-1.pdf.
140. ICH. Final concept paper establishment of a new ICH guideline on "General principles on plan, design, and analysis of pharmacoepidemiological studies that utilize real-world data for safety assessment of medicines"; 2022. Available from: https://database.ich.org/sites/default/files/M14_ConceptPaper_2022_0405.pdf [Accessed 25 Jul 2022].
141. Austin E, Lee JR, Amtmann D, Bloch R, Lawrence SO, McCall D, et al. Use of patient-generated health data across healthcare settings: implications for health systems. JAMIA Open 2019;3:70–6.
142. Heijlen R, Crompvoets J. Open health data: mapping the ecosystem. Digit Heal 2021;7:20552076211050167.
143. Peng C, Goswami P, Bai G. A literature review of current technologies on health data integration for patient-centered health management. Health Inf J 2020;26:1926–51.
144. Efpia. Position on a European health data space; 2020. Available from: https://www.efpia.eu/publications/downloads/efpia/position-on-a-european-health-data-space/.
145. Genovese S, Bengoa R, Bowis J, Harney M, Hauck B, Pinget M, et al. The European Health Data Space: a step towards digital and integrated care systems. J Integrated Care 2022;30:363–72.
146. WHO. WHO director-general declares the ongoing monkeypox outbreak a public health emergency of international concern; 2022. Available from: https://www.who.int/europe/news/item/23-07-2022-who-director-general-declares-the-ongoing-monkeypox-outbreak-a-public-health-event-of-international-concern [Accessed 25 Jul 2022].
147. EMA. EMA response to the monkeypox public health emergency; 2022. Available from: https://www.ema.europa.eu/en/news/ema-response-monkeypox-public-health-emergency [Accessed 25 Jul 2022].