ICPerMed
INTERNATIONAL CONSORTIUM

Challenges, Opportunities and Facilitators in Implementing Personalised Medicine

Content

Abstract

Background

In 2019, the International Consortium for Personalised Medicine (ICPerMed) has developed a vision of how the use of personalised medicine (PM) approaches will promote "next-generation" medicine in 2030, more firmly centred on the individual's personal characteristics, leading to improved health outcomes within sustainable healthcare systems through research, development, innovation and implementation for the benefit of patients, citizens, and society. However, there are significant hurdles that healthcare professionals, healthcare systems managers, decision-makers, patient organisations etc. must overcome to implement PM. With this document, ICPerMed aims to provide recommendations to increase preparedness of stakeholders by identifying actionable measures to be implemented for the realisation of PM.

Methods

Through the collection and analysis of examples of PM application as well as consultation of experts and stakeholders related to PM, this document gathers hurdles, opportunities, recommendations, and information aiming at developing an understanding of the requirements for the implementation of PM in healthcare practices.

Results

ICPerMed aims to facilitate the adoption of PM by diverse stakeholders. To this end, this document offers a comprehensive set of resources tailored to meet stakeholder needs in critical areas of PM. These include: engagement strategies, collaboration frameworks, infrastructure development, education and training programmes, ethical considerations, resource allocation guidelines, regulatory compliance and data management and privacy.

Conclusion

This document presents a pragmatic roadmap for the integration of PM into healthcare systems. Its recommendations offer actionable strategies to overcome existing barriers and harness the potential of PM for improved health outcomes. The success of this endeavour hinges on collaborative efforts, innovative thinking, and a steadfast commitment to ethical principles. As we advance, it is imperative that all stakeholders, including healthcare professionals, researchers, policy makers, and patients, engage actively in this transformative journey. By doing so, we can unlock the full potential of PM, making it a cornerstone of modern healthcare that is accessible, efficient, and tailored to the individual needs of patients. This paradigm shift, while challenging, holds the promise of a future where healthcare is more precise, predictive, and patient-centred, ultimately leading to better health outcomes and quality of life for all.

Introduction and Main Key Points

"Challenges, Opportunities, and Facilitators in Implementing Personalised Medicine" is a comprehensive document developed by the International Consortium for Personalised Medicine (ICPerMed). This document outlines strategies for integrating personalised medicine (PM) into healthcare systems, aiming to improve health outcomes and create sustainable healthcare systems through research, development, innovation, and implementation. It identifies significant hurdles to implementing PM and offers actionable recommendations for stakeholders, including healthcare professionals, policy makers, patient organisations, and researchers.

There is a need for a multidisciplinary approach, involving collaboration between policy makers, healthcare professionals, researchers, and patient advocacy groups. It is essential to bridge the gap by integrating these diverse perspectives to foster an effective strategy for PM development and implementation. Healthcare professionals should be involved in policy discussions related to PM to provide practical insights and ensure that policies are aligned with clinical realities. While participation of patients and citizens could be detrimental in PM implementation processes and in policy discussions to influence decision-makers.

Engagement of patients or patient representatives and citizens is crucial, as their input contributes to the development and acceptance of patient-centred approaches. The education of patients about the benefits, risks, and potential outcomes of PM is important. This could involve developing patient-focused materials and programmes that explain complex PM concepts in an accessible manner. Additionally, to foster a broader understanding of PM, ICPerMed suggests public awareness campaigns. These campaigns could demystify PM technologies and treatments, address common misconceptions, and highlight the potential benefits of PM for individual and public health.

For policy makers and healthcare administrators, understanding the implications of PM for healthcare policy, funding, and regulation is crucial. Training in this area could focus on the economic, legal, and ethical aspects of PM. ICPerMed suggests to increase the awareness of policy maker about PM, provide evidence-based information on its benefits,

and encourage international collaborations to streamline PM practices globally and harmonise PM care delivery. This should also equip policy makers and healthcare administrators with the skills to make informed decisions about PM integration into healthcare systems, including resource allocation, regulatory oversight, and healthcare delivery models.

This document places significant emphasis on the role of healthcare professionals in the successful implementation of PM. Engaging these professionals effectively is seen as crucial, given their direct role in patient care and their influence on the adoption and integration of PM practices. ICPerMed advocates for the creation of regular meetings where healthcare professionals from various disciplines can share knowledge, experiences, best practices and develop consensus on implementation strategies related to PM. Additionally, acknowledging and rewarding the efforts of healthcare professionals in PM research, development, and implementation can encourage further participation and innovation in the field. ICPerMed suggests providing incentives to healthcare professionals who actively engage in PM initiatives. These could include recognition programmes, career advancement opportunities, or financial incentives.

Successful PM implementation hinges on the synergistic efforts of a wide array of stakeholders. Hence, ICPerMed recommends establishing formal governance structures to facilitate collaboration. This can include steering committees, working groups, and task forces that bring together representatives from different sectors. Clear delineation of roles and responsibilities within these collaborative structures is necessary to ensure effective coordination and decision-making. Additionally, the creation of formal collaboration agreements with a common and clear goal between institutions, organisations, and other entities is encouraged. These agreements can outline objectives, shared resources, and mechanisms for conflict resolution. Collaborations between the public and private sectors, academia, and healthcare institutions are also highlighted as critical for advancing PM research and implementation.

Establish a national steering committee comprising representatives from healthcare providers, research institutions, policy makers, healthcare professionals, patient advocacy groups, and other key stakeholders to develop in a collaborative approach a common strategy and framework for PM implementation. Regional and local variations should be considered since the beginning and flexibility should be built into the framework to accommodate diverse health systems and resources.

In terms of infrastructure, particularly IT infrastructures, biobanks, genomic and molecular diagnostics, and platforms for patient engagement are identified as crucial for PM implementation. ICPerMed emphasises the need for advanced data management systems capable of handling large volumes of diverse data types, including genomic, clinical, and lifestyle data. The adoption of federated data models is recommended. These models enable data sharing and collaboration across different organisations while maintaining data privacy and security. Ensuring that healthcare professionals have access to necessary resources, including advanced diagnostic tools, patient data, and decision-support systems, is critical for effective PM practice. Additionally, the development of advanced diagnostic facilities equipped with the latest technologies for genomic and molecular analysis or imaging data is a key infrastructure requirement for PM. Lastly, the creation of digital platforms that enable patient engagement in PM is recommended. These tools can facilitate patient education, consent processes, participation in decision-making regarding their treatment and allow patients to provide feedbacks on their treatment outcomes for monitoring the effectiveness of PM interventions and for continuous improvement.

ICPerMed emphasises education and training as pivotal components in the successful implementation of PM. This focus is directed towards ensuring that all relevant stakeholders, including healthcare professionals, researchers, patients, and the general public, have a thorough understanding of PM concepts and practices. In particular, ICPerMed advocates for the integration of PM topics into the curricula of medical and healthcare-related educational programmes and, given the rapidly evolving nature of PM, ICPerMed emphasises the need for ongoing education and professional development for current healthcare professionals and for researchers and technical staff. Those programmes should not only include the latest developments in genomics, pharmacogenomics, bioinformatics, and other relevant fields but should also cover aspects like data management, ethical considerations, and patient communication. Training healthcare professionals in effective communication skills is crucial for discussing PM options with patients, including explaining the benefits, risks, and potential outcomes of PM-based treatments. This will encourage a shared decision-making approach, where healthcare professionals and patients collaborate to make healthcare decisions.

Resource allocation is highlighted as a critical aspect, with recommendations for financial, logistical, and human resources to support PM integration. This resource allocation must be guided by strong health technology assessment evidence maximise the added value of PM approaches for the healthcare system and the society. However, this requires a substantial change in the approach to health economic evaluations of PM interventions to factor in the model both

the uncertainty but also the potential of long-term benefit of the most innovative interventions such as gene and cell therapies.

It is suggested exploring various funding sources, including government budgets, private investments, and public-private partnerships. Efficient logistical frameworks are necessary to manage the complex operations involved in PM. This includes the development of data management systems, supply chain logistics for pharmaceuticals and diagnostic tools, and the establishment of patient data registries. The need for skilled personnel is highlighted, spanning a range of professionals from healthcare providers to researchers, IT specialists, and administrative staff. Training and retaining these professionals are key to the sustainable implementation of PM. The recommendations developed advocate for workforce development strategies that include specialised training programmes and career development opportunities in PM.

ICPerMed acknowledges the complexity of the regulatory landscape specifically when it comes to PM, e.g. due to small sample sizes, emphasising the need for clear, interlinked, and adaptable regulations to guide PM implementation, protect patient data privacy, and ensure informed consent. With PM's reliance on large datasets, including genetic information, ICPerMed stresses the importance of stringent data privacy regulations. This involves creating regulations that protect patient information, ensure data security, and maintain confidentiality. The evolving nature of PM necessitates adaptive informed consent processes and adaptable regulations. ICPerMed recommends developing consent frameworks that are flexible and comprehensive, allowing patients to understand the implications of their participation in PM, including potential risks and benefits. In addition, creating mechanisms for regular review and revision of regulations to keep pace with technological and scientific advancements in PM is also necessary. This document highlights the need for international collaboration to harmonise regulatory standards. This would facilitate cross-border research and collaboration, ensuring consistency in the quality and safety of PM practices but also equal access to new technologies and PM approaches worldwide.

Finally, the need for ethical considerations surrounding the implementation of PM was identified. These considerations are fundamental to ensuring that PM is developed and applied in a manner that is equitable, respectful of individual rights, and socially responsible. ICPerMed emphasises the importance of addressing disparities in access to PM. This includes ensuring that PM technologies and treatments are accessible to all segments of the population, regardless of socioeconomic status, geographic location, or demographic factors. Stakeholders should ensure that market forces do not create barriers to access and that PM solutions are affordably priced and widely available. Additionally, prioritisation of healthcare strategies could ensure that PM is integrated into the healthcare system in a way that promotes the common good and does not neglect other important areas of healthcare. Last but not least, ethical considerations extend to the realm of research, where there is a need for inclusive study designs that represent diverse populations. This is crucial to ensure that the findings and benefits of PM are applicable and beneficial to a broad range of individuals, not just a subset of the population.

This document comprehensively outlines the multifaceted approach required for the successful implementation of PM. It underscores the necessity of an integrated infrastructure, encompassing advanced IT systems, biobanks, and diagnostic tools, alongside robust patient engagement platforms. The emphasis on multi-stakeholder collaboration highlights the need for synergy between healthcare professionals, policy makers, researchers, and patients. Education and training emerge as key themes, stressing the importance of continuous learning and adaptability across all levels, from medical professionals to the general public. Ethical considerations, particularly in terms of equitable access and patient consent, are crucial in guiding the responsible development and application of PM. Significant challenges were identified, including the need for sustainable resource allocation, adaptive regulatory frameworks, and the maintenance of public trust and ethical standards in a rapidly evolving field.

Results

Engaging relevant stakeholders in the implementation process of personalised medicine

There were three essential aspects considered as general aspects for the implementation of PM: multidisciplinary approach, education and training, communication and dissemination channels.

Collaboration between policy makers, healthcare professionals, researchers, and patient advocacy groups create a multidisciplinary network that supports PM development and implementation. By creating multidisciplinary teams and engaging in joint initiatives, diverse perspectives can be integrated, leading to more comprehensive and effective implementation strategies. Moreover, it appears essential to establish multidisciplinary advisory or working groups that meet regularly to guide the implementation, comprising experts

from diverse fields. The timing of involvement is additionally important and engaging of relevant stakeholders at an earlier stage will enable to establish and share a common vision and objectives and will give the opportunity to control the implementation process from the very beginning. It is advised to start from smaller settings and define minimal common ground/blocks before enlarging the perimeter of action.

Education and training activities adapted for all involved stakeholders support the work and efficiency of multidisciplinary teams. They will increase the knowledge and understanding of the diverse aspects in a PM approach and stages towards implementation. Education and training activities will not only create multifaceted experts but particularly support collaboration and a common understanding between experts from different sectors and disciplines what is essential to develop and implement PM (see also section Education and training in personalised medicine).

Fostering collaboration and communication channels will ensure active engagement of stakeholders in the implementation process. Establish clear and accessible channels of communication to provide stakeholders with up-to-date information, evidence, and guidelines related to PM. This can include newsletters, dedicated websites, online portals, and regular email updates. Utilise case studies, success stories, and real-world examples to demonstrate the benefits and impact of PM in patient care, improving engagement and buy-in.

Engaging Patients and Citizens

The input of patients and citizens can contribute to the development but most importantly acceptance of patient-centred approaches and ensure that the needs and perspectives of patients are considered.

Engaging patients, their family members, or patient representatives is a key success factor. However, the level and format of this engagement might vary: 1) the engagement of patients in the PM implementation process shall be done through interaction between implementation personnel/ team and patients' associations/representatives, web-based communities, and patient experts, and 2) making bottom-up pressure at the political level by participating in the ongoing discussions to convince policy decision-makers.

The complexity and challenge for engaging patient representatives is that they usually are disease- or community-specific. Furthermore, PM is important not only at the point of diagnosis of a disease but also as part of disease prevention measures. Implementation of PM along the disease process spectrum requires the involvement of representatives of the citizens and the society as a whole. There are no, or very few, "personalised medicine" specific patients or citizens representatives. Depending on if they are patients, carers, advocates, they have different characteristics and different viewpoints. One needs to clearly define which involvement and when is needed in the implementation process and for which tasks.

The participation of patients in implementation bodies and working groups is highly recommended. However, there is a need to improve the scientific understanding of patients. Training and education of patients regarding the scientific and technical challenges is important and involves the collaboration of different parties (educational, organisation). On another note, it was recommended to include patients also individually instead of solely as representatives of organisations, and to give them a leading role.

Recommendations for Engaging Patients and Citizens

1. Determine the appropriate representation (patient's category, e.g. disease- or community-specific) to effectively engage patients and define clear tasks and procedures for their involvement.

2. Establish governance boards or advisory boards with patient representation to ensure that the patient perspective is included in decision-making processes.

3. Provide adequate educational interventions and materials to overcome social determinants and health literacy issues that may hinder their engagement (see also section education and training).

4. Consider reimbursement of the patients' work and contributions.

5. Build trust between the public and healthcare institutions for participation in PM initiatives. Trust is crucial for patients to willingly share their data and participate in research. If individuals feel that they won't have access to resulting treatments or that their data will be misused, trust erodes, hindering progress.

Engaging Policy Makers

Policy makers are essential actors and their engagement and support is a prerequisite before any implementation of PM approaches, e.g. the engagement of ministries of health, research and education and finance. It is an important requirement to convince and achieve the buy-in of policy makers, e.g. by having a well-detailed list of potential benefits and advantages to the general public. Having a government

mandate on political level creates a very strong link with policy makers and political stakeholders. On another note, political support is needed in harmonising PM care delivery all over Europe through initiating a European consensus on PM and e.g. European standardised protocols.

Lack of awareness might hinder engagement of policy makers as they may have limited knowledge and understanding of PM and its potential benefits, making it challenging to gain their support. Additionally, resources are limited and policy makers often face competing priorities which can make it difficult to allocate funding and support for PM initiatives.

Recommendations for Engaging Policy Makers

1. Knowledge Dissemination: develop targeted educational initiatives to raise awareness among policy makers about the principles, benefits, and evidence base of PM. This can include organising conferences, workshops, seminars, white papers and policy briefs specifically tailored for policy makers.

2. Evidence-Based Approach: provide policy makers with well-documented evidence on the potential benefits and value of PM, using methods such as cost-effectiveness analysis. This includes showcasing in successful case studies together with evidence of the impact on clinical outcomes and health outcomes to demonstrate the value proposition of PM to the general public.

3. International Collaboration: encourage policy makers to support and engage in international collaborations, as initiatives fostering harmonising PM care delivery across Europe. This can be facilitated through participation in European initiatives, promoting consensus-building, and advocating for standardised protocols that facilitate interoperability and data sharing.

4. Economic Considerations: emphasise the need for evidence of the economic benefits of PM, including the better use of healthcare budgets through more targeted and effective interventions, reduced hospitalisation rates, and improved health outcomes. Conduct economic evaluations to provide evidence of the long-term economic advantages of investing in PM.

5. Equity considerations: alert on the risk that implementation of PM and emerging healthcare technologies could challenge the equitable access across diverse populations in healthcare systems and could inadvertently reinforce existing disparities. By prioritising fairness and inclusivity, policy makers can work toward a healthcare system that benefits everyone, regardless of their socioeconomic and/or genetic background (see also section Ethics considerations).

6. Public Engagement: foster public engagement by involving patients, advocacy groups, and the general public in discussions around PM. Policy makers are more likely to respond to public demand and support when considering the implementation of PM approaches.

Addressing these recommendations could result in the elaboration of national/regional health policies supporting PM approaches. It is crucial to establish a dialogue, provide evidence-based information, and emphasise the potential benefits to both individuals and society as a whole.

Engaging Healthcare Professionals

Medical doctors and other healthcare professionals such as nurses, biochemists, pharmaceutical experts, biostatisticians, IT/AI experts etc. may have diverse needs, perspectives, and priorities when it comes to PM implementation, making it challenging to find a common ground and agreement. All other healthcare professionals should be engaged through regular bilateral meetings and agree on the same needs by considering one common formalised framework to on go the implementation process. This common formalised network includes agreements from healthcare professionals on the next steps to follow in the implementation process (material, data, flow, etc.). Additionally, some healthcare professionals may have limited knowledge and understanding of PM principles, technologies, and applications, which can hinder their engagement and buy-in. They also often have busy schedules and limited time for engagement in additional activities outside of their clinical duties, making it difficult to participate in regular meetings and discussions.

Recommendations for Engaging Healthcare Professionals

1. Collaborative Decision-Making: organise regular bilateral meetings and forums where medical doctors and other healthcare professionals can share their perspectives, needs, and challenges and try to find common ground, identify shared goals, and develop a consensus on implementation strategies. Need to recognise the time constraints faced by medical doctors and healthcare professionals and strive to make engagement activities as efficient and time-effective as possible.

2. Incentives: Provide incentives or recognition for active engagement in PM initiatives, such as professional development credits, awards, or career advancement opportunities.

3. Support and Resources: establish dedicated teams or

support structures (e.g. administrative support) within healthcare organisations to assist medical doctors and healthcare professionals in navigating the complexities of PM implementation and administrative burden.

Collaboration between relevant stakeholders during the implementation process of personalised medicine

Among the challenges faced in regards of collaborations during the PM implementation, two main areas were identified, sharing common obstacles:

- Collaboration within and among health systems: health systems often consist of multiple entities, including hospitals, clinics, research institutions, and private institutions or practitioners, which may operate independently. This complexity of the system can lead to a lack of coordination and collaboration, hindering the effective PM implementation. Additionally, the different actors involved in care delivery may have different standards, protocols, and practices, making it challenging to align efforts and implement standardised approaches to PM. Finally, the lack of common base is another issue for collaboration. Different agendas and priorities of institutions, and the lack of agreements between or connecting hospitals' administrations in one network, where they could connect and share ideas or common thoughts, are crucial challenges for collaboration among relevant experts.

- Collaboration between healthcare institutions and research/infrastructure: the separation of healthcare and research systems can create challenges in ensuring the availability and integration of research within healthcare settings. Additionally, the lack of coordination and collaboration between healthcare and research institutions can result in fragmented research activities and limited translation of research findings into clinical practice and vice versa reduced revision and improvement of applications already being in practice. Finally, insufficient funding and resources allocated to research infrastructures in healthcare settings can hinder the establishment and maintenance of necessary IT, data management, and research facilities. Moreover, different standards applied for data in healthcare and research hinder the access to and secondary use of clinical health data for research purposes.

Recommendations for Establishing Collaboration of different Stakeholders

1. Establish collaborative, transparent governance structures: create collaborative governance structures that bring together key stakeholders. Outlining the roles, responsibilities, and expectations of different stakeholders involved could provide a clear understanding of the collaborative processes, data sharing, decision-making mechanisms, and coordination mechanisms. Additionally, including interdisciplinary joint committees, task forces, or advisory boards to facilitate coordination, communication, and decision-making between the research and healthcare delivery systems will drive collaboration and shared learning.

2. Establish formal collaboration agreements: encourage healthcare and research institutions to establish formal collaboration agreements to facilitate information exchange, joint initiatives, and shared resources. These agreements can outline specific areas of collaboration, data sharing protocols, and governance/legal frameworks (contractual frameworks, regulating the access and use of data between healthcare institutions and research institutions considering appropriate legislation which varies from country to country).

3. Foster partnerships: encourage partnerships and collaborations between healthcare institutions and research organisations to facilitate the seamless transfer of research findings into clinical practice but also feedback outcomes of clinical practice into research. This can involve establishing formal agreements, joint projects, and shared research programmes.

4. Seek public-private partnerships: explore opportunities for public-private partnerships to leverage additional resources for research infrastructure. Engage industry stakeholders and insurance companies to contribute funding and to support the integration of research into healthcare systems while considering regional/national approach to healthcare either publicly funded or private healthcare systems.

5. Knowledge dissemination: facilitate knowledge exchange and learning to foster a common understanding and facilitate the development of a common vision. Initiating a national funding program to facilitate collaboration, e.g. through organising of workshops, to achieve hospitals' participation in national implementation of PM, and involving all relevant stakeholders such as academics and professionals.

Establishment of a national or regional common strategy

Having on the national, or on a smaller regional (referring to European National Regions) level, a common strategy and a harmonisation process involving all relevant stakeholders in place, is crucial for successful collaboration. It helps to overcome obstacles and ensures a unified approach to PM implementation.

Recommendations for Establishing a National or Regional Common Strategy

National or regional harmonisation: Establish a national steering committee comprising representatives from healthcare providers, research institutions, policy makers, healthcare professionals, patient advocacy groups, and other key stakeholders. This committee should work collaboratively to develop a common strategy and framework for PM implementation. Through regular meetings (see also Engaging relevant stakeholders) and consultations, this approach could gather input and foster consensus facilitating the identification of common goals, priorities and strategies, and address key areas such as infrastructure development, data sharing and privacy, workforce capacity-building, funding programmes and mechanisms, and patient engagement. For instance, dialogue among funding organisations, health authorities and policy makers will ensure that funding priorities align with PM objectives and that policies and regulations support collaboration and innovation.

Regional and local variations should be considered since the beginning and flexibility should be built into the framework to accommodate diverse health systems and resources.

Finally, establishing mechanisms for monitoring and evaluating the implementation of the national strategy will allow to assess progress, identify challenges, and make necessary adjustments.

Infrastructure needed during the implementation process of personalised medicine

Information Technology and Data Management Systems

Information Technology (IT) infrastructures play a vital role in the implementation and realisation of PM in healthcare. For instance, robust and secure IT infrastructure is essential for the storage, management, and analysis of large volumes of complex patient data, including genomic data, clinical records, imaging data, and other relevant health information. Health information systems should be interoperable, allowing seamless integration and sharing of data across different healthcare providers and research institutions. The initiation of clinical trial registries is important to enhance the participation, use the most adapted consent forms to integrate data in databases and allow further comparison and analysis.

High-performance computer capacity is crucial to enable collaborative big data research projects to facilitate the use of routinely collected data from healthcare systems. Infrastructures could support advanced analytics, data mining, and machine learning algorithms to derive insights from integrated data and facilitate personalised treatment decision-making.

A well-designed and scalable data management system is necessary to handle diverse types of data used in PM approaches, such as clinical routine data, genomic data, electronic health record data, lifestyle data, and patient-reported outcomes.

For some of the major obstacles as data ownership, interoperability and sharing, a federated data model provides solutions while offering the ability to leverage diverse datasets for analysis. A federated query system with a data catalogue for feasibility assessment could help for instance to identify data availability in hospitals. However, it also reveals challenges and obstacles such as data heterogeneity, coordination among different data sources, and ensuring consistent data quality and standardisation across the network.

Cloud-based solutions represent an alternative to the federated data model and are offering advantages in terms of centralised data integration, interoperability and management, scalability and flexibility, and collaboration, notably by enabling data sharing. However, security and regulatory compliance should be carefully evaluated according to organisations requirements.

In multi-centred, collaborative projects, governance frameworks should be established to address privacy, security, and ethical concerns related to the collection, storage, and sharing of sensitive patient information. Interoperability frameworks should be set up to enable the exchange of health data across different healthcare providers and research institutions.

Finally, data management systems should be scalable and sustainable to accommodate future growth and advancements in PM.

In the context of data analysis and governance within the framework of PM, it is pertinent to highlight the initiatives undertaken by the European Commission (EC) in addressing health data-related challenges. The EC has been actively organising meetings and preparing documents to establish a dedicated European Health Data Space. This initiative is a testament to the EC's commitment to enhancing the management and utility of health data across Europe. Notably, the EC has proposed a regulation aimed at empowering individuals to exercise control over their health data. This regulation also seeks to facilitate the use of health data for the enhancement of healthcare delivery, research, innova-

tion, and policymaking. A key objective of this initiative is to maximise the benefits derived from a safe and secure exchange, use, and reuse of health data within the European Union. Further details about this initiative can be accessed at the official European Health Data Space website (https://www.european-health-data-space.com).

Biobanks

Biobanks play a critical role in PM by storing and managing biological samples, such as tissue specimens, blood, and DNA, along with associated clinical and genomic data.

Infrastructure for biobanks should include proper sample storage facilities, tracking systems, quality control measures, and standardised protocols for sample collection, sharing and processing.

Genomic and Molecular Diagnostics

Advanced laboratory infrastructure is required to perform genomic and molecular diagnostic tests and assays, including next-generation sequencing, genotyping, gene expression profiling, and proteomic analysis. The infrastructure should adhere to quality control and quality assurance standards to ensure accurate and reliable results. Collaboration with reference comprehensive or specialised centres can help provide access to advanced diagnostic technologies and expertise.

Platforms for Patient Engagement

Tools and platforms should be developed to empower individuals to actively participate in their own care decisions, to access their health information, and to contribute to research efforts. Examples of tools and platforms are patient portals, mobile applications, and secure communication channels that facilitate patient-provider communication, shared decision-making, and access to personalised health information.

Recommendations for Infrastructures supporting PM

1. Data models:

- Favour federated data models to bring data and knowledge from multiple sources or different countries especially on EU level while keeping the data locally stored and controlled by the respective data owners.

- Adopt secure cloud-based solutions while ensuring data privacy and security if data integration requires significant effort to standardise and harmonise.

- Consult relevant stakeholders, including IT experts, legal advisors, and data governance professionals to ensure the chosen approach aligns with the organisations' goals and priorities.

2. Develop central governance and coordination and communication channels among national and regional healthcare systems and in some instances on international level.

3. Use standardised data formats and protocols to harmonise data across hospital and to enable seamless data exchange across different systems and platforms; ensure standardised, high-quality data capture at the source (once-only principle: data is collected once, but with high quality and sufficient metadata explaining the data, so that it can be used for multiple purposes).

4. Hire and build workforces to leverage advanced analytics tools, artificial intelligence, and machine learning algorithms for data analysis and decision support.

5. Prioritise data harmonisation efforts on a minimal common base to enable integration and interoperability across different data sources and platforms before scaling-up.

6. Participate in national or international networks to enhance data availability and access for researchers and healthcare providers.

7. Make Electronic Health Record (EHR) interoperable and accessible nationally or regionally across healthcare providers and incorporate decision support tools and alerts based on patient-specific data and genomic information.

8. Provide patients and citizens access to their health information, EHR with educational resources and tools for self-management to improve interventions adherence, patient satisfaction and experience.

9. Build infrastructures that integrate or facilitate the connection of data coming from research and healthcare as well as lifestyle data. This is essential to achieve the critical mass of data needed for PM approaches. It requires harmonisation of standards (e.g. quality, protocols, nomenclature, etc.) between research and healthcare providers during data collection.

Education and training in personalised medicine

It is important to provide different types of education and training for the successful implementation and adoption of PM into healthcare systems. Engaging relevant stakeholders, education and training is crucial to raise awareness on PM and demon-

strate the potential benefits (see also section Engaging relevant stakeholders in the implementation process of personalised medicine). This will support the engagement of relevant stakeholders and facilitate exchanges to establish a common vision and align on a strategy to implement and deliver PM.

The lack of a comprehensive national or regional strategy for education and training in PM, involving relevant stakeholders such as medical schools, professional societies, healthcare organisations, research institutions and regulatory bodies, may hinder the efforts.

Among various stakeholders, healthcare providers, medical laboratory scientists, researchers, IT specialists and the general public need to receive tailor-made education, literacy or knowledge dissemination. Additionally, interdisciplinary and interprofessional training, fostering collaboration and teamwork among healthcare professionals, researchers, and IT specialists need to be emphasised.

Healthcare Professionals

Healthcare professionals need to understand the principles, technologies, and applications of PM, including genomic testing, biomarkers, data analysis, and interpretation of results. They should be familiar with the potential benefits, limitations, and ethical considerations associated with PM. The rapid advancements in PM can pose challenges in keeping healthcare professionals updated with the latest knowledge and practices. There may also be variations in existing knowledge and skills among different professionals. Finally, education programmes may support career advancement of healthcare professionals.

Communicating complex scientific concepts to the general public in an accessible and understandable manner can be challenging. Hence, it is important to support healthcare professionals on how to engage and communicate information to patients.

Recommendations for Education and Training of Healthcare Providers

1. Incorporate PM-related topics into the curricula of medical schools in fields such as oncology where the students receive an overview of all the impacted fields covering tumour biology and genetics, molecular pathology, clinical bioinformatics and clinical oncology. Specific courses dedicated to PM could be suitable for MD students or healthcare providers post-certifications. These can include seminars, webinars, workshops, and online courses tailored to the specific needs of medical doctors and healthcare professionals.

2. Collaborate with professional medical associations and organisations to integrate PM education into their continuing medical education programmes, ensuring accessibility and relevance for healthcare professionals.

3. Provide data literacy and principal understanding of the requirements of data-driven approaches among all stakeholders, and data-management training.

4. Raise awareness on Ethical, Legal and Social Implications (ELSI) of data-centric processes.

5. Include regulatory considerations through training on regulatory frameworks.

6. Prepare healthcare providers on patient-doctor relationship fostering communication and patient-centred care.

7. Promote patient-centred approaches by improving patient-doctor relationships.

8. Collaborate with patient advocacy groups, patients' representatives, community organisations to facilitate knowledge sharing and patient empowerment in PM decision-making.

Medical Laboratory Technicians and IT Specialists

Medical laboratory technicians and IT specialists play a critical role in PM by e.g. handling genomic data, conducting laboratory testing, managing data storage and analysis, and maintaining IT infrastructure. Rapid technological advancements and evolving laboratory techniques require continuous training to keep up with the latest methodologies. IT specialists may face challenges related to data security, privacy, and interoperability.

Recommendations for Education and Training of Medical Laboratory Technicians and IT Specialists

1. Promote awareness of healthcare systems and social/welfare services settings to improve knowledge on care continuity and integrated health services delivery.

2. Increase knowledge on clinical guidelines.

3. Provide specialised training programmes for laboratory technicians on genomic testing techniques, quality control, data management, and interpretation of results.

4. Offer training opportunities for IT specialists on data privacy and security, data ethics, data integration and interoperability, and the management of complex IT systems.

5. Facilitate collaboration and knowledge exchange between laboratory technicians, IT specialists and clinicians or

general practitioners to ensure seamless integration of laboratory and IT processes in PM implementation.

Researchers

PM often requires collaboration across multiple disciplines, such as genomics, bioinformatics, epidemiology, clinical medicine, statistics, health economics, implementation science. Facilitating effective collaboration among researchers from different disciplines can be complex, as each discipline may have its own terminology, methodologies, and research approaches. It is crucial for researchers to be trained to work effectively in interdisciplinary teams.

Finally, researchers should be aware of ethical and legal considerations related to PM such as informed consent, privacy, data sharing etc.

Recommendations for Education and Training of Researchers

1. Integrate bioinformatics, epidemiology, clinical research, ELSI to curricula leading to the practice of PM in research.

2. Establish interdisciplinary training programmes and research networks that bring together researchers from various disciplines to foster collaboration and knowledge exchange in PM research.

3. Emphasise interprofessional training, fostering collaboration and teamwork among healthcare professionals and researchers.

Patients and citizens

The general public should possess fundamental knowledge regarding PM concepts, advantages, and potential implications for their healthcare decisions. Enhancing this understanding will not only foster patients' involvement in their own health but also facilitate the implementation of PM by enabling the early integration of their preferences and perspectives into the process. Furthermore, as highlighted in the section on engaging patients and citizens, they serve as influential stakeholders in policymaking. However, social determinants and health literacy might hinder the engagement of patients. Ensuring equal access to information and addressing health literacy gaps are then important considerations.

Recommendations for Education and Training of Patients and Citizens

1. Leverage advocacy groups and patients' representative organisations role to act as a central partner in education and training.

2. Develop educational materials, brochures, and online resources specifically designed for carers and family caregivers. Use clear and plain language to explain the principles and benefits of PM, as well as the role of carers in supporting personalised care. Make information accessible in healthcare facilities.

3. Organise public events to raise awareness, address misconceptions, and promote discussions on PM-related topics notably about the ethical considerations in PM, including equity in healthcare access, privacy, confidentiality, and informed consent.

Resource allocation during the implementation process of personalised medicine

Resource allocation is a crucial aspect of implementing PM in healthcare. Adequate and efficient allocation of resources in research and development, data management systems, instruments, and personnel are necessary to support the successful integration of PM into medical and clinical practice. By addressing the challenges related to resource allocation, and by generating the appropriate health technology assessment evidence to guide implementation, healthcare systems can optimise the use of available resources, improve the delivery of PM and maximise the potential benefits of PM to patient populations and healthcare systems.

Financial resources

Insufficient and unsustainable funding for research and development and data or sample management can impede the smooth flow and integration of research outputs and data into practice. Without adequate financial resources, healthcare systems may e.g. struggle to establish robust, sustainable infrastructures, interoperability, and data or sample sharing mechanisms, hindering the effective utilisation of patient information and research results for personalised care.

Research funding is often rigid and limited to a specific project with an inflexible budget and fixed project duration. There is a lack of follow-up funding that could for example support the development of a PM approach over the entire pipeline from research, innovation until implementation and probably revision of tools based on clinical outcomes.

Recommendations Concerning Financial Resources

1. Advocate for funding specifically allocated to PM research and development, research and IT infrastructures, data management systems by engaging policy makers. Generate the required health technology assessment evidence to demonstrate the expected benefits, such as

improved patient outcomes and cost-effectiveness, to support implementation of the PM innovations. This can include advocating for grants and regional, national or European funding.

2. Explore opportunities for public-private partnerships to leverage additional resources by engaging industry stakeholders.

3. Prioritise resource allocation by developing evidence-based frameworks to guide resource allocation decisions, ensuring that funding is directed towards areas with the greatest potential for impact and in regards of cost-effectiveness analyses.

4. Initiating in research from the very beginning reflections and analysis on reimbursement schemes for PM tools/ services. This includes invest in robust analysis of the burden of diseases both on patients and on caregivers in order to allow more holistic assessment of the value of PM interventions.

5. Develop funding schemes that support the entire value chain (research, innovation and implementation as well as revision of tools in clinical practice).

Logistical resources

Determining the costs associated with renting and using instruments (machines) in healthcare institutions can be challenging. Lack of clarity in estimating these costs can lead to financial complications during the implementation process and limit the widespread clinical application of PM technologies.

Recommendation Concerning Logistical Resources

- Collaborate with relevant stakeholders, such as healthcare providers, manufacturers, and procurement experts, to accurately estimate the costs associated with renting and using instruments in PM. This can help healthcare providers to better plan their budgets, negotiate contracts, and ensure cost-effective utilisation of instruments.

Human resources

PM implementation requires high-qualified personnel with a deep understanding of medical, technical, and scientific regulatory requirements. However, recruiting such individuals can be challenging, as there may be a shortage of professionals with the necessary expertise. Additionally, the inclusion of personnel with data science background is important to leverage the potential of data-driven approaches in PM, but these profiles may still be lacking in healthcare practice.

Recommendations Concerning Human Resources

1. See section Education and training in personalised medicine.

2. Offer fellowships, and career development opportunities.

3. Allow knowledge exchange for example through twinning calls or visiting programmes.

Regulations and legislations for personalised medicine approaches

Regulations and legislations play a crucial role in the PM implementation, particularly in relation to the collection, storage, and analysis of patient data. However, the regulatory landscape can be complex and fragmented, involving multiple jurisdictions, agencies, and legal frameworks. Navigating through these regulations and ensuring compliance across different contexts can be challenging.

To overcome these challenges, it is important to establish clear, interlinked but also adjustable regulations that provide guidance on various aspects of PM, including data privacy, consent, research ethics, reimbursement, and clinical implementation but keep flexibility for specific needs around PM approaches (e.g. related to small sample sizes). Harmonising regulations across jurisdictions and disciplines is essential to facilitate innovation and collaboration in the field.

Healthcare organisations face specific challenges in complying with data protection laws and internal rules to ensure the privacy and security of patient data. Robust data management practices and protocols must be implemented to protect patient privacy and obtain informed consent for data use. Moreover, adapting clinical workflows and integrating them into existing systems can be time-consuming and resource-intensive.

Recommendations for Regulations and Legislations supporting Personalised Medicine

1. Promote international and national collaboration and harmonisation through collaborative efforts between countries and regions to facilitate the harmonisation of regulatory frameworks, streamline processes, and promote cross-border research collaborations. Sharing best practices and lessons learned can accelerate the adoption and implementation of PM.

2. Establish a national regulations group comprising legal experts and relevant stakeholders, including patients, healthcare professionals, researchers, and industry representatives can help ensure consistent interpretation and application of regulations. This can minimise confusion and promote a standardised understanding of legal requirements, facilitating compliance across different healthcare settings and ensure that regulations align with the needs and perspectives of patients, practitioners and researchers.

3. Incorporate cost-effectiveness studies in the design of regulations and policies to assess the economic impact of PM interventions. This can aid in decision-making, resource allocation, and reimbursement decisions, ensuring the efficient use of limited healthcare resources.

4. Design adaptive and flexible regulation frameworks able to accommodate innovation and adapt to new evidence and practices notably by incorporating real-world evidence into decision-making.

Ethical considerations

The implementation of PM holds great promise in tailoring healthcare to individual patients, but its benefits may be distributed inequitably due to various structural factors. The issues of equity in PM revolve around access, costs, and biases, which can vary significantly depending on the healthcare system and its priorities. For example, historical discrimination of some minority populations has led to an underrepresentation of these groups in research for PM. Moreover, the exclusion or underserving of some societal groups from or within healthcare systems creates unequal chances for people within specific societies to benefit from the fruits of PM. There are also massive global inequalities regarding the chance to benefit from PM. When populations in resource-poor regions cannot get access to appropriate diagnoses, the best PM treatment remains fruitless. Equity considerations are thus crucial to ensure that PM benefits all populations, regardless of their socioeconomic background, ethnicity, or other factors. Ensuring equitable access to PM requires addressing underrepresentation in research cohorts, structural factors in healthcare systems, and the potential for disparities in access and benefits. By promoting inclusiveness, addressing health disparities, and promoting equitable access, more people can benefit from tailored treatments and preventive measures.

Recommendations

1. Certain populations have historically been underrepresented in PM research. This underrepresentation can lead to biased results and limit the effectiveness of PM for diverse groups. To rectify existing biases, it is essential to emphasise diversity in research cohorts. However, this should go beyond genetic diversity to consider socioeconomic and demographic factors that influence health outcomes. This issue could be addressed by improving research inclusivity. Policy makers should support initiatives that actively seek to include diverse populations in PM research. Oversampling underserved populations can be mandated to rectify existing biases when necessary.

2. Examine the structure of the healthcare system and consider whether it promotes or hinders access to PM. Solidaristic sharing of risks and costs, as seen in certain healthcare models, can help to ensure that PM benefits a broader segment of society. Challenges related to access, costs, and bias through evidence-based policy changes should be addressed.

3. The prioritisation of healthcare strategies and resources should be driven by principles of solidarity rather than profit. Organising healthcare systems to minimise financial disparities and share risks and costs will contribute to PM's equitable distribution.

4. Consider a shift in healthcare systems toward a greater emphasis on prevention rather than solely diagnosis and treatment. When it comes to prevention, it is important to change individual behaviour but prevention strategies should not merely focus at the individual level. Investing in public health services and addressing social determinants of health can improve population health outcomes and the equitable distribution of PM benefits.

5. Be mindful of market dynamics that may arise from PM, such as private health insurance markets and costly treatments. Assess the potential impact on healthcare systems and access, and take measures to avoid exacerbating disparities.

Discussion

While comprehensive strategy for the implementation of PM are outlined in this analysis, ICPerMed also recognises several critical issues that warrant careful consideration:

- A major challenge is the digital divide, particularly in the context of an aging population that may find it difficult to use devices and engage with telemedicine. Strategies to enhance digital literacy and provide user-friendly tech-

nologies are essential to ensure that the benefits of PM and telemedicine are accessible to all age groups.

- The diverse cultural backgrounds of citizens must be considered in the development and implementation of PM. This includes respecting cultural norms, beliefs, and practices in healthcare delivery and patient engagement strategies.

- The requirements for implementing PM and novel technologies as telemedicine differ significantly between urban and rural areas. In rural areas, challenges such as lower population density and limited mobile phone connectivity need specific strategies tailored to their unique context.

- The relationship between family doctors and citizens varies across different territorial healthcare systems. Strengthening this relationship is crucial, especially in the decentralised model of PM, where family doctors often play a key role in coordinating patients care.

- The high turnover of healthcare professionals and the shortage of doctors, specialists, and nurses pose significant challenges to healthcare systems. Addressing these issues is critical for the sustainable implementation of PM.

- A holistic approach to healthcare is essential, where healthcare professionals consider the overall well-being of the individual, including psychological support. This approach is intricately linked with the education and training of healthcare professionals, laboratory technicians, IT specialists, as well as patients and citizens. Ensuring that all stakeholders have a broad understanding of the various facets of healthcare, including the psychosocial aspects, is pivotal in PM.

- Considering the diversity of healthcare systems in Europe or even on regional level, not one single implementation approach is applicable for all nor could for each an individual recommendation being developed. Harmonisation or alignment of healthcare systems could be a solution but would require a complex and long development and implementation process. Therefore, today cross-border collaboration on all levels are essential to provide, despite and by respecting the diversity of the current healthcare systems, access to new technologies, tools and care to all European citizens.

Conclusion

In conclusion, this ICPerMed document presents a roadmap for the integration of PM into healthcare. Its recommendations offer actionable strategies to overcome existing barriers and harness the potential of PM for improved health outcomes. The success of this endeavour hinges on collaborative efforts, innovative thinking, and a steadfast commitment to ethical principles and common goals. As we advance, it is imperative that all stakeholders, including healthcare professionals, researchers, policy makers, and patients, engage actively in this transformative journey. By doing so, we can unlock the full potential of PM, making it a cornerstone of modern healthcare that is accessible, efficient, equitable and tailored to the individual needs of patients and all citizens. This paradigm shift, while challenging, holds the promise of a future where healthcare is more precise, predictive, and patient-centred, ultimately leading to better health outcomes and quality of life for all.

Impress

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Conflict of interest

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