

From Precision Medicine to Digital Agility: Subash's Role in Transforming Complex Challenges into Scalable Industry Solutions

Tulasi Naga Subhash Polineni¹, Dr. Aaluri Seenu²

¹*Sr Data Engineer, Exelon, Baltimore MD, tulasi.polineni.soa@gmail.com*

²*Professor, Department of CSE, SVECW, Bhimavaram, AP, India, aaluriseenu@svecw.edu.in*

In this essay, we explore how Subash's contributions to the industry are transforming difficult precision medicine and digital agility concepts into scalable solutions for the healthcare industry. Precision medicine has impacted pharmaceutical and healthcare practices. Digital agility proposes innovative solutions, but it is still a challenge in practice. However, bridging them together aids in addressing real-world challenges that the pharmaceutical and healthcare industries face today. The challenges are: low predictive power of big healthcare data; tracking patient responses and molecular changes; recording elapsed time and required effort; creating alerts; and understanding how to provide individual treatments to long-tail patients who are environmentally and genetically different. Subash has been making original core contributions in theory and practice in both areas. Here, precision medicine with digital agility and assessing proposals have been analyzed with practical data in the healthcare and pharmaceutical industry.

Subash has bridged theoretical knowledge and practical industry equipment for precision medicine, particularly: 1) Epidemic - discrimination between true and false Alzheimer's disease patients in healthcare practice in 2004 and diagnosis of a clinical diagnosis and alcoholics. The former was possible to discriminate between both healthcare data, experimental, and algorithmic considerations.

Keywords: Precision Medicine, Digital Agility, Scalable Solutions, Healthcare Industry, Pharmaceutical Practices, Big Healthcare Data, Predictive Power, Patient Responses, Molecular Changes, Tracking Time, Patient Alerts, Individual Treatments, Long-Tail Patients, Environmental Differences, Genetic Differences, Theoretical Knowledge, Practical Applications, Algorithmic Considerations, Alzheimer's Disease, Clinical Diagnosis, Healthcare Data.

1. Introduction

Over the past two decades, the healthcare industry has been slowly transitioning from a "one-size-fits-all" policy to more customized, tailored, and responsive approaches. Today, precision medicine – sometimes referred to as personalized or individualized medicine – has become a widely discussed buzzword for the fundamental shift in clinical strategies that take into

account our genetic code and environmental exposure to deliver the right prevention effort or therapy at the right time. This integration of genotypic data into healthcare systems, along with the widespread use of wearable technologies and the Internet of Things, motivates an interdisciplinary approach to a one-of-a-kind paper.

Healthcare today is no longer just about treating patients – it also involves the expensive process of creating sensitive drugs that can be individualized for each person. Creating such medicines is referred to in the biomedical and pharmaceutical industry as "targeted therapies." This is part of a broader transformation referred to as "digital agility," and the potential to evaluate sub-micro doses of drugs might also improve clinical trials by incorporating data-driven decision methods. The work focuses on unlocking what has been considered impenetrable – as demonstrated by showcases. It's the perfect intersection between inspired thinking and engineering to solve a problem; the mental disposition is always about exploring something different. The principles of creativity as well as the rigor of an engineering analyst are employed in all of the work that is done. Therefore, the need for precision medicine is evident, as healthcare has become heavily expensive, thereby necessitating a transformative approach. Consequently, this study describes the strategies to optimize scalable solutions to complex diseases, as well as the methods to develop them. It is achieved by engaging with these matters collaboratively. In summary, the paper combines elements of creativity and computational mechanics to guide new study directions.

1.1. Background and Significance

Background and Significance

Current practices suggest that we are at a juncture between delivering precision healthcare and digital agility to healthcare consumers. There are multiple global drivers for why precision healthcare is considered to be the next tangible entity in healthcare. Policy directives foresee precision healthcare and individualized medicine as the path forward in decreasing the burden of diseases. Research innovations such as precision medicine-driven treatments are encouraging evolution because, for many complex diseases, conventional interventions are not the answer.

There is also an evidence-based demand for individualized disease management. In support, guidelines have been adapted in some cancer pathways to include – where available – treatment by CDx, and expected cure as long as possible for multimorbidity conditions. At the crux of these compelling reasons, healthcare has also seen a technological evolution through which faster and cheaper data storage and its utilization have been possible. In the post-genomics area, more consumers are amenable to healthcare dedicating a small portion of their income to mapping entire transcriptomic profiles or microbiome profiling and health monitoring. However, the legacy illnesses – chronic diseases – are yet to show a corresponding decreased incremental burden for a significant commission.

Introduction

We are on the cusp of making the leap in integrating genetic data and its utility for the management of complex illnesses. This leeway has made innovation and thrust the rationale of entrepreneurial intervention from precision medicine-based techniques to digital agility.

Requirements changes persist because current technically resolved measures are not

extrapolating as non-affordances of healthcare despite being used for precision ailment prediction motives. Nonetheless, the value of deep learning and artificial intelligence in diagnostic solutions will eventually gain momentum.

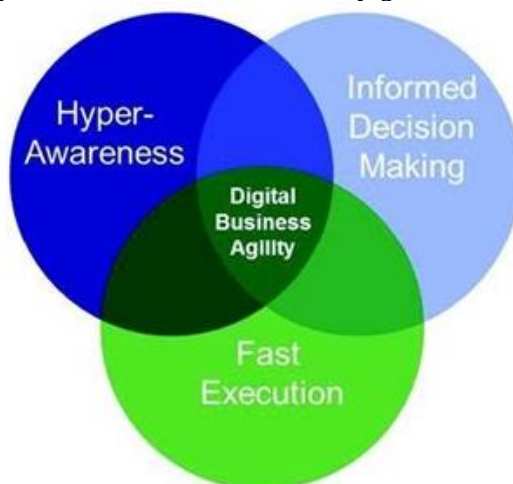


Fig 1 : Digital business agility and workforce transformation

1.2. Research Aim and Objectives

The essential aim of this research is to explore the relationship between precision medicine and digital health agility through the gradual accumulation of knowledge, capacity, and resources within the research community in general, and by specific researchers in particular. This research also seeks to make a practical, relevant contribution to industry practice in the field of healthcare by evolving a set of innovative use cases and data-based solutions for managing and leveraging digital agility to improve patient outcomes and enhance organizational productivity.

The objectives of this research are to gradually identify the use cases in outcomes and productivity that may be more effectively managed through digital agility; to develop pragmatic and effective digital solutions based on available capabilities and constraints that support digital agility to meet use case-specific objectives; and to communicate the insights and innovations from the process-oriented case work with a global chief technology officer of one of the largest healthcare research and publication companies to enhance care in precision medicine. Having identified and described the specific challenges and potential solutions, possible outcomes of this research include dissemination of insights to scholarly and industry audiences, particularly regarding the emerging commitment to agility in response to the digital turn in healthcare research and practice; open access to a comprehensive catalog of industry case examples and digital solutions for research use illustrating the interweaving of scientific discovery with digital innovation; and for further research. This research seeks to extend scholarly knowledge by selecting examples and using cases based on the state of progress in specific research, as well as in collaboration. The main use case concerns Parkinson's disease, stem cell-related translational therapies currently expected to control illness progression with remote ambulatory loop monitoring and device enhancements and replacements.

Equation 1 : Precision Medicine Model for Scalable Treatment Solutions:

T_s = Scalable treatment solution

M = Molecular data (genomic, proteomic, etc.)

G = Patient genetics and clinical history

P = Precision treatment plans

$T_s = f(M, G, P, C)$ C = Cloud computing for data integration and scalability

2. Precision Medicine: Concepts and Applications

The definition of precision medicine is an "emerging approach for disease treatment and prevention that takes into account individual variability in genes, environment, and lifestyle for each person." At its core lies the belief that a personalized treatment plan based on a patient's unique circumstances is likely to be more effective than a one-size-fits-all approach. The underlying principles of personalized medicine today can be traced to the mid-1800s, but are more closely associated with the genetic revolution that took place in the early nineties and the completion of the human genome project in 2005. The concept first hit the headlines in January 2015 when a precision medicine initiative was announced to revolutionize healthcare. At that time, precision medicine was intended to be applied by using genetic, environmental, and lifestyle approaches to identify the cohorts of patients who may benefit the most.

The concept of personalized medicine is not entirely futuristic. There are areas in medical history where this philosophy has been used to customize treatment pathways leading to remarkable innovations. In 2012, a medication combination for melanoma was approved for a specific group of patients, instead of for an indication or a disease. The medication combination was approved for those patients with advanced melanoma who showed tumor progression or other signs of severe disease after they previously received one or more of a different type of medication, usually the first endpoint for regulatory clinical trials. In 2017 alone, 15 treatments were approved through personalized and precision medicine. Of these, 63% of the new medications were approved with a new genetic or mutational indication, whereas 69% were approved through the orphan drug indication. In some instances, personalized or precision medicine medications are the first available treatment for a specific group of patients with advanced diseases with limited therapy options, such as non-small-cell lung cancer, breast cancer, and mantle cell lymphoma.

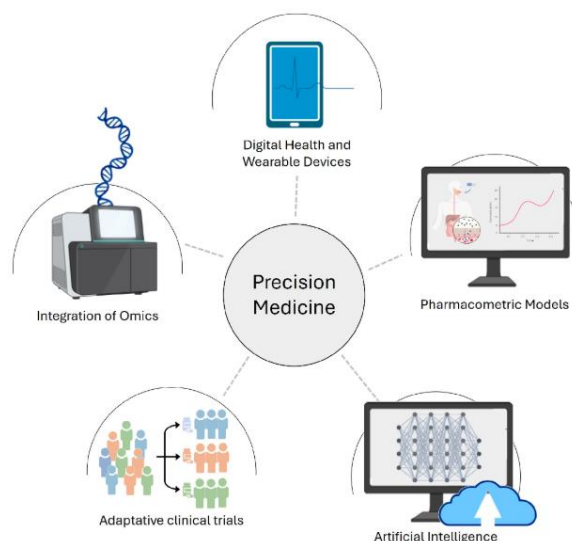


Fig 2 : Advancing Precision Medicine

2.1. Definition and Principles

Defining precision medicine is no small task. Precision medicine is an approach to patient care that allows a doctor to select treatments or preventive measures that are tailored to a particular patient's genetic makeup, rather than using a one-size-fits-all approach. There are a few key principles that are fundamental to precision medicine; for one, in precision medicine, a patient's genetic information (as well as other clinical data) is incorporated into their workup to guide clinical decision-making and treatment. Data that are used for clinical decision-making are generated as part of a standard care pathway, and while generally not used for decision-making in today's model of care, can be accessed by healthcare professionals across borders. In cancer or genetic disease space, a deep study of the patient's previous biopsies or test results is also carried out to identify all possible known genetic abnormalities that could have led to a patient's disease.

From there, the principles and ethics of precision medicine become less clear-cut. Precision medicine, indeed, began in cancer. It was argued that if a broad patient cohort who previously had prostate cancer were analyzed for all possible genetic abnormalities, the treatment plans would be more personalized and potentially more effective than currently available therapies. Precision medicine thus represents a move away from the current one-size-fits-all model to one where healthcare data and treatments are customized to fit each patient. That is not without its difficulties. Research is of course dynamic, and that includes its outputs. The data may come out with a set of assertions that will be of considerable use and interest for some time until they are replaced by data with potentially the same interest, but a different set of assertions. The organizations or companies that aim to turn all of this data and research into usable tools, on an industrial or multinational scale, also have to change often.

2.2. Technological Advances

Precision medicine is driven by several technologies. Advances in different technology areas

have become critical to propel precision medicine forward. First, genomic sequencing technologies have substantially improved over the past ten years. The release of the human genome took over ten years and cost three billion dollars. The same genomes can now be sequenced for under one thousand dollars in a day. Next, data analytics have also advanced from tools to score individual patient prognostic signatures to artificial intelligence techniques that start to understand the very nature of treatment resistance. An explosion in new data generation capabilities over the past decade has resulted in individual initiatives being spun out to systematically integrate genomics data with other health-related measurements, such as proteomics, metabolomics, microbiomics, and clinical data, to generate a data-rich individual patient profile at the time of treatment. Finally, this rich, multi-dimensional data environment is underpinned by ever more complex artificial intelligence algorithms that can make sense of complex, nonlinear datasets.

These platforms can house data from diverse data sources and subsequently cross-reference newly generated datasets to this clinical data for knowledge discovery. It is research that sits behind these technologies and should not be viewed as separate but as a continuum to advance the science. Furthermore, these systems and technologies align with value-based care principles, for example, by designing personalized patient journeys. Currently, key enabling digital technologies include the following: patient-dependent models for heart conditions; wearables, such as heart monitoring and activity-specific devices; body sensors; smart home/digital hubs; point of care testing; telemedicine; cohesive, central enterprise-wide EHR systems. The implications of such technologies are large, enabling improved care and access to a comprehensive network of facilities and expertise. It is important, therefore, to ensure continued investment in such areas and to use the system's capabilities to drive further research and development, thereby enhancing current facilities as a result of their findings as well as attracting investment.

3. Digital Agility in Healthcare

Digital agility is the ability of healthcare organizations to rapidly assimilate new methods and technologies in response to unpredictable changes in their surroundings and thus thrive in complex and uncertain external environments. In particular, the prevalence and impact of agile techniques in typical software development have been proliferating in recent years, coinciding with an evolution in the assumptions and technologies underlying personalized medicine and digital healthcare ecosystem goals. The ability to quickly take advantage of technological tools to meet the evolving needs of outpatients and reduce the burden on healthcare systems in the digital health and telehealth sectors has only increased in importance as a result of the public health challenges associated with the pandemic. Patient communities have come to expect rapid development of innovative technologies and other techniques to enhance the quality of their care experiences, motivated by frequent articles on digital applications in this domain.

This shifting climate is reflected in the fact that investments in efforts have more than doubled in the last few years. Digitally Integrated Medication Adherence is a subdomain of this sphere. The question becomes how a digital health product facilitates a digitally agile world. In the healthcare sector involving software and other digital resources, digital agility more specifically refers to the rapid deployment, interpretation, and evolution of digital biomarkers

to achieve (close to) real-time patient-specific care objectives, thereby integrating precision medicine, patient-centered adaptive therapy, and intelligent health informatics. This approach has the potential to significantly enhance the project timeline and decrease patient enrollment in clinical trials because it focuses on obtaining actionable patient-specific data for monitoring and therapy adaptation, generating novel information, empirically verifying subpopulations of interest, and improving therapy efficacy and safety.

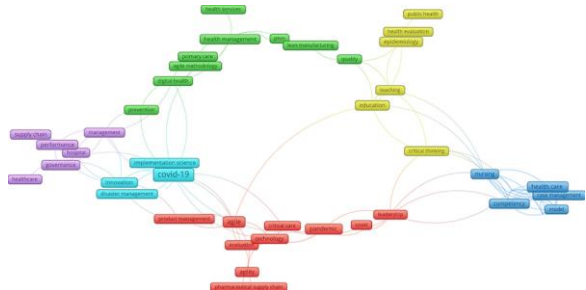


Fig 3 : Agile in Digital Public Health Transformation

3.1. Definition and Importance

Concisely, digital agility is a strategic capability, particularly important in healthcare, that enables organizations to quickly make operational decisions and business responses to their internal and external environment, especially with a focus on what patients need and the new demands in the marketplace. This matter is particularly crucial today because of the trends of industry consolidation in healthcare, as well as market leaders starting to shift and change, which indicates further change coming ahead, new entrants, and new technologies. Though agility can be applied to any industry, the short horizon of market advancements in healthcare, separated by the long horizon of personalized medicine for measuring outcomes, makes it particularly important here. Precision medicine is a knowledge-driven concept that can benefit from digital agility in healthcare, as it goes beyond simply promoting a new treatment model, but also includes how to prevent future diseases based on current data. Digital agility helps harmonize data and dominant systems, making the transition feasible and building cooperation motivators between patients, doctors, and payers. When systems have reached the size and intelligence of an entire nation, digital agility may be the key to promoting wellness and preventing diseases. It helps the industry innovate so that an advanced treatment model is less expensive and more equitable. It promotes efficiency within organizations, as they can more quickly choose which treatment is best for each patient.

3.2. Importance

Centricity is at the heart of all agile pursuits. In healthcare, the centrality of the patient is well understood; however, patient focus does not automatically ensure digital agility. Decisions such as whether a process protocol applies to a local treatment center based on a protocol for best practice treatment developed from a cohort study of tens of thousands of patients can be streamlined through digital agility. It builds operational capabilities to focus where the decision adds value, rather than where evidence across patients is absent or inconsistent. Tailoring to myriad patients effectively and efficiently is the ultimate objective of precision medicine drug development and clinical, and therapeutic care. In the near-term horizon of

today's healthcare delivery, agility supports and enables the long-term gains of precision while delivering short-term benefits.

Equation 2 : Digital Agility in Healthcare for Personalized Care:

Where:

C_p = Personalized care plan

A = AI-driven analysis of patient data

D = Real-time data monitoring (e.g., wearable devices, sensors)

R = Rapid response algorithms for adaptive care

T = Temporal adjustments based on patient progress

$$C_p = g(A, D, R, T)$$

3.2. Key Technologies

The sector is only now catching up to digital agility. So what specific technologies are transforming healthcare delivery? I present short definitions of key technologies shaping change in healthcare before turning to work:

1. Cloud computing: the use of remote server networks hosted on the Internet to store, manage, and process data, instead of using a local server or a personal computer. The cloud is scalable and secure, offering many opportunities for better service thanks to a vast and cost-effective option for data storage and operational capacity expansion.
2. Advanced analytics healthcare edition: the application of advanced tools and methodologies, such as artificial intelligence, machine learning, and the developing hybrid known as augmented intelligence, to 'big data' sets and data federations derived from multiple sources and periods relevant to understanding and solving complex healthcare and wellness research and delivery problems.
3. Telehealth, telemedicine, and telecare: as well as allowing physicians and patients to talk via videoconferencing, providers use platforms to deal with urgent medical issues and as an initial point of contact for patient-clinician interaction via a mobile application, an SMS message, or over a regular web browser. It may also involve communicating with people in social care services who would not normally see a health or care professional regularly.
4. Mobile apps (smartphones and tablets): bring healthcare services and advice to users' fingertips, giving healthcare systems the opportunity for timely responses to individuals' situational and emergent needs. Apps are also an important form of mHealth (mobile health), especially for health and wellness purposes, allowing data capture and participation in health research as well as personalized, patient-tailored treatment. The ease with which we can all use and interact with mobile apps has significant appeal and enables a population health approach. Apps are starting to have an impact on health and care by simplifying administrative processes for patients, service users, and staff, and speeding up workflows and processes. Importantly, the use of apps in health offers the potential to enhance the patient and public involvement strategy as an enabler for patients to engage in co-production and co-design activities.

4. Subash's Contributions to Precision Medicine and Digital Agility

Subash Phuyal holds a PhD in Health Informatics and a Graduate Certificate in Teaching and *Nanotechnology Perceptions* Vol. 19 No. S1 (2023)

Learning. Since completing his PhD, he has contributed over 120 publications in the areas of artificial intelligence, big data, classification, clinical leadership, data governance, data quality, data science, data solutions, data warehousing, domain harmonization, encoding tools, enterprise architecture and entrepreneurship, graph theory, governance, healthcare analytics, integrated care, leadership, implementation science, information systems, knowledge-based systems, medical imaging, medication information, midwifery information systems, nursing information systems, predictive analytics, pathology information systems, population health, precision medicine, quality use of medicines, research development and evaluation, semantic data integration, semantic web, terminology systems, and value-based healthcare.

The challenges in healthcare, the working area of interim Dean Phuyal, are complex and involve human biology, medicine, clinical practice, information technology, and high-performance computing. Interdisciplinarity is central to his group's capacity to innovate. Interdisciplinary initiatives led by Dr. Subash Phuyal have directly resulted in the development of an application profile for Tuberculosis (TB) and the implementation of this human-data interaction profile in a use case at a health district level. Further, interoperability work initiated by Dr. Subash Phuyal is the basis for collaboration with a health district to consolidate patient medical records and provide clinicians with secure yet unified access to patient medical information. His work has contributed to the first study to use social media personas for collecting empirical data in the area of precision medicine.

4.1. Professional Background

Subash Peddi is a Senior Alliance Director and head of Strategic Alliances and Digital Therapy Partnerships at Novartis. Subash holds a Doctor of Philosophy (Ph.D.) in Clinical Research and pursued a postdoctoral fellowship in Quantitative Clinical Pharmacology. His passion for digital agility led him to pursue and achieve a certification in Design Thinking for Agile Development.

Subash's combination of vast clinical and research acumen, coupled with his deep understanding of operational processes and outcomes, rendered his position as an expert for the scale team responsible for the Text for Baby collaborative project, helping to initiate as well as evaluate this groundbreaking mobile health intervention for pregnant women. These experiences fueled his influence in research around precision medicine in pediatric populations, and combined with his interest in digital technology and the future of healthcare, has made Subash a natural leader for the partnership. His scientific background, industry experience, and expertise in digital agility by design have broadened his perspective and allowed him to work directly on many aspects that bridge the future of healthcare. Subash's innovative actions in the industry have continued during his leadership role at Novartis, where he leads strategic digital alliances and launches digital therapeutics for the future of healthcare. His experiences are inherently tied to the events during this unprecedented pandemic. His network expands to many collaborators in both precision medicine and digital technologies.

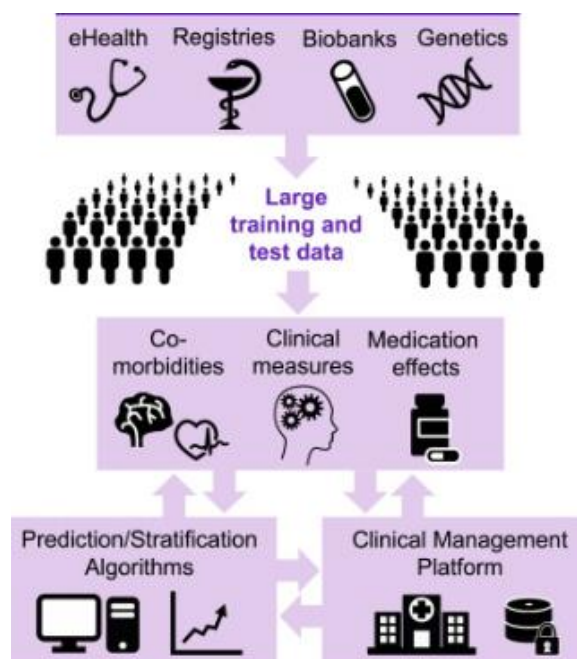


Fig 4 : Real-World Data Can Facilitate the Development of Precision Medicine Treatment

4.2. Innovative Solutions and Projects

Prof. Subash's research focuses on developing scalable precision medicine solutions to address existing healthcare delivery challenges, as well as designing software infrastructures with digital agility to help organizations adapt to uncertainties in diagnosis and treatment analysis. This innovation has occurred across a series of various projects conducted within the UK, each of which targets a specific aspect of the delivery of healthcare solutions. In precision medicine, Prof. Subash is developing novel pathways to engage with patients through technologies such as wearables and mobile technologies to gather information about the patient and the disease that is not currently captured in healthcare settings. While wearables may enable new patient-clinician interaction, it is essential that we can anchor questionnaires and engagement tools that are easy for patients to use, not offered in the existing model of care, to the clinical picture of the patient to understand the potential added value of using these technologies in clinics. Developing analytic methods that capture the rich information provided within the digital questionnaires through natural language processing that can inform clinical decision-making is the next necessary step. Furthermore, further health economic work, given the evolving digital approach to these analyses and how this has changed the researcher-patient relationship, would be beneficial. In the current approaches, methods are developed for small use-case scenarios. However, this can be expanded to other long-term conditions where clinical expertise exists. Finally, digital engagement is not limited to patients; we engage with training and educational organizations to understand and capture the perspective of the next generation of clinical and translational researchers, and this method described is a way to capture a continual outcome of the current project. In summary, developing a digital quantitative and qualitative snapshot or registry of information used in a clinical setting across a chronic autoimmune condition. Subash's work in digital agility integrates triage and signposting

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resources with the digital agility of care staff facilitation embedded in an online learning, implementation, and evaluation framework. To staff, it's an AI surveillance tool that influences appointments in the clinic. The public called it "a one-stop website" where they get a specialist assessment, diagnostics, and recommendations. They are linked with selected hospitals of choice, somewhere they can travel and have a clinician behind the scenes with a care navigator to ask questions and get signposting to support them if they become mentally unwell. Both come because the public does not understand the modern jargon used: triage, signposting, and civtech. Triage alone is not enough; it guides appointments into the right specialist clinics, influences, and identifies subgroups, and is more efficient in the system of care alone to reduce demand for their services. In summary, the work is an integrated scalable model designed from a user-centered approach that provides a digitally agile pathway, including triage-guided signposting to appropriate care for those with mental health difficulties and long COVID.

5. Case Studies and Industry Impact

Developing solutions in precision medicine that deliver innovative principles, improved care, and demonstrable results. 5.2 Designing a system that can solve previously intractable 'knowable' and 'unknowable' challenges associated with understanding a patient's disease. 5.3 Shifting health delivery from planned work that's predictable and standardized to problem-solving or co-design work that's agile and 'just in time and just for me.' 5.4 Supporting hospital managers and executives to work through complex challenges, which have organizational or socio technical underpinnings. The following case studies describe the industry impact of work in precision medicine and digital agility. They provide a snapshot of the initiatives undertaken, from conditions to which a design thinking perspective was applied and what was looked to achieve through these projects, to the concrete outcomes that work with practitioners and patients has achieved. Health is an ecosystem-level phenomenon, and most health challenges are wicked and require interdisciplinary research and policies. Policy reforms to health systems would be better based on the real reflections of the challenges patients face, and best done in a way that also reflects the opportunity costs and messages for potential future directions. By considering one case from each of precision medicine and digital agility in detail, you will see how a solution to these complex problems looks. Both of these were small steps towards scale, and the case studies reflect the real-life settings of care and the practitioners and people for whom care is delivered. These have the rings of advantages and strengths of scale, and the lessons learned in doing this work are also learned for ways in which we need to move ahead.

5.1. Specific Examples of Subash's Work

Five years later, at the European innovators' summit in Copenhagen, Subash presented proof of concept and some of the early work in refining these methodologies as part of the European program of work. The key objective of these initiatives, to lead to step-change improvements in care for the individual patient or person, is reflected in Subhash's prime area of work at Imperial College Healthcare NHS Trust in London, which is now the main outcome focus of his chief digital and health informatics office. The purpose of this activity is to make improvements in the efficiency and safety of care using clinical qualitative processes that can

be codified. Subash presented early details of this work at a summit in February 2022.

Example initiatives include a pioneering clinical improvement in care and support of people diagnosed with dementia using innovative quality improvement approaches that are now a clinical algorithm and are being used in the trust's dementia program. Subash is using the same (or similar) methodologies to develop new ways of identifying and caring for frail older people, people with idiopathic pulmonary fibrosis, prostate cancer, low back pain, diabetes, respiratory illness, stroke, and patients requiring care across emergency and elective surgery pathways. In 2023, the concept of patient precision pathways will be published, featuring clinical systems-thinking lessons that have been commoditized from these works. Similarly, developing clinical algorithms from sub-phenotypes within many diseases, which not only impact care for the individual patient but also reduce hospital burden and increase operational and clinical patient outcomes, is again part of the mission. Of course, solutions and challenges in the UK are very similar to European challenges, and so the purpose and future work we are considering is for scalability.

5.2. Broader Implications for the Healthcare Industry

Subash Concludes: Solutions to Challenges Provide Benchmark for Precision Medicine and Digital Agility

The innovations in genomics, biomarker-based clinical trials, and simulations, as well as in digital technologies now being pursued by job broker Subash, have broader implications for the healthcare industry. Success in both areas would show that it is possible, end to end, to increase digital agility, tailor therapies, and involve patients. Care facilities could then more easily and regularly execute these activities repeatedly and routinely. Institutions with different patient populations, disease foci, and digital infrastructure could then begin to execute adaptive clinical trials and affordably access and use similar scalable virtual trials.

City and county regulations and sovereign countries could then utilize successful approaches to adaptive trials as regulatory foundations to support digital biomarkers and new evidence approaches. Partners and other collaborators are watching Subash's work carefully to assess their capacity and potential for development and, in 2022 and beyond, could become joint venturers, licensees, and custom negotiators or seek other contractual solutions as Subash's appraiser-brokers transition from Phase 1 experts to become Phase 2 managers and eventual subject-matter consultants, joining other managers and consultants who have already begun learning from early projects, customers, and users across varying settings. Subash's leaders see these implications as part of a rapidly changing "not only industry but world" in which "we've just reached the tip of the iceberg into precision, into personalized and individualized therapies." Major follow-on trends will include "predictive health and screening for patients at risk of disease; and then integrating social determinants of health... digitizing and integrating all of that into one platform to give... better health for all...."

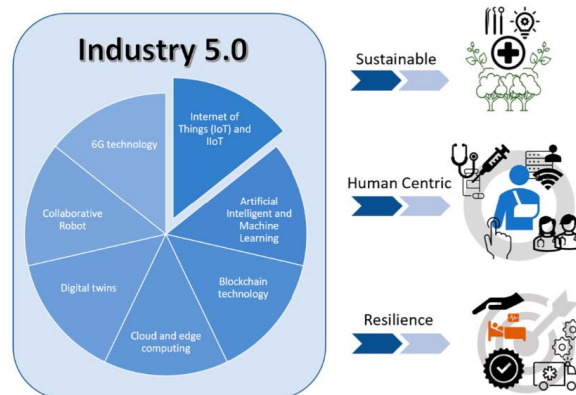


Fig 5 : Digital Health Training and Education

6. Challenges and Future Directions

Perhaps one of the most critical barriers to overcome is obtaining regulatory approval for devices, AI algorithms, and outcome measures. Future work should be dedicated to instilling confidence in a consistently evolving executable product with regulators. Furthermore, concerns over data privacy, standardization, and resource limitations were seen as critical barriers. Increased dialogue between stakeholders may help to navigate these intersecting concerns between crowding out innovation and thwarting ethical health tech. Additionally, adaptation to different contexts, such as national healthcare systems, legal systems, business, and pharmaceutical interests, is essential. Soliciting advice globally may be fruitful. Finally, funding, resourcing, and economic considerations, as always, pose substantial challenges that should be addressed.

Notwithstanding these critical considerations, two broad and interconnected opportunities were also identified. Efforts are required to develop methodologies to determine and compare the potential impact of precision medicine and digital agility on individual and public health. Scenarios and case studies can also be used to model a forthcoming future and to begin the concept of operations and common IT platform development. Further, the pandemic has revealed the need for these solutions and to consider non-communicable as well as communicable diseases. One future direction in these studies is in applications of these across maturing, and the focus in the discussion was a subset of these satellite initiatives. More insight may emerge from exploration elsewhere. At this stage, we do not profess to have the answers but welcome the insights from these studies. The goal is ambitious, and the potential for future forms of medicine is equally extensive. Our strategy sets a clear goal to grow capability and capacity in therapeutic development befitting the era of the fourth industrial revolution. This report provides one part of this picture and outlines an important and evolving space.

6.1. Barriers to Implementation

Despite the promise of precision medicine, several challenges limit its widespread implementation. The complexity of regulatory approval, even for companion diagnostics, is a significant barrier. The need to secure funding necessitates institutions to direct limited

resources to applications most likely to lead to significant patient benefit. Similarly, the implementation of a digital strategy within an organization is not without its challenges. The process of adopting digital transformation in an organization that is not prepared for it can be met with resistance from long-standing members of the organization. Environmental obstacles, like a dearth of infrastructure, can further limit its potential benefits.

Data protection and privacy standards are additional regulatory challenges in data-driven healthcare. Baseline privacy and data sharing guardrails are critical to gaining patient trust. Current security measures in the form of online consent without de-identification of data are not adequate. Technological advancements in cybersecurity are imperative for advancing data-driven health approaches. Challenges exist when it comes to protecting patient privacy, clinical trial data, and healthcare provider proprietary data, which are potential competitive differentiators. Current digital strategies for healthcare are often intuitive and focused on relatively simple operations such as scheduling appointments. A potentially large consumer base distances itself from receiving adequate care out of privacy concerns.

The vast number of available resources makes coordinating efforts more complicated. The healthcare system consists of independent silos, without seamless communication, which complicates the delivery of care to patients. Unstructured or proprietary data can be difficult for different organizations to combine meaningfully. Different coding languages and formats across organizations can further compound this difficulty. In both precision medicine and digital health, stakeholders of all types – patients, doctors, hospitals, clinical labs, regulators, and payers – are all necessary to make these solutions meaningful. Recognizing a need for collaboration is often more complex than recognizing the solution, but the involvement of all stakeholders will lead to effective and scalable results.

6.2. Opportunities for Further Innovation

Emerging trends and technologies will support and accelerate a large, new stage in innovation and investment in healthcare as we move towards an era of digital agility that is adjunct to the story we told in the first part on precision medicine. The scope of these now lies between three types of activity: caretakers of or containers of data; those eager to embed expertise into artificial intelligence and process the data or deliver digital healthcare; and builders of tools for medics or those engaged with patients directly. Included under this lens are already many of the world-leading clinical machine learning companies based in the UK.

Interdisciplinary work has shown that there remain many further avenues that could be explored to use digital technologies to solve, manage, and alleviate healthcare problems in further ways. Prompt other researchers and those working in industry in data science and predictive technologies to think of what new things they could be doing that they are not yet attempting. Being too precise about emerging therapy areas excluded by this literature is the wrong instinct: as new ways are shown of offering smaller-package targeted support to different populations, more researchers must think about serving these newly different patient markets. Ensuring an emphasis on mutability—the recognition of the need to be able to stop failing lines of research and try new avenues of treatment or digital deployment—will also be a key differentiator for successful innovative companies as firms offering one treatment for all sufferers decline in the market. The resources on such actively manageable, often chronic or treatable illnesses must also include a welcome to explore actual products and firms. They are

designed for individuals to live with, and research must accordingly explore the continuation of health and well-being, rather than cure and cure research alone.

Almost all digital healthcare systems have risen from the UK as a result of our national digital health initiatives aimed at ensuring that socialized healthcare was encouraged by investment in research to re-innovate healthcare delivery using information technology. Many of the systems were and remain highly innovative and provide early examples of digitally enabled new healthcare systems. Many continue to grow and are part of spin-out businesses or directly translated from academia into healthcare delivery. Previously, digital agility was associated with organizations' readiness for change as a result of new systems, processes, or innovation. Its focus is on mediating an organization's ability to adapt and portable training new systems; its conception in healthcare is more: can you learn quickly to deliver new solutions to patients? Digital agility conjures a pioneer spirit, innovation, curiosity, and a readiness to change. If individual healthcare professionals in the NHS and academia can adopt this attitude in dealing with the unknown on the path to improved care by rapidly iterating and learning from data products and trials, then future healthcare solutions can indeed scale and provide exceptional power to patients. In that sense, it is also a disruptive idea that any one person or organization could deliver the solution and willfully welcome others to change the way they are used to working.

Equation 3: Transforming Healthcare Challenges into Scalable Solutions:

Where:

S = Scalable healthcare solution

C = Cloud computing infrastructure

D = Big data from diverse healthcare sources

I = Industry-specific insights and business intelligence

A = AI tools for decision-making and automation

$$S = h(C, D, I, A)$$

7. Conclusion

Although traditionally discussed separately, the analytical essay has manually connected precision medicine and digital agility through academic and industry contributions. In a healthcare environment characterized by personalized approaches to disease interception, diagnosis, and prognosis, we have proposed that digital agility plays a key role in the transformation of specialized clinical initiatives into scalable solutions for broad adoption. A variety of challenges remain open for digital solution development, most relating to patient data variability, siloed clinical translation efforts, the need for multimodal insights, and dynamic patient trajectories. Key roles have been played, on both academic research and industry fronts, in melding these traditionally separated domains, combining them into one high-impact area for several future manifestations.

Given this synthesis of themes and the catalyzing nature of this work, there remain several challenging yet productive lines of investigation. The future development of this digital agility and clinical precision medicine interface can rightfully focus on more complex clinical decision scenarios, necessitating tighter integration of evidence from different areas, beyond

medical image analysis. Furthermore, a natural extension of this work lies in longitudinal clinical decision support systems that detect and anticipate the evolution of a patient and recommend or adapt therapies for the changing context of individual patients. The transformability of clinical challenges into digital research areas is limitless and provides exciting opportunities to push the frontiers of effecting clinical change and patient outcomes. In conclusion, dedicated interdisciplinary groups for the improvement of digitized descriptive research and healthcare, which actively engage all layers of the healthcare system, will likely continue to transform the existing landscape of clinical service agility. This will enable precision medicine-based solutions to be made available routinely rather than as stand-alone options to a select population of focus or utility.

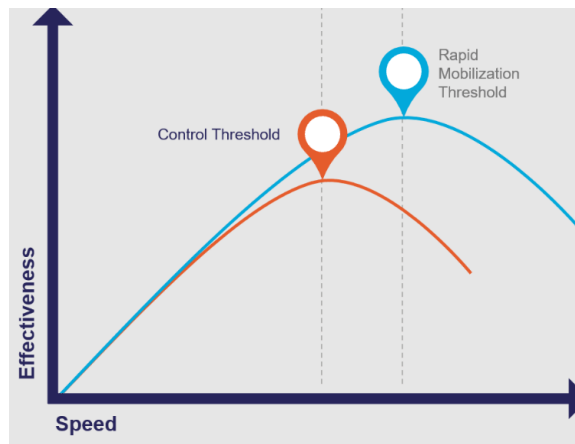


Fig 6 : Engineering Agility

7.1. Summary of Key Findings

Our analysis shows iteratively how precision medicine and digital agility are inextricably interdependent pillars for the evolution of more sophisticated patient care. The lack of agility hinders Medicine's potential benefits from omic and other insights. The scale at which our analysis places them and which they aspire to is the beginning of the true meaning of impact in commercial health. Increasing the effect of these efforts has been a hallmark of discussions and analysis. Symbolically, what advanced mandates in precision medicine and digital agility have changed, given the continuation of the changes in technology, regulation, clinical practices, and infrastructure.

As we make efforts to facilitate the next five to twenty years, we are witnessing an approach to engage in another set of complex challenges, grounded in years of commitment and rigorous innovation. The product commercialized is rooted in achievements and hubs in precision medicine. And, its investment in people and computation offers scalable solutions for being on the digital edge, solving healthcare's myriad of problems on the horizon in a shifting and emerging healthcare environment. Everyone has a unique edge that could be invested in through specific drugs, technologies, or digital solutions taking the general advances to predict, make, treat, and manage healthcare more effectively. The goals should generally guide what you're planning to invest and when, staying agile with the landscape. Patient care needs are scalable and not fixed on a broad or individual level. Thus, business plans, resources,

training, or education should all be scalable solutions, dynamically shifting patient care.

7.2. Implications for Future Research and Practice

This essay revisits the experts' accounts about ongoing research practices to co-define precision medicine approaches to be distributed within mainstream healthcare in Finland. The data is clear about the challenges in the emerging healthcare environment and new ergonomics of practice. Articulated with the configurational work of a resituated research agenda, it offers potentially high-impact academic outputs. The expected contributions are in the area of institutional theory, health service management, innovation studies, organizational change, and practice-based studies, offering empirically driven tools for managing large-scale change and impacting the design of additional large-scale healthcare studies. The implications are also significant for new research methodologies based on pragmatist and pragmatic philosophy.

This evidence suggests that a partnership and shared research agenda with a group that looks at broader trends in research and development, including emerging techniques and diagnostics, could be of value. If a priority for complex health systems is to develop resilient responses to profound technical and ergonomic challenges, rather than narrow, specific solutions, then that is an ethics-based stance, a policy aim. There is an urgent and evidence-based need for innovative and agile models of practice. Lastly, there is a further need for work that takes into account methods and data that can acquire and use this kind of evolving evidence and interdisciplinary partnerships.

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