

Editorial

# Advancements in Medical Imaging and Image-Guided Procedures: A Potential—Or Rather Likely—Paradigm Shift in Diagnosis and Therapy: Understand Disruption and Take Advantage of It!

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## 1. Introduction

What were our product development goals in medical imaging and image-guided therapies in recent decades?

Easy answer: Our technological developments and their integration in medical devices, tools, and workflows were based on real and validated clinical needs in combination with their subsequent continuous improvements.

MRI (Magnetic Resonance Imaging) systems—as an example—have been employed for 40 years now and since then have become significantly less time-consuming, more “intelligent”, easier to install, and are the standard system for the diagnosis of many diseases. They are still, however, complex, very expensive, and not available in many places.

So did this approach to innovation lead to the development towards a new healthcare vision, and did it solve any major health-related challenges (unequal access, demographic changes, move towards prevention, increasing cost, sustainability, and others)?

Answer here: Not really! But to a certain extent, it is also understandable, as no real business model and incentives exist for such a move.

This is because clinical needs in the current healthcare system and delivery model are almost exclusively based on the concept and task of diagnosing a sick or injured individual and determining whether subsequent follow-up therapies and recovery processes need to be performed [1].

This, of course, will remain a major part of what we expect from “sickcare” in the future, with the

**Incremental Future Development Goal:** To improve the current quality of traditional clinical approaches and the clinician experience as well as that of the patient through more intelligent and precise imaging capabilities for diagnostic and image-guided therapies!

### *Reverse and Frugal Innovation*

From an innovator’s and also an entrepreneurial perspective, and looking at the aforementioned global challenges and sustainable development goals, we should, however, also “develop something that provides adequate quality for 90% of the cases at a price point of 10% of the current approach”.



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For example, to stick with the above example, can you develop a MRI that would provide satisfactory images and diagnostic evaluations for 90% of the cases at a cost of USD 100k or 50k instead of USD 750k-1Mio?

This is something we call “Frugal Innovation”, and it could lead to some disruption i.e., replacing an existing technology and approach, which is always coupled with a novel business model) in a particular area/segment. “Frugal” products are not only significantly cheaper, but they are also typically much more sustainable; in our MRI example case, the equipment was made of non-superconductive materials and more portable, employed less material, consumed less power, and allowed for more democratic access.

“Frugal Innovations” are often developed or introduced out of local needs. Developing dedicated products for such a market would help to democratise the provision of healthcare services. However, it also comes with a drawback for the established companies: What if these systems were actually effective? This could then adversely affect high income nations, which we call “Reverse Innovation” [1].

Additionally, these low-cost products and services could also lead to “Health Democratisation”, creating a more equitable and inclusive healthcare system that empowers people to make informed decisions about their health, regardless of their background, income, or location. Some products that could be particularly helpful to achieve are health literacy programs, and health tools and devices that address local health issues through inexpensive digital devices (e.g., smartphone-based) and provide AI-powered medical advice based on sensory input.

Future health innovations must continue to improve traditional medicine, but they must also create new and exponentially advanced medicine.—This is also needed to decrease the gap between low income and high income nations. Advanced medicine is currently far from being globally available.

As innovators, we should be empathetic and create a Future Of Health that we desire, a so-called *new medicine*, a novel way of employing technology for Prevention, Prediction, and Precision/Personalisation for an empowered/engaged and Participating individual that will benefit from Prolonged health (the health span needs to equal the lifespan, which is extended)—the 5Ps of the Future of Health (see Figure 1).



**Figure 1.** 5P Future of Health - with Purpose for People and Planet (Copyright 2023 by Michael Friebe, licensed under Attribution-Non-Commercial-ShareAlike 4.0 International. To view a copy of the license, visit <http://creativecommons.org/licenses/by-nc-sa/4.0/>).

We must also occasionally dare to look into innovations and health delivery options that we want to see in the Future of Health!! This is especially valuable with the emergence and convergence of several exponentially developing technologies that will undoubtedly revolutionise many areas, including diagnostic imaging and image-guided therapies (IGT). With artificial intelligence, large language models, high-temperature superconductors,

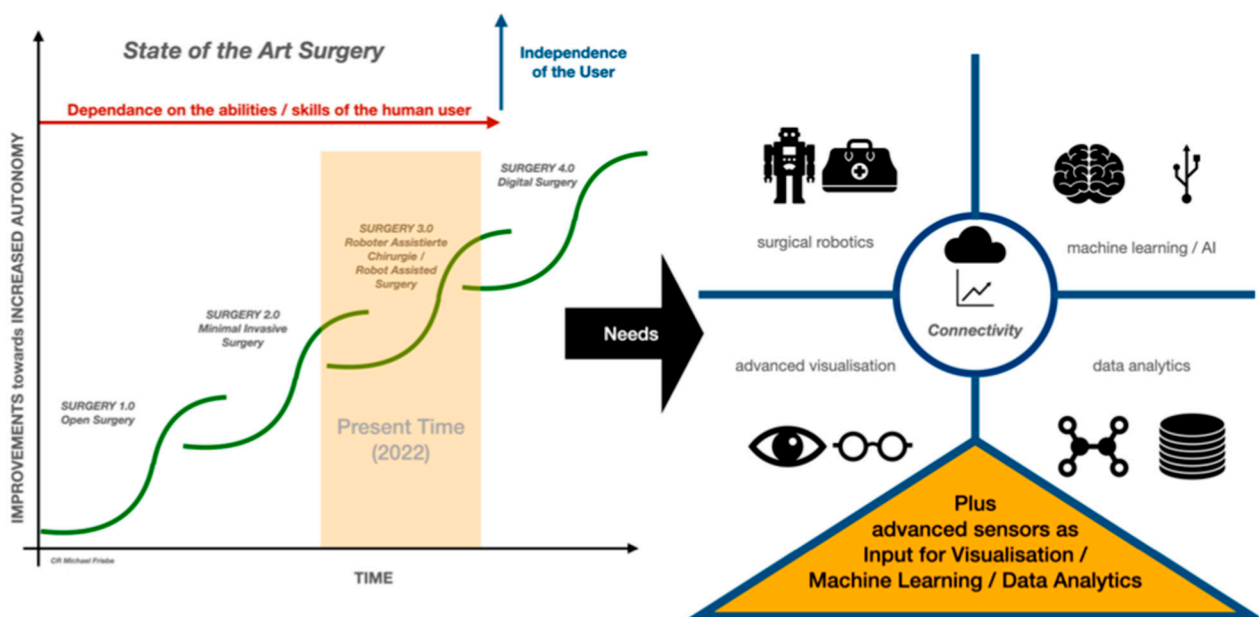
novel sensor approaches, autonomous robotics—to name just a few—we will experience much faster development cycles and diagnostic results than we can currently fathom [2–4].

Having said all this: The authors have no idea how the future, and everything it encompasses, will develop. The point is to keep an open mindset and try to avoid linear thinking, which will likely no longer be effective.

“Any sufficiently advanced technology is indistinguishable from magic”, the third law of Sir Arthur Clarke (futurist, author, and inventor) from 1973, fits quite well in this context!

Diagnostic imaging has revolutionised healthcare by providing valuable insights into diagnosing diseases and guiding minimally invasive therapies. In recent years, the integration of advanced signal processing methods, sensor fusion, artificial intelligence (AI), deep learning, and big data approaches has resulted in significant improvements. These developments are reshaping the workflow and value of medical imaging, leading to potentially transformative impacts on diagnostic evaluation and therapy responses.

Figure 2 shows a vision of what might happen to minimally invasive and image-guided surgery with the integration of advanced sensors and visualisation, machine learning, and data analytics. The independence on the abilities and skills of the individual user will eventually be eliminated, solving a huge education and, subsequently, availability problem [5–8].



**Figure 2.** State-of-the-art (minimally invasive) surgery. Moving towards the next level—digital (minimally invasive) surgery—requires a combination of several exponential technologies and will eventually lead to a greater independence of the individual user’s capabilities. This, in return, will likely increase the number of systems being employed and reduce the associated costs.

## 2. Development Advice

As medical imaging and image-guided procedures continue to evolve, researchers and practitioners must collaborate to explore disruptive concepts in this domain. The development of more sophisticated and accurate image segmentation techniques, along with improved sensor fusion, will assist in the progression of innovative hybrid concepts that redefine the future of healthcare. Furthermore, exploring the integration of auxiliary signals and modalities promises to unlock new avenues for point-of-care approaches and minimally invasive therapies [9–15].

Current and future drivers should include the following:

- **Higher accuracy and precision**, as inaccuracies can lead to misdiagnoses or delayed diagnoses. Inaccurate or imprecise image-guided procedures and therapies can com-

promise patient safety and treatment effectiveness, necessitating enhancements to achieve the highest level of precision possible.

- **Early detection and treatment** that improve the chances of successful treatment and better patient outcomes. Timely detection is especially critical for conditions with high mortality rates, such as certain cancers and cardiovascular diseases.
- **Workflow efficiency improvements** can streamline time-consuming processes, such as image acquisition, analysis, and interpretation. These can be optimized with advanced algorithms and automation.
- **Accessibility and affordability of diagnostic imaging and image-guided procedures** remain significant concerns in many parts of the world. Significantly reducing the cost of these is essential for their deployment in resource-limited settings. In other words, **10x not 10%**—how do we reduce the cost by a factor of 10 rather than incrementally by 10%.
- **Further enhancements in point-of-care imaging** can bring medical imaging to remote areas and underserved communities, ensuring equitable healthcare distribution—**10x not 10%**.
- **Integration of multimodal data**, embracing the concept of personalised medicine, which requires the integration of multiple data sources for comprehensive patient assessments. Enhancing diagnostic imaging and image-guided procedures to incorporate multimodal data, such as genomics, proteomics, and patient history, can empower healthcare providers to make more informed decisions, leading to personalised treatment plans and improved patient outcomes.
- **Eliminate or reduce the limitations of current imaging modalities** by adding sensors, AI, or other modalities (e.g., audio or light) [16,17].
- **Advancements in image-guided therapeutic techniques**, like targeted drug delivery, focused ultrasound, and gene therapy, to unlock the full potential of these cutting-edge treatments, bringing about transformative changes in patient care.

However, what we also need are processes, products, and initiatives that

1. Lower the cost and increase affordability . . . and not just by 10%, but >90% (**10x not 10%**);
2. Deal with the increase in human longevity, which comes with huge innovation requirements and simultaneously provide huge opportunities.
3. Develop tools and devices/services that assist in the shift from expensive care to lower-cost care (e.g., from “acute care hospital” to “acute medical center”, from “acute medical center” to “homecare”, or from “homecare” to “it does not even happen because it was prevented”).
4. Help to redefine the role of governments with respect to health, its economics, and benefits for the people’s needs and demands (which leads again to prevention—nobody wishes to become sick).
5. Help to reincentivise and rework (or even disrupt) the current healthcare business model.
6. Develop tools and devices that will empower and enable every individual to take care of their own health through the availability of health data and provide them with the ability to use that data as they wish.
7. Provide tools and devices for a novel medical education system that must follow and integrate critical thinking, health system science, health wellness, disease prevention, and highly relevant innovation and entrepreneurship skills in the future.
8. Ensure that they help provide/ensure equal health access as well as your development. This should be a global goal for health innovators.

### 3. Conclusions

Future development in diagnostic imaging and IGT will continue to follow the approach of continuous improvements and benefit from advancements in sensor developments, data fusion, and machine learning.

An uncommented and unedited large language program query (OpenAI—ChatGPT 3.5) on the future of diagnostic imaging and IGT is presented here as well (see Table 1) that also highlights the need for frugal innovations.

**Table 1.** Large language program query on the future of diagnostic imaging and IGT (OpenAI, ChatGPT 3.5).

| <i>ChatGPT on “Future of Diagnostic Imaging”</i>   | <i>Chat GPT on “Future of Image Guided Medical Procedures”</i>  |
|--|---|
| <i>The future of diagnostic imaging is promising, as it continues to evolve with cutting-edge technologies and innovations. Advancements in medical imaging modalities, such as AI, deep learning, and sensor fusion, will enhance image quality, accuracy, and efficiency in diagnoses. Multimodal imaging and real-time image-guided procedures will enable more personalized and precise patient care. Furthermore, the integration of frugal innovation will drive the development of cost-effective and accessible imaging solutions, expanding diagnostic capabilities to underserved areas. As research and technology progress, the future of diagnostic imaging holds the potential to revolutionize healthcare, improving early detection, treatment planning, and overall patient outcomes.</i> | <i>The future of image-guided medical procedures is driven by the integration of cutting-edge technologies. Innovations in medical imaging modalities, such as advanced signal processing, sensor fusion, AI, and deep learning, will enhance accuracy and precision in diagnoses. Multimodal image fusion, combined with real-time guidance, will enable more effective and minimally invasive therapies, revolutionizing patient care. Frugal innovations will promote cost-effective and accessible imaging solutions, extending medical imaging to remote and underserved areas. As research and collaboration continue, the future holds the promise of personalized, efficient, and transformative image-guided medical procedures for improved patient outcomes.</i> |

Further significant cost reduction and quality improvements in advanced imaging modalities (e.g., USD 50k for MRI); point-of-care diagnostics (e.g., 3D handheld ultrasound for USD 2k); novel diagnostic systems combining light and audio; and hybrid combinations of several modalities for lightweight, portable, intelligent, connected, and dedicated systems might develop novel business models, disrupting the existing markets and product offerings. Technologies will develop extremely rapidly and lead to surprising results.

Plan now for the future and for possible disruptions by assuming certain technological improvements and increased availabilities due to cost reductions, even if there is no current business model available or in sight yet.

It is important, however, for innovators to also adopt a novel exponential mindset and to rethink the development value propositions for future-oriented products and devices.

We are on the verge of partly disrupting the current fee-for-service and sickcare model of health provision, and therefore also need a development mindset with a [1–3]

*disruptive development goal for diagnostic imaging and IGT that attempts to anticipate the future of healthcare delivery, that combines it with the transformations of exponential technologies, and that has the objective of creating novel and advanced medicine for all!*

In conclusion, this Special Issue, “Latest Trends and Disruptions for Diagnostic Imaging and Image-Guided Procedures and Therapies”, marks a crucial moment for medical imaging and image-guided treatments. The studies gathered here highlight the dedication of researchers, doctors, and creators to push beyond the usual methods. By embracing new ways of thinking and making healthcare accessible to all, these findings enable a fresh approach to medical care. With a focus on accuracy, ease of access, and using varying types of information, these works aim to create better, personalised healthcare. This Special Issue is a sign of how scientists are working together to ensure a future in which improved health is possible for everyone.

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