

# Towards Individualised Medicine through Medical Technology

acatech (Ed.)



In response to the new challenges facing modern medicine, Individualised Medicine has once more come to the fore as a healthcare strategy in recent years. Individualised Medicine is based on the realisation that patients' medical conditions are significantly affected by their individual biological characteristics as well as the influence of their individual lifestyle and environment. These factors affect the likelihood of a patient to develop a particular disease, the disease's progression and the patient's response to currently available treatment options. The goal of Individualised Medicine is to identify the relevant factors influencing the individual disease of each individual patient through precise diagnostics in order to enable selection and delivery of highly effective preventive therapies with minimal side effects. In this context, stratified and tailored medicine can act as effective strategies for implementing Individualised Medicine in a healthcare setting. Precision medicine in particular is one of the key tools that modern medicine can use to deliver the Individualised Medicine vision.

In addition to the widely discussed opportunities, challenges and consequences of a molecular genetic and pharmacological approach to Individualised Medicine, numerous developments in medical products as well as system and process solutions attest to the contribution made by medical technology to various aspects of Individualised Medicine. It is critical to deliver strategies focused on needs, quality and benefits in order to ensure optimal patient care – the aim must be to maximise patient safety using the latest scientific, technological and medical advances.

In the past, the main types of medical technology and products included imaging systems, laboratory diagnostic equipment and laboratory technology, various types of diagnostic and therapeutic devices, implants and rehabilitation aids. Today, innovative cell and tissue technologies, telemedicine, e-health and software applications, information and communication services and health management products can all be added to this list.

There is nothing new about the basic concept of Individualised Medicine. Physicians have always used individual patient data and phenotypic disease factors to make differential diagnoses that enable therapeutic decisions to be tailored to the individual patient and disease. Nevertheless, recent advances in human genome research, pharmacology and medical technology mean that Individualised Medicine can now be practised far more precisely and comprehensively than ever before. The challenge is to provide adequate proof of the efficacy of individualised medical

## At a glance

- The concept of Individualised Medicine is becoming increasingly important in an ageing society where the growing demand for solutions to prevent and treat chronic or multiple diseases is accompanied by calls for a stronger focus on patients as individuals.
- Innovations in medical technology make an essential contribution in this context.
- Current priorities include diagnostic procedures for describing patients' individual biomedical characteristics, technology-based systems that enable more precise and less traumatic surgical procedures, and custom-made prostheses and implants.
- A number of ethical, regulatory and economic issues must be resolved so that medical technology can be used to enhance the healthcare provided to individual patients.
- Key challenges include the protection of patients' medical records, regulation of medical products and the intelligent use and pooling of research and patient data.
- It will also be necessary to establish the use of individualised medical products in the healthcare system and ensure their affordability.



products and procedures. On the one hand, better patient stratification allows Individualised Medicine to deliver the statistically supported proof of efficacy demanded by evidence-based medicine (EBM) through clinical trials with smaller, more homogeneous patient groups. On the other hand, the fact that Individualised Medicine uses customised treatment solutions for individual patients means that current proof of efficacy methods will need to be refined.

## The key medical technologies that are enabling Individualised Medicine

### Biomarker-based stratification using imaging techniques and in vitro diagnostics

In modern medicine, patients medical history as recorded during the consultation of their physician can be supplemented through a wide range of diagnostic techniques that employ innovative advances in medical technology to provide an ever more accurate picture of the individual biomedical characteristics of patients and their specific conditions.

Imaging plays a key role in every part of the chain of medical care. The data from ultrasound, CT, MRI and PET scans and increasingly also from optical imaging depicts biological processes in the individual through local biomarkers, helping to detect diseases in their early stages and monitor treatment progress and success. In fields such as radiation oncology, therapy and diagnosis are increasingly being combined under the “theranostics” approach. However, the huge range of diagnostic techniques available today can make it difficult to choose the right one, particularly in the context of Individualised Medicine. It is therefore essential to employ appropriate guidelines that weigh up the quality of the test results against patient comfort and financial cost.

Laboratory in vitro diagnostics (IVD) involves a systemic, pathogenesis-oriented approach based on measurements of the physical, (bio)chemical and genetic properties of samples taken from the human body. It complements the patient information obtained through imaging techniques, enabling precise and comprehensive individualised diagnostics. This in turn provides a basis for the prevention, prognosis and treatment planning and monitoring of both lifestyle diseases such as cancer, atherosclerosis and diabetes, and of infectious diseases. Efficient laboratory diagnostics are facilitated through the centralisation of laboratory services. In contrast to the increased centralisation and efficiency provided by industrial laboratories, there is also a trend

towards decentralised laboratory diagnostics (point-of-care testing) carried out directly at the patient's bedside, in the operating theatre, in the ambulance or at the scene of accident. The unique advantage of this approach is that the results are immediately available on the spot. This not only saves time but also means that the test results can be used to make quick decisions about further diagnostic and therapeutic measures.

Companion diagnostics is a cutting-edge area in point-of-care testing. Companion diagnostics refers to biomarker-based diagnostic tests for determining a therapy's suitability for a particular person, but is also used increasingly in direct patient self-testing, for example of glucose levels in diabetes patients. This completely changes the way how informed patients see themselves, resulting in improved compliance and measurable positive effects on individual disease progression. However, the controversy surrounding direct-to-consumer tests has highlighted the risks associated with self-testing and made it clear that this innovative form of diagnostic testing as a means of therapeutic support is only medically justified if patients are informed about the details, in the simplest scenario by their physician.

### Enhanced precision through image-guided and computer- and robot-assisted systems

Demographic change has led to a growing number of elderly, multimorbid patients. This has resulted in an increased demand for surgical procedures that are as precise and non-traumatic as possible in order to improve quality of treatment, quality of life and to reduce complications as well as the duration of hospital stays. The use of innovative medical technology products and procedures to enable more precise surgical interventions is essential for the concept of Individualised Medicine.

Surgery directly guided by (real-time) imaging using semi-autonomous computer-assisted navigation systems is of particular importance in this context. In addition, preoperative imaging can be employed to produce individual patient models that not only enable an improved treatment planning and allow therapeutic outcomes to be predicted more accurately, but also make it possible to train the planned surgical procedure. The use of medical technology products for these purposes is particularly widespread in the fields of neurosurgery, cardiovascular and oncological surgery and image-guided biopsies. In radiotherapy, individualised treatment means that tumours can now be treated with far greater precision and fewer side effects.

The challenge for Individualised Medicine is to make the most modern and effective therapeutic technology available to all



patients, but to ensure that the benefits of this technology have been properly assessed beforehand. Because these technologies are constantly and rapidly evolving, it is often not possible to collect the required long-term efficacy data.

### **The development of custom-made prostheses and implants**

The huge range of available medical prostheses and implants demonstrates the fact that therapeutic medical technology solutions are successfully used to replace or provide anatomical and functional support for pathologically altered organs and organ systems. In this high-tech medical field, many optimisation strategies are based on the concept of personalisation.

Numerous examples of customised medicine are provided by passive implants based on precise 3D anatomical and functional imaging. The benefits of customisation can be seen in the individual contouring and surface functionalisation of cardiovascular stents and orthopaedic as well as dental implants to match the patient's anatomy.

Unlike passive implants, active implants are equipped with their own energy source. Precise, multimodal functional diagnostics are particularly valuable in helping to decide on the optimal cardiac, audiological or neurological implants for patients. The chosen solution is based on the patient's individual needs, with individual programming of a range of parameters for therapeutic purposes and telemedical monitoring. In addition, innovative biosensor technology makes it possible to measure a wide range of biomarkers for functional diagnostics and post-operative monitoring of tissue vitality and to take individual preventive measures based on the results.

At present, the majority of these active implants perform either a diagnostic or a pre-programmed therapeutic function. Theranostic implants that combine diagnostics and therapy in a single system will be the next step in active implants. In theranostic implants, individualised therapeutic measures are taken within a closed loop system when sensors detect pathological changes in the body.

Many purely technological implants have already become the standard of care for supporting or replacing anatomically or physiologically impaired organs. However, these implant systems are frequently still unable to guarantee sufficient individual biocompatibility to last a patient's lifetime. This can cause serious clinical complications that entail high risks for patients and represent a significant financial burden for the healthcare system. In

order to address these problems, a huge amount of effort is currently going into the development of biohybrid implants that combine excellent patient tolerance thanks to the use of biological materials with the mechanical stability and functionality of technological implants. In particular, the use of autologous cells taken from the patients themselves makes it possible to produce individually customised implants such as decellularised heart valves and tissue for skin replacement or the functionalisation of technological aids and implants. There are many ways in which these advances can contribute to the interdisciplinary research field of regenerative medicine, not least through the use of biotechnological cell-based therapy methods and tissue engineering. The interest in the development of biohybrid implants is indicative both of the technology's huge innovative potential and the high clinical demand for this type of solution. The timely deployment of individually customised implants promises to reduce the number of hospital stays, maximise patient mobility and thus maintain quality of life.

### **Integrated and intelligent use of research and patient data**

Digitalisation will be an increasingly important feature of the future of medicine as a whole. All measurement values and laboratory data, images, medical histories, diagnoses and previous treatments will be available as digital data sets. If these data sets are to be used to provide and optimise healthcare focused on patients' individual needs, it will be necessary to pool the data even if it comes from very different sources. It will also be important to make sure that the data is universally and directly accessible to anyone with the relevant access authorisation wherever it can be of benefit to patients. Finally, it will be crucial to ensure optimal data analysis so that the data can benefit both current patients and future patients with similar conditions.

It will be possible to meet many future requirements of medical information systems without using special big data processing techniques. The issues that still need to be addressed include potential interfaces, data access permissions, data privacy, regulatory matters and refinancing. Nevertheless, it is already becoming clear today that there are some fields such as oncology where big data techniques can be used to generate knowledge that allows patients to benefit from individualised treatments.

In the future, the medical data obtained in a clinical setting using certified medical equipment will increasingly be supplemented by information acquired through point-of-care testing, self-testing and healthcare apps. At the same time, the groups of people who use medical data will become much more



diverse. On the one hand, there will be healthy people who are interested in or enjoy finding out about their own medical data. There will also be people who think they might be ill and need help to decide whether they should go to the physician. Finally, there will be a third group of people who really are ill and who expect professional treatment supported by approved medical technology systems.

Telemedicine solutions employing wearable or implantable sensors are increasingly being used to monitor patients' condition for both preventive and therapeutic purposes. In addition to the patient's biological characteristics, telemedicine also incorporates their individual lifestyle into their care regime. This makes it a particularly suitable tool for supporting and delivering Individualised Medicine as a key component of patient-centred care. Unfortunately, the integration of telemedicine systems into healthcare provision has not progressed at the same rate as their technical performance. Despite the positive experiences in various pilot projects, far more reservations have been expressed about payment, liability and data security than about the systems' technical capabilities. In actual fact, however, the interfaces are well-defined, there is an adequate level of network security and effective data protection methods are available. It is therefore necessary to find ways of promoting higher acceptance of telemedicine in the medical profession and the underlying payment structures.

In the light of this debate, there is a need to assess the importance of medical information systems and telemedicine to Individualised Medicine. We need to ask which developments should be promoted in order to maximise the benefits for individual patients.

## General requirements for delivering Individualised Medicine through medical technology

### Address the wide range of ethical issues

Analysing the ethical issues associated with the use of medical technology to deliver Individualised Medicine presents a significant challenge in several respects. In addition to the concept itself, the challenge first and foremost relates to the high diversity of applications for the technology and the correspondingly wide range of issues requiring medical ethical assessment. Moreover, since many areas of application are still in their infancy it is difficult to predict how they will develop. This means that the assessment of potential scenarios is purely hypothetical. Consequently,

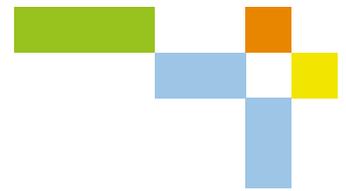
the further away a technology is from implementation, the likelier it is that significant ethical problems will be identified, making a reassessment necessary once it has actually reached the early stages of implementation. It is clear that the potential to abuse some of the latest developments in Individualised Medicine – rather than using them to benefit patients – does exist for those with the inclination to do so. As a result, there is a danger that new technologies could be assessed as ethically unacceptable simply because they have the potential to be abused or manipulated. All of this goes to show that a given ethical evaluation will ultimately depend on the medical technology in question and its current stage of development. Nevertheless, there are several individual, social and medical ethical issues that urgently need to be resolved prior to the widespread implementation of Individualised Medicine. In particular, these include matters relating to data privacy, big data, informational self-determination, individual responsibility, fair access, ensuring a patient-centred approach and the potential for patients to be (de)stigmatised through Individualised Medicine.

### Medical data protection

Individualised Medicine has a growing requirement for various kinds of comprehensive medical data and parameters in order to permit patient stratification. In this context, medical technology has an important role with regard to medical data protection. As well as the diagnostic procedures that generate patient data in the first place, medical information technology for processing and analysing data is also key to Individualised Medicine. The same applies to individualised medical products such as prostheses and implants. The law governing medical products regulates their functional safety, but does not address the issue of data security. A further challenge for data security comes from the growing trend towards systems and technology engineering in the healthcare system. A case in point is the recently adopted E-Health Act which provides for the introduction of a nationwide telematics infrastructure that will allow different healthcare providers to connect with each other via patients' electronic health cards.

### Regulation of medical products

Increasingly, medical products approximate the tightly regulated drug approval mechanisms, leading to a process that is in some cases now far more complex, time-consuming and costly. This means that manufacturers of medical products will have to change their mode of operation, sometimes resulting in higher costs and financial exposure, especially for small and medium-sized enterprises. For research institutes whose R&D



findings contribute to technology transfer, it is becoming increasingly important to ensure that aspects relating to the conformity assessment of any potentially emerging medical product are incorporated into basic and applied research from an early stage. Particular challenges exist with regard to both custom-made medical products and combination products that blur the boundaries between medical products and drugs.

A lack of properly validated methods means that it is currently impossible to carry out an adequate **clinical benefit assessment** of the use of medical technology products and procedures to deliver Individualised Medicine. This makes it harder to meet the basic requirements for their introduction into clinical practice. It is therefore necessary to develop and validate appropriate methods such as clinical registers of medical products or patient models that predict the outcome of diagnostic and therapeutic procedures, as well as to define universally accepted clinical benefit assessment parameters and criteria. The fundamental problem caused by the long timeframes required for clinical assessments compared to the short innovation cycles of medical products is even more acute in the case of Individualised Medicine.

Safety, particularly of patients, is a prime consideration in the placing on the market of medical products and the regulation of the associated safety and performance standards. Nowhere is this more true than for individualised medical products incorporating different technological, biological or pharmaceutical components. Supporting R&D programmes through the targeted compilation and dissemination of regulatory information could play a valuable role in helping to get individualised medical technology onto the market.

### Reimbursement of individualised medical products

In order to persuade health insurance schemes to cover the reimbursement of individualised medical technology products and procedures so that they can be widely employed to deliver better healthcare, it will be necessary to establish their use throughout the healthcare system and ensure their affordability on the market. Since limited resources are a given, it will be up to healthcare policy to strike the right balance between different and in some cases conflicting individual interests and the public good. The big challenge facing the medical technology-based diagnostic and therapeutic techniques used in Individualised Medicine is to generate a sufficiently robust empirical evidence base to justify the widespread allocation of budgetary resources. In addition, the overall system governing the reimbursement of individualised medical products and procedures in Germany is both complex and lacking in transparency.

Furthermore, payment practices and other **financial aspects** are the subject of ongoing review. Overall, the complexity and unpredictability of the regulatory environment makes the development of medical products an extremely risky business for companies. Because of the risks, companies may choose not to pursue some ideas and concepts, thereby denying patients their potential benefits.

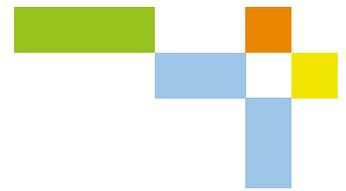
It is likely that individualised medical products will lead to higher overall costs at the system level. Demand will increase, since many patients for whom no or only limited treatment options were formerly available will now have the opportunity to receive (more) targeted and (more) effective therapies. Prices will also rise, since the treatments are often aimed at small patient groups – because R&D costs remain the same irrespective of patient numbers, the cost per patient will therefore be higher. Furthermore, Individualised Medicine will lead to major changes in human resources, structure, service delivery processes and organisation, how the cost of treatment is reimbursed and patient behaviour.

## Recommendations for government, industry, academia and the general public

The successful implementation of Individualised Medicine in a modern healthcare system will largely depend on the extent to which the developments described above are used to benefit patients. There are two levels at which the corresponding measures can be taken. Medical technology can:

- drive the research, development and evaluation of individualised medical products and their translation into clinical practice. It can also help to assess the patient benefits of these individualised medical products using methods that have been specially developed for this purpose; and
- help to deliver better quality and enhanced healthcare delivery structures through its focus on the individual. However, concomitant research into the structure of the healthcare system will be required in order to identify opportunities for this kind of general improvement.

Significant reform will be required at both levels for Individualised Medicine to become accepted healthcare practice and to enable the relevant statistical evidence to be collected and evaluated. In view of the numerous reservations that are emerging in the public debate on new technologies and their



potential risks, it will also be necessary to inform the general public and involve them in the development of and concomitant research into the healthcare system.

acatech has formulated the following recommendations to support this reform process:

### **Fundamental requirements for the implementation of Individualised Medicine**

1. Targeted development and implementation of digitalisation in medicine: This is a key requirement for the implementation of Individualised Medicine, especially for solutions that are strongly reliant on the combination of healthcare technology with information and communication technology. The establishment of a national database for the key funding priorities would enable efficient data exchange for research and treatment purposes, as well as better assessment of the benefits.
2. Systematic development and refinement of patient models, knowledge-based information systems and clinical decision support systems, together with their systematic testing and validation using specially developed guidelines for all medical disciplines.
3. Research into new materials and production techniques and concepts for making individualised medical products, especially custom-made technological or biological therapeutic implants.

### **Innovation process**

4. Promote translation by establishing partnerships between research, industry and clinical actors of the same standard of excellence. Regional translation centres can provide a suitable platform for delivering significant improvements in the utilisation of research findings to support Individualised Medicine in the field of medical technology, accelerating adoption of the relevant products within the healthcare system and harnessing their commercial potential.

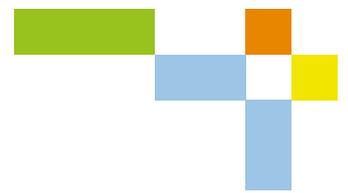
5. Establishment of a national committee comprising representatives of the research community, the medical technology industry, clinical practice and the relevant regulatory authorities and committees. The committee would be tasked with developing appropriate criteria and guidelines for assessing the efficacy, quality as well as benefits of individualised medical technology products and procedures, including clinical trials.

### **Organisational requirements**

6. Pool medical technology research and translation activities in cooperation with partners from the medical technology industry and clinical practice. These activities should be pooled through a virtual national centre for Individualised medical technology, in order to make the most of Germany's huge potential in the field of medical technology for Individualised Medicine.
7. Ongoing development of the funding programmes of the Federal Ministry of Education and Research (BMBF) in the field of individualised medical technology, together with the establishment of a Medical Technology Review Board at the Deutsche Forschungsgemeinschaft, in order to make the most of medical technology's untapped potential for Individualised Medicine.
8. Ensure the readiness of the healthcare system structures for testing and cost-benefit assessment of innovative medical technology products and procedures for Individualised Medicine.

### **Concomitant research and public information**

9. Increase concomitant research into the structure of the healthcare system. This should address the issues of regulation, economics and reimbursement, healthcare delivery and public acceptance through the lens of medical technology's contribution to Individualised Medicine.



	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
Legislators, ministries (BMBF, BMG, BMWi)	■		■	■	■	■	■	■	■
Regulatory committees and authorities (BfArM, G-BA, IQWiG, PEI)					■		■	■	
Medical technology industry		■	■	■	■	■			
Medical technology research institutes	■	■	■	■	■	■			
Research associations (DFG, foundations)	■	■	■			■	■		
Payers (statutory and private health insurance schemes)	■							■	■
Medical societies (scientific, AWMF)	■	■			■			■	■
Users (DKG, VUD, German Medical Association)	■	■		■	■	■			■
Patients (selfhelp groups)	■								■

#### Overview of recommendations and who they are aimed at

**R 1** Digitalisation, **R 2** Patient models and guidance systems, **R 3** Production of individualised medical products, **R 4** Translation through cooperation, **R 5** Assessment of efficacy, quality and benefits, **R 6** Bundling of expertise and resources, **R 7** Research funding, **R 8** Structures in the health care system, **R 9** Concomitant research and public information

The size of each square symbolizes the importance of the recommendation for the respective addressee.



## About this acatech POSITION PAPER

In 2014, a joint statement by the German National Academy of Sciences Leopoldina, acatech – National Academy of Science and Engineering and the Union of the German Academies of Sciences and Humanities set out the prerequisites for and consequences of a molecular genetic and pharmacological approach to Individualised Medicine. This executive summary is based on the acatech POSITION PAPER, which complements the 2014 statement by describing current developments in medical products and system and process solutions for different key technologies that demonstrate the essential contribution made by medical technology to various aspects of Individualised Medicine.

## Series editor: acatech – National Academy of Science and Engineering, 2017

### acatech Office

Karolinenplatz 4  
80333 München  
T +49 (0)89/52 03 09-0  
F +49 (0)89/52 03 09-900

### Berlin Office

Pariser Platz 4a  
10117 Berlin  
T +49 (0)30/2 06 30 96-0  
F +49 (0)30/2 06 30 96-11

### Brussels Office

Rue d'Egmont/Egmontstraat 13  
1000 Brussels (Belgium)  
T +32 (0)2/2 13 81-80  
F +32 (0)2/2 13 81-89

[www.acatech.de](http://www.acatech.de)  
[info@acatech.de](mailto:info@acatech.de)

This executive summary is based on the German-language publication: acatech (Ed.): *Individualisierte Medizin durch Medizintechnik* (acatech POSITION PAPER), Munich: Herbert Utz Verlag 2017. The original version of this publication is available at [www.acatech.de/publikationen](http://www.acatech.de/publikationen) or [www.utzverlag.de](http://www.utzverlag.de).