Healthcare 2030

A view of how changes on technology will impact Healthcare in 2030

Laboratório do Futuro

PESC Programa de Engenharia de Sistemas e Computação

COPPE UFRJ Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia

Universidade Federal do Rio de Janeiro

Relatório técnico nº 764 - Janeiro/2020

v.1.0

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Overview

In this chapter we present the aim of this report.

Introduction

1. INTRODUCTION

Thousands of years ago the ability to transform elements of nature into useful tools allowed human societies to survive and thrive. Even simple primitive technologies were capable of causing enormous changes. In prehistory these changes occurred at a slow pace. Over time, however, technological developments began to occur more and more rapidly.

The speed of change seems to have accelerated after the first industrial revolution and, consequently, society has changed dramatically since that time. The introduction of hydraulic and steam engines brought the shift from manufactured output to industrialized production. This transformation affected not only the man-work relationship, but also the social relations and even the environment.

Examples like the industrial revolution show the power of technological change. It acts as a driving force capable of pushing the limits of human capacity and breaking down the barriers of what until that time were seen as impossible, so that a simple change may be able to shape society and the universe around us in a way previously inconceivable. However, one must be prepared for the consequences of such changes, as they are not only accompanied by benefits. The emergence of new technologies has not only positive repercussions. Negative impacts can also occur and the results can be catastrophic if left unattended.

The analysis of emergent technologies and their consequences in the world we live are crucial to understand the future. Thinking ahead and reducing, or even avoiding, the negative impacts of events is a necessity that we must always seek, especially in an environment of constant technological changes as in the present day.

Nowadays, healthcare around the world cannot effectively reach patients living or passing through areas further away from large centers, such as rural regions. In addition, the treatment of some diseases usually begins a little late, as diagnosis tends to be made after the patient notices the clear symptoms of the disease and goes to the doctor. However, in some cases the symptoms appear when it is too late to start the treatment. Fortunately, the technological advances that we will see in the coming years will be able to solve the two problems mentioned.

New technologies will make it easier to detect disease even before symptoms appear and to perform medical examinations and appointments in remote places. This new perspective allows healthcare to be increasingly inclusive and preventive, allowing countless lives to be saved regardless of where you live. However, as stated earlier: if we do not immediately think about how to mitigate the problems to be faced in the coming years, we may not enjoy the benefits of this technological change and, in addition, we may end up generating a catastrophic outcome.

In this report we present our vision of how changes in technology will impact healthcare in the next 10 years. In this analysis we explore three possible scenarios in 2030, namely: pessimist scenario, optimistic scenario and likely scenario. The first one considers the best outcome for all trends; the second one considers the worst possible outcome; and the last one considers the trends we judged most likely to happen. This report, however, does not consider the possibility of large-scale wars, disruptive technological advances or a global catastrophe until 2030.

While it is not possible to accurately predict which path we will take and what the future will look like, it is essential that major issues be debated to try to find the best possible path for society and to avoid negative impacts as much as possible. We believe that the main topics that should be discussed by policy makers, entrepreneurs and doctors are as follows:

1. **Software regulation**: How to properly regulate health-related applications and systems to prevent them from damaging the health of the population by prescribing the wrong drugs (or other errors) while maintaining a quality standard that enables the population to easily identify the credibility of the system? How should patient data privacy issues be handled?
2. **Unemployment**: How to prevent the success of software and AI from causing mass unemployment in various areas of

The most likely scenario for healthcare in 2030 presented in this report may be summarized in the following points:

1. The use of software and AI for diagnosis and medical prescription will increase, but will not be used by much of the population, as there will still be much distrust about them. And therefore mistaken self-medication impact will suffer no changes. Even so, there will be a steady increase in the regulation of these applications due to the growing number of unreliable applications.
2. Applications offered by healthcare centers and hospitals will allow patients to schedule a completely remote, partially remote or face-to-face consultation. The machines will act at the initial stage of this consultation, performing an initial diagnosis and screening of patients. Then a doctor will review the diagnosis and talk to the patient, sending the prescription through the app itself.
3. Many medical devices that currently occupy a considerable space in hospitals will have portable versions. However, portable versions will not completely replace their originals, but will primarily be used to perform procedures when access to a hospital is not feasible and as a pre-examination that will indicate the need for a more thorough look.
4. The quality and life expectancy of people will increase, especially for people living in rural or isolated areas whose treatment is so difficult to perform today due to the long distance from hospitals and the lack of equipment to perform the necessary examinations in these regions.
5. Technology will become even more present in the medical career. Doctors will be supported by a wide range of technologies. Therefore, the doctor will have to learn how to deal with this overwhelming amount of technologies. Thus, the demand for courses and specializations related to technology and medicine will increase.
6. Artificial intelligence will play a central role in many activities, being present in both doctors 'and patients' lives. It will be used to make small diagnoses in patients, support doctors in various outpatient activities, detection of new disease and epidemics, help semi-autonomous ambulance drivers to drive more efficiently and many other things.
7. A large mass of data collected by applications and devices will be widely studied by researchers using Big Data tools to discover new treatments for disease. Despite the potential benefits, some users will be afraid to share their data.
8. The 3D printer will be used in conjunction with IoMT (Internet of Medical Things) interfaces and more efficient energy generation (and storage) technologies to create easier-to-use prostheses with longer battery autonomy.

medicine? What strategies should be used to solve this problem, if it becomes a reality?

3. **Social Security**: How should be designed the tax system to address the issue of population aging and mass unemployment?

4. **Education**: Which direction should education go in order to improve both patient healthcare and employment for future health professionals? Should it relate more to technology or the humanization of treatment? Should it focus more on any specific area or aspect, such as elderly health?

5. **Elderly healthcare**: With the aging of the population it is expected that performing surgical procedures become riskier due to the fragility of the organs in advanced ages. How should Medicine evolve to deal with the aging population? Should there be a greater investment in research and clinics focusing on elderly health?

The findings presented in this report reflect our mission to conduct interdisciplinary research to explore scenarios and to base solutions for governments, organizations and societies, helping them to move towards a more egalitarian, participatory and sustainable society.

This report is organized as follows. The following page shows a summary of the most likely scenario for healthcare in 2030. The second chapter of this report presents some current global trends and their possible impacts. In the third chapter we present and detail three possible scenarios of the future: an optimistic scenario, a pessimistic scenario and a likely scenario.

Part 1:
Key Trends of Healthcare

In this part, we analyze the key trends that drive the future of Healthcare.

2. SOFTWARE

Medical Software, Software as a Medical Device (SaMD) or Software as a Healthcare Product are software with one or more medical purposes that are not part of hardware that is also a medical device[1]. This concept was established by the International Medical Device Regulators Forum (IMDRF), a group of medical device regulators from several countries who voluntarily work together to regulate medical products that vary from country to country. The member countries of the group are Australia, Canada, China, Europe, Japan, Russia, Singapore, the United States and Brazil, the latter having ANVISA as the health regulatory agency [2].

Further, Software as Health Product is divided between Medical Device Software and Non-Medical Device Software. In that way, according ANVISA [3], "software bound to the health surveillance shall be those intended for the prevention, diagnosis, treatment, rehabilitation or contraception of humans".

As already mentioned, the Medical Device Software do not need hardware that is classified as health device, they run by default on an isolated computer [3]. An example of such software is:

- Radiotherapy planning software;
- Software for diagnostic image processing;
- Software for modeling and prediction of surgical positions;
- Software for patients for the purpose of diagnosing, monitoring or treating a physical, mental, or disease condition.

In other way, the Software as Part of a Medical Device shall be connected to hardware designed exclusively for health purposes, being part of them [3]. There are some examples of this kind of software:

- Software that transfers medical device information;
- Software that controls or monitors the functions of a medical device (patient's heart monitor, blood pressure measurement, and so on).

Lastly, Non-Medical Device Software is not primarily intended for the "prevention, diagnosis, treatment, rehabilitation or contraception of humans" [3]. As an example it is possible to mention:

- Software that transmits data to the patient for their knowledge;
- Electronic records;
- General software (spreadsheets, text editors, among others).

According to Paul Wicks et al. [4], one of the great actual health-related challenges is the management and prevention of chronic diseases. However, the study says that this challenge could be solved with the software advantages, like:

- Increase efficiency in healthcare, thereby reducing costs
- Improvement in care due to easy communication
- Empower patients to consciously self-medicate.

In the context of self-medication, there is concern about the quality of information so that patients do not self-medicate in the wrong way. Despite this, social networks such as PatientsLikeMe demonstrate that the knowledge of the population, in this case, of other patients should be shared between them. The social network was created by Jamie and Ben Heywood in 2005 with the aim of "allowing patients to share, compare and contrast different diagnoses and treatments with people who have the same conditions anywhere in the world". The network currently has more than 600.000 users and more than 100 published researches in the health area.

A PatientsLikeMe, as well as other social networks and software on the market, also has its mobile version, making it easier to use, since medical software is not restricted to just using the computer. Several mobile applications run software that helps both doctors and patients perform treatments, self-medicate, and provide diagnostics.

In the mobile applications context, the constant increase in accessibility caused by the widespread popularization of mobile devices that support versatile and powerful platforms, such as Android, can bring benefits and risks, requiring attentive and careful use of them.

According to a study conducted by Juniper Research [5], the number of health service users on mobile devices is expected to exceed 157 million by 2020, more than tripling the 50 million 2015.. The branch of mobile applications moves billions of dollars around the world, and the health sector in this context is also significant. The industry of mobile health applications (also known as mHealth apps/mobile Healthcare apps) moves more than $ 1.3 billion today and is expected to reach $ 20 billion by the year 2020 [6].

Nowadays the healthcare and wellness software already have a wide range of functionalities. Warn the user to take a medication or drink water, assist in feeding control and exercise routine, and monitoring the glycemic rate.

2.1. Mobile Apps

Mobile applications with a medical and health focus are changing the health scenery. While medical devices with embedded software have existed for more than two decades, the arrival of touch-screen smartphones, smart Bluetooth technologies and internet connection has brought a slew of applications designed for every need, from monitoring body temperature, to measuring heart rate. Today's health and medical applications are becoming smarter, multi-functional, and easier to use.

In the past many health and life science companies have focused on manufacturing medical equipment and devices for hospitals and physicians. Now, they are migrating to medical and healthcare applications more and more. Most of these programs are intended for direct use by patients and consumers, rather than by professionals in the industry. This has brought about a paradigm shift in people's perceptions of health, making healthcare more accessible to users.

Currently, there are about 43,700 medical and health applications only in Apple Store. However, not all programs are genuinely for healthcare. Only about 54 percent of medical and health applications are really utilitarian for healthcare, according to a co-author report by Murray Auiken, executive director of the IMS Institute of Healthcare Informatics [7]. The report further estimates that 69% of medical and health applications are targeted to consumers and patients, while 31% of them targets clinical use.

With ease of creation and distribution through online application stores, medical and health applications are no longer new. Any group of people with sufficient knowledge of diseases, medical conditions and software development can create an application and distribute it over the internet. According to da Rocha et al. [8], "The range of education and health-related applications includes applications that have serious, scientific information [developed after extensive study] to those that do not fit into health promotion practices because of their amateur and science-based production leaves users unprotected".

Therefore, the user can search for applications that serve the intended purpose, download the software on their smartphones and use it to monitor their own health.

This facility to obtain medical care will result in a financial save both for patients and for doctors because as the patient can dispense in-person appointment for diagnoses and recommendations for remedies and medical devices for home use, doctors can also take advantage from using applications in their medical procedures to their patients. It is estimated that in addition to providing cost savings to patients, remote mobile patient monitoring will save $36 billion in general health care costs by 2020 [9].

With this wide range of patients' mobile applications, the risks are imminent, as the professionals dedicated to taking care of them are being excluded from the process. Applications for treatments and diagnostics need to be well designed and programmed with enough caution so that the patient is always safe to follow what is being shown.

All this process will also lead to an increase in the admission to hospitals of patients who have misused a drug or who did not obtain an expected result in their "home" treatment. This could generate a concern for governments, which will regulate more strongly the sale of drugs in drugstores. Therefore, it is estimated that by 2025 this will lead to an increase in drugs held at drugstores because they require medical prescriptions to be sold, since many drugs would be sold without prescription from a health professional, but rather by recommendations from applications of health.

On the other hand, applications can be linked to medical appointment and make the doctor-patient relationship more cooperative [10].

An interesting point to note is that this increase of patients' adherence to the use of applications will lead to healthy competition with the clinics and private hospitals, as they will be updated to stimulate patients at their stations. It is estimated that by the year 2025, integration of both doctors and patients in health applications can contribute greatly to both sides, making the doctor-patient relationship more cooperative and, consequently, more cooperative medicine.

Another interesting point is the economy, both financial and time. In the present day, with work, family and the like, more and more the human being is busy throughout his day, involved with his obligations and transportation around the city. The time to take care of yourself going to the doctor ends up being left out and the health applications, if used correctly, can meet the medical needs of the person. For simple cases, such as diabetes control, pressure, instructions on a medicine bottle, most of the applications related to it prove to be very useful. For cases requiring more care, doctor-patient cooperation may become more necessary. Even using an application, the doctor can act directly with the patient. That is, m-health applications can save time and money for both doctors and patients in the future.

A study by Stefan Biesdorf and Florian Niedermann on the McKinsey & Company website [11] in 2014 showed that 75% of interviewees from different countries wish to use health services in digital media, but at the time the existing services were ineffective, so that the functionalities developed did not meet the real needs of respondents. In addition, the study also indicates which of the digital media interviewees most used in the last 12 months and among them some of the most used services were websites, e-mail services and mobile applications.

2.2. GRAPHIC SURGERY SIMULATION

The technology was able to advance the most diverse areas of medicine, but it was probably the surgeries that received the most contributions. In the past, a surgical planning was done manually, through simple exams such as x-rays, and even drawings made by the doctor himself, giving him the necessary measurements and calculations for the operation [12].

Many surgeries have not been successful in the past because there are no control and simulation techniques. In plastic surgery, for example, the patient was not sure how the end result would be. The doctor was based on past experiences and sketches performed through examinations, but not always the result met the expected and / or the patient was satisfied.

Thus, if surgical procedures were previously hostage to the lack of resources, they are currently "driven by navigation and follow-up software to facilitate the medical profession and provide the patient with the highest possible safety". In addition, visual planning software allows "access to the surgical site is determined prior to surgery, minimizing the risk of incidents and problems" [12]. In addition to bringing better results and greater patient safety, virtual surgical schedules are faster than conventional designs, giving the surgeon even more input on the patient's anatomy, allowing him to have a more realistic picture of the case yet in time of planning [13].

All this improvement in surgical planning also generates more confidence in patients, and it is estimated that by 2030 the number of people adept to submit to some kind of surgery will increase significantly.

According to Renaud Lafage et al. [14], "integrating a new technology can change the current way of planning / simulating surgeries". For him, machine learning, which is currently already used for facial detection and recommendation on websites, can be used in many areas of medicine and will bring countless benefits such as:

- Improvement in surgical results;
- Reduction of complications during surgery;
- Reduction of complications after surgery;
- Reduction of mechanical failures;
- Reduction of hospital costs;
- Reduction in the duration of surgery;
- Reduction in surgery planning time;
- Reduction in the number of surgical tools to be sterilized;
- Reduction in the cost of logistics / acquisition of industries.

With machine learning applied to medicine, it would be possible, for example, to improve the results of spinal surgery, and with image recognition, it would be possible to identify possible pathological areas in the human body [14].

In this sense, virtual reality simulators also play an important role in medicine. Currently they are being used to simulate laparoscopic surgeries, that is, surgeries where a camera is inserted through the abdomen of the patient so that, following the images, the surgeon can make small interventions. Currently, most medical simulators do not have visual quality, unlike what happens in video games, which are increasingly realistic. Because of this, a number of studies are being conducted to refine these visual simulators and consequently ensure skilled and well-trained surgeons and more successful surgeries [15].

The expectation of Luengo, one of the participants of the project that will use computer graphics to improve the virtual simulators, is that by 2019 its simulator is ready [15]. With this, it is expected that by 2020 a greater number of virtual simulators will be used to train surgeons. And consequently, new computer graphics techniques will emerge to enhance these virtual simulators.

Other research are also being developed to represent the internal structure of human organs, such as the liver [15].

Finally, with the advancement of medical software, it is also estimated that new medical software will emerge, thus reducing the cost of selling the software itself and the cost of surgeries.

3. Internet of Medical Things (IoMT)

The Internet of Things (IoT) is a term for a system of interrelated devices that interact with each other over the Internet. This paradigm allows heterogeneous objects to communicate and make decisions without human being obliged to intervene in this interaction. This communication applied to everyday objects can, for example, be used to create smart houses.

When it comes to healthcare, IoT can bring significant developments. It can, for example, increase process efficiency, bring more peace of mind to staff and a better quality of life for patients. Almost 60% of the organizations have already adopted healthcare IoT, also known as Internet of Medical Things (IoMT), and realized cost savings, improved their profitability, visibility and customer experience [16].

3.1. Sensors

In this work we considered sensors as devices that detects and respond to physical properties. And in the context of IoMT (Internet of Medical Things), we structured this section presenting Brain-Computer Interfaces (BCIs) as the main application of a broad set of sensors. In Table 1, we present classes of devices grouped as BCI devices and other kinds of general purpose sensors and their techniques.

3.2. Brain-Computer Interfaces

Brain-computer interfaces (BCI's) provide their users communication and control channels that do not depend on peripheral nerves and muscles [17]. They are devices that monitor and decode brain activity and create control signals to control virtual or physical objects [17], [18].

Table 1: Sensor Methods, Technologies and Techniques.

	Methods	Technique
BCI	ElectroEncephaloGraphic (EEG)	field potentials
	Magnetic Resonance Imaging (MRI)	field potentials
	Functional Magnetic Resonance Imaging (fMRI)	field potentials

	MagnetoEncephaloGraphy (MEG)	field potentials
	Stead-State Visual Evoked Potential (SSVEP)	field potentials
	Single neuron activity recorded within cortex	spikes
	ElectroCorticoGraphic (ECoG)	field potentials
General purpose sensors	**Technology**	**Technique**
	Triboelectric Nanogenerator	inertia into electricity
	Body Sensor Network (BSN)	Bluetooth
	Wireless Sensor Networks (WSN)	ZigBee & Bluetooth

Since the ElectroEncephaloGraphy (EEG) was first described, in 1929, there are speculations that it might be used for communication and control. Initially the interest in BCI development came mainly from the hope that this technology could be a valuable new augmentative communication option for those with severe motor disabilities. Early in the 1970's, the Advanced Research Projects Agency (ARPA, the same that sponsored the initial development of the internet) of U.S. Department of Defense became interested in technologies that provided a more intimate interaction between humans and computers and included "bionic" to the motor disabilities applications. A more general label of "biocybernetics" became the main source of support for bionics research in the ensuing years. One of the directives of the biocybernetics was to evaluate the possibility that biological signals, analyzed in real-time by computer, could assist in the control of vehicles, weaponry, or other systems. The most successful project showed that a human could to control the movement of a cursor through a two-dimensional maze[19], [20].

Our review showed that we still have a lot ground to cover until get commercial consumer healthcare products or even other smart home control, entertainment and gaming, or communication and control product lines aligned with the today's vision of direct connecting the brain to on-line resources like artificial intelligence algorithms, virtual reality and Internet of Things devices, substituting input devices like keyboard, mouse or touch screens.

One of the problems is the information transfer rate (bits/min) very limited and another is the data acquisition methods based in invasive techniques. In the year 2000, the information transfer rate ranged from 5 to 25 bits/min [19]. At that time the technologies supporting functional BCI devices was mainly EEG and single-neuron.

Ming Cheng et al. [21] presented a brain-computer interface that could help users to input phone numbers, the system was based on the steady-state visual evoked potential (SSVEP). The average transfer rate over all subjects was 27.15 bits/min, and the system was important because was a non-invasive technique for signal recording. Another aspect is that BCI often require extensive training, from several hours to several months. BCI based on evoked potentials may not require extensive training but require a structured environment. Another invasive method, more stable, in the long-term, than single-neuron and with higher spatial resolution (tenths of millimeters versus centimeters), broader bandwidth (0-200 Hz versus 0-40 Hz) and higher amplitude (50-100 μV maximum versus 10-20 μV) than EEG, is ECoG (ElectroCorticoGraphic) that is based on a subdural electrode arrays, therefore it depends on a surgery to implant those arrays, this technique is presented by Eric Leuthardt et al. [22].

3.3. Lab on a Chip

When it is about the field of the Internet of Medical Things, we could say that Lab on a Chip is quite a developed research area if we consider how young it is. This area has been researched just since 2013. Right now there are many functional prototypes for disease detection and monitoring and so more Lab equipment that can be helpful in hostile areas.

Also, such equipment can easily reach the healthcare systems of low income countries and cause a fall in the examination prices followed by the popularization of the healthcare system. Not only the lab equipment can cause this but also the disease detection devices can diagnose diseases in early stage when the treatment, is more effective and less aggressive in most cases. The early treatment can also extend life expectancy.

The point of care devices which were analyzed can change the game when it comes to prevent diseases and death, mainly in chronic cases, doing a better monitoring on which the physician can follow up the patient every day and his answer to medication. It's important to point that those devices are going to increase electronic records causing big data problems and information security issues, which can create new Jobs.

4. Big Data in Medicine

In the Information Technology field, the world has been experiencing an explosion in the capacity of production, storage, consumption and data sharing in recent years, driven by the expansion of telecommunications networks and the increasing use of mobile devices [23], bringing new research and innovation opportunities based on the analysis of large volumes of data. Among different definitions for the term Big Data, one of the most common refers to the current computational capacity, pointing it as a "data set that cannot be captured, managed and processed by computers in general within an acceptable scope" [24]. This "data explosion" manifests itself in several areas [25]; the benefits of the application of Information Technology in the area of Medicine are also visible, translating into the generation of increasing volumes of medical and health records, and also for the data generated by IoT.

The health area is also experiencing the benefits of adopting large-scale Information Technology in the form of devices, equipment, or the simple exchange of information in communities on the web [26], as shown by recent research growth in the field of Health Information Technology (HIT) [27]. The intense use of HIT brings the generation of numerous medical and health data from medical records [28] (such as electronic records, patient history, test results and laboratory tests, etc.), as well as genomic data (genotype, genetic sequencing) and payment (health insurance forms, medical prescriptions, feedback and patient responses) [26]. Table 2 lists examples of medical platforms and data set generated can be seen in analyzing this large scale of data enables more comprehensive and accurate reporting, facilitating timely decision making, minimizing patient risk, and reducing clinical cost.

Table 2: Examples of data sources in the health field adapted from Marion et al. [29].

Data source	Generated data
Electronic Health Records (EHR)	Clinical documentation, patient history, outcome reports, and patient requests
Laboratory Information	Laboratory results

Management Systems (LIMS)	
Monitoring or diagnostic instruments	It includes everything from images (for example, MRI) to numbers (for example, vital signs), as well as text reports (interpretation of results)
Health insurance forms	Information about what was done to the patient during a visit, the cost of these services and the expected payment
Pharmacy	Information on compliance with requests for medication
Human Resources and Supply Chain	Lists of employees and their roles in the institution; location and use of medical supplies
Real-time location systems	Positions and interactions between assets and people

4.1. ELECTRONIC HEALTH RECORDS (EHR)

The emergence of the electronic medical record, or Electronic Health Record (EHR), has links to a comprehensive interagency organization based on centralized patient health records in the 1990s in the United States. This approach resulted in patient data records systems seeking to maintain and improve the quality of health care [30].

Currently the term Electronic Health Record is being widely used. Conceptually, EHRs comprehend, in an integrated way, interinstitutional and longitudinal data from health records and treatments. In this way, the recorded data are not only useful for a specific treatment, but for the general health of the patient. There is, therefore, a change of vision as a consequence of the application of technology [29] and the patient comes to be regarded as an active element in their treatment by providing these historical health records.

As health institutions, small and large, move from traditional paper-based patient records to electronic health records (EHRs), which in the last decade has turned out to be a trend in hospitals and clinics around the world [31], new opportunities are emerging for analysis and use of data captured in routine care. Thus, EHRs may contain family, social, surgical and medical history; allergies and immunizations; laboratory results; clinical findings; clinical orders; and other specific information [32].Depending on the EHR configuration, this information may exist in distinct fields or be captured as part of free-text notes [33].

Research opportunities brought about by the adoption of EHRs include not only traditional research methodologies, involving relatively small segments of patients, but also large-scale data mining analyzes, spanning hundreds of thousands or even millions of patients at the same time, requiring new computational approaches. The use of these registries enables a significant and comprehensive clinical knowledge, as well as a deeper understanding of disease patterns.

Analysis of literature and expert opinion [30] helps to raise desirable requirements in good quality EHR systems: data security; privacy and data protection; portability, performance, maintainability and reliability; usability; content; interoperability.

Data security can be subdivided into four sub-classes such as confidentiality, integrity, availability and authenticity. Confidentiality may be understood as the degree of protection against unintentional and unauthorized disclosure. Integrity can be seen as the degree that the system is able to protect itself from unauthorized and unintended changes. Availability refers to the ability to offer the data whenever the requirements are met. And authenticity refers to the ability of the system to guarantee the origin of the data.

Privacy and data protection covers third party misuse requirements and in the suggested classification it overlaps in some points with security. Portability, performance, maintainability and reliability are the ability of the system to perform well with available resources and are non-EHR specific qualities. Usability refers to the system being user friendly and accessible to all types of users, in addition to being easy to understand [34].

Variability is also a concern for EHRs, which are quite diverse in their structure and design. Despite their diversity, some core components are present in most EHRs, such as diagnostics, procedures, medications, progress notes, assessments, and plans.

Despite the consensus of the benefits of adopting EHR, in the United States there is a slow adoption by health care providers [34] and few have a completely comprehensive system. There may be barriers of different natures in the adoption of EHR systems, such as financial, user resilience, interoperability problems or politicians.

4.2. Massive Open Online Medicine (MOOM)

The large body of medical, laboratory, and clinical data from various databases, such as the EHRs mentioned above, exposes the possibility of establishing a connection between these databases and analyzing these data on a large scale, allowing investigation and projection of disease occurrence in a particular individual or region, considering the data set of an area, or the individual's own kinship lineage.

MOOM (an acronym for Massive Open Online Medicine) presents itself as a proposal for integrating and analyzing data on a global scale, with the objective of expanding knowledge about diseases, symptoms, treatments, medicines, DNA sequences and other data related to medicine. One of its main idealizers, Eric Topol [35], [36] defends the idea of a database of patient data sharing in a common knowledge repository that is able, for example, to provide matching resources to approximate the data of a newly diagnosed individual, compared to all that were previously combined [37]. Such a platform can play an important role not only in the continuing education of physicians, but also in bringing medical knowledge to the general public [38]. According to research cited by the author, it is estimated that 80% of people would like to share their medical data if such a resource existed [39].

Despite its benefits, the initiative addresses patient privacy issues, data ownership, and professional ethics issues of physicians, and therefore requires a new way of thinking and doing medicine first [39].

5. Telemedicine and Robotics

Robotics can be defined as "the intelligent connection of perception with action" [40]. From the first robots, built in the 60s, that combined two technologies, numerical control machine tools for manufacturing and teleoperators for remote manipulation of radioactive materials, several innovations were made in the development of this technology that allowed the proliferation of robots from factories to several sectors, one of them being health [41].

One of the first applications of robotics in the field of health was the ROBODOC - launched in 1992 and approved by the Food and Drug Administration (FDA) as a fully automated robot in 2008, the robot was used for the insertion of implants in orthopedic surgeries [35].

Since then, sales of medical robots have risen from 1,300 in 2015 to 1,600 in 2016 (23% increase) and are expected to grow 25 % in 2017, reaching 2,000 units sold in that year. The projection for the following years is even more promising, between 2018 and 2020, it is expected that the sale of medical robots is 10,700 units, an average greater than 3,500 robots per year for the period [42].

The sales value of medical robots reached $1.6 billion in 2016, which corresponds to 34% of the total sales value of professional service robots [42]. Medical robots are the most valuable service robots, with an average price of approximately $ 1 million per unit, including accessories and services.

5.1. SURGICAL ROBOTICS

Robotic surgery can be defined as "performing surgery using an intelligent machine that is able to plan and perform surgical maneuvers based on its ability to integrate various external information" [43].

It can be considered that the area of robotic surgery emerged in 2000 when the first surgical robotic system, Da Vinci, was approved by the FDA and, since then, there has been an exponential increase in the use of robotic technology in several subspecialties of surgery [36].

Robotic surgery brings advantages such as allowing the introduction of minimally invasive techniques, better view of the field of operation and greater stability and precision, but several disadvantages of robotic surgery are responsible for its somewhat cautious adoption [44]. One of the disadvantages of robotic surgery is the high cost not only of the robotic system (the da Vinci system costs around $ 1.5 million), but of its instruments that are not accepted by the system after a number of surgeries and also the maintenance that in the case of the da Vinci system costs approximately US$ 150,000 per year [44], [45].

One of the reasons for this high price that hinders the advancement of the application of robotics in surgery is the virtual monopoly that Intuitive robotics, the company that bought the DA Vinci system in 2003, owns on the market [45], [46]. It is believed that the fall of some patents of the company will allow an increase of the competition and consequent reduction of the prices, making the robotics in the area of surgery can be even more used [45], [46].

In addition to the cost of the robotic system, the operating room needs to be adapted to receive the robot that is usually large and difficult to move, which causes a problem for the management of hospital surgical equipment [46].

Another relevant issue is the need to expand the knowledge base on the impact of the use of robotic surgery on the results of operations [46].

Despite all these challenges, robotics is currently applied in several areas such as urology, orthopedics and neurology. By way of example, it is worth briefly describing the main surgical robot, da Vinci.

Figure 1: Da Vinci System. Surgeon's console (left) and nurse on operating table next to robot arms.

The da Vinci system has been used in more than 3 million surgeries and can be used in 7 different types of surgeries (cardiac, colorectal, general, gynecological, head and neck, thoracic and urological). Figure 1 shows the console used by the surgeon to command the system and the arms of the da Vinci system robot. Some features of the da Vinci system can be highlighted:

- Magnified view that gives the surgeon a 3D HD view of the inside of the patient's body;
- Ergonomically designed console where the surgeon sits during operation;
- Operating table where the patient is positioned during surgery;
- Wristed instruments capable of bending and rotating more than the human hand.

5.2. ROBOTICS FOR REHABILITATION

In health, in addition to surgery, another area where robotics has advanced is rehabilitation [42]. Within this field, the main application is gait training, followed by rehabilitation of upper limbs.

Compared with robotics for surgery, where patents have secured a monopoly, the area of robotics for rehabilitation does not suffer from this problem because there are more than ten robots on sale in the market for gait training only. In order to demonstrate some robots of this field, two robots with different approaches will be presented, a dynamic exoskeleton and a static one [47].

ReWalk Personal (Figure 2) is a dynamic battery powered exoskeleton with hip and knee motors that control movement through changes in the user's center of gravity. This type of robot assists patients who are in a high level of locomotion (Functional Ambulation Category or FAC 3, 4 or 5) [47].

Figure 2: ReWalk Personal.

Lokomat, on the other hand (Figure 3) is a static exoskeleton and therefore, it is aimed at patients in the lower levels of locomotion capacity (from FAC 0 without trunk control to FAC 1) [47]. The product offers dynamic weight support, adjustable robotic orthosis, interactive feedback and allows full control of the training session for the therapist involved through an interactive dashboard.

Figure 3: Lokomat.

Part 2:
A view of Healthcare in 2030

In this part, we develop three scenarios for the Future Healthcare: the optimistic, which considers the best outcome for all trends; the pessimist, which considers the worst; and the likely, which considers the trends we judged most probable.

6. OPTIMISTIC SCENARIO

In this scenario, we present an optimistic foresight in how healthcare will be in the year of 2030. We present our view for the next years if the best of the changes come to be, using the trending changes identified in the Key Trends of the Future.

6.1. SOFTWARE

Health-oriented software will aid in the management and prevention of chronic diseases, increasing individual healthcare and reducing the risks of self-medication. The use of health-oriented software will also lead to a reduction in queues at health centers and hospitals, and these will offer better quality services to patients who really need presential medical supervision.

With the high number of users, these applications will provide an accurate comparison between different treatments for the same diagnosis, helping physicians in the prescription of medicines using the indicators exposed by these tools. This will lead to a considerable increase in successful medical treatments.

Medical consultations will, in principle, be carried out in software capable of providing direct contact between patient and physician, making them more accessible to the general population. The waiting time for a call will drop considerably, as it will not be necessary to go to a particular location to make an appointment. This will lead to an average increase in the frequency with which the population makes medical consultations, thus increasing disease prevention. Hospitals and medical centers will only receive cases where the patient’s physical presence is necessary, and this will reduce the time and improve the level of care.

Patients who require special monitoring, such as autistic, will gain quality of life thanks to the use of follow-up software. The amount of specialized software offers will be high, thus reducing the costs for treatments of these diseases. Even so, such software will be properly regulated, so that there are guarantees for the patient that the application will comply with the promise, without risk to patients.

In this scenario, doctors will be better able to perform surgeries, thanks to simulation software and surgery planning. This will lead to an increase in successful surgeries, with lower patient risks. Software that aid surgeries will cause a significant drop in the time a surgeon takes to operate a patient, while software that aid planning will reduce pre and post-operative time.

With better management of outpatients and surgeons, the average price of surgeries will fall, making people with less financial conditions to use this type of treatment when necessary.

6.2. INTERNET OF MEDICAL THINGS (IOMT)

Mobile devices and wearables will be used to perform various medical checks. It will be possible to perform medical checks using portable equipment, ensuring access to these exams in rural and far areas, without the need for transportation to a hospital. Continued monitoring devices will be used to help prevent various diseases and anticipate various clinical conditions such as heart attacks and strokes, making lives saved thanks to early diagnosis. It will also be possible to identify at an early stage, through these devices, serious diseases such as cancer. This type of diagnosis will greatly increase the patient's chances of cure, greatly reducing cases of death from diseases that need diagnosis and treatment as soon as possible.

The use of non-invasive Brain-Computer Interfaces (BCIs) will allow control over prostheses and exoskeletons, as well as technology capable of giving tactile feedback to patients, humanizing the use of these technologies and increasing patients' quality of life. The amount of possible tasks to be performed with BCIs will increase significantly, making this a technology not only used for patients but replacing many devices currently used by people, such as keyboards and mice. This will facilitate the use for medicine, since the population will already be in use of this type of tool.

There will also be integration of IoMT devices with Artificial Intelligence (AI). AIs will work collecting and analyzing data from ongoing patient monitoring, being able to perform diagnoses, prescribe treatments and surgeries. With this, human physicians will be increasingly focused on discovering cures for new diseases and creating new treatments. Surgeries will be performed entirely by AIs and robots, with constant communication with patient monitoring devices. AIs will also assist in the discovery of new diseases and in the potential emergence of epidemics, alerting authorities about the problem.

Autonomous ambulances, driven by AI and activated by the patient's IoMT devices will be used to attend patients who need urgent ambulatory care, before a human even realizes the need.

The use of IoMT devices will further reduce unnecessary demand in health centers and hospitals, thereby reducing queuing and waiting time, as well as better redirect resources to patients who really need to be in those locations.

6.3. BIG DATA IN MEDICINE

Large-scale data mining, covering thousands of patients, will be performed with the data captured in these applications. This will lead to more clinical knowledge of physicians, and will increase understanding of disease patterns. New professionals, experts in data analysis and medicine, will be able to detect potential new epidemics and discover new diseases.

Such new diseases will be recognized quickly, and the correct treatment will likewise be discovered more quickly. Patient diagnosis will be faster and treatment with fewer errors due to comparison of symptoms and user profile with other users with similar symptoms and profiles.

6.4. TELEMEDICINE AND ROBOTICS

There will be a large number of suppliers of robotics technologies for performing surgeries, leading to a tougher competition and consequently reducing the cost of these technologies. The investment in these technologies will be high, and with the low cost of the technologies, a large part of the population will have access at the time of having surgery. Robot surgeons will be widely used, further decreasing the duration and increasing the accuracy of surgeries. Most surgeons will be able to use this type of technology, enabling such professionals to operate in various locations without the need for physical presence. The most complex surgeries will be performed by specialists anywhere in the world, due to the ability to Internet connection of these robots, leading to a decrease in medical errors.

3D printers will be able to print many types of materials, even organic tissue. Such printers will be used in surgeries to supply materials to surgeons, as well as to help rebuild the organs, skin, and bones of patients in need. New surgeries will be performed thanks to full organ printing capabilities in 3D printers, reducing organ donation problems.

The use of robotic technologies in rehab will be common, with the use of exoskeletons to aid patients. The virtual and augmented realities will be used in the robots that aid the rehabilitation, besides being applied gamification techniques for the treatments.

Solar energy and wireless power transmission will be a reality in this scenario. Robots and machines will use solar energy, which will allow them to have a wider field of action. Wireless power transmission will also be used by these robots and will give autonomy to this rehabilitation technology, leaving them practically in continuous charge and decreasing the need for batteries, making them lighter and less expensive to be manufactured.

7. Pessimist Scenario

In this scenario, we present a pessimist foresight of how healthcare will be in the year of 2030. We present our view of the upcoming decades if the worst is to happen, using the trending changes identified in the Key Trends of the Future.

7.1. Software

Health-driven software will grow disorderly, without any regulation and will not have any validation of trained physicians, making their use as dangerous to people as self-medication.

Due to the high utilization of this type of software, it will lack work for specialized doctors, reducing the number of qualified professionals. With the high rate of self-medication without qualified medical evaluation, health centers and hospitals will overcrowd with patients who did not have the correct treatment for their illnesses or otherwise misused medications. Overcrowding will be aggravated by the lack of qualified doctors. This will lead to a race to train new professionals in the area, which will lead to low-skilled and inexperienced professionals serving the majority of the population.

The search for health applications will decrease the demand for appropriate treatments, leading to a serious financial crisis in the health sector. The closure of health centers and hospitals will be unavoidable, which will make it difficult for the population to find adequate medical treatment. In addition, new dependents will come up with the wrong prescription of strong drugs.

Due to the serious health problems faced by the population, there will be a significant increase in the number of surgeries done, leading to increased waiting lines. Fewer health centers and hospitals and the use of inexperienced physicians will pose a high risk for patients requiring surgery.

7.2. Internet of Medical Things (IoMT)

The inaccuracy of monitoring equipment will cause false occurrences of medical diseases. There will also be cases where, because of failure, these devices do not identify or fail to report problems such as heart attacks or strokes, putting the lives of patients at risk. Several lawsuits against manufacturers will be moved, which will force a strong regulation on the part of the rulers, making it impossible to popularize these technologies and making their formal use in medicine unfeasible. Data capture failures will also preclude any analysis of them, making this technology not contribute to any advancement of medicine.

The AIs used for surgeries and medical consultations will not be developed enough, causing several errors that endanger the lives of the patients. Wrong data analysis of the sensors will help the wrong decision making of the AIs. The lack of reliability will cause the population to discard the use of these technologies in medicine, which could be improved in the future to be used for the benefit of the population.

7.3. BIG DATA IN MEDICINE

Poorly constructed software will provide diagnosis and prescribe medications based on unreliable data analyzes, which will lead to increased cases of serious illnesses by the lack of early treatment. Data poorly collected and poorly analyzed by professionals who are not trained to the task will hinder the treatment of certain diseases, making healing even more difficult for patients. The software will not have standard for data generation. Contradictions between data collected by different software will confuse even more population and doctors.

The collection of information of these applications will happen in a disorderly way and there will be a lot of leakage of information. This information will be used for ads and purposes other than the health guarantee of the population, invading the privacy of those who need treatment.

7.4. TELEMEDICINE AND ROBOTICS

New companies in the robotics field will come together to combine prices in a kind of cartel, causing the costs of this technology not to decrease. With this, a large part of the population will not have access to health-driven telemedicine and robotics. The specialization of physicians in this area will continue to be expensive, making few physicians able to use these technologies, which will be restricted to large hospitals that have the capacity to purchase the equipment and labor necessary for its operation.

In this scenario, 3D printers will not yet have the ability to print organic tissues, which will make it impossible to use these printers in surgeries. Virtual and augmented reality software will be extremely expensive, causing few physicians to have contact with these technologies.

For this scenario, the use of solar energy will not be a reality, and the transmission of wireless energy will prove impracticable due to the low transmission efficiency. The prostheses, therefore, will not have energy autonomy, causing the industry and academia to lose interest in the area, with less research and slower and more costly advances. The result will be difficult to control prostheses that do not contribute to the patient's life.

8. LIKELY SCENARIO

In this scenario, we present a likely foresight in how healthcare will be in the year of 2030. We present our view for healthcare in 2030 if the most probable trends become true, using the trending changes identified in the Key Trends of the Future.

8.1. SOFTWARE

Healthcare software will not be used by a large part of the population. Many people will not rely entirely on technology and prefer classic face-to-face medical consultant. However, a portion that cannot be disregarded will be leaving your health in charge of medical software. This will force authorities to regulate these applications by making them comply with technical standards, which will ensure the satisfactory functioning of these tools. On the other hand, this will reduce supply and increase the cost of such treatments. Health centers and hospitals will adapt by offering their patients the face-to-face and software care, still using a human doctor behind the application to increase the reliability of their services for users who are afraid to use fully automated software. For this reason, the software will serve as support, with little supply of fully automated medical prescription and diagnostic software.

Although there are fully automated software and AIs acting in the diagnosis and medical prescription, the regulations imposed by governments and the population's fear of relying solely on software will make the managers of these tools always have a professional capable of validating the information.

The regulation will force medical prescription software to comply with a set of standards to generate valid prescriptions. Pharmacies and drugstores will only accept valid prescriptions, thus avoiding the risks of prescriptions made by unreliable agents.

Regulated applications will be paid in a subscription system, and will be included as a service in health plans. You will also be able to pay for each use, such as a private consultation. Free applications will be restricted to social networking for patient information exchange and wellness tips, which do not pose an imminent health risk as a wrong medical prescription.

Health centers will adapt their physical units to offer services that are not available through software, making physical spaces still necessary and fully utilized. Likewise, professionals capable of dealing with these technologies will emerge, with more and more offers of courses that relate technology and medicine.

The advancement of computer graphics will aid in the training of medical surgeons as it will allow the creation of increasingly realistic simulators. The support given by software will also aid doctors in decision making in surgery. A new concern in the training of surgeons will be the ability of the surgeon to analyze the amount of information that will be exposed to.

8.2. Internet of Medical Things (IoMT)

Portable examination equipment will be a reality, but with limitations. They will be able to detect some types of diseases and will serve as a pre-exam, which will indicate to the patient the need or not to look for more complete exams. Even so, these devices will help the population of remote areas to receive some type of medical treatment, even if this is not ideal.

IoMT interfaces will aid in the use of prostheses and mechanical organs, but with restrictions due to errors that may occur. The mass of data generated by these devices may or may not be shared for analysis, depending on the user's choice.

Artificial intelligence will be highly active in patients' lives, supporting physicians in various outpatient activities, and even being able to perform small diagnoses. However, because of regulation, the diagnosis performed by an AI will need to undergo validation from properly registered physicians. Researchers will use IAs to detect new diseases and epidemics, and AI will be a strong ally of science in seeking a cure for these diseases. Ambulances will be semi-autonomous, making it possible to move faster, but still need human oversight because of regulation. Some sensors will be able to request medical distress, while also providing data to the medical teams that will be able to assist the patient.

8.3. BIG DATA IN MEDICINE

The large mass of data generated by IoMT applications and devices will be widely studied in developed countries, while developing countries will not be able to deal with all the information. There will be leaks of patient information that will force the regulation of the use of personal data in those applications, where the user can choose whether or not his or her data will be used. Depending on your profile, some users will be more likely to accept the use of your data, which may bias studies in the area. However, researchers will use the information generated by the various applications to discover new ways of treating diseases.

8.4. TELEMEDICINE AND ROBOTICS

Medical robot offerings will increase, automatically reducing your acquisition and implementation costs. However, the cost will continue to be high and such technologies will not be available to everyone, being restricted to medium and large hospitals. In any case, its benefits will cause many studies to occur in the area in order to perfect these technologies, being a trend in the academy.

Despite the increased use of robot surgeons, trained professionals will be required to handle them, since AIs will not yet be fully trusted to perform complex surgeries. This will increase the number of courses in the area.

Surgeries at a distance will be a reality, but with the need for the physical presence of a qualified medical team to solve problems that may occur. More complex surgeries that require a great team will not yet be done at great distances, with the use of robots only as a support for the surgeons who will be in the next room.

Virtual reality will aid in the training of medical surgeons, while augmented reality will support the professional at the time of surgery, showing patient indicators and supporting medical decisions. Objects created in 3D printers will be used as prostheses in surgeries, and it will be possible to use even small organic tissues, although it is not yet possible to print whole organs or more complex tissues.

The use of robotic prostheses will be a reality for a large part of the population. However, complete exoskeletons will only be available for a small portion, as it will still cost a hefty price. Simpler prosthetics will aid patients in the rehab, although still with limitations. New technologies of energy generation and storage will increase the autonomy of such prostheses, but will not be enough to make them totally autonomous, needing to go through a recharge cycle that will limit or make it useless temporarily.

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This work is published on the responsibility of the Director of the Laboratório do Futuro. The resulted analysis herein does not necessarily reflect the official views of the PESC, COPPE or the Universidade Federal do Rio de Janeiro.

Acknowledgements

This work was coordinated by Carlos Eduardo Barbosa under the supervision from the Laboratório do Futuro Director, Jano Moreira de Souza. Our researchs group includes: Alan de Oliveira Lyra, Arthur Ferreira de Souza, Beatriz Helena Neto, David Wagner Soares de Almeida, Diogo Vieira de Oliveira, Herbert Salazar dos Santos, Izandro Monteiro Metello, Jonathan Augusto da Silva, Leonardo Duarte de Almeida de Azeredo, Liliane Neves de Oliveira, Marcelle Ramos Panzariello, Rafael de Sant'anna Corrêa Nunes, Thiago Damasceno Souza, and Yuri de Oliveira Lima.

Please cite this publication as:

Barbosa, C.E.; Lima, Y.; Lyra, A; Santos, H.S. dos; Oliveira, D.V. de; Souza, A.F. de; Neto, B.H.; Almeida, D.W.S.; Metello, I.M.; Silva, J.A. da; Azeredo, L.D.; Oliveira, L.N.; Panzariello, M.R.; Nunes, R. de S.C.; Souza, T.D.; Souza, J.M. de, 2020. Healthcare 2030: A view of how changes on technology will impact Healthcare in 2030. Laboratório do Futuro – UFRJ, Rio de Janeiro.