Consequences of ICT-innovations on division of labor in health care – a socio-technical analysis of telemedicine

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Abstract. ICT-innovations provide a continuous stream of new possibilities in health care. In combination with medical technology they enable applications of telemedicine in several fields of medicine. This article analyzes selected published cases to explore different types of telemedicine and their impact on the division of labor in the context of globalization. The analysis is structured by the concepts of the mikropolis framework.

Keywords: ICT, innovation, telemedicine, health care, division of labor, mikropolis

1 Introduction

The ongoing development and implementation of ICT-innovations during the last decades had major influence on globalization. They enabled standardized global finance transactions within parts of a second and are the basis of worldwide supply chains. New ICT is also being adopted in the health care sector and drives the globalization processes there. Despite the tremendous changes of intra-organizational processes, especially in hospitals, the most important facet of ICT-use is discussed under the headline of telemedicine or eHealth. The simplest definition of telemedicine is: Patient and medical staff are not at the same place at the same time but they are connected by ICT. Within the last years diverse applications of telemedicine were developed and became an integral part of some working routines in health care today [1].

Scientific literature provides a variety of projects and evaluations of ICT development and implementation in the field of telemedicine. Some of them already have or are expected to have a notable influence as an enabling factor for globalization of the health care industry. The applications of telemedicine can be differentiated regarding the medical discipline (e.g. radiology, pathology, dermatology). In comparison, the diffusion of telemedicine varies between these fields. Today, teleradiology is the most advanced area while others like telesurgery are rather seldom used in common clinical processes. Effects on the division of labor can be found in published cases within each discipline as well as in articles that provide an overview of a field or telemedicine applications as a whole, but no systematical review on the effects of ICT enabled telemedicine on the division of labor has been published. The motivation of this article is to provide such an overview and to identify important factors and common structures among the analyzed cases. Therefore, the research question addressed in this article is: Which expected and realized consequences does the ongoing delivery of ICT-innovations in the field of telemedicine have on the division of labor in the context of globalization?

2 Method and theoretical foundation

The research presented in this article is a structured and qualitative analysis of select cases of the adaption of ICT-innovations in the context of telemedicine published in scientific journals. The selection of the cases discussed here was based on the following criteria: The case should describe a project setting with one or more organizations involved. These organizations should be globally distributed or the project should provide an outlook that it may be performed in an international arrangement in the future. Also, the cases should discuss the intended and realized direct and indirect effects on the division of labor, costs, quality of care, the patient-physician-relationship and the patient's perspective. In comparison, the cases should be most distinctive regarding these criteria and cover a broad range of ICT-applications in different medical fields. For this analysis a consistent analytical framework is needed which allows identifying the important aspects and their interrelation.

The mikropolis framework is a transdisciplinary framework for analyzing the reciprocal effects between ICT development and use in organizations and society [2,3]. It has been developed at the department of informatics at the University of Hamburg in cooperation with the mikropolis network [4] and has three pillars: First, it is used as an integral part of teaching (didactics). Second, it is used as a consulting tool within ICT-innovation and -implementation processes. And third, it is an analytical research framework for conducting transdisciplinary research. The analytical research framework is linked to fundamental social theories, such as Giddens's theory of structuration [5] and its adaption into IS research by Wanda J. Orlikowski [6,7]. Though it fundaments lie in sociology, psychology, political science and economics, IS research is the home of the mikropolis framework [8]. For the research question addressed in this article the model can provide a set of important aspects on the basis of its analytical concepts. In order to identify the changes in the division of labor the appropriate concepts and related research questions are derived from the mikropolis framework (see table 1).

Table 1 Analytical concepts and related research questions

Concept	Research question
actors / interests	Who is involved? What are his / her interests?
ICT-drivers	What are the ICT-innovations that enable a certain application in telemedicine?
socio-technical core	How is the ICT-based work structured?
micro-context	How is the interaction between users and developers of the ICT-systems structured?
macro-context	How do the processes of globalization and ICT-innovation-processes in health care affect each other? What are the guiding principles and ideas ("Leitbilder")? Which legal aspects and regulation in the health care system (e.g. financing) influence the development and use of ICT-Innovations? Do standards or standardization processes play an decisive role in the project?
formalization gaps	Are any preliminary or necessary formalization gaps affected?
historical perspective	Are there any aspects of a technology utilization path described that affect the current development?
innovation	What are the drivers and barriers affecting the adoption and diffusion of the telemedicine application?
division of labor	What effects on the division of labor are addressed directly or indirectly?

3 Analysis of selected cases

The eight cases analyzed in the following paragraphs have been selected according to the criteria mentioned in the preceding section. They cover different medical fields, use different technologies and lead to different consequences regarding the division of labor. Considering the tremendous amount of literature published in the area of telemedicine other interesting cases have to be omitted. Also, other aspects important to globalization in health care like trans-border-projects within the European Community or the global use of information on health care issues on the internet are not discussed here as they do not belong to the field of telemedicine in the stricter sense. As the division of labor is the main focus of the article, the medical outcome of telemedicine regarding quality of care, medical errors, and other factors cannot be addressed here in depth.

3.1 Teleradiology: Offshoring of image interpretation

The most common application of telemedicine is teleradiology. Modern medical imaging devices produce images in standardized digital formats. For several years the DICOM-standard [8] is now being supported by most imaging equipment. The images vary in size depending on the modality, examination type and body region. Conventional radiographs – especially mammograms – may be up to 100 MB in size, the data of the latest high resolution CT scanners can reach up to several GB per examination. The examination itself in most cases is not performed by the physician but by a radiologic technologist. The radiologist than interprets the images and writes a report on it. With the diffusion of picture archiving and imaging systems (PACS) and their integration into the radiology information system (RIS) the whole process of image distribution and report generation can be performed on the basis of ICT which enables the reporting physician to be at a remote location.

In the US and other countries hospitals begin to outsource the reporting on images [9,10]. The partners for this outsourcing may be located in the hospital's neighborhood (nearshoring) or even around the globe, for example in India (offshoring). There are mainly three reasons named in the literature, why this is done: First, as a result of the time difference between US and India, the radiologists in US may sleep at night while a colleague in India (also called "nighthawk") writes down his findings. Second, as the costs of labor in India are lower than in US, the hospital is able to save money. And third, it has been reported, that there already is a lack of radiologists in US which may as a result of an aging society increase in the future.

The perquisite for teleradiology is the digital availability of medical images. Data is generated by medical devices like CT or MRT-scanners and then transferred to a picture archiving an imaging system (PACS) where they are stored. To transfer the images to a remote location, a broadband connection is needed due to the high amounts of data. When patient data is communicated together with the images, the transfer also has to be secured. To view the images, appropriate displays with a high resolution are needed at least for conventional radiograms. Reducing costs is in most cases the primary interest of hospital management or the leaders of radiology departments that leads to the outsourcing activities. The other reason that is mentioned is the shortage of radiologists expected in face of the aging society. Teleradiology services are provided by companies who build their business model on it. Therefore they are interested in establishing and maintaining the division of labor. Indirectly the health insurance and the patient are involved in this scenario. Like in the pre-tele-era in radiology departments the activities of producing an image and reporting on it can be easily separated. With the easy of transporting digital images around the globe the process remains quite the same. When images are read by a radiologist in India and transferred back to US the report has to be checked and signed by the US physician. This is also called "ghosting" and is required for reimbursement, because only US health care organizations are authorized to issue an invoice.

The division of labor in teleradiology is mainly based on different wages in US and India for people with a comparable qualification. The argument of a shortage of qualified staff needs to be differentiated. It can refer to a lack of spending for further recruiting followed by a utilization of medical resources in another country. In the long run this can lead to a shortage in the low-wage country or to a loss of quality in care there because well educated physicians seek the opportunity of earning money with teleradiology. A condition that will remain to exist is the time difference and the possibility of enabling people work at their local daytime. Even when wage differences are reduced, this argument for offshoring of image reading stays valid.

3.2 Remote monitoring of intensive care unit (ICU) patients

While the reporting on radiologic images is an asynchronous process, the monitoring of ICU patients has to be performed synchronous. The monitoring systems used on modern ICUs capture a great variety of a patient's vital signs like ECG, blood pressure, oxygen saturation and temperature. These parameters are displayed on a bedside terminal and additionally can be transferred to a remote system. To keep a whole ward under control, modern systems use standard networks to providing a central console with the possibility to program alarms settings.

Diverse projects in the US tested, if a central monitoring center for ICUs with an expert physician for intensive care (intensivist) can provide better medical results [9,11,12]. Several hospitals today run their ICU without having an intensivist on site. The remote intensivist uses a console which allows him to look at the vital signs and the ICU's information system. This is augmented with a video and audio-link that can be used to watch the patient lying in bed. To keep in touch with the on-site staff, this equipment and a telephone can be used. A special vendor of this outsourcing equipment combines several existing technologies like monitoring equipment, digital radiography, audio and video conferences, interoperable HL7-based information systems and reliable network connections to enable an external intensivist to manage an ICU remotely. Besides the medical staff which is directly involved in the care process the scenario is also driven by the vendor of this system and the IT-staff on both sides. While the main interest of the IT-vendor is to sell his systems, the hospital management is interested in providing a cost efficient and high quality care. Especially larger hospitals see this scenario as an opportunity for growth.

The outsourcing of ICU monitoring establishes a clear distinction between the "normal ICU staff" and the professional intensivist that is underlined by the remote location. This combination of on-site and off-site work depends on the availability of all relevant data to the remote expert. A complex stream of data has to be transferred and interaction has to be enabled. As a result, the intensivist is a highly specialized person who may not have any direct contact with the remote patients.

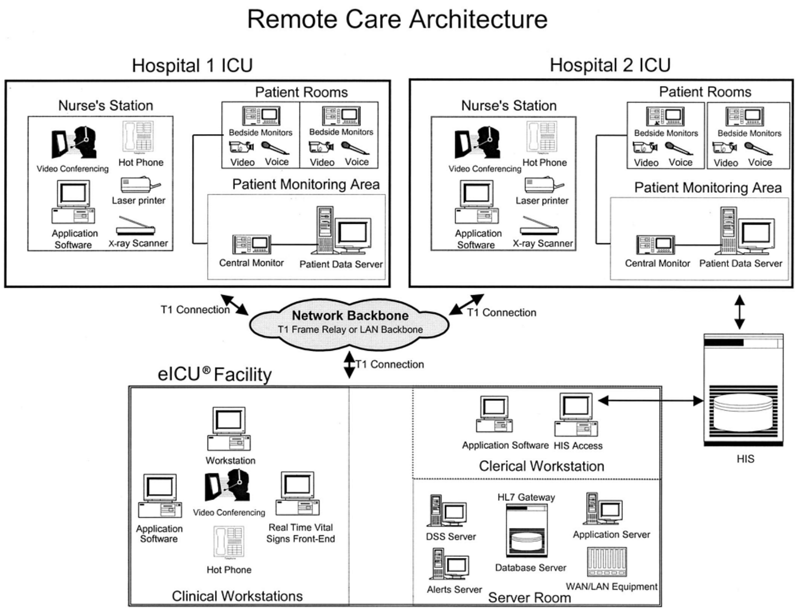

Figure 1 Outsourcing of ICU monitoring [11]

3.3 An international telepathology center as a part of cancer research

Telepathology is another telemedicine application that does not require the patient to be at the locus of analysis and reporting. A tissue sample is taken from the patient (e.g. in cancer diagnostics), prepared and afterwards digitalized with a camera. This photo can be transferred – together with a related question – to the pathologist, whether he is sitting next door or around the planet. Dietel, Nguyen-Dobinsky and Hufnagl report on an international center for telepathology [13]. The fundamental idea of this center is to provide a platform for other pathologists to acquire a second opinion on cancer material which is hard to assess. They can send or upload a photo of a tissue to the consultation center via Internet or E-Mail. Afterwards the center distributes the case and the related question to qualified international experts who create a report on the image material. The results are transferred to the requesting pathologists via the consultation center. This process is illustrated in figure 1.

The telepathology center is enabled by two technological drivers that have to be combined. To acquire the image in a digital format the requesting pathologist needs a digital camera that is appropriate to make a photo of the desired tissue section. To transfer this image to the telepathology center and further to the international experts, the internet is used (email or http-based transfer). The main new actor in this scenario is the telepathology center that acts as a broker to identify the adequate international experts regarding a certain question. The main interest of the physicians involved is to get a second or third opinion in a complex case. Additionally, a case database can be established that may be used to identify similar cases and as an eLearning tool or data resource for research. The involved ICT is based on standards and is easy to use. The asynchronous character of this scenario restricts its use to non-critical situations. As long as payments are not part of the cooperation, it is mainly based on the resources the international experts invest to keep this service alive. A motivation for this may be the possibility to use these cases for own research.

The telepathology center and the people requesting and reporting together enable a new division of labor. The center is a new actor that has to build up the needed technical infrastructure and keep it alive. It also has to recruit people that use the platform on one or both sides to establish a social network. The setting is an example for international expert sourcing and a center acting as a broker service. In the long run, it should be observed which capacities of pathologists are available for teleservices and if it is possible to create a business model for the central infrastructure.

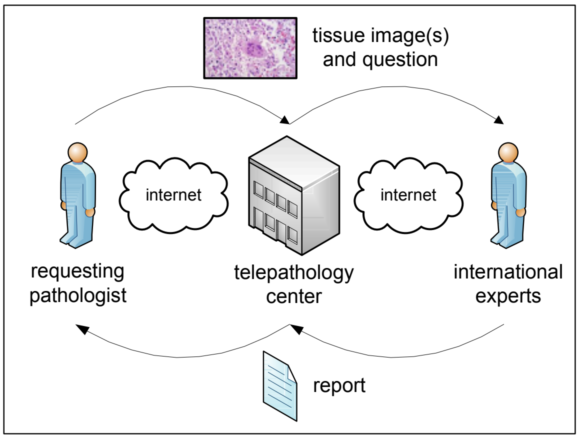

Figure 2 Telepathology center [according to 13]

3.4 Telecardiology and home care

In the field of cardiology a central goal is to improve the quality of life and to reduce the costs of patients with coronary artery disease and chronic heart failure [14]. The combination of appropriate medical devices for home use (ECG, body weight scale, blood pressure equipment) with data transfer to a telemedicine center and the 24/7-monitoring there aims at reducing the rate of hospitalization, improving the quality of live and saving money. The high frequency of monitoring which can be achieved when it is performed at the patient's home allows an early detection of degradation of the patient's health status. The telemedicine center can react to this situation by initiating the appropriate action which can be a phone call or the notification of an ambulance. As the cardiac diseases are widely spread, telecardiology can be part of disease management programs.

Telecardiology as described here is based on medical devices for home use that allow data exchange with a telemedicine center. To gather the data and manage the patients this center needs an information system that supports the processes and tasks within the center. The project described by Roth et al. is initiated by a health insurance company and the operating company of the center. They address the patients with certain heart diseases directly or via the general practitioners asking them, if they like to participate in telemedicine program. For the operator of the telemedicine center the whole scenario is the fundament of its business model. While the health insurance company seeks to reduce costs and improve the quality of care, the patients are interested in sustaining a good quality of live. Mainly two new ICT-related activities are getting important: First, the patient has to use the digital equipment at home properly, and second, the staff at the telemedicine center has to run the processes there that heavily rely on their own IS. The goal of reducing the rate of hospitalization has been achieved in this project.

Telecardiology as described here is only possible if the patient is able and willing to carry out telemedicine-related tasks at home regularly. He is doing a part of the diagnostic work on his own and gets a "working patient". The telemedicine center is a complete new type of organization which carries out the task to monitor and manage the patient's illness. A new division of labor is operative in this case. The "old" structures begin to work, when an ambulance is called and the patient is brought to a hospital.

3.5 Teledermatology

Teledermatology can be performed as an asynchronous store-and-forward or as a synchronous real-time application [15]. In both cases the patient and the dermatologist are at different locations. When using a store-and-forward technology, the process is asynchronous and an image taken from a patient's skin is transferred to a central system where it can be picked up by the dermatologist who analyzes the pictures and writes a report. In a real-time setting the patient is linked to the dermatologist by a teleconferencing system which is often augmented with additional equipment like a digital camera. The patient (and in some cases another physician) discusses the illness-related issues via the teleconferencing system.

While the store-and-forward-scenario is quite the same as in telepathology, the real-time application leads to another division of labor. The patient becomes directly involved in the diagnostic task and interacts with a remote physician via teleconferencing system. As the general practitioner may be involved at the patient's location or not, two different settings can be differentiated in the real-time scenario. When the general practitioner is involved the session is also a medium for eLearning as he is working together with a specialist to discuss the patient's illness. ICT-drivers in this scenario are either internet applications (store-and-forward) or teleconferencing systems and digital cameras integrated in the system. Both scenarios are used to benefit from the diagnostic capabilities of a remote expert. This is especially useful for general practitioners who can use this system to make a better diagnosis without sending a patient to a remote physician. The division of work in this setting is based on the different skills of the physicians involved. Like in teleradiology and telepathology it is possible to send the required data that can only be collected in the presence of the patient. In the case of teledermatology this is even easier as in some cases a standard digital camera is sufficient. This aspect also enables a scenario in which the patient can take a photo at home and send it to a remote physician without going to a doctor's practice.

3.6 Telesurgery

There is a great variety of possibilities for physicians to get involved in remote operations [1, 16]. The simplest way is a teleconsultation or telementoring connection. The most complicated and technical advanced way is remote or virtual-presence surgery where a physician can control the instruments at a remote site. The higher the degree of remote involvement the more challenging it is to provide the appropriate technical infrastructure (reliable and redundant broadband connections, robotics, etc.). Several cases showed that telesurgery is possible but until now it is not widely spread.

Telesurgery is the most time-critical application in telemedicine and requires reliable and redundant network connections. As a break-down during a surgery can lead to a problematic situation additional physicians should be at the place where the patient is. While for teleconsultation or telementoring only a teleconferencing system suitable for the operation room environment is needed, real telesurgery demands complex robotic systems. Telesurgery is mainly a substitute for a travel that an expert could do instead. During the operation the surgeon does not save any time, it is more likely that remote operations will need longer than local ones. Until now it is unclear how "real" telesurgery can contribute to health economical efficiency. The situation may change if robotic systems will be able to perform an operation on their own.

3.7 Webcasting, teleconsultation, and other applications in a telemedicine network between Europe and Africa

Telemedicine is also used to link European institutions and African physicians as a part of foreign aid programs. While the core of the RAFT-Network is the Geneva University Hospitals, the partners are located in 10 French speaking African countries [17]. The main telemedicine application within this network is the webcasting of interactive courses. It is complemented by teleconferences, teleconsultations and other activities that aim at knowledge transfer, quality and evaluation.

A circumstance shaping the RAFT-project is the low bandwidth of internet access in many regions of Africa. Webcasting technology used in this project is build to work under such conditions. The available technology is used by hospitals in Geneva to share self created eLearning content with physicians in African hospitals. As the content is being developed in French, the partners should be located in francophone countries to avoid a translation and to enable easy communication. The whole setting is driven by the will to transfer medical knowledge to underdeveloped regions and to provide a continuing education. The technologies used enable this in a cheap way.

While differences in medical knowledge between regions in the world continue to exist the task to "transfer" it to the unprivileged countries remains. The project described here can also be understood as help to self help as acquired knowledge can be spread at the remote location once it is "transferred".

3.8 Aerospace medicine

The International Space Station (ISS) has a multipurpose ultrasound system installed on board. It can be used to perform a "focused assessment sonography for trauma" (FAST) [18]. The study of Sargsyan et al. showed that a remotely guided FAST examination is possible with excellent clinical results and speed. The technical setup in this study had to deal with 2-second communication latency and reduced video frame rate. The astronauts at the ISS, the assisting ground physician and the space agency are relevant actors. Since people went off to space it has always been a task to providing them with medical services. The scenario under consideration showed that sonography equipment can be used in a real-time application. It may be generalized to a setting where the patient is far away and only connected via satellite.

The work needed to perform this diagnostic task is divided between the astronaut in space and the physician at the space center. With increasing distance between earth and the astronauts, latency will rise up to a limit where real-time applications will not be an option. The international cooperation to provide health care for astronauts in space will get more important when a moon base is established or a spaceship starts towards mars.

4 Consequences of telemedicine on global division of labor

As a result of the analysis the effects of ICT-innovations on division of labor can be summarized. Altogether, nine patterns of division of labor can be identified in the cases: brokers or telemedicine centers as *new actors*, *offshoring* due to lower wages or time difference, outsourcing as *nearshoring* due to shortage of staff and costs, *second opinion*, *knowledge transfer*, *expert help* for other physicians, *patient as co-worker*, and cooperation in *space projects*.

There are some dimensions that turned out to be crucial to evaluate the impact of ICT-Innovations in telemedicine on the division of labor. The first aspect to be mentioned is the basis of the prefix "tele", the *spatial distance* between the patient and the physician. Though every kind of data can be transferred to any location in the world within seconds as long as the network in between is stable and fast enough, the spatial distance is not irrelevant. The need of getting into personal contact with each other may still be an important aspect hindering a global distribution of activities. The spatial distance is directly related to the crossing of national borders. When activities are relocated to an organization in another country, a whole bunch of problems arises (law, language, reimbursement, etc.).

The second important dimension is *qualification*. To perform certain activities on a defined level of quality special qualifications may be needed. Ensuring the capability of involved people can be supported by institutions like certificates and accreditation. A consequence of telemedicine may also be a high specialization ("superspecialization") of physicians regarding a dedicated field of medicine.

The third dimension is the *technology* required to realize the setup of a telemedicine environment. With different kinds of technology varying types of telemedicine can be realized while each requires different skills by the people using it.

Additionally, the *language* barrier remains an important aspect in medical outsourcing. Though the vision of "semantic interoperability" [19] is being intensively researched at the moment and tackled in concrete projects, until now it is far from being a solid bridge across the trench. On the one hand, outsourcing is easy when the native language of one country is understood by the remote partners like in the teleradiology projects with India. On the other hand, medical translation services can enable a cross-language interaction [20]. Of course, the utilization of a translation service generates additional costs and needs extra time.

It also becomes clear that globalization in the context of telemedicine has different dimensions. The teleradiology case shows how a clearly defined and formalized service can be *offshored* to another country. Communication between experts in the second opinion scenario may be considered as *globalized research* as long as special cases are discussed and published like in the telepathology case. In the telecardiology scenario described in the case the service itself is provided with a national focus, but the operator of the service center is an *international company*. Two other aspects of globalization were addressed in the last cases. The first demonstrate telemedicine as a part of *knowledge transfer to a developing country* (help to self help), while the second shows the *international cooperation in space projects* like the ISS which are also examples of global research projects.

Despite the consequences on division of labor the division itself again influences other factors. Many applications aim at reducing costs by offshoring a part to a country with lower wages. The productivity is affected when expert knowledge can be made available when and where it is needed. Experts in health care may develop to "super experts" focused on a small niche of medicine ("superspecialization") and a patient may have to take an active part in his home environment ("working patient"). On the level of nations the health systems actors may find to new forms of worldwide cooperation and create a new area of competition.

Starting with the question of how the latest ICT-innovations effect the division of labor in the area of telemedicine it turned out that different fields of medicine are more or less suitable for the adoption of outsourcing and offshoring. In many cases the diffusion is not hindered by technical aspects like bandwidth or missing functions, but by the difficulties arising in the field of law, liability and reimbursement. Both systems tend to be slow reacting and a hindering factor to the diffusion of new applications of telemedicine. These aspects are discussed in the next section.

5 Outlook on future research and political issues

Patients' self-determination should be kept in mind during the projects and discussions ahead: Do patients have the freedom to choose whether they are diagnosed and treated by a local or a remote physician? Or should the patients at least be informed in case a remote physician is involved in the process? Or will decisions of who performs which activities in the patient treatment process be made behind the scenes? This is not only a question of legislation but also touches the qualifications (understood as a "layer of abstraction") and the patients' autonomy. The acceptance of patients for the outsourcing of medical activities should be continuously monitored and set into relation with cost savings and improvements in care. Regarding the research on telemedicine it will not be enough to reduce the patients' role to the aspect of "acceptance" [21]. Whether a patient "accepts" a new technology (while being directly affected by it or not) is far less important than the aspect of self-determination. It seems to be an important question in the future, if and how the patients' will can be integrated in the globally fragmented health care processes of tomorrow.

The telemedicine of tomorrow will be much more pervasive and based on standard technology than today. "Assisted living" at home and portable insulin pumps connected with a telemedicine center are part of reality today. Step by step ICT advances closer and closer towards the human body to create "body-area-networks" [22]. The experience mankind made with ICT in the past showed that security and safety should be considered in the first drafts of a new system and get a part of the whole development and use cycle. Otherwise, it will be health and not data that is attacked by worms and Trojan horses.

As more and more medical devices produce results as digital data which can be transferred to any place in the world easily and quickly, the influence of telemedicine is expected to rise in the future. The examples discussed in this article show that costs of telemedicine use depend to a high degree on how standardized and therefore interoperable the systems are. To foster the global diffusion standard setting should be pushed forward. The DICOM-case is a good example of how a globally used standard can be developed and brought into practice. Research should tackle this big issue – standards – together with the economic and political system. Standards are needed to enable interoperability of technologies and to make (tele-) medical services and skills comparable. Other parts of the fundament beside the standards for a diffusion of telemedicine are laws and the reimbursement rules by public health systems. Today, the national health care systems are so different from each other that a transfer of telemedicine applications from one to another may not be possible due to different structures and legislation [23].

More high quality research on the interrelation of telemedicine, quality of medical treatment, costs and the division of labor should be conducted to research the success factors and barriers of medical outsourcing and cooperation in a global context. Only when the broad diversity of factors and their mutual influences are taken into account, the transition of medical treatment to a globally distributed setting can be understood and designed purposeful. With the diffusion of medical equipment to the patients' home these settings also include non-professional contexts. Progress in science and technology development also challenges the role of people in the medical processes. Advances in the processing and analysis of medical images may one day lead to the question whether the reporting is done by a cheap offshore center or by an image reporting program. The procedure of "ghosting" may be kept alive in such a setting to ensure the liability of a "real person". But the goal of further automation and the advances in image processing will challenge cheap labor in the future. The introduction and use of such systems should be monitored by exhaustive research to ensure the quality of care.

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