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Review

Telemedicine and its impact on cancer management

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Abstract

The latest dramatic progress in the technologies of the computer industry is likely to increasingly influence the oncologist's daily routine. Besides well known and established telemedical services such as videoconferencing, the most influential trends are the spread of digital hospital infrastructures with unlimited, secured access to all relevant patient information. This article seeks to summarise the most imminent influences of telemedical developments on the future of the oncologist: the effects of telemedical services and electronic infrastructures on clinical workflow and on medical quality management. In addition, the history of telemedicine, recent technologies and the performance of electronic patient records are described.

Keywords: Telemedicine; Oncology; Quality management

1. Introduction

In the past decade, the term telemedicine has evolved from describing some abstract, rather experimental approach to a serious technique merging conventional medicine with modern technology. From 1960 to 1980, the first 'real' telemedical applications highlighted interactive visual communication between healthcare professionals for consultation or training, sometimes with rather artistic applications linking specialists from all over the world to find a joint solution in a single patient. The dramatic progress in computer technology has fostered a more holistic view on informatics in medicine: to process and distribute all relevant patient information electronically. In contrast to the anecdotal use of telemedical applications up to a decade ago, current telemedical developments imply fundamental changes in the medical professional's daily workflow by delivering electronic patient records and enabling free access to them. In addition, decision support, quality assurance or other data processing services added on to these digital infrastructures also target improved treatment outcome and efficiency of disease management. This article describes the most imminent influences of telemedical developments on the future of the oncologist.

2. Telemedicine: from past to present

In 1998, the World Health Organisation (WHO) defined telemedicine as

> " ... the delivery of healthcare services, where distance is the critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of healthcare providers, all in the interest of advancing the health of individuals and their communities."

Based on this definition, the earliest documented telemedical treatment dates from the year 1666, with a physician examining a plague patient from the opposite side of a river, minimising his risk of infection [1]. During the 19th century, postal communication with a physician was not uncommon, with the diagnosis and a prescription returned by the medical professional upon written description of the patient's symptoms [1]. With the emerging electronic age, telegraphy was the first means recorded to deliver distant medical support: in 1917 in a rural area of Northwest Australia, a postal official was instructed to perform a cystostomy on a

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patient with severe pelvic injury [2]. With the growing success of the telephone in the 20th century, distant home care by phone gained reasonable attention; in 1964 first reports of data transmission via the telephone described set-ups for remote ECG monitoring [3,4]. In 1959, the first functionally interactive televised medical programme was used at the Nebraska Psychiatric Institute, USA to conduct regular group therapy sessions [5]. In 1968, Massachusetts General Hospital, USA established a videolink to Boston's Logan airport, and more than 1000 patients have been examined using this link [6]. The first true telemedical network servicing 10 rural sites in Vermont and New Hampshire, USA with consultation and tele-education dates back to December 1968 [7]. In the years following up to the late 1980s, a rapidly growing number of telemedical pilot projects were introduced to the medical community, most of them focusing on teleconsultation or tele-education for potential delivery to medical professionals in rural areas. However, since at that time the equipment necessary was equivalent to a television studio, tremendous expense in hardware and network communications never permitted distribution of such services outside projects funded by public or industrial grants [8].

Following the natural and sometimes unfortunate barriers in medicine, increasing performance and decreasing costs of computing and networking equipment has led to distribution of telemedical activities mainly within the limits of medical subspecialties during the late 1980s and early 1990s, i.e. teleradiology or telepathology [9,10]. Specifically technology-driven radiologists have demonstrated keen interest in these new applications, usually by practising remote consultation services through videoconferencing [11]. As a result, teleconsultation in radiology has been the first telemedical service to be fully reimbursed at least in the USA.

During the past decade, the vision of telemedicine has changed radically. The success of the Internet and, more importantly, of its standardising, powerful and inexpensive technology, has enabled the development of universal hospital infrastructures. The electronic patient record, as rudimentary as it may look in most institutions today, is easily accessible through integration concepts i.e. based on the technology of the World Wide Web [12,13]. As a consequence, electronic patient information distribution in- and outside the hospital has become possible, with a suspected dramatic impact on medical workflow: the wave of electronic data management as implemented in commercial businesses since the 1970s has finally caught up with the physician on his rounds.

Hard on the heels of these developments, again mostly triggered by the success of the Internet, the idea of new business ventures offering telemedical services may be seen as the latest trend in medical informatics, bringing the telemedical century back to its roots of remote care and consultation. Telemedical services may be divided into primary and premium services. Primary services have widely been accepted by patients and medical professionals, offering distribution of general medical information through the Internet. Considering interactive premium services, only teleconsultation and remote diagnosis in radiology have officially been accepted by health insurances in some countries for reimbursement. Other premium services such as remote image processing, remote image fusion, remote three-dimensional (3-D) surgery or radiation therapy planning, or even remote data archiving do not yet play a significant role [14].

In conclusion, the maturation of telemedicine during the last century has come full circle: with the dawning of the electronic age, fancy programmes delivering costly interactive television applications led the way to projects limited to medical subspecialties, mostly offering visual telepresence of specialists to rural areas or within educational programmes. A further holistic view on the management and distribution of medical data has recently been made possible through inexpensive technologies promoting complete hospital information infrastructures, promising potentials in workflow optimisation and productivity increases. Finally, attention is moving 'back' to new, high-tech telemedical services, ranging from the universal telepresence of the medical specialist to applied virtual reality for education and training.

3. Digital hospital infrastructures: the merger of traditional medicine and information technology

A key factor in the establishment of telemedicine or electronic data management in patient care is the existence of digital hospital infrastructures. The overall objective is to make the actual patient information accessible and transferable in digital form. Preferably, this is achieved by more or less complete electronic patient records. The major problem in implementing such a universal health record is the complexity of modern patient care: all patients treated in hospitals undergo multidisciplinary treatment including laboratory or radiological examinations, and usually have received previous diagnostics or treatment by other practitioners or healthcare institutions. The data forming a patient's history tends to be extremely heterogeneous, with respect to both its varying origin as well as to its multimedial appearance: a complete patient record consists of textual, graphical, image and even video information. During the past 5 years, an increasing number of concepts have been presented to the medical community. Most of these models offer an integration of the digital information sources already existing in a given hospital. Two main factors account for the dynamic progress in this field of research: firstly, standardisation efforts of the past few years have generated a universal communication standard in medicine which is HL 7 [15]; in medical image communication, DICOM has evolved as the standard ensuring the consistency of further developmental work [16]. Secondly, through Internet technologies the medical software engineers have advanced tools for information distribution. Major advantages of Internet tools and standards for information distribution is their availability in most doctors' offices and, of crucial importance, their independence of specific computer platforms. However, even though hospital information systems have successfully been implemented in all modern hospitals in western Europe to facilitate patient administration and billing, patient records carrying the actual medical content are still incomplete in most cases or limited to departmental subsystems. Besides the problem of integrating preexistent departmental systems that, to make things worse, often communicate in some proprietary 'standard', networking facilities are frequently underdeveloped in hospitals which have been designed before the era of medical informatics, and necessary investment in network infrastructure is usually high.

Confronted with the need to establish information technologies in the personal clinical environment, the oncologist's key objectives, as well as his objections, have to meet the following criteria: performance, security, efficiency and validity.

3.1. Performance

As previously mentioned, digital hospital infrastructures ultimately intended to form or support an electronic patient record, suffer from high complexity, both technically and with respect to the data volume to be covered. Most of the recent applications favour the use of Internet technology for access to the data [17–19], and HL7 as the integration module [20–22]. In addition, CORBA (Common Request Broker Architecture) has attracted increasing interest as integration middleware for medical or other subsystems. CORBA defines standardised interfaces to 'Object Oriented Services' across most usual platforms, and it is available in the public domain [23–26]. Integration middleware as described may well form the basis of an electronic patient record; in most cases, it is the lack of financial resources restricting realisation of more elaborate concepts including a master function of the hospital information system (i.e. to ensure unique patient identification from the moment the patient enters the hospital).

The bottleneck of such a system's performance (outside the appropriate user interface and the general feasibility of the application [27]) is usually the network infrastructure behind it. This is especially true if the infrastructure in question is also intended to transport radiological images which may easily make up over 90% of medical data. However, when discussing the performance of electronic systems in general, careful comparison with conventional data handling is necessary. In studies analysing conventional versus electronic archiving in radiological departments, time savings of up to 1 h were measured for the completion of a computed tomography (CT) study since allocation of previous examinations tends to be time-consuming (or even unsuccessful at times) in conventional archives [28,29]. When a new network infrastructure is to be built, it is advisable to add high bandwidth applications such as B-ISDN in areas of extensive data traffic (i.e. from the radiology department to intensive care units) [30]. With the latest generation of desktop PCs, no differences in the computing speed of high-end workstations apply, and functions requiring the highest computing capabilities such as postprocessing of computed radiographs do not suffer substantial time delays due to hardware restrictions.

3.2. Security

Privacy of data is one of the most important issues to be addressed when applying electronic infrastructures in a medical environment. Authorisation by login and password is usually sufficient to regulate access to the system within a closed infrastructure such as a hospital network; however, identification of a caller's address or phone number is mandatory if external access is sought. Once logged into the system, server administration must ensure role-based navigation, to prevent review of records not directly related to the physician seeking access. Documentation of access to the system and, most important, documentation of changes to a patient record as well as the time they took place is essential to ensure the integrity of an electronic patient record. In most European countries, legal authorities have accepted digital signatures, thereby enabling paperless data handling and transmission between medical professionals [31]. For transmission of medical data over public networks such as the internet or ISDN, encryption of data, already highly recommended today, is likely to become mandatory in future [32]. No authoritative indication has been given yet if 40 bit encryption as supplied by SSL (Secure Socket Layer) which is associated to common web-browsers is sufficient. As an alternative, IPsec (Internet Protocol Security Architecture) with 128 bit encryption may be provided; however, additional software installation is required by the client and server, and the speed of transmission suffers from extensive encryption or decryption delays in cases of high data volume such as images [33,34]. Services offering the administration of encryption ('trust centres') with private and public keys for encryption and reconstruction have successfully been tested in initiatives funded by the European Commission [35].

3.3. Efficiency

The most prominent keywords in publications evaluating the effects of telemedicine in clinical settings are 'quality assurance' and 'workflow management'. Quality assurance summarises benefits to the individual patient and thus to the overall healthcare system through delivering standardised care at the highest level at all times. In a world of boundless communication, distribution of standards in patient treatment is followed by cross-checks for consistency and plausibility of treatment data delivered by a hospital or practitioner. Some studies, usually working on a single specific disease, have already demonstrated the effects of close quality control without applied electronic infrastructures [36–38]. It seems obvious that the simplification of medical information flow through telematics will foster improved results in quality assurance.

The other keyword attracting increasing interest in research into digital infrastructures in healthcare is 'workflow management', implying modifications of the physician's routine in patient treatment. In general, the physician's routine in most medical specialities has not undergone major changes within the last 100 years; however, looking into commercial businesses and the effects electronic data management has had on them, dramatic changes may be anticipated in the medical field once data handling has been transformed to the electronic mode. Consequently, tools such as the Critical Pathway Method (CPM), approved in economics rather than in medicine, are being used more frequently to identify key elements and drawbacks in patient management [39]. In principle, even small steps such as the implementation of digital speech recognition have already proven considerable effects on workflow improvements and efficiency gains [40]. More complex decision support systems, still under research, help also to improve the workflow as they have demonstrated positive effects on quality assurance [41–43]. However, it should be clear that in as far as electronic applications have to keep up with the physician's needs [27,44,45], it is in contrast unavoidable that the physician has to adapt his workflow to digital infrastructures to gain optimal results [46].

3.4. Validity

It is quite obvious that, whatever electronic patient record is retrieved or some interactive telemedical service is used, the data in question have to be complete and, with radiology or pathology examinations, image data have to be of appropriate quality for review. Aspects such as integrity of data, documentation of changes and digital signature have been discussed in the security section. Validity of medical images is a concern if suboptimal viewing applications such as regular desktop PCs are used for diagnostic review or if lossy compression techniques are applied to cut transmission time at low bandwidth. These restrictions specifically apply to images with high bits and low image noise (such as computed radiographs with $\geqslant 10$ bits); CT, magnetic resonance imaging (MRI) and angiograms, as well as colour images from pathology show higher tolerance to decreased display quality [47,48]. Consequently, concepts for access and visualisation of electronic patient records (which usually do not contain pathology slices) foresee high-end workstations in areas where diagnostic quality is essential (i.e. the radiology department, emergency room), and inexpensive low-end PC viewing stations for simple image review and verification (i.e. wards, outpatient clinic). Diagnostic image review is likely to suffer from strong lossy image compression; however, showing that moderate lossy compression usually does not endanger diagnostically valuable image information, one may consider leaving the decision whether a compressed image still has acceptable quality to the radiologist responsible for the diagnosis. There is certainly wisdom in this since in all radiological examinations today, some radiologist acknowledges the final image's quality based on rather subjective impressions anyway (including hard parameters such as exposure time, film or digital image processing...). Moreover, under certain circumstances lossy image compression such as by wavelets may even lead to better diagnostic accuracy through a reduction of image noise [49,50].

4. Quality management by telemedicine in Europe

European healthcare systems are under considerable pressure. The demographic profile of the population is changing. More people need treatment, and new and expensive types of treatments are being developed. The average spending on healthcare in Europe is approximately 7–9% of the gross domestic product (GDP) [51]. Although the spending has more or less doubled as a proportion of the GDP over the past thirty years, there is a growing demand for a reduction in the cost of healthcare services and for an improvement in the quality of the treatment.

At present, there is a growing public awareness of healthcare, resulting in an increasing pressure on government healthcare officials to enable access to the best available treatment at a reasonable price. Several times over the past years, publications in the lay press in the UK, Germany, France and Holland have illustrated the differences in treatment outcome of cancer patients between different hospitals, regions and countries. For example, the *Sunday Times* (UK), 14 June 1998:

"Sufferers from prostate cancer, which affects 13 000 men a year, are almost twice as likely to die within five years if they are treated in Bexley and Greenwich health district, south London, compared with those treated in Kensington, Chelsea and Westminster less than 10 miles away".

To overcome this problem, clinicians and hospitals need to invest in and implement computerised methods for quality management in daily clinical practice.

If the quality of patient care is improved the citizens of the European Community will gain considerable benefits, medically as well as economically. It is estimated that if state-of-the art cancer treatment based on the latest, internationally validated treatment methods is fully implemented on a European scale, improvement in survival rates will range from 5 to 10%, meaning that potentially 90 000 to 180 000 lives can be saved each year in the European Union. These results can be reached by means of real-time, computer-assisted monitoring of both staging and treatment procedures (pathology, surgery, chemotherapy and radiotherapy) which offer optimal treatment.

It is anticipated that the number of patients with severe complications after cancer treatment will be similarly reduced. In addition to these quantifiable benefits there are the social and psychological benefits for the patients involved, which — although difficult to quantify — are substantial. Therefore, there are considerable economic, medical and social incentives amongst the users in the healthcare professions and healthcare administrators to prioritise investment in and procurement of computerised methods and systems which can bring about such considerable improvements.

A typical example of the benefit of quality management has been observed in two major trials of the Radiotherapy and Breast Cancer Clinical Co-operative Groups of the European Organization for Research and Treatment of Cancer (EORTC), executed in nine European countries. The results indicate that the large variations in treatment outcome, shown in a previous trial to be between 4 and 32% of local recurrences at 5 years, could be considerably reduced in a subsequent trial [52].

On the basis of the above facts, the participants in an European Union funded project, CONQUEST — Clinical Oncology Network for Quality in European Standards of Treatment — saw the challenge in improving the quality of healthcare. They sought to reduce or eliminate the variations in recurrence and survival rates for patients after cancer treatment, which are known to exist between and within the EU countries, by developing computerised generic quality management systems [53].

An important outcome of the CONQUEST project is the development of the conceptual framework as well as the definition of the basic medical content of a quality management support system. Based on this system, the CONQUEST Quality Management Support (CQMS) demonstrator was developed. The CQMS consists of three modules: a basic Electronic Patient Record (EPR) module, a registration module and a quality management support functionality module as well as an image processing tool.

The basic EPR module takes care of the more general aspects of an electronic patient record such as database operation, data protection, user administration, authorisation, administration of patients, providing historical accounts of patient data, print facilities, archive of new documents and shredding of documents.

The main goal of the registration module is to provide a tool that works in daily clinical routine. It allows the clinicians to prospectively document clinical data during the diagnostic process and the course of treatment of breast cancer. Its use also ensures high quality data due to prospective data entry and it covers documentation of clinical data generated during the course of (breast) cancer treatment including medical events such as preoperative outpatient clinic, radiology, cytology/pathology, surgery, postoperative outpatient clinic, radiotherapy, chemotherapy, hormonal therapy and follow-up. It is important to note that rationales for decisions as well as prescriptions and reports on the treatment performed on the patient are documented.

The quality management support functionality module supports three types of functionality; concurrent audit, quality surveillance and retrospective audit (Fig. 1). This module is the essential CQMS core giving clinicians support in the quality management process during the diagnostic process and in the course of treatment of breast cancer, and it provides a tool for quality performance in relation to specified quality indicators. The modules developed support concurrent audit, retrospective audit and quality surveillance. Furthermore, a decision support system for individualised prescription of postsurgery therapy in breast cancer patients has been developed (BreastScan).

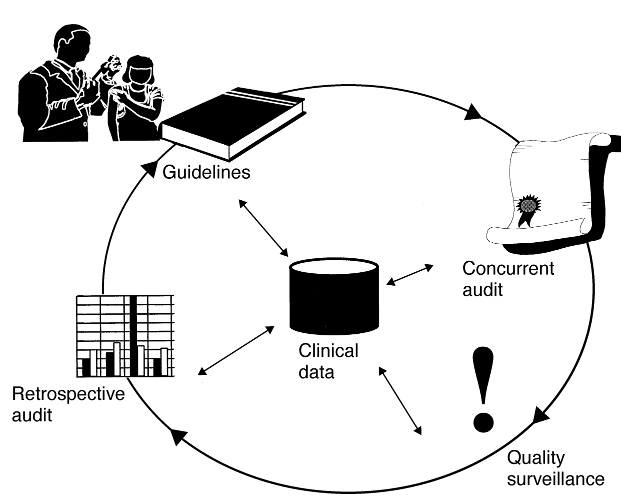

Fig. 1. The CONQUEST integrated quality management system.

The main purpose of the work was to provide non-oncologists with an effective tool for the management of breast cancer patients and to provide a useful and effective teaching instrument for oncologists in training and oncology nurses. The system allows individualised therapy based on patient-specific characteristics and tumour biology and extension. Recommended regimens are updated, easily applicable even in small non-specialised centres, do not require sophisticated technology or special expertise to be administered and allow results in terms of overall survival and local or distant control of relapses largely comparable with more aggressive and toxic combinations. In order to use this system over a large number of hospitals it needs to be adapted to the local hospital information system.

Within the same project, image registration tools have been developed in order to link the EPR to the images obtained from diagnostic and therapeutic procedures for a particular patient. With the image registration tools it is possible to match MRI and CT scans for the use of radiotherapy planning, for example in prostate patients. It also allows assessment of the accuracy of radiation delivery in individual patients during their treatment. Off-line quality assurance [54] is now carried out using these tools in a multicentre phase III randomised clinical trial for prostate cancer randomising between two radiation dose levels (68 versus 78 Gy).

For on-line review and teleconsultation the 3-D image viewer and image registration module with DICOM access has been developed (Fig. 2). This allows clinicians and technologists in radiology and oncology to operate interactively with 3-D image information. The viewer component may be integrated in many products, due to its OLE and VCL (Borland) interface. The component is specifically aimed at image fusion of CT, MRI and positron emission tomography (PET) images. It supports interactive 3-D image re-slicing, measurement tools, various image cutting and overlaying options and supports all common integer and floating point data formats in black and white and colour.

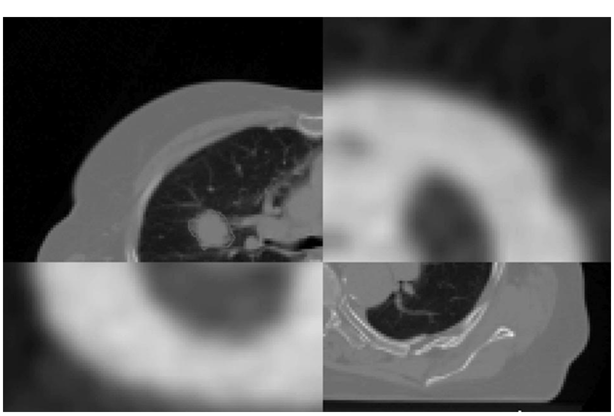

Fig. 2. Matching of CT images with PET scan and tumour delineation facility.

5. Future visions for telemedicine in cancer treatment: from workflow management to telemedical services

How will telemedicine influence the oncologist's future routine? As previously outlined, only the universal spread of digital hospital infrastructures can trigger the efficient use of electronic data handling, in other words: the prerequisite for medically efficient and economically justified use of telemedicine is a digital infrastructure in healthcare. With the electronic patient data at hand in the family practitioner's office, the outpatient clinic or in the ward, the physician's means to actively optimise patient management according to international standards ('Evidence based medicine') are truly increasing. In addition, electronic data handling allows mechanisms for quality control, ranging from context-sensitive data brokers analysing an individual patient's course of disease to treatment outcome statistics for a particular health institution. This will offer the patient an optimal treatment scheme even if he or she is living in a remote area. In addition, as previously mentioned, it is expected that improved treatment quality will result in a 5–10% higher survival rate. This expectation can be supported by the results of a study in Denmark in which it has been shown that a significant reduction of the local recurrence rate in patients with breast cancer has resulted in a 9% improvement in the 10-year survival rate [55].

The second advantage of digital hospital infrastructures accessible from in- and outside a hospital is the expected impact on medical workflow management. Once the interaction between medical professionals themselves or a physician and the patient can easily be analysed, better planning capabilities, optimal analysis of bottlenecks in a patient's treatment course and the detailed evaluation of problems leading to pathway failures (Fig. 1) are within reach.

Once natural use of digital information sources is adapted by a broader medical community, new and truly visionary telemedical services are likely to spread dramatically. Today, USA figures in particular, imply increasing telemedical interactive service usage. The number of teleconsultations in the USA grew from approximately 5000 in 1995 to over 40 000 in 1997 [14]. This trend is supported specifically by studies about patient satisfaction with teleconsultations [56,57], whereas clinical data of treatment and efficiency improvements is often rather suggestive than conclusive due to a lack of randomised trials [58]. However, economic market research does foresee yearly growth rates for telemedicine of up to 35% (overall healthcare growth rate expected at 3% in the USA); the USA market for telemedicine is estimated to reach $3 billion by the year 2002 based on the high growth rates of leading market segments and an assumption that full reimbursement for telemedicine services will continue to become more common [59]. Europe and the Pacific Rim combined may represent cumulative telemedicine expenditures of 1.4 billion Euros by 2001 [60].

However, in contrast to the use of the Internet as a source of information specifically for patients themselves, interactive telemedical services today are not yet accepted as part of the clinical routine. However, in the near future with universally networked hospital information sources, businesses will be created offering commercial services such as remote archiving, remote trials administration and management, advanced remote radiation therapy planning and image processing, virtual reality for education and training, or other services that offer resource sharing as their primary benefit. Many of the technologies needed to perform these services are already available [61–65]; in times of limited resources, political vision and courage are needed to foster investments in the underlying digital healthcare infrastructure. Until that moment, the most impressive effect of telemedicine will remain the informed patient, entering the physician's office with Internet recommendations about the appropriate treatment and which hospital to consult.

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