Teleradiology: Evolution and concepts
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A B S T R A C T
Teleradiology has become a reality for several years now, but its existence still has not been freed from all controversies. From the beginning the military has been the driving force for teleradiology. Today teleradiology has many purposes worldwide ranging from services for expert or second opinions to international commercial diagnostic reading services. Ten years ago image quality, transmission speed and image compression were important issues of debate. Today the focus is on clinical governance, medico-legal issues and quality assessment. The increasing use of teleradiology reflects the changing world of clinical practice, service delivery and technology.

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1. Introduction
Teleradiology is often defined as the electronic transmission of radiographic images from one geographical location to another for the purposes of interpretation and consultation. The increased development and deployment of digital imaging systems and the quickly increasing availability of high bandwidths allowing transmission of large data volumes at high speed have dramatically widened the scope of this medium. Teleradiology has been subject of a number of health technology assessments in different countries with regard to the context of use [1–4]. Advantages and disadvantages have been described extensively. Nevertheless other important aspects of teleradiology such as clinical governance, medico-legal issues and quality assessment, have not yet been studied in great depth. Looking in the future the distinction between PACS and teleradiology will be blurred and virtual organisations with distributed capabilities can become reality. In this article we will describe the ongoing debate about teleradiology.

2. The beginning
Teleradiology was first developed for military purposes. Field units could send radiology images to hospitals at the home country for diagnosis and further patient management. The first commercial teleradiology systems in the eighties worked with camera systems or video-grabbed selected hardcopies for subsequent digitized image transfer. An improvement was the introduction of the laser digitizer, which also had the disadvantage of being able to handle only one image at a time. In the mid-eighties the first generations of PACS were installed in the medical environment for clinical evaluation. It soon became clear that the change from analogue to digital processing of medical images could change the workflow dramatically [5]. Teleradiology had become a reality, but it took another ten years before the relatively low performance and high costs of the computer systems available at that time would develop into feasible applications. Besides the lack of affordable image handling systems the high cost of data transmission was also a serious hurdle hindering a more widespread implementation of teleradiology. However during the last decade most technical limitations have resolved thanks to the widespread introduction of digitization processes in radiology practices and the low cost of Internet communication [6]. In the early days, when the analogue–digital conversion of video signals was being used for capture of cross-sectional images, the preservation of image quality was an important issue. To improve transmission speed several data compression techniques were used and analysed. These remained controversial until the arrival of more advanced techniques such as wavelet-compression, allowing the transmission of good quality images at reasonable speed. Until some years ago those issues like image quality, transmission speed and compression techniques were subject of intensive debate. Nowadays attention is more directed towards issues such as clinical governance, medico-legal and quality assessment.

3. Clinical environment
There is a wide variety of settings in which teleradiology can be used [6,7]:

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A well known example of the use of teleradiology is obtaining expert or second opinions. In Tirol in Austria a telenuero-radiology-network was created between three rural hospitals and a university hospital for triage of acute neuropatients. Between October 2007 and March 2008 there were 744 teleradiology patients. The observed teleneuroradiology-network guarantees Tyrolean healthcare-providers to diagnose and treat patients with acute neurological symptoms in a time period off less than 60 min [8].

From the beginning the military has been a great promoter and driving force of teleradiology. During the Balkan war in the mid-nineties a deployable teleradiology system was installed. From 1995 to 1997 more than 20,000 digital diagnostic examinations were acquired, transferred and archived using this system [9].

Teleradiology can also play a significant role in humanitarian and disaster-relief operations, e.g. during the 212th MASH medical treatment of casualties following a large earthquake in the Kashmir region of Pakistan in 2005 [10].

Likewise, as there is a wide variety in applications for teleradiology, many different service and business models exist, for example: after-hours 24/7 coverage, radiology services in remote areas, and subspecialty readings or expert readings, e.g. cardiac imaging and virtual colonoscopy.

Reasons to make use of teleradiology services can be a growing or changing workload, a structural or temporary shortage of radiologists, and a shortage of expertise. In some situations teleradiology is also used for educational purposes.

Teleradiology in its ‘purest’ form is simply transmitting images from one location to another. This can be limited to intra-mural applications in a given situation:

- teleradiology ‘integrated’ in a hospital with or without different locations,
- point-to-point (hospital to radiologist’s home),
- regional hospital networks (e.g. Scandinavia and Spain) [11].

When used for extra-mural applications, images are transmitted to:

- an accredited (international) teleradiology reading centre [12], possibly even in a different time zone, e.g. ‘Nighthawk services’.
- to radiological experts for specialised reading services, not available in the hospital (e.g. virtual colonoscopy),
- another hospital, academic (tertiary) centre or diagnostic centre (for second opinion),
- an expert centre for training purposes, giving support during the start up phase of a new technique (e.g. virtual colonoscopy).

In the United States almost 70% of all radiology practices reported using teleradiology [13]. In 2003 primarily academic practices were less likely to use teleradiology than private radiology practices. According this study, the most common purpose of teleradiology is to transmit images to radiologists at home; about a quarter of the users sent images to outside radiologists (Fig. 1). A significant increase of teleradiology was seen in the prevalence of PACS. Although no published data are available, it is likely that in Europe the increasing availability of PACS in hospitals has similarly led to the possibility to transmit images to the radiologists’ homes, to ease the burden of being on-call. In the Netherlands a number of academic centres are also using teleradiology because of staff shortages. Several commercial teleradiology companies are currently active within the EU, but the presence of different healthcare and legal systems in the EU member states make the situation much more complex than in the US.

These extra-mural applications can be very complex, because often integration of different information systems is required. Not only the PACS systems of different locations have to communicate, but also the information coming from the different RIS and HIS systems has to be integrated [14]. Also aspects such as confidentiality and data integrity have to be taken into account.

4. Commercial international teleradiology

In the future there will be no distinction between PACS and teleradiology. Virtual imaging organisations (or expert reading centres) will become reality [15]. The following question arises: Will teleradiology profoundly change the way we practice our profession?

Can radiology services almost completely be outsourced when we keep in mind that less than 10% of the total radiology production, namely vascular and interventional radiology, is exempt from outsourcing? Theoretically yes, but more likely no. Radiologists have many other tasks besides reporting images such as: justification of request, ad hoc problem solving, optimising and tailoring individual

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**Fig. 1.** Prevalence of teleradiology use in the United States in 2003 and the purposes for which teleradiologic transmission was used. Data are from Ebbert et al. [13].
examination techniques, conferencing in multidisciplinary teams, organising workflow and quality control. On the other hand in many institutions there is a growing tendency towards overflow of workload, which can be explained by the increasing demand for imaging procedures throughout Europe. This overflow could be addressed by teleradiology [16]. Teleradiology should be regarded as a valuable option for solving this type of overflow problems. Introducing teleradiology however is not plug-and-play. Before starting to send images using teleradiology the stakeholders need to formulate a clear agreement about the following aspects [17]:

- How the clinical information is transmitted and integrated?
- How the previous images/procedures and the reports are made available?
- How quality assurance is organised? (See next chapter)
- Is single or double reading requested?
- What turn around time is needed?
- What language is used in the situation of cross-border teleradiology?
- What legislation is involved in the country of the patient?
- What about privacy and integrity of data?
- How the communication between referring physicians and radiologists is assured?
- How are all these processes validated?
- What medico-legal aspects are to be dealt with?

All these issues are part of the so-called clinical governance code as will be discussed more in depth in the next chapter. In the last decade several commercial cross-border teleradiology centres became active in Europe. These centres develop an unmatched concentration of expertise and industry-level quality controls (e.g. by using double readings in every cross-sectional examination) [18]. Also in the field of mass-screening programmes these centres can play an important role. At the moment in several European countries mass-screening programmes are put out to tender.

It is expected that the role of teleradiology will increase and that teleradiology centres will take up their role in the delivery of imaging services.

5. Clinical governance

In the economic and business world we have seen the widespread introduction of terms like “corporate governance” or “governance codes” (e.g. code Buyse in Belgium or code Tabaksblat in the Netherlands). Also in healthcare a comparable term can be seen: “clinical governance” [19]. The term was introduced at the end of the nineties in the UK [20]. Since then the profile and prominence of clinical governance has grown rapidly. Clinical governance has originated out of the need for real accountability for the safe delivery of health services.

Teleradiology companies as well as healthcare organisations are accountable for continuously improving their quality of services and maintaining high standards of care by creating an appropriate working environment. Such a definition has led to numerous interpretations as to what clinical governance actually is. Is it continuous quality management or is it all about clinical audits? It is easier if clinical governance is seen as an umbrella term. Many components and themes can be found underneath. All these elements, when effective, combine to lead to good clinical governance.

Clinical governance covers areas of:

- Patient, public and career involvement.
- Planning, communication and governance arrangements, and cultural behaviour aspects.
- Risk management (incident reporting, prevention, and control of risk).
- Staff management and performance.
- Education, training and continuous professional development.
- Information management (patient records, confidentiality, security).
- Communication with all stakeholders.
- Clinical effectiveness (clinical audit management, learning through research and audit).

Clinical governance is a mixture of topics that are of importance in the management of each enterprise in which medical or clinical services are delivered, in order to assure the overall quality of these services. There is no doubt that good clinical governance in teleradiology is of utmost importance. As described before, every teleradiology environment will be unique. The same counts for the specific clinical governance. Every teleradiology environment will need a unique clinical governance code to which the involved partners agreed.

6. Total quality management in a teleradiology environment

Total quality management regards quality at all levels: workflow management, the infrastructure (IT, communication) and the medical services. Quality of the process includes issues of security, privacy, liability, and data transmission. The most stringent norms and regulations should be followed. Rules published by the joint NEMA/COCIR/JIRA Security and Privacy Committee can be used as a guide at the transmission of patient data and images [21]. Regarding security there are several policies: information security policy, data security policy, physical security policy, network security policy and e-mail acceptable use policy. Also several guidelines can be used, e.g.: encryption guidelines, laptop security guidelines, anti-virus guidelines and security incident guidelines. Security and confidentiality can be realized by using VPN and encrypted mail, data integrity by using DICOM and lossless compression, non-repudiation, individual accountability by authentication via individual access codes on RIS/PACS systems. During the process several validation checks have to be performed to be sure that there is no loss of images, loss of electronic requests or inconsistencies between images and request. When using a business intelligence software for automated validation there is a proactive approach with faster detection and retrieval of incomplete studies.

A good technical infrastructure, including an integrated RIS/PACS and state-of-the-art diagnostic workstations, is a prerequisite.

Radiologists (and the teleradiology company) must have liability insurance to cover their work in each client’s home nation. Additional licences or specialist registrations are still needed in some European countries, even within the EU. Good communication between the teleradiologist and the referring clinician or local radiologist is essential. Teleradiology cannot replace the role of the radiologist as a consultant or the direct interaction with the referring physician. One solution to cover this disadvantage is the mentioning of the mobile phone number of the reporting radiologist on every report to ensure that the referring clinician can easily contact the reporting radiologist. There should be a possibility to view images simultaneously for discussions from different locations at any time.

High quality reports in terms of content and language are essential in the field of teleradiology. As mentioned before a clinical governance policy needs to be agreed upon between the teleradiology centre and the referring institution. Preferably there should be regular clinical audits not only to ensure that reports are
comprehensible and correct, but also to verify the accuracy of the reading skills of the radiologists. In an effort toward more transparency full details of the clinical audit can be passed on to the clients as part of for example a monthly performance report. This report could also include figures on the actual turnaround times compared to those as agreed upon in the SLA (Service Level Agreement), response times to telephone calls, feedback from patients and/or referring clinicians, etc.

7. Legal framework

On the regulatory side the proper registration of the radiologist must be recognized by the regulatory body of the EU-member state in which the hospital outsourcing the radiology reporting service is located, and medico-legal responsibilities of both the referring hospital and the reporting teleradiology entity should be properly documented in a contract. It has to be very clear whether the patient has a legal relationship with the referring hospital only or whether a legal relationship with the teleradiologists is established as well. Implicit or explicit patient consent is a topic for further academic discussion. Fortunately, insurance companies have already understood these requirements and have made proper medical liability policies available.

In order to stimulate international e-health services the EU has developed a robust set of directives such as the e-Commerce Directive, which certainly addresses some of the issues relevant to e-health services, the Transparency Directive, the Personal Data Protection Directive, the e-Privacy Directive and the Directive of Recognition of Personal Qualifications. Off course member states have to transpose and implement these directives in the respective national legislations [22]. Last but not least there is the e-Health Action plan, launched by the European Commission in 2004, in which all member states committed themselves to adopt national roadmaps for e-Health. For the provision of teleradiology services the Personal Data Protection Directive remains of utmost importance. Directive 95/46/EC of the European Parliament and of the Council of 24 October of 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data was published in the Official Journal of the European Communities [23]. The Directive supports the general principles established by the United Kingdom Data Protection Act of 1984 which was followed by its logical successor, the Data Protection Act 1998. The EU Directive on Personal Data Protection requires that transfer of personal data is supported by a stable IT infrastructure and stresses the need for patient data safety. The responsibility for compliance is put under the responsibility of the “data controller” i.e. the sender of the personal data, responsible for meeting the criteria of transparency, legitimate purpose and proportionality. The personal data may be processed insofar as it is adequate, relevant and not excessive in relation to the purposes for which they are collected and further processed.

Under the scope of current legislation the referring hospital and the teleradiology service provider are responsible to ensure that patient confidentiality is secured in both the transmitting and receiving country. Therefore transfer of patient data needs to be secured by VPN or HL7 connections. Access to patient data should be limited to a “need to know” basis and patient records should not be stored longer than necessary for interpretation of the images and a possible discussion of the radiology reports between the relevant physicians during a reasonable period thereafter.

8. ESR

Also the European Society of Radiology (ESR) is engaged with the teleradiology environment and published a White Paper on teleradiology [24] as well as a position paper on teleradiology [25].

The ESR is convinced that teleradiology is a reality that is here to stay, and will even expand. However, the ESR also has legal and medical concerns as described in this paper. In a response of the ESR on the document “Communication on Telemedicine” issued by the European Commission the ESR stated that teleradiology is not equivalent to “telereporting radiological images” but is a medical act at its own right, consisting of different phases: evaluation of examination requests, selection of the most appropriate imaging strategy, optimisation of examination performance, customisation of imaging protocols and integration of clinical and imaging information into the radiological report [26]. Teleradiology is therefore not the provision of a healthcare service, but medicine through the use of ICT.

The ESR is convinced that the success of teleradiology will ultimately depend on the quality of care provided to the patients, and therefore stresses the importance of establishing accreditation for teleradiology providers that are homogeneous throughout EU and also mandatory for providers from outside Europe.

The ESR and the European Commission both support the statement that the most important challenge for teleradiology is to ensure that it develops in a manner that benefits patient care and ensures overall patient safety, and does not in any way reduce the quality of radiology provided to the citizen.

9. The Future

The use of teleradiology reflects the changing world of clinical practice, service delivery and technology. The delivery of health is changing and teleradiology is part of that change, which also includes the globalization of radiology [27,28]. The challenge today is to overcome the general inability to seamlessly integrate teleradiology systems with other (locally existing) health care information systems when data need to be transmitted between different institutions or to an outside provider [29].

Market analysts of Frost & Sullivan have estimated that the 91 million digital radiography examinations that took place in 2006 are expected to grow to 198 million by 2010, with most of the increase coming from MRI and CT/PET. They also estimated the annual growth of the teleradiology market during that period to be around 30%. Based on national estimates they expect that by the year 2011 somewhere between 4% and 20% of the total amount of imaging procedures will be reported remotely. Norway and the USA are specifically mentioned as the two countries leading the pact. According to Ebbert et al. 22% of all imaging studies were sent to outside radiologists in 2003 [13]. A briefing paper prepared for the European Health Telematics Association (EHTEL) in 2008 identified teleradiology as one of the most rapidly adopted forms of telemedicine service [30].

This change has advantages but also has potential threats to the quality of care provided to patients and to the radiologist’s interaction with their clinical colleagues. It is important that the quality of radiological services provided for the patient is of a high standard. It is also important that those providing the service are properly trained, are registered with the appropriate authorities and undergo continuing update through Continuing Medical Education (CME). The services provided must be open to audit and the ability to discuss cases with those reporting the studies must be available.

10. Conclusion

The future teleradiology portfolio, which delivers imaging related services in a new unprecedented way, will consist of e-
Consultation and second opinion, e-Image processing, analysis and supporting services (e-Archiving and e-Training) [16]. The full potential of teleradiology to change paradigms of care is not yet known. Substantial experience is required to understand the possibilities [28]. Off course the future of radiology cannot be predicted, but keeping in mind the trends and developments, one does not need a crystal ball to predict an increasing role for teleradiology as part of PACS in the delivery of imaging services.

Conflict of interest

The authors Frits Barneveld Binkhuysen and Erik Ranschaert state that there is no conflict of interest regarding this article.

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