Eur. Radiol. 10, 1472–1482 (2000)

Computer applications

European Radiology

Review article

Teleradiology requirements and aims in Germany and Europe: status at the beginning of 2000

M. Walz[1], C. Brill[1], R. Bolte[1], U. Cramer[2], B. Wein[3], C. Reimann[1], M. Haimerl[4], G. Weisser[1], K.J. Lehmann[1], R. Loose[5], M. Georgi[1]

[1] Department of Clinical Radiology, Klinikum Mannheim, University of Heidelberg, Theodor-Kutzer-Ufer, D-68135 Mannheim, Germany
[2] Management of the Profession Organization of German Radiologists, D-81245 Munich, Germany
[3] Clinic for Diagnostic Radiology, Technical University of Aachen, D-52057 Aachen, Germany
[4] Institute for Algorithms and Cognitive Systems, University of Karlsruhe, D-76128 Karlsruhe, Germany
[5] Department of Interventional and Diagnostic Radiology, Klinikum Nürnberg Nord, D-90340 Nuremburg, Germany

Received: 20 January 2000; Revized: 19 April 2000; Accepted: 20 April 2000

Abstract. Specific radiological requirements have to be considered for realization of telemedicine. In this article the goals and requirements for an extensive implementation of teleradiology are defined from the radiological user's point of view. Necessary medical, legal and professional prerequisites for teleradiology are presented. Superior requirements, such as data security and privacy or standardization of communication, must be realized. Application specific requirements, e.g. quality and extent of teleradiological functions as well as technological alternatives, are discussed. Each project must be carefully planned in relation to one's own needs, extent of functions and system selection. Topics like legal acceptance of electronic documentation, reimbursement of teleradiology and liability must be clarified in the future.

Key words: Teleradiology – Telemedicine requirements and impacts

Requirements of social and health politics

The leading industrial nations are currently undergoing a shift from service societies to information societies [1]. Despite the enormous increase of telecommunication services, especially the use of the Internet, we are still at the beginning of this process [1, 2]. In contrast to previous experiences with modern technologies, medicine – and physicians as its representatives – has seemed to apply itself slowly in this process [3], at least in Europe: for example, in 1998, only 18% of the physicians in Germany used the Internet. This may change now as the newest survey (end of 1999) reports approximately 60% of Internet users. Physicians are often surprized by their patients, who have already made use of the modern information technology [4]. New means of communication, such as e-mail, are, except for scientific purposes, rarely used in the present practices of medicine [5, 6]. The changes in technology achieved over the past years have not been realized yet and the importance of information technology is increasing slowly in the medical world [5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, , 22, 23, 24].

Politicians and health insurances have already acknowledged some advantages of information technology. In their opinion, all kind of data, concerning the health care system and the patients, should be gathered at the health insurances or their medical suborganizations [25]. This could strengthen the influence of the insurance companies, e.g. because of an enlarged financial controlling, by higher influence on politics and citizens through information management or by directing the patients by well-equipped patient information services.

The German Roland-Berger Study "Telematics in Health Services", published in 1998, points out that telemedicine enables an essentially improved communication between the different participants of the health care services [3]. The demand for a close cooperation of patient care in hospitals and private offices will be fulfilled easier with the help of modern telecommunications. Therefore, the participants must work together and legal questions have to be answered [3, 26]. In a situation of increased competition, in particular between the hospitals, the improvement of information transmission to the referring physicians and patients, and also the quality of science, are furthered, e.g. via teleconsultations. In the economical view of the hospitals the customer's – the patient's and referring physician's – benefit and binding are very important factors.

One should not forget that the mental attitude and the requirements of the patients are changing. For instance, in elective surgery patients are much more informed and critical than they were previously. Health care providers have to consider much more for their patients, not only in what concerns the medical sector but also in providing them with information and other services [27].

Correspondence to: M. Walz

The position of (tele-)radiology within the medical environment and in telemedicine

Specific requirements or needs have to be taken into account for radiology. Therefore, teleradiology has its own area in the field of telemedicine [28, 29, 30, 31, 32, 33, 34, 35, 36,'37]. In future solutions, the integration of teleradiology into telemedicine, e.g. by enforcement of the electronic patient record, will be a necessary task. Teleradiology includes the supply of radiological services for distant locations, any transmission of radiological images and in general the telecommunication in the radiological field. Related fields to typical telemedicine applications are, for example, the digital transmission of reports, image demonstrations and examination requests, background information and other organizational improvements such as electronic scheduling. Transmission of radiological images is possible from a radiologist to another physician, to a specialized centre for image postprocessing, or, without the participation of any radiologist, between different disciplines concerning an image-based therapy decision. Telecommunication in radiology can also consist of online demonstration and discussion, educational applications within radiology or scientific working between different partners and product support, as well as maintenance with the use of computers over a long distance.

Teleradiology as a leading factor in telemedicine

Radiology has gained a central position between medicine, technical sciences and informatics. Modern visualization, such as multimodal and multidimensional presentations, have become possible due to close cooperation between technical and medical experts [38]. New technical developments and modern communication have been introduced very often through radiology, e.g. sonography or electronic image and report distribution. In the past decade the demand for radiological images in various clinical disciplines has increased, especially in surgery, e.g. for pre-operative simulations and intra-operative navigation [38, 39]. Nearly all types of medical information which are relevant for telemedicine, e.g. text, images, image sequences or sound, can be found in radiological diagnostics and are used in teleradiology.

Whereas in Germany there was a lot of discussion about sense, kind of use and quality of teleradiology applications, we find that in other countries, due to their geographical prerequisites, these systems are already in routine use [6, 10, 11, 14, 28, 29, 30, 31, 33, 34, 36, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61].

High requirements and competence in teleradiology

Because of the big image data volume of radiological images and their impact on medical diagnostics, teleradiology causes a high demand on network capacity [35, 36]. The data volume can reach, for example, in breast diagnostics several hundred of megabytes (MB) per case. The typical CT transmission in the KAMEDIN study contains a mean of 36 images at 0.5 MB per image, which means 18 Mb per case. Due to the fast development in MRT and CT, the number of images per examination may increase to a few hundred in the near future [62]. Also, the improved spatial and temporal resolution in MRT as well as in angiography results in higher technical requirements.

Teleradiology is often conducted via ISDN by sending the images before the interactive communication while simultaneous action on both sides takes place [62, 63]. In this case an unnecessary delay is avoided. In the German ANARAD-I study (analysis of requirements in teleradiology by German radiologists 1997) we found that the demand for network capacity is expected at 8 MB/s in the next 5 years to enable effective and routine teleradiology [30, 34, 37]. Taking a look at the financial aspects of work time, the potentials of the use of telemonitoring during an examination and the fast improvement of communication infrastructure in most European countries, this vision of the users concerning communication bandwith may become reality. At this time we still do have many discussions on quality requirements, e.g. the use of lossy compression, and on questions concerning data security [30, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73].

Since the introduction of DICOM 3 as the worldwide standard communication protocol in medical imaging, the electronic transmission of images has become easier. This benefit will increase in the next years because of the exchange or removal of older, non-compatible imaging equipment and software applications. As additional factor the experiences with departmental or hospital information, archiving or communication systems (HIS, RIS, PACS) has increased the understanding, acceptance and competence in the area of modern communication technology among radiologists and referring partners [44].

Central field of diagnostics and services in medicine

In addition to the aforementioned aspects, the central medical and economic significance of radiology in most diagnostic processes must be discussed. Before therapy can start, diagnosis is demanded. During the diagnostic process patients usually have one or more radiological examinations. The way diagnostics or therapy are continued depends on the results of the first examinations. The faster the result – the report and the images – is available, the shorter is the stay of the patient and the faster and better is the treatment of the patient [9, 12, 13, 74, 75, 76, 77, 78, 79]. The pressure on costs increases with the demand of the health insurances on shortening the stay of the patients, or the fact that cost-intensive divisions are closed or get less money. Furthermore, we find the introduction of "global" amounts (pre-operative diagnostic estimated at a flat rate, limited amounts for complete cases). Using expert consultations, the

Table 1. Use of teleradiology

Consultation
Emergency consultation
Expert consultation
Clinical communication and cooperative work
Clinical demonstrations and discussions
Image and report distribution service for other medical fields
Image distribution for cooperations and equipment communities
Service of radiological knowledge, surveillance and reporting
Live transmission of radiological examinations (e.g. in interventional procedures)
Other fields
Education
Access to high technology and sciences
Connection to reference databases
Technical quality surveillance
Support and maintenance concerning radiological equipment
External archiving systems

number of examinations can be reduced and the diagnostic process can be optimized. For teleradiology it is important that expensive equipment, such as CT and MRT, exists in many countries only at central service points (e.g. in big private offices, sometimes even only in big hospitals). To influence time factor, we need fast transmission of reports and images over distances. To use radiological equipment in a reasonable, economic way, cooperation between hospitals and private offices will occur through the use of networks and teleradiology.

Due to the pressure exerted by the health insurances, expectedly bigger clinical departments will grow and smaller departments will even disappear, at least in densely populated areas, which means that not every hospital will be able to serve all common medical fields. This will also lead to an increasing demand for telecommunication with radiological images when the patient must be transferred from one hospital to another. Simultaneously, we find, for instance in Germany, the tendency to install CTs in smaller hospitals [59]. These hospitals are not able to serve the patients outside of routine hours with the same quality as bigger hospitals or cannot provide CT examination and reporting by radiologists during the night at all. This fact may also cause the implication of teleradiology because of interhospital competition and the fear of hospital closure by health insurances [36, 59, 60, 80].

Use of applications in teleradiology

Applications

The main applications of teleradiology for European countries can be subdivided into three parts (see Table 1):

1. Consultations. First of all, there is the emergency consultation. [9, 11, 30, 34, 61, 81, 82]. An example is the neurosurgical consultation with the reduction of hard-copy or patient transports and, of course, faster discussions about diagnosis and therapy. Expert consultation can be used in difficult cases in special areas (e.g. paediatric radiology, neuroradiology) or when new technologies are introduced to increase the quality of reports [31, 34, 40, 42, 58, 83].
2. Clinical communication and cooperative work. The results of radiological examinations can be discussed with the referring physicians in teledemonstrations. They are best prepared as a combination of image and report. Original image data can be transmitted to radiotherapy or surgery for computer-assisted therapy. This furthers the teamwork in and between the different medical fields and links ambulant and hospital treatment [47]. Cooperative work with the use of telecommunication (telecooperation), e.g. between radiology departments of different clinics, or between private offices, can also be realized [9, 48, 53, 84].
3. Other applications. Because of the increasing need for quality, teleradiology may help to close gaps in education and may support the diagnostic process by access to reference databases [37, 85, 86]. Scientific cooperation, product support and maintenance technical quality control in digital examination procedures and external archiving will become easier [30, 37].

Ability of technological principles for different applications

Regional and structural differences lead to specific requirements for teleradiology [36]. In densely populated areas we find a high number of modalities and specialists, a good infrastructure concerning data networks with low communication costs and short traffic ways. In rural areas there is a reverse situation. In conclusion, in cities cooperations will be founded in order to decrease the costs of investment and maintenance, and to increase the capacity utilization of expensive equipment. Potential therapy delays and costs due to the transport of patients will be less important because of the short distances. With the implementation of high-speed channels, cooperative work (telecooperation) will be facilitated, e.g. between radiological departments of different hospitals. In rural areas the cooperations will increase the quality of patient management, with fewer personnel in some cases. This improves the competitiveness, e.g. through the implementation of central on-duty services or central expert consultation.

Table 2 shows the ability of technological principles of some applications [35]. Teleradiology will only be used on a greater scale if the following requirements of the users and the local prerequisites are fulfilled [28, 32, 36, 37, 52, 60, 62, 87]:

1. Functionality of the system
2. Speed of the system
3. Compatibility of the system
4. Practical work-flow implementation

Table 2. Aptitude of different teleradiological principles. ++ Very suitable; + suitable; *0* unnecessary; – not suitable

	Asynchronous communication (offline)	Synchronous communication (online)	Videoconference
Emergency consultation	+	++	+
Expert consultation	++	++	+
Demonstration/discussion	–	++	+
Image and report distribution	++	0	0
Radiological report	+	+	+
Education	+	++	+
Scientific cooperation	++	+	0
Technical quality surveillance	++	+	–
Support and maintenance	+	0	++

Table 3. Teleradiology: relevant areas of law

Law of contract and clearance
Liability and insurance
Data security and obligation to secrecy of physicians
Profession order
Health care laws
Laws of telecommunications

Legal and competitive issues

Legal issues

From the medico-legal point of view, the existing law must firstly be interpreted in a new situation and, secondly, the law must be adapted and expanded to complete the legal frame of information technology and telemedicine applications [23, 30, 32, 80, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99]. In Table 3 the relevant information concerning legal questions of teleradiology in Germany is presented. It also shows the duty of archiving and the problem of acknowledging electronic data by courts. In Germany, for instance, the latter can be achieved through application of the signature law and, subject to the approval by the judges, by approved authentication and integrity measurements and by the evidence of transmission and receipt of documents. A cooperation of law experts, physicians and politicians is necessary to find and to establish solutions in order to fulfill requirements of medical standard, radiation protection and the professional rules in teleradiology, as well as privacy regulations, and in order to solve questions concerning liability in following examination steps:

1. Indication and order of examinations, selection of diagnostic procedure
2. Monitoring of the patients during examination
3. Image data transmission and reporting
4. Documentation and transmission of report
5. Archiving

Questions on costs and clearing

Due to teleradiology, there will be a shift in clearing modalities. Since in the U.S. many teleradiology applications are considered as useful tools, e.g. in serving rural areas without a radiologist available or by expert consultations, these applications have often been covered by health insurances [100]. In Germany and in most of the other European countries, however, no clearance for telemedicine services exists. Only in a few cases may consultation and expert opinion be paid. In Germany prerequisites of reimbursement are the personal execution of examination and report – allowing delegation to assistants, but only under close supervision – a personal contact between physician and patient, and the application of medical diagnostics or therapy at only one location [99, 101]. Clearing paragraphs applicable to teleradiology services are valued too low or require more deliveries than necessary and are therefore unsuitable. Presently, the German clearance regulations – and in most other European countries – are not able to catch the changes of teleradiology for improved medical care and cost reduction. Often reimbursement of teleradiology can only be realized in situations where fewer rules are in force and fee contracts can be arranged independently, e.g. in most agreements between hospitals.

Prerequisite of personal execution of medical work

The German law and physician orders (order of profession and permission, civil orders concerning the contracts between physicians and patients and order of clearance) proceeds from the basic principle of personal execution of work [99, 101]. This is valid for medical treatment in private practice, but also in hospitals when treating patients of private health insurances. In the imagination of the creators of these laws and orders the doctor's work still is done by himself (alone) – at least in principle – and usually in private offices. In most of the other European countries, especially in the southern and northern part as well as in community- or state-dominated health care systems, the requirements of complete personal execution are lower than in Germany and realization of teleradiology becomes easier.

Thus, the physician is liable for his whole work. The outpatient work of several physicians together in a "joint venture" is still seen as an exception and needs special permission, at least for treatment of patients of public insurances [101]. Even if it is absolutely necessary in fields such as radiology, nuclear medicine or radio-

Table 4. Potentials of cost reduction in teleradiology

Cost reduction by:
Diminution of hardcopies
Reduction of transport costs
Decrease in expenditures for provision or utilization of radiologists
Fewer examinations because of better planning of diagnostic steps
Organization management
Better yield of equipment
Faster reports resulting in shorter stays in hospital
Additional income because of:
Better service resulting in increased patient numbers
Higher income out of reimbursed teleradiological services
Advantages that are not related to or difficult to express in money:
Digital transfer of images for planning of therapy (e.g. radiation therapy and neurosurgery)
Optimizing of organization (equipment, personal and place management)
Less loss of images and better availability of images
Synergistic effects with PACS
Reduction of radiation exposure
Faster and better diagnostic findings
Higher satisfaction level of patients
Better reputation
Support of sciences and education
Connection to quality surveillance management and reference databases
Higher image quality for telereport
Better documentation
Contracts with industry

therapy, which require expensive equipment, this principle may be seen as inexpedient. Here the advantages of bigger or cooperating units are obvious.

Cooperative teleradiology-supported work in elective cases is presently impossible by German regulations. The construction "The radiologist at one location is liable for the patient examination and the other radiologist is liable for the report of the examination" cannot be realized apart from emergency situations [101]. There are fewer legal problems if teleradiology is used for second opinion, consultation, etc. Furthermore, in the hospital sector in Germany an undivided work process (one treatment–one doctor) is not requested by clearance regulations of public health insurances [101]. In the future the international competition will increase. Therefore, the sooner radiologists use and test teleradiology – its possibilities and risks, its advantages and dangers for quality – the better they are prepared for coming changes.

Economic efficiency analysis

When it comes to evaluating teleradiological applications under the aspect of economic efficiency, some advantages, such as the reduction of costs for patient or image transport to neurosurgical consultations, can be found [11, 102, 103]. The validity of the studies on economic efficiency is often limited, however. In many teleradiology scenarios the standard economic factors, e.g. transport costs, do not lead to cost savings. Sometimes, there exist reservations against economically driven solutions because of quality and liability reasons. Factors such as better diagnostic quality, shorter stays of patients in hospitals and better organization can only be evaluated in long-term studies (see Table 4) [9, 12, 18, 74, 75, 76, 78, 79, 104, 105, 106]. However, our analysis of economic efficiency of different teleradiology scenarios in 1996, investigated with the KAMEDIN system, showed that teleradiology can be cost-effective even if only the "hard" facts are considered [62, 76, 79].

Requirements for teleradiology

Requirements of German radiologists

In 1997 a teleradiology questionnaire was sent to 4400 German radiologists (i.e. at least 1000 radiological institutions) [30, 34]. The aims of the study were the analysis of the present and future requirements in teleradiology from the radiologists' point of view. The response rate was approximately 5% concerning the radiologists and approximately 15% concerning the institutions. Several comparable parameters, such as distribution of equipment (77% had CT, 50% MRT, 87% PCs, 75% ISDN, 50% Internet, nearly 50% workstations and networks, 30% used DICOM 3) or size of institutions were similar to known figures from other studies, e.g. by industry or medical associations [14, 117, 124]. Forty-eight percent of answers originated from hospitals vs 52% from private practice. Fourteen percent of answers represented the opinion of universities, of which 32% were teleradiology users. The last two figures certainly overestimate the mean values; however, all the influences can be registered and separated by group-based evaluation.

The results showed that 47% of responders felt well informed about teleradiology, 49% not enough and 3% not at all. Even among teleradiology users only 13% felt completely informed. Image and report transfer, as well as interfaces to reference databases, educational applications, technical quality surveillance and product support (maintenance), were considered to be increasingly important areas. Smaller institutions (one to three doctors) judged expert consultation as more important than bigger institutions. Image and report distribution service were of more interest for private practice.

The main requirements (Fig. 1) of radiologists are standardization of the systems, system stability and good image quality. Links to RIS and PACS were considered especially important for those who already work with these systems (60% rated them "very important" vs 33% for those without PACS). From a medico-legal point of view there was a demand for an as strong as possible association between report and image, appropriate data security, documentation and liability questions. The introduction of fair payments was mainly a matter of the radiologists in private practice.

Several statements can be made about image quality: 68% demanded at least a comparable quality to the conventional hardcopy; 32% asked for original quality which presently means transfer of the digital data from

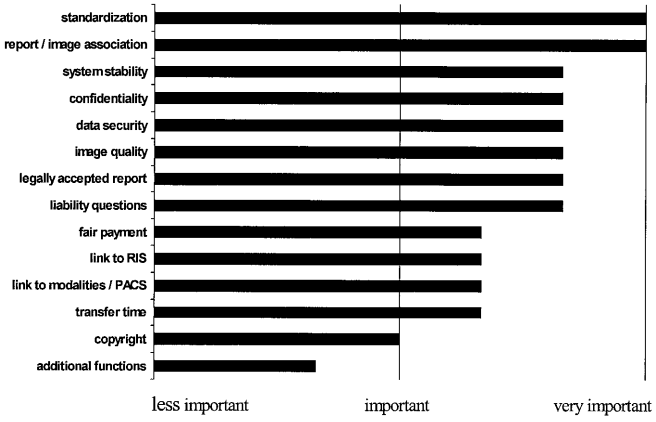

Fig. 1. User requirements for teleradiology (results of German radiologists questionnaire ANARAD, 1997–1999)

the modality to the local teleradiology system and further to another teleradiology system with high visualization quality. Most of radiologists thought that lossy compression should be allowed if no loss of relevant information occurred, and that all images should be transferred for consultation each time [30, 34, 37].

Scenario: emergency CT–teleradiology

Different scenarios of teleradiology exist in Germany: expert consultations, report and image distribution, radiological and clinical demonstrations, and cooperation of institutions at different locations [35]. Among these different teleradiology scenarios the emergency CT consultation service for a smaller hospital at nighttime is typical for Germany. The teleradiological task can be performed by a specialist on call of a larger clinic or of a cooperating group of radiologists outside the hospital. In most cases the resident at the smaller hospital, who points out the indication of the examination, takes part in the radiological process by monitoring the patient during the examination.

Medical specialist standard

Basically in any kind of physician work, the common standard of medical specialists must be met according to German court decisions – concerning the process of radiological examination in detail and indication of examination, the information and consent of patient, monitoring during examination, documentation, and report and discussion of the case [80, 98, 107]. This means that the physicians who take part in the work flow have to fulfill the medical specialist standard or at least must be able to fulfill the standard in cooperation with a colleague by the use of teleradiology. The responsibility includes the work of the radiology technician. Furthermore, the specialist standard is related to the catalogues of allowed and required medical procedures of each speciality. This means that for a CT examination the non-radiological specialist must have an additional qualification or has to be guided by a radiological specialist.

Teleradiology and radiation protection: the German law as an example

Due to the German regulation of radiation protection, e.g. the "Röntgenverordnung" (X-ray ordinance), which arises from European rules, the person responsible for the radiation protection must ensure that technical or organizational problems are recognized and solved as soon as possible, and that enough staff is available in order to avoid any unnecessary radiation exposure of human beings [80, 108, 109]. Due to these requirements, this person should be close to the equipment during regular times and available within a short time in emergency cases.

It is in principle allowed only to CT-specialized physicians or radiographers to apply X-rays with CT on human beings (§ 25 Röntgenverordnung). The medical indication for a radiological examination can be set by the referring physician, but then he has to fulfill the specialist standard in his medical field, and he should, of course, cooperate with the radiologist. For the decision concerning the "if and how" of the use of X-rays a radiologically experienced specialist is needed [80, 109, 110]. The German X-ray ordinance by itself does not state that this specialist must be present at the location of the CT. Older statements and court decisions point out that the specialist must either be present or available within short time, but these statements do not apply to the new situation created by teleradiology [80, 110].

In the opinion of German radiologists, "pure" teleradiology – without any CT-experienced doctor at the local equipment – may be used only in emergency consultations to follow the quality requirements and the specialist standard. Especially during off hours, the existing radiological service in smaller hospitals can be worse than with the use of teleradiology [34]. In elective radiological examinations, "pure" teleradiology is presently not able to keep the same quality as provided by a radiologist at the CT location.

Obligation to privacy and data security

In medical information techniques and image communication "The right information at the right time at the right place" as well as the requirements of data security and privacy must be met at the same time (see Tables 5, 6). A harmonization of privacy regulations in Europe is on the way due to the European directive 95/46/EC which should be transposed into state laws since 1998 and also describes the prerequisites for interstate communication. New models for access rights and management, e.g. for the electronic patient record (EPR), must be developed [111, 125].

These techniques have to regard dynamically changing circumstances and roles of participating persons including exceptional cases such as emergencies. All ac-

Table 5. Requirements related to secrecy, documentation and data security

Privacy and secrecy
Access only for authorized persons
Access rights structured by groups, roles and zones
Secure authentication mechanisms
Usage of additional information such as place, time, time tables for personnel
Principle of minimal rights
Cryptography, anonymization, pseudonymization
Avoidance of data joints
Avoidance of recognition, e. g. by reconstructed images of the face
Securing of systems against unauthorized access
Securing of data transmission
Organization and education
Realization of the right of informational self-determination
Right and surveillance of disposal
For patient
For trusted persons such as treating doctor
For responsible persons concerning the data, e. g. doctor, administrator
Obligation
Availability
Integrity

cess rights should be derived from the querying person and its actual context by security mechanisms such as automatic authentication and authorization. These mechanisms must be implemented in a reliable and transparent fashion so that the medical staff as well as the patient do not need to have more extensive knowledge about security matters.

On the other hand, the patient should be informed about the teleradiological action itself, e. g. the consultation of another expert. The patient should gain knowledge and control about necessary transfer of his personal data. From the legal point of view in this case access to personal data should be derived from permission by the patient. But there is also the possibility to gain access rights by permission through law or special roles, e. g. in the case of emergencies. Data security laws as well as data security concepts and mechanisms must take these particular competing dependencies in medicine into account.

There exists a great demand for a carefully constructed hierarchy of access rights which can be derived from personal roles and special permissions. In the technical implementation these rights need to be reproduced in hierarchies of cryptographic keys. The keys must be organized in different levels of abstraction due to personality, medical care relations and specific roles. In addition, a technical level has to be included, which guarantees that no direct access to the data is possible, so that administrators and technical staff cannot read data without permission. This does not only involve data explicitly related to patients, but also anonymized data. Because information about individuals might be reconstructed from the data, e. g. from image data, the anonymization is often not sufficient to guarantee the privacy of the data.

Some of the above-presented aspects even go beyond common data security laws and others set up new requirements derived from modern patient care. The necessary combination of these requirements in a single system makes it even harder to find solutions in medical information technology and telemedicine concerning the privacy of patient-related data. At the moment teleradiology should be realized in accordance with carefully structured security concepts for the access and transfer of personal data, including anonymized data and second-order information, e. g. the documentation of reports. All data transmission and processing has to be consistent with medical work flow and law.

Requirements concerning teleradiology functions and control of quality

For the use of teleradiology in routine, a defined quality of image presentation and communication is required [54, 113, 114, 115]. The main requirements to teleradiology systems in the opinion of German radiologists are standardization and stability, which means the technical requirements for a simple, reliable and common use of teleradiology in the patient care (Fig. 1). Other important factors are, for example, optimized image quality and data transmission speed. The definition of the necessary image quality depends on the application type and the special requirements of the users, which range from simple report transmission with attached selected images or demonstrations with lossy compressed images up to image-based therapy decisions or (tele)radiological reporting for which the quality of the original DICOM image is needed (Fig. 1).

Therefore, the imaging and the disciplines relying on images have to consolidate their definitions for image quality and the needed teleradiology functions. The quality of a teleradiology system must be controlled in regular times and the results have to be documented [113]. The requirements are defined in part in studies that evaluated the quality of report on monitors and in the technical orders [33]. The CT and MRT examinations can be done with well-equipped PC systems without losing any information [113]. The ACR standard for teleradiology may be of help here [113]. Depending on the monitor, graphics adapter, the PC system and the software, the comfort and the time consumed for the report can differ within a wide range. Implications for high-resolution examinations (mammography, bone or thorax examinations, angiography) are grey-scale inversion, magnification, adjustment of brightness and contrast (interactive window-level regulation) [60, 116].

For demonstration or image and report distribution, the quality requirements are less high because the report of the examination is already available [113]. A transmission of only a selection of images is possible in these cases because it is common in clinical demonstrations to present only the relevant parts of an examination. The image-quality requirements to reference databases and for education are similar to those of printed atlases [117]. The advantages of multimedia should be

Table 6. Requirements from patient care

Authentication, integrity and obligation
Physician must be sure to which patient the data belong, which examination the data are based on and what kind of manipulation has been done
Documentation of authentication and used procedures is needed, at least in certain cases, to fulfill medical and legal requirements. The authentication procedure must be safe, easy and personal
Requirements for acceptance of digital data as documents have to be realized in the technical, organizational and legal environment. Also receipt of data must be provable
Central patient data administration/telearchives
Models for handing over limited access rights, e.g. from patient to doctor or from one doctor to another, have to be developed.
In certain situations, even apart from emergencies, physicians must be able to use the patient data, e.g. for a requested letter or a summary of the case, without the personal presence or a new authorization of the patient
Security of the physician's control of external databases, always threatened by improved techniques for decryption, has to be fulfilled, e.g. by periodic reauthentication/encryption procedures
Standards in the transmission of information
Transfer of results of examinations and therapy to other physicians or to a database must be easy and fast. A transmission standard and correct data integration into systems of the recipients is needed.
Data security procedures must be implemented with only minimal influence on medical work flow to achieve acceptance of users
System access and interoperability
Interoperability of clinical systems must be guaranteed
Authorized access from one system to another system must be possible without disturbance by interposed firewalls or communication servers
System support and administration
Data of patients must not be accessed by persons who look after the technical sides of the system
Supply of anonymous data
There has to be the possibility to extract anonymous data for statistical evaluation, science, demonstrations, education, prevention or economical analysis
Obligation to secrecy
Physician–patient relationship must not be endangered at any time
Surveillance of quality
Evaluations for quality surveillance have to be guaranteed
Use of unsafe soft- or hardware for scientific reasons
Soft- or hardware that are in development or evaluation have to be implemented into computer systems which are used for patient care; therefore, solutions are needed to keep safety for patients and personnel at the same time
Risk-decreasing steps must include possible mistakes of users
High system availability and safety
There have to be developed breakdown concepts to provide availability of needed information at any time of emergency; however, during routine use of the system these concepts should not disturb the medical work. The user must be able to believe in the system, which means that the system performs tasks in the way in which it is expected

used, e.g. the usage of multimodal and multidimensional presentations, cine views as well as hypertext links.

Regarding the video transfer systems, the experiences with teleradiological projects have shown that errors ranged from 1.6 to 4 % in contrast to the original images [58, 115, 118, 119, 120, 121]. The transmission of original DICOM 3 data sets will increase the safety of report to the usual quantity [122]. Requirements for the kind of contact, synchronous or asynchronous transfer mode have to be defined as well [28]. A synchronous (online) communication mode may be necessary in emergency consultations.

To keep the functionality breakdown concepts are needed. The availability of the transmission systems has to be, depending on the use of the systems (e.g. emergency vs elective cases), guaranteed to different safety standards, up to the usage of redundant systems and archives [123]. Simple and cheap systems with limited stability can be used for non-acute situations. But DICOM 3 should be available as communication protocol for all systems.

In a telemedicine workshop (Mainz, Germany, February 1999), a concept for safe and standardized teleradiology was discussed. According to these discussions, medical images should be transmitted either via point-to-point lines by the use of the DICOM protocol or via router (Internet or ISDN) with the use of key and authentication concepts (Fig. 2). This technique, used with success in many projects, can be installed easily and promises state-of-the-art safety patterns. Also the integration into platforms such as "Deutsches Gesundheitsnetz" (German health network) can be achieved. In order to attain a wide compatibility of the systems in Germany, the workgroup of information technology of the German Roentgen Society and the industry will develop a catalogue of requirements that uses this router-based configuration. They should also list the machines that are compatible and use the required key concepts and authentication systems [124].

From teleradiology to telemedicine

Teleradiological or telemedical solutions are still in many cases proprietary, which means company specific. The wide use of digital communication will need an

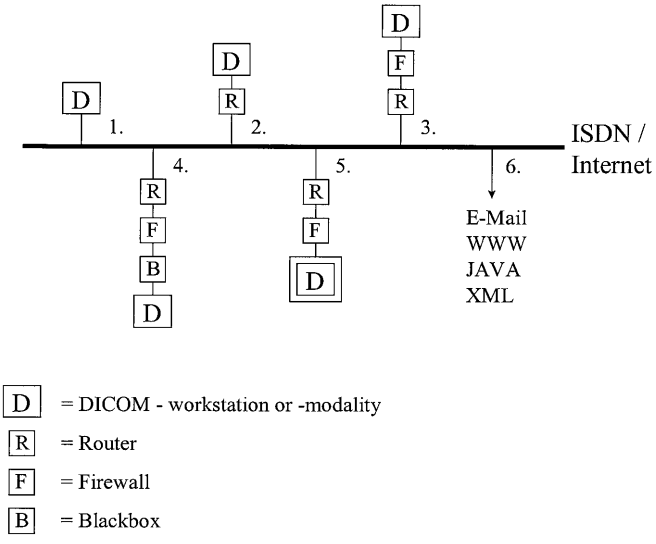

Fig. 2. Technical possibilities of a teleradiological communication. *1* Connection of report workstation with local safety functions; *2* simple connection by router with limited safety functions; *3* connection by router and firewall with higher safety and configuration possibilities; *4* interconnection of a proprietary blackbox that translates the DICOM data stream to other protocols, maybe with additional safety functions; *5* additional key-concept- and authentication programs on the DICOM workstation itself; *6* automated take-over of the contents of the DICOM communication to other Internet communication protocols (intermediate solution to present telemedicine concepts)

open platform with integrated safety concepts and access regulations. The first step to this solution will be the aforementioned way, based on a cheap DICOM-based image communication between as many radiological departments and private offices as possible in Germany. This communication platform can be extended to other clinical fields. Furthermore, new functions can be integrated, e.g. documentation of report, an organized teleradiology infrastructure, improvement of the financial basics and, last but not least, the step from teleradiology to telemedicine.

Acknowledgements. Results presented in this article arise from ANARAD study (Analysis of Teleradiology in Germany), which was supported by DFN and BMBF. Results were also taken from the SFB 414: "Computer and sensor based surgery" and from the work groups of the health network "Rhein Neckar triangle" in Germany.

References

1. Die Welt im Internet. Dossier (1/1998) Spektrum der Wissenschaft, Heidelberg
2. Zimmerman JL (1995) Growth of the Internet and its impact on health care and society. NY State Dent J 61: 64–69
3. Telematik im Gesundheitswesen – Perspektiven der Telemedizin in Deutschland – (1998), Studie der Roland Berger und Partner GmbH im Auftrag der Bundesministerien für Bildung, Wissenschaft, Forschung und Technologie sowie für Gesundheit, Bonn
4. Glowniak JV (1995) Medical resources on the Internet. Ann Intern Med 123: 123–131
5. Bellon E, Van CJ, Suetens P, Marchal G, van SW, Plets C, Oosterlinck A, Baert AL (1994) Multimedia E-mail systems for computer-assisted radiological communication. Med Inf Lond 19: 139–148
6. Worth ER, Patrick TB, Klimczak JC, Reid JC (1995) Cost-effective clinical uses of wide-area networks: electronic mail as telemedicine. Proc Annu Symp Comput Appl Med Care, pp 814–818
7. Brauer GW (1992) Telehealth: the delayed revolution in health care. Med Prog Technol 18: 151–163
8. Casarella WJ (1996) Benefits of teleradiology. Radiology 201: 16
9. DeCorato DR, Kagetsu NJ, Ablow RC (1995) Off-hours interpretation of radiologic images of patients admitted to the emergency department: efficacy of teleradiology. Am J Roentgenol 165: 1293–1296
10. Dure SP, Fymat AL (1997) Teleradiology: Will it transform the practice of radiology? Radiology 203: 49A–50A
11. Goh KY, Lam CK, Poon WS (1997) The impact of teleradiology on the inter-hospital transfer of neurosurgical patients. Br J Neurosurg 11: 52–56
12. Graf VD, Schulenburg JM, Uber A, Köhler M, Andersen HH, Henke KD, Laaser U, Allhoff PG (1995) Ökonomische Evaluation telemedizinischer Projekte und Anwendungen. Nomos Verlagsgesellschaft, Baden-Baden, pp 1–180
13. Greenes RA, Bauman RA (1996) The era of health care reform and the information superhighway. Implications for radiology. Radiol Clin North Am 34: 463–468
14. Hynes DM, Stevenson G, Nahmias C (1997) Towards filmless and distance radiology. Lancet 350: 657–660
15. Jennett PA, Watanabe M, Hall WG (1995) The use of advanced computer technology to enhance access to health care and to respond to community needs: the results of the evaluation of a technology-based clinical consultation service. Medinfo 8: 1479–1481
16. Kauffmann G (1998) Teleradiologie – Zukunftsvision oder Sackgasse? Fortschr Röntgenstr 169:M32–M33
17. Kaufmann G, Klose KJ (1998) Teleradiologie quo vadis? Fortschr Röntgenstr 169: 64–66
18. Klein MS, Ross FV, Adams DL, Gilbert CM (1994) Effect of online literature searching on length of stay and patient care costs. Acad Med 69: 489–495
19. Lerner EJ (1997) Telemedicine. Slow in coming. NJ Med 94: 71–72
20. Martinez R, Chimiak W, Kim J, Alsafadi Y (1995) The rural and global medical informatics consortium and network for radiology services. Comput Biol Med 25: 85–106
21. Merrel RC (1995) Telemedicine in the 1990's: beyond the future. J Med Syst 19: 15–18
22. Nagy K (1994) Telemedicine creeping into use, despite obstacles. J Natl Cancer Inst 86: 1576–1578
23. Scherrer JR (1995) Communications: future needs and present solutions. Int J Biomed Comput 39: 47–52
24. Sommer TJ (1995) Telemedicine: a useful and necessary tool to improving quality of healthcare in the European Union. Comput Methods Programs Biomed 48: 73–77
25. Referentenentwurf eines Gesetzes zur Reform der gesetzlichen Krankenversicherung ab dem Jahr 2000 vom 25.5.99, Bundesministerium für Gesundheit, Bonn
26. Bundesarbeitsgruppentreffen vernetzter Praxen, 20.6.98, Frankfurt
27. London JW, Morton DE, Marinucci D, Catalano R, Comis RL (1995) Cost effective Internet access and video conferencing for a community cancer network. Proc Annu Symp Comput Appl Med Care, pp 781–784
28. Barnes GT, Morin RL, Staab EV (1993) infoRAD: Computers for Clinical Practice and Education in Radiology: Teleradiology: Fundamental Considerations and Clinical Applications. RadioGraphics 13: 673–681
29. Baum S, Caplan A (1996) Teleradiology: friend or foe? Radiology 201: 16–17

30. Bolte R, Walz M, Lehmann KJ, Hothorn T, Brill C, Hothorn L, Georgi M (1998) Teleradiology: results of a questionnaire of German radiologists. J Telemed Telecare 4 (Suppl 1): 69–71
31. Cawthon MA, Goeringer F, Telepak RJ, Burton BS, Pupa SH, Willis CE, Hansen MF (1991) Preliminary assessment of computed tomography and satellite teleradiology from Operation Desert Storm. Invest Radiol 26: 854–857
32. Freyschmidt JC (1999) Haftungsrechtliche Aspekte der Konsiliartätigkeit. Fortschr Röntgenstr 170: 4–6
33. Goldberg MA (1996) Teleradiology and telemedicine. Radiol Clin North Am 34: 647–665
34. Walz M, Klose KJ, Wein B (1999) Bericht zu Teleradiologie-Aktivitäten und -Ergebnissen der ANARAD-Studie und AGIT. RöFo 170: M107–110
35. Walz M, Lehmann KJ, Loose R, Bolte R, Schinkmann M, Georgi M (1996) Evaluation of new teleradiology systems: concepts, application areas and requirements. In: Lemke HU, Inamura K, Vannier MW, Farman AG (eds) Computer assisted radiology. Elsevier, Amsterdam, pp 549–553
36. Walz M, Wein B, Lehmann KJ, Bolte R, Kilbinger M, Loose R, Günther RW, Georgi M (1997) Ziele, Anforderungen und Rahmenbedingungen der Teleradiologie: Eine Bestandsaufnahme. Radiologe 37: 260–268
37. WWW.rzuser.uni-heidelberg.de/ ~ n17/anard.html
38. Schuhmann D, Seemann M, Schoepf UJ, Haubner M, Krapichler C, Gebicke K, Reiser M, Englmeier KH (1998) Computergestützte Diagnostik basierend auf computergestützter Bildanalyse und 3-D-Visualisierungen. Radiologe 38: 799–809
39. Satava RM (1995) Virtual reality, telesurgery, and the new world order of medicine. J Image Guid Surg 1: 12–16
40. Berry RF, Barry MH (1998) Evaluation of a personal-computer-based teleradiology system serving an isolated Canadian community. Can Assoc Radiol J 49: 7–11
41. Caramella D (1996) Teleradiology: state of the art in clinical environment. Eur J Radiol 22: 197–204
42. Cook JF, Hansen MF, Leckie RG, Francoise JJ (1995) AKA-MAI Project: teleradiology in the Pacific. J Digit Imaging 8: 20
43. Davis MC (1997) Teleradiology in rural imaging centres. J Telemed Telecare 3: 146–153
44. Drew P, Kalinowski J, Lorah L, Lydon M (1997) Users' perceptions of picture archiving and communication systems and teleradiology. J Digit Imaging 10: 86–88
45. Earnest F (1997) Real world teleradiology. J Digit Imaging 10: 14–16
46. Ferguson EW, Doarn CR, Scott JC (1995) Survey of global telemedicine. J Med Syst 19: 35–46
47. Franken-EA J, Berbaum KS, Smith WL, Chang P, Driscoll C, Bergus G (1992) Teleradiology for consultation between practitioners and radiologists. Ann NY Acad Sci 670: 277–280
48. Franken EAJ, Harkens KL, Berbaum KS (1997) Teleradiology consultation for a rural hospital: patterns of use. Acad Radiol 4: 492–496
49. Hassol A, Gaumer G, Irvin C, Grigsby J, Mintzer C, Puskin D (1997) Rural telemedicine data/image transfer methods and purposes of interactive video sessions. J Am Med Inform Assoc 4: 36–37
50. Lally JF (1997) Teleradiology and a specialty at risk. Am J Roentgenol 169: 598–599
51. Lenzen H, Meier N, Bick U (1997) Telemedizin. Möglichkeiten und Perspektiven. Radiologe 37: 294–298
52. Mun SK, Elsayed AM, Tohme WG, Wu YC (1995) Teleradiology/telepathology requirements and implementation. J Med Syst 19: 153–164
53. Noro R, Hubaux JP, Meuli R, Laurini RN, Patthey R (1997) Real-time telediagnosis of radiological images through an asynchronous transfer mode network: the ARTeMeD project. J Digit Imaging 10: 116–121
54. Perednia DA, Allen A (1995) Telemedicine technology and clinical applications. J Am Med Assoc 273: 483–488
55. Reid JG, McGowan JJ, Ricci MA, McFarlane G (1997) Desktop teleradiology in support of rural orthopedic trauma care. Proc AMIA Annu Fall Symp, pp 403–407
56. Reponen J, Lahde S, Tervonen O, Ilkko E, Rissanen T, Suramo I (1995) Low-cost digital teleradiology. Eur J Radiol 19: 226–231
57. Sheng OR, Hu PJ, Au G, Higa K, Wei CP (1997) Urban teleradiology in Hong Kong. J Telemed Telecare 3: 71–77
58. Slovis TL, Guzzardo DP (1991) The clinical usefulness of teleradiology of neonates: expanded services without expanded staff. Pediatr Radiol 21: 333–335
59. Walz M (1997) Telebefundung: Vom CT – Bereitschaftsdienst zum Befundungszentrum. Radiologe 37:M45–M64
60. Walz M (1997) Wie soll eine anwenderorientierte effektive Teleradiologie aussehen? Radiologe 37:M14–M20
61. Yamamoto LG (1995) Wireless teleradiology and fax using cellular phones and notebook PCs for instant access to consultants. Am J Emerg Med 13: 184–187
62. Bolte R, Lehmann KJ, Walz M, Loose R, Lütgemeier J, Seibert F, Busch C, Schinkmann M, Georgi M (1996) Radiologisch-medizinische Desktop-Konferenzen – Klinische Evaluation des Teleradiologiesystems KAMEDIN im Routinebetrieb eines radiologischen Instituts. Akt Radiol 6: 199–202
63. Engelmann U, Schröter A, Baur U, Schroeder A, Werner O, Wolsiffer K, Baur H-J, Göransson B, Boräv E, Meinzer H-P (1996) Teleradiology system MEDICUS. Computer assisted radiology. Elsevier, Amsterdam, pp 537–542
64. Baur HJ, Engelmann U, Saurbier F, Schroter A, Baur U, Meinzer HP (1997) How to deal with security issues in teleradiology. Comput Methods Programs Biomed 53: 1–8
65. Epstein MA, Pasieka MS, Lord WP, Mankovich NJ (1997) Security for the digital information age of medicine: issues, applications, and implementation. J Digit Imaging 10: 122–127
66. Frank MS, Lee H, Kim Y, Rowberg AH, Lee W, Riskin EA (1994) Evaluation of a combined two- and three-dimensional compression method using human visual characteristics to yield high-quality 10: 1 compression of cranial computed tomography scans. Invest Radiol 29: 842–847
67. Makris L, Argiriou N, Strintzis G (1997) Network and data security design for telemedicine application. Med Inf 22: 133–142
68. Norton SA, Lindborg CE, Delaplain CB (1993) Consent and privacy in telemedicine. Hawaii Med J 52: 340–341
69. Persons K, Palisson P, Manduca A, Erickson BJ, Savcenko V (1997) An analytical look at the effects of compression on medical images. J Digit Imaging 10: 60–66
70. Roger FH (1989) Security threats and trends in society. Med Inf 14: 219–225
71. Smith JP (1995) Authentication of digital medical images with digital signature technology. Radiology 194: 771–774
72. Stoeger A, Springer P, Dessl A, Giacomuzzi SM (1997) Offene Fragen zum Thema Teleradiologie aus aktueller Sicht. Akt Radiol 7: 228–229
73. Willenberg C (1997) Lösungsansätze für die Sicherung medizinischer Dokumente durch elektronische Unterschrift und Verschlüsselung. Radiologe 37: 305–312
74. Bergmo TS (1996) An economic analysis of teleradiology versus a visiting radiologist service. J Telemed Telecare 2: 136–142
75. Heckermann D, Wetekam V, Hundt W, Reiser M (1997) Nutzwert- und Wirtschaftlichkeitsanalyse verschiedener Teleradiologieszenarien. Radiologe 37: 285–293
76. Lehmann KJ, Walz M, Bolte R, Schinkmann M, Busch C, Georgi M (1997) Einsatzmöglichkeiten des KAMEDIN-Teleradiologiesystems unter besonderer Berücksichtigung einer Wirtschaftlichkeitsanalyse. Radiologe 37: 278–284
77. Matzko M, Adelhard K, Nissen-Meyer S, Klose P, Sprenger D (1999) Filmlose Befundung und Bildverteiung an Zuweiser am Beispiel einer radiologischen Gemeinschaftspraxis. Radiologe 39: 316–319

78. Stoeger A, Strohmayr W, Giacomuzzi SM, Dessl A, Buchberger W, Jaschke W (1997) A cost analysis of an emergency computerized tomography teleradiology system. J Telemed Telecare 3: 35–39
79. Walz M, Bolte R, Lehman KJ, Lütgemeier J, Georgi M (1999) Economic analysis of teleradiology applications with KAMEDIN. In: Nerlich M, Kretschmer R (eds) The impact of telemedicine on health care management. IOS Press, Amsterdam, pp 208–216
80. Walz M (1999) Teleradiologie: Formale und qualitative Voraussetzungen für Ärzte und MTA. Radiologe 39:M50–M51
81. Gray W, O'Brien D, Taleb F, Marks C, Buckley T (1997) Benefits and pitfalls of telemedicine in neurosurgery. J Telemed Telecare 3: 108–110
82. Ludwig K, Bick U (1997) Kommerzielle Teleradiologiesysteme in Deutschland. Radiologe 37: 336–339
83. Binkhuysen FH, Ottes FP, Valk J, de Vries C, Algra PR (1995) Remote expert consultation for MRI procedures by means of teleradiology. Eur J Radiol 19: 147–150
84. Gale ME, Vincent ME, Robbins AH (1997) Teleradiology for remote diagnosis: a prospective multi-year evaluation. J Digit Imaging 10: 47–50
85. Achenbach S, Alfke H, Klose KJ (1997) Teleteaching mit CONRAD. Von der Fallsammlung zum interaktiven Lehrsystem. Radiologe 37: 299–304
86. Richardson ML (1995) A World-Wide Web radiology teaching file server on the Internet. Am J Roentgenol 164: 479–483
87. Krupinski E, Maloney K, Hopper L, Weinstein R (1997) Evaluation of radiologist performance using telemedicine services. J Digit Imaging 10: 83–85
88. Allaert FA, Dusserre L (1995) Legal requirements for tele-assistance and tele-medicine. Medinfo 8: 1593–1595
89. Berger SB, Cepelewicz BB (1996) Medical–legal issues in teleradiology. AJR 166: 505–510
90. Brahams D (1995) The medicolegal implications of teleconsulting in the UK. J Telemed Telecare 1: 196–201
91. Brannigan VM, Beier BR (1995) Patient privacy in the era of medical computer networks: a new paradigm for a new technology. Medinfo 1: 640–643
92. Brenner RJ, Westenberg L (1996) Film management and custody: current and future medicolegal issues. Am J Roentgenol 167: 1371–1375
93. Freyschmidt J (1999) Über die Verantwortlichkeiten des Radiologen in der Skelettradiologie. Fortschr.Röntgenstr 170: 1–4
94. Kamp GH (1996) Medical–legal issues in teleradiology: a commentary. Am J Roentgenol 166: 511–512
95. Netzer T, Mairinger T, Gschwendtner A, Mikuz G, Markl C (1996) Der rechtliche Status der Telemedizin in Österreich. Wien Klin Wochenschr 108: 555–559
96. Rosenblum JB (1995) Legal aspects of computerized medical records. Legal Med:205–225
97. Schunk K (1999) Rechte und Pflichten des Radiologen bei der Indikationsstellung und Anwendung radiologischer Verfahren. Fortschr Röntgenstr 170: 7–15
98. Ulsenheimer K., Heinemann N (1997) Rechtliche Aspekte der Teleradiologie. Radiologe 37: 313–321
99. Ulsenheimer K., Heinemann N (1999) Rechtliche Aspekte der Telemedizin: Grenzen der Telemedizin?. MedR 5: 197–203
99. Whelan LJ (1997) Teleradiology legal issues. J Digit Imaging 10: 17–18
100. Fisher GR (1995) Telemedicine and the payment system. PaMed 98: 32–34
101. Cramer UH, Walz M (1998) Persönliche Leistungserbringung in der Teleradiologie. Radiologe 38:M25–M29
102. Hahn CH, Handels H, Rinast E, Bernardes P, Busch CH, Kuhn V, Miehe J, Will A, Putzar H, Rosler K (1995) ISDN based teleradiology and image analysis with the software system KAMEDIN. Medinfo 8: 1511–1514
103. Smits HL, Baum A (1995) Health Care Financing Administration (HCFA) and reimbursement in telemedicine. J Med Syst 19: 139–142
104. Halvorsen PA, Kristiansen IS (1996) Radiology services for remote communities: cost minimisation study of telemedicine. Br Med J 312: 1333–1336
105. Kearney B (1996) Health technology assessment. J Qual Clin Pract 16: 131–143
106. Pelletierfleury N, Fargeon V, Lanoe JL, Fardeau M (1997) Transactions, costs, economics as a conceptual framework for the analysis of barriers to the diffusion of telemedicine. Health Policy 42: 1–14
107. Konferenz der Lehrstuhlinhaber für Radiologie e.V., Stellungnahme (1994) CT – Ferndiagnostik?: Persönliche Leistungserbringung in der Radiologie. BVDRN – Info 9/94: 14–15
108. Dixon AK, Dindy P (1998) How much does radiation dose matter? Lancet 352: 1082–1083
109. Röntgenverordnung – RöV: 10. Verordnung über den Schutz vor Schäden durch Röntgenstrahlen vom 8.1.1987, zuletzt geändert durch Gesetz über Medizinprodukte vom 2.8.1994
110. Kramer R, Zerlett G (1991) Röntgenverordnung: Kommentar zur Verordnung über den Schutz vor Schäden durch Röntgenstrahlen. In: Reihe Deutsches Strahlenschutzrecht, Band 2, 3. Auflage, Verlag W. Kohlhammer, Deutscher Gemeindeverlag, Köln
111. Walz M, Bolte R, Reimann C, Haimerl M, Westermann M, Georgi M (1999) Patientenversorgungs- und datenschutzgerechte Bildkommunikation: Ein Widerspruch? RöFo 170:S231
112. Bundesdatenschutzgesetz (BDSG) (1990) Gesetz zur Fortentwicklung der Datenverarbeitung und des Datenschutzes vom 20.12.90, BGBl. I S. 2954–2955 (zuletzt geändert durch das Gesetz zur Neuordnung des Postwesens und der Telekommunikation vom 14.9.94)
113. ACR Standard for Teleradiology, Resolution Nr. 21 (1994), amended Resolution Nr. 53 (1995)
114. Houtchens BA, Allen A, Clemmer TP, Lindberg DA, Pedersen S (1995) Telemedicine protocols and standards: development and implementation. J Med Syst 19: 93–119
115. Paakkala T, Aalto J, Kahara V, Seppanen S (1991) Diagnostic performance of a teleradiology system in primary health care. Comput Methods Programs Biomed 36: 157–160
116. Ricke J, Kleinholz L, Hosten N, Bergh B, Zielinski C, Thomsen J, Vierroth V, Emmel D, Kanzow J, Felix R (1996) Teleradiologie: Einsatz eines Multimedia-PC für den Zugriff auf elektronische Patientenakten und Telekonsultationen. Fortschr Röntgenstr 165: 188–191
117. Lehmann KJ, Walz M, Bode A, Teubner J, Stahl J, Georgi M (1996) Aufbau einer klinisch-radiologischen CD-ROM-Datenbank am Beispiel fokaler Leberläsionen. Fortschr Röntgenstr 165: 42–47
118. Carey LS, O'Connor BD, Bach DB, Hobbs BB, Hutton LC, Lefcoe MS, Lyons RO, Munro TG, Paterson RG, Rankin RN et al. (1989) Digital teleradiology: Seaforth – London network. Can Assoc Radiol J 40: 71–74
119. Santis DJ di, Scatarige JC, Cramer MS, Kim MH (1990) Feasibility of digital teleradiology for imaging evaluation of patients with acute right upper quadrant abdominal pain. Radiology 177: 707–708
120. Kagetsu NJ, Zulauf DR, Ablow RC (1987) Clinical trial of digital teleradiology in the practice of emergency room radiology. Radiology 165: 551–554
121. Kehler M, Bengtsson PO, Freitag M, Lindstrom B, Medin J (1996) Radiological videoconferencing in Sweden. J Telemed Telecare 2: 161–164
122. Lee BR, Allaf M, Moore R (1999) Clinical decision making using teleradiology in urology. AJR 172: 19–22
123. Bashshur RL (1995) Telemedicine effects: cost, quality and access. J Med Syst 19: 81–91
124. WWW.uni-marburg.de/mzr/agit
125. Fisher F, Madge B (1996) Data security and patient confidentialty: the manager's role. Int J Biomed Comput 1996: 115–119