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# The German teleradiology system MEDICUS: System description and experiences in a German field test

Uwe Engelmann [a,*], A. Schröter [a], U. Baur [a], O. Werner [a], M. Schwab [a], H. Müller [a], M. Bahner [b], H.P. Meinzer [b], E. Borälv [c], B. Göransson [b]

[a] *Deutsches Krebsforschungszentrum (German Cancer Research Center), Abteilung Medizinische und Biologische Informatik, Im Neuenheimer Feld 280, D-69121 Heidelberg, Germany*
[b] *Abteilung Onkologische Diagnostik und Therapie, Im Neuenheimer Feld 280, D-69121 Heidelberg, Germany*
[c] *Uppsala University, CMD, Centre for Human-Computer Studies, Lägerhyddvägen 18, S-75237 Uppsala, Sweden*

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**Abstract**

MEDICUS is a teleradiology system which has been developed in a joint project of the German Cancer Research Center (Deutsches Krebsforschungszentrum) and the Transfer Center Medical Informatics (Steinbeis-Transferzentrum Medizinische Informatik) in Heidelberg, Germany. The system is designed to work on ISDN lines as well as in a local area network. Special attention has been given to the design of the user interface and data security, integrity, and authentication. The software is in use in 13 radiology departments in university clinics, small hospitals, private practices, and research institutes. More than 25 thousand images have been processed in 6 months. The system is in use in six different application scenarios. MEDICUS is running under the UNIX operating system. The connection of the modalities could in most cases not be realized with the DICOM protocol as older machines were not equipped with this standard protocol. Clinical experiences show that the MEDICUS system provides a very high degree of functionality. The system has an efficient and user friendly graphical user interface. The result of a comparison with other systems shows that MEDICUS is currently the best known teleradiology system. Cost reductions are already obvious, but additional research has to be performed in this field. An even more powerful commercial successor is currently under construction at the Steinbeis-Transferzentrum Medizinische Informatik in Heidelberg. 

*Keywords:* Teleradiology; DICOM; PACS; Evaluation; Field test; Experiences

## 1. Introduction

MEDICUS is a teleradiology system which has been developed in a joint project of the German Cancer Research Center and the Transfer Center Medical Informatics in Heidelberg, Germany. The project has been funded by DeTeBerkom, Berlin, a subsidiary of the Deutsche Telekom AG. Before we started to develop a teleradiology system, we looked at the definition and asked the future users about their needs. The American College of Radiology (ACR) defines teleradiology in the following way [1]:

> Teleradiology is the electronic transmission of radiological images from one location to another for the purposes of interpretation and/or consultation. Teleradiology may allow even more timely interpretation of radiological images and give greater access to secondary consultations and to improved continuing education. Users in different locations may simultaneously view images. Appropriately utilized, teleradiology can improve access to quality radiological

* Corresponding author. Tel.: +49 6221 422382; fax: +49 6221 422345; e-mail: U.Engelmann@DKFZ-Heidelberg.de.; URL: http://mbi.dkfz-heidelberg.de/

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interpretations and thus significantly improve patient care.

A system analysis has been carried out at the beginning of the project to find out the users' expectations and needs for a teleradiology system. The results have been used to define the functionality of the MEDICUS system.

It was very obvious that standard teleconference software products could not satisfy the medical users' needs. Such systems are not integrated in the clinical environment, do not support the medical image formats or communication protocols ACR/NEMA [2] and DICOM [3], and do not handle 12 bit images. However, no radiology-specific functionality has been developed yet. The available standard application sharing products cannot be used for cooperative work in radiology since they are not powerful enough: In our context, we want to work on sets of images (studies and series). The size of a typical data set is 30 images of half a Mbyte each, which results in 15 Mbytes for one patient study. Flipping from one image to another would take more than 30 s with such a tool on ISDN lines. Such a delay cannot be accepted in an interactive, cooperative session. Thus, specialized programs must be developed.

The German Cancer Research Center and the Transfer Center Medical Informatics in Heidelberg, Germany, developed the teleradiology system MEDICUS in a 2-year project (August 1994–July 1996). The map in Fig. 1 shows the medical partners of the project where the system has been implemented.

## 2. The MEDICUS system

The following sections describe system features of the developed system.

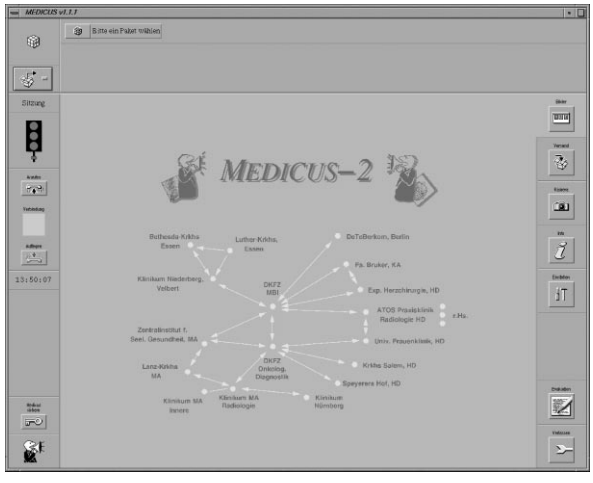


Fig. 1. The user interface of MEDICUS showing the application sites.

### 2.1. Data sources

Images from different sources (e.g. imaging modalities, video cameras, document scanners) can be imported into MEDICUS. The transfer of the image data from an MRI or CT scanner to the MEDICUS workstation is automated as far as possible, so that the medical personnel can simply invoke the standard export function on the CT or MRI console to start the transfer process. The transfer process is either based on the DICOM protocol (where possible) or on TCP/IP or DECnet-based functions.

### 2.2. Patient database

The header information of the image files is evaluated to store the images with the accompanying alphanumeric information in the patient database. The MEDICUS program organizes the image data by study ID, patient names, image series, image No., etc. Thus, the user sees the data in a structure similar to that of his CT/MRI console. Users are no longer confronted with the operating system, cryptic file names, or transfer programs.

### 2.3. Data submission

Image data can be submitted to a different machine with three mouse clicks. The clicks are used to identify the study (click 1), to select the addressee (click 2), and to activate the submission (click 3). The user can select a subset of images and write a cover letter which will be sent with the images. Image data is collected in folders. Several folders are collected in packets. The packet is sent to the communication partner.

### 2.4. Data security concept

We developed and implemented a data security concept for MEDICUS [4,5]. The European Union is supporting an initiative for evaluating the security aspects of such systems. In ITSEC, the security criteria are described [6]. An associated evaluation manual ITSEM is also available [7]. Both these EU publications are compatible with and extend the concepts suggested by the US department of defense in the TCSEC 'Orange Book' [8]. In Germany, the 'Bundesamt für Sicherheit in der Informationstechnik' in Bonn (BSI, Federal Bureau of Security in Information Technology) published an IT Security Manual [9], which adopts the concepts described in the EU publications mentioned above. The security concept described here was developed in strict accordance with the procedure defined in the IT Security Manual.

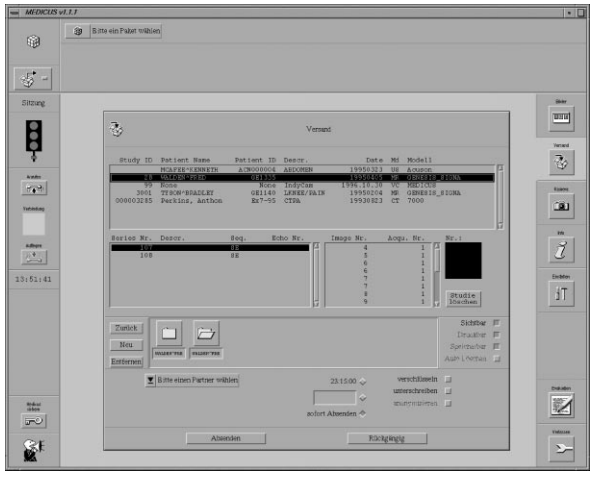

Fig. 2. The SEND task of MEDICUS.

### 2.5. Data protection

As a result of the data security concept, it is possible to restrict the rights of the addressee on the image data. The following restrictions are possible (Fig. 2): (1) only viewable in a teleconference with the sender; (2) not exportable; (3) not printable; and (4) automatic removal after the teleconference. The packet is encrypted with a public key encryption system PGP [10]. The public key of the addressee is used for the encryption. The packet is signed with the digital signature of the sender and a checksum of the data is calculated. This ensures data integrity, authentication of the sender and privacy.

Furthermore, all local data is encrypted with a symmetric key encryption method. Transmitted and received images are logged in special log files which are protected with a checksum.

The public keys of the users are certified by a trust center which checks the identity of the key owners. Certified keys have a digital signature of the trust center. The MEDICUS system checks the public keys of the users for valid certificates.

### 2.6. Data transfer

The data is internally buffered in a transfer database, where they wait for submission at a user-defined time and date. The transfer process copies the data to the target machine into a shared database. The data is also stored locally in a shared database, after the remote machine has acknowledged the transfer. The data transfer is usually performed off-line, because a typical data set contains several Mbytes of data, which can take up to several hours on an ISDN line. One CT image (512 by 512 pixels, 2 bytes/pixel) can be transferred over an ISDN line with two b-channels (64 Kbit/s) in about 33 s without compression. Typical image series have 30 to 60 images and sometimes more than 240 images in the case of MR mammography.

### 2.7. Teleconference

A teleconference is initiated by a conventional telephone call. The conference partners invoke the MEDICUS application. One of the partners establishes the connection to the other one with a mouse click. Then, both partners see the same transferred shared data. Both can open packets and select images. Images can be displayed in different ways (e.g. normal size, magnified, 4 or 6 images side-by-side, etc.). It is possible to analyze the gray values and regions of interest (area or density values). A section of the image can be magnified. The viewable gray-value range can be changed in a similar way as the classical level/window function of CT or MRI consoles. The image data and interactive manipulations on the images are synchronized during the cooperative session so that both partners see exactly the same contents on the screen. The mouse cursors of both partners are visible (Fig. 3).

### 2.8. Online video images

It is possible to grab images during the cooperative session from a video camera (or other video device) and to submit the video image to the conference partner (Fig. 4). The images can optionally be compressed with JPEG to accelerate the transfer of the image.

## 3. Basic features of the system

The following section summarizes the underlying key features of the MEDICUS system.

ISDN is the physical target network. A standard $S_0$ telephone plug is used to communicate with the basic

Fig. 3. The image viewing task.

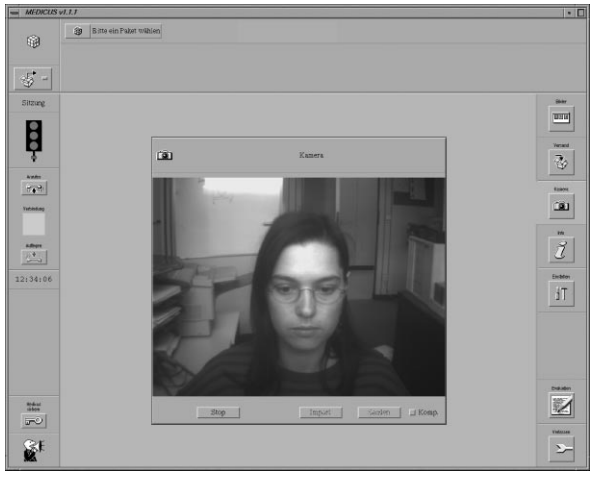

Fig. 4. A screen shot of the video task.

rate interface (BRI) of the computer. The bandwidth of one ISDN interface is divided into two 64 Kbit/s b-channels and one 16 Kbit/s d-channel for signalling information. Supported protocols in Germany are the old 1TR6 and the new Euro-ISDN protocol DSS-1 (or NET-3). Standard protocols are used for interprocess communication. TCP/IP is used in conjunction with PPP (point to point protocol) on the ISDN line. Thus, the system is not restricted to ISDN networks, but can be used on other TCP/IP based networks as well.

The system is mainly a communication system. Since a UNIX system offers the best connectivity features, and also more security and reliability features than the classical PC operation systems, we have based the MEDICUS system on the UNIX operating system.

### 3.1. Portability

The system is portable to different UNIX hardware/software systems. Development platforms are the Silicon Graphics INDY workstation and LINUX PCs. SPARCstations under SunOS/Solaris, DECstations under Ultrix, DEC AXP-Systems under DIGTAL UNIX, and HP systems under HP/UX are supported as well.

### 3.2. Programming and development tools

The system is programmed in ANSI C. The user interface is based on X11/R5 and OSF/Motif 1.2. No GUI tool has been used in order to avoid dependence on such a tool and to protect the portability of the system. The Purify tool (Pure Software B.V.) has been used to check the C code. Some GNU tools are used (e.g. GNU dbm [11]).

The graphical user interface is based on results of cognitive psychology and a medical style guide for efficient medical user interfaces [12]. It is implemented with the X Window System and OSF/Motif. The user can work with the system even without any knowledge of an operating system, and has no contact with the UNIX file system or commands. Instead, the system presents the information in familiar medical concepts, such as patients, studies, examinations, and images. Existing functions (e.g. level/window manipulations) of the CT or MRI console are also available in the system.

Digital imaging modalities are directly connected to the MEDICUS system. The image transfer works in the background without user interaction (where possible). The DICOM protocol is the ideal communication method. Since this standard is not yet generally available (everywhere), we implemented TCP/IP and DECnet-based transfer mechanisms as well. MEDICUS supports the image communication and file standards ACR/NEMA [2] and DICOM [3]. Since propriety formats exist in the field, it is necessary to process these formats as well (e.g. SOMATOM, MAGNETOM). Further image sources are supported. Images can be captured from various video sources, e.g. camera, video recorders, ultrasonic scanners. The open interface allows extension of the input sources.

### 3.3. Offline data transfer

Since huge data sets must be processed, data transfer is not feasible during cooperative sessions. Instead, the data transfer is performed before the session (during less expensive hours). The data is collected in packets and folders.

### 3.4. Online data transfer

It is possible to capture and submit image data during a teleconference. A connected video camera allows images and data to be acquired from film or other documents.

### 3.5. Viewing station functionality

Since the image data is available at the MEDICUS workstation, it is possible to use the workstation as a classical viewing station as well. Several workstations can be distributed in the hospital, which share the database of a central MEDICUS workstation via NFS.

## 4. Results of a field test

The project started with 15 medical partners. Two partners left the consortium during the project as it was not possible to connect their CT scanners with the MEDICUS workstation for an appropriate amount of money (over US$ 35 000 installation costs each). The remaining 13 partners came from a private radiological practice, small hospitals, university clinics and a re-

search institution. Ten partners are located in the Heidelberg/Mannheim area in South-West Germany, two partners in Essen in the North-West and one partner in Nürnberg in the South-East. The installation of the MEDICUS system started in December 1995. The system was installed at all sites in April 1996. A system evaluation started then and is still going on. All users started with a learning and test phase for several weeks. Five institutions are using the system in daily clinical routine. The number of program invocations has been logged since April 1996. A more sophisticated logging system was installed in June 1996. Different evaluations have been performed on these data.

### 4.1. Accounting numbers

The 13 MEDICUS partners used the program 3327 times during 9 months (from April to December 1996). The last 7 months (June–December) have been investigated in more detail (Table 1). The program has been used 2632 times in that period. More than 25 301 images from CT and MRI have been imported to the MEDICUS system. 21 258 images in 521 packets have been sent to other medical partners via ISDN. Usually, one packet contains one study with several series of images. The average number of transmitted images in one study was 43. Four partners produced 99% of the traffic.

The partners realized 140 teleconferences. The typical duration of a teleconference was 5 min. All teleconferences where shorter than 10 min. The mean conference preparation time was 2 min. This time is reduced to some seconds (3 mouse clicks) when no accompanying letter is written.

### 4.2. Application scenarios

The different institutions are using the system in very different scenarios. One partner (University Clinic Mannheim) has two systems in his clinic and is using it on a local Ethernet for inhouse communication. It is not necessary to transmit the image data explicitly from one system to the other since both systems share the same database. In that context, the MEDICUS system acts more like a viewing station with teleconference capabilities.

Table 1
MEDICUS accounting numbers (6/96–12/96)

| | |
|---|---|
| Program invocations | 2632 |
| Partners | 13 |
| Imported images | 25301 |
| Transmitted images | 21258 |
| Transmitted studies | 521 |
| Number of teleconferences (by ten partners) | 140 |
| Typical duration of a teleconference (min) | 5 |

Another partner (Radiology Department at the German Cancer Research Center) is using MEDICUS to deliver images and a short diagnosis to the referring physicians in two smaller hospitals (Ev. Krankenhaus Salem, Krankenhaus Speyerers Hof). The findings are discussed between the radiologist at the cancer center and the clinicians (internal medicine or urology) in teleconferences. The same radiologists send images to the gynecological radiology of the University Hospital in Heidelberg. The CT images are further processed by a radiation therapy planning system.

One small hospital (Ev. Lutherkrankenhaus, Essen) is sending images to the radiology department of a clinic (Klinikum Niederberg, Velbert), where the images are reported. The teleconference functionality is not very often used for this purpose.

Another important application scenario is the transmission of images for scientific purposes. The image processing group at the German Cancer Research Center receives images from several (radiological) partners for basic research in image processing or clinical trials with new image processing methods. The results are sent back to the physicians for the discussion of the results.

Yet another application scenario, which is asking another radiologist for his/her second opinion, was used only occasionally. Our experience is that this is at the moment not a major task for a teleradiology system. An important reason for this is the problem of reimbursement of expenses from the health insurance institutions.

One very important result of the field test was that our medical partners improved mainly existing and very well established cooperations. Very few new cooperations have been established for the usage of teleradiology in routine, which might be caused by the limited number of connected sites.

### 4.3. Technical experiences

The following experiences have been made when the teleradiology network was built: it was first planned to connect all imaging modalities with the DICOM protocol and image file standard with the MEDICUS systems. But at that time, not one of the radiological partners had a device which supported this standard. Instead, we had to connect each of the ten devices 'by hand' in close cooperation with the vendors and their field technicians. The connections are based on the DECnet and TCP/IP protocols. NFS, FTP and remote copy functions had to be used to realize the image transfer. It could be seen that openness and cooperation of the vendors are inversely proportional to their share of the (German) market. ACR/NEMA 1.0 and 2.0 were the best available standards. For nearly every machine, we had to adopt the image import function for vendor or machine-dependent exceptions.

The usage of UNIX workstations has not been proven to be a drawback in the clinical environment. INDY workstations (Silicon Graphics) have been used as the standard platform as they come with all necessary hardware options (ISDN, video, audio, frame grabber). The machines can be switched on and off like a PC, have an easy-to-use graphical desktop interface, but the power and security of a UNIX system. Existing personal computers can also be used under the Linux operating system.

No major problems have been encountered with the ISDN telephone lines of the German Telekom. Only one connection was out of order for one day after a heavy thunderstorm which destroyed some switching equipment of the Telekom. Two different ISDN protocols are in use (1TR6 and Euro-ISDN or DSS-1) simultaneously. The protocol conversion is done automatically.

### 4.4. Clinical experiences

Thirteen application sites are using the MEDICUS system now, covering all different teleradiology scenarios. The department of oncological diagnostics and therapy at the German Cancer Research Center has been routinely using the MEDICUS system since December 1995 for teleradiology communication with two regional hospitals (Ev. Krankenhaus Salem and Krankenhaus Speyerers Hof) and the department of gynecological radiology, University Hospital, Heidelberg. In this setting we gathered experience using teleradiology for routine consultations between radiologists and clinicians; for expert consultations, for scientific cooperations and for data transfer for radiotherapy treatment planning.

Experience from this application scenario covers: the MEDICUS system is a tool providing a very high degree of functionality. This starts with the necessary data import, which uses existing copying functions of the digital imaging modalities and automated background procedures. This can usually be done by an engineer. The transfer of image data via ISDN as basis for teleradiology conferences needs only a minimal amount of mouse clicks and can easily be done even by inexperienced users.

An accompanying short notice of results can be added. The MEDICUS system is used very easily during teleconferences. The system speed is good. Even new users not being firm in the handling of computers can be guided through the teleconference session by easy explanations through the telephone. The system offers the basic image workstation procedures like level/window manipulations or densitometry. All functions are accessed very easily. Data privacy is secured, which is very important for the transfer of patient-related data, and leads to improved acceptance by clinicians and patients. The introduction of the teleradiology system MEDICUS can lead to reduced costs for the copying of film material, which is often necessary for the information of the treating physicians. In our experience, this cost reduction exceeds the additional costs for using the ISDN lines. Additionally, the information flow is improved, resulting in accelerated information and treatment of patients. This may lead to further cost reductions. Larger studies are needed for final evaluation of this aspect.

### 4.5. Comparison with other systems

It is not easy to compare MEDICUS with other teleconference tools or viewing stations. Not many results about field tests in teleradiology have been published. The results of the field test of the KAMEDIN project of the German Telekom have been published by Rienast [13]. The number of installations in both field test (MEDICUS 13 and KAMEDIN 14) were similar. MEDICUS has been used much more often than KAMEDIN 2632:694. The efficiency of MEDICUS was up to ten times better with respect to conference preparation time. A short conference preparation time is essential for the acceptance of a teleconference system. The duration of MEDICUS teleconferences a quarter of the time compared to KAMEDIN. As the amount of data which had been 'processed' during the teleconferences was nearly the same one can see that the KAMEDIN system is also less efficient for use during the teleconference. The KAMEDIN system is the future teleradiology product of the Deutsche Telekom AG sold under the name: DOXX-Radiologie.

Walz compared MEDICUS with KAMEDIN, MedVision (Evergreen/MDS), ProShare (Intel Corp.) and the GE AdvantageWindows workstation (GE Medical Systems) [14]. The aspects teleconference, reporting functionality, telecommunication functionality, image input/output, and basic requirements have been compared. The result of his comparison was that MEDICUS was the best system for teleradiology in that context.

### 4.6. Conclusion

MEDICUS is a valuable and functional tool with dedicated teleradiology capabilities. In various studies, these functions have proven superior to other existing systems. The existing security concept is a bare necessity for any further usage of teleradiology systems. MEDICUS leads an improved information flow in clinical settings, making an accelerated treatment of patients possible. Cost reduction capabilities are already obvious, but additional research has to be performed in this field.

The Steinbeis-Transferzentrum Medizinische Informatik in Heidelberg is currently developing (and re-implementing) a commercial teleradiology system CHILI based on the experiences of the MEDICUS project.

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