The newly built Berlin-Marzahn Casualty Hospital came into service on 3 September 1997, under the joint responsibility of the Berlin regional government and the professional societies. Several years earlier, the important decision had already been taken that the hospital would operate with as little film and paper as possible, and that the Institute for Radiology would be totally digital. The order for the complete radiology department was entrusted to Philips.

As early as November 1996, the future users of the radiology facilities began to plan the contents of the department, within the given technical framework. This process led to a harmonization of the proposals from Philips, and from the future users. This, in turn, formed the basis for a detailed schedule of responsibilities. In addition, the technical changes had to be discussed, and the timetable for the start-up had to be planned. Recruitment of the physicians and radiographic technicians for the new department took place in parallel with the technical planning. Equal emphasis was placed on high professional competence, and on experience in data processing and computer techniques.

In June 1997, the team of physicians and radiographic technicians began the work of defining the structure of the radiological information system, and entering the basic data. In the remaining weeks before the hospital became operational, there was a precisely planned programme of personnel training, particularly in data processing, but also with respect to the individual systems. Since September 1997, the Institute for Radiology has been in full digital operation.

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An important consideration for the structure of the radiology department is the marked interdisciplinary working method within the hospital. Thus, the three principal disciplines (maxillofacial surgery, neurosurgery and ENT) share a pool of 36 floating beds, which can be used by any of the individual disciplines as required. In addition, there is a variable allocation of the patients to the different clinics, with a corresponding variation in the distribution of images. An outstanding feature is the extremely good information flow within the hospital, and the universal readiness to discuss and solve problems in an uncomplicated manner and in direct contact with one another.

The hospital has a total of 468 beds. Table 1 shows the distribution of beds over the various clinics and departments. In addition to those shown, the hospital also has an institute for pathology.
Technical requirements

The hospital has a local-area network with a total length of 430 kilometres, comprising FDDI, Fast Ethernet and Ethernet. The connections available for medical imaging and image distribution are 10 M bit links, either shared or switched, or 100 M bit links, depending on the priorities.

There is a hospital information and communication system (HICS) supplied by the Dataplan Company. Patient data entered in this system are passed to the RIS Radiological Information System (Rados R) via an HL7 link. The RIS is a very important component within the network, as it not only provides access to the patient administration, with links to the PACS system, but also co-ordinates the patient and image data. Appropriate RIS interfaces provide data transfer to the individual imaging modalities. These include several bucky systems for digital projection radiography using storage phosphor screens, and three read-out units. In addition, the radiology department has a multifunctional digital fluoroscopy system, a system for digital subtraction angiography, a CT system, an MR system, a diagnostic ultrasound system with colour doppler, several mobile X-ray units, C-arms and an orthopantomography system. There is also a digital chest radiography system and a mobile CT system. Images from all these systems are transferred to the digital image archive (ArchiM edis) via appropriate DICOM interfaces. In the systems using storage phosphor screens, the read-out units are backed by an EasyVision RAD registered, as the link to the image archive, and the CT system is connected to an EasyVision CT. The angiography and MR systems are connected to an EasyVision Angio and EasyVision MR workstation respectively.

The image archive consists of a juke box with a temporary 600 Gigabyte image store. The final image storage is on digital-optical discs (WORMs). An important component in the image archive is the ‘workflow manager’. The images received from the specific modalities are

Fig. 1 a, b. The entrance area and the generously proportioned main hall of the new Berlin-M arzahn Casualty Hospital.

Networking of equipment and systems via an internal glass-fibre network.

Fig. 2. Schematic diagram of the RIS PACS network for image distribution and archiving.
Transferred following predefined rules to specific diagnostic workstations (DWS).

The diagnostic area for the physicians is equipped with four DWS diagnostic workstations. These are double monitor systems, each with two 2K monitors, for assessment of conventional X-ray images. The DWS installed in the emergency room has four high-resolution monitors, in order to cope with the high image throughput. There is also a Result Viewing Station (RVS) in the MR suite. This has four 1K monitors for comparing image sequences from previous examinations with the current images. Another RVS with two monitors is used for CT diagnosis. The EasyVision CT, EasyVision MR and EasyVision Angio workstations are also used for diagnosis, as well as for postprocessing the image data, including multiplanar reconstruction (MPR) and 3D display.

Image acquisition and archiving

Entry of the patient data at the individual modalities is no longer necessary, due to the link with the RIS. In the rooms for digital projection radiography with storage phosphor screens, the appropriate exposure parameters are set together with the booking and scheduling of each examination. After the storage phosphor screen has been read out, the images are processed on the EasyVision RAD according to a protocol specified by the user. If necessary, the radiographic technician can optimize the layout (collimation etc.) The images are then sent to the image archive for final storage.

The images passed by the workflow manager to a specific DWS are copies of the originals in the archive. If the physician making the diagnosis at the DWS makes additional changes to the image, in order to improve settings relevant to the diagnosis, the modified version can be stored in the archive as an additional copy.

After the diagnosis, the findings entered in the RIS are inseparably combined with the image as pixel data, and stored in the archive. The remaining imaging modalities (with the exception of projection radiography) transmit their images to the archive following a similar procedure. Only the intermediate phase of the EasyVision RAD is absent. The EasyVision CT, MR and Angio workstations serve for postprocessing and, to some extent, for diagnostic evaluation. New images which have been processed in these workstations are stored together with the originals in the archives (e.g. multiplanar reconstructions).

In the case of technical faults or incorrect data entry, the assignment of patient data to images can be interrupted in individual cases, leading to the occurrence of NAD (non-allocated data). Non-allocated data are displayed in a special list on the DWS, and can be correctly allocated at a later stage. This work requires the greatest care, as it could otherwise lead to incorrect combination of patient data and image data. Checking the accuracy of the data is the responsibility of the radiologists.

Angiography can be regarded as a special case. Here again, only the radiologist decides whether individual images from the buffer memory should be permanently stored in the image archive, or whether special events in the dynamics of contrast flow should be stored as a complete series. The decision can be regarded as striking a balance between economy in the image archive, and diagnostic relevance, including the relevance to group evaluation.

Diagnosis and distribution of results

At present, the clinical query as well as important information from the case history is passed from the workstation to the radiology department in writing, together with the examination request. The link between the HICS and the RIS, intended for this purpose, is now undergoing final testing before becoming operation.

At his workstation, the radiologist finds the preloaded images corresponding to the written
request in the worklist of the workflow manager. The images are already available at the workstation, and can be called up within a few seconds. Beside every DWS, there is an RIS PC with a dedicated report-writing program, so that the radiologist can enter the text directly into the RIS using a combination of prepared text modules and his own input via the computer keyboard. This is the fastest way of recording the diagnosis.

An alternative method is, of course, dictating the report and having it entered via an RIS PC in the typists’ office. At present, the product in both cases is still a report printed out on paper. The H L7 link to the HIS, with direct electronic transmission of the report to the station requesting it, is still in the final test phase. In the axial imaging and angiography rooms the reports are, in principle, dictated and typed out in the typists’ office. A speech-recognition system that can be integrated in the RIS is planned for the second quarter of 1998.

Rados R has several built-in stages in the release of the report (assessed, tested, rejected) which ensure that the report is only released after it has been checked by a specialist or senior physician.

Image distribution in the hospital

As the images only exist in electronic form, efficient distribution among our clinical colleagues within the hospital presented a major problem, both in the design phase, and when the system became operational within the hospital routine. The distribution system had to meet two requirements:

- assessment of the images in the individual workstations, in the ambulances and in the operating room
- demonstrations by the Institute of Radiology for the various clinical departments

At present, there are 62 PC viewing stations throughout the hospital, which have a direct connection to the image archive, allowing the clinical colleagues to transfer images to their own workstations using specialized viewing software, and to assess the images there. The software is easy to understand and use. In the initial phase, instability in the image transfer occurred due to a combination of problems (network, software, hardware). In addition, the waiting time for individual images was not always satisfactory, depending on the network load at that moment.

A new version of the software, installed in February 1998, produced a clear improvement in both the handling and the speed of the image transfer. In addition, a ‘scheduler’ was brought into use that makes it possible to reload marked images and image series into the PC viewing stations between 21.00 and 05.00 hours, i.e. in a period when there is little load on the network, so that they are available on the local hard disk for immediate assessment the following morning.

After eight weeks of routine operation, those workstations were identified that have a particularly high image requirement per unit of time. A total of ten workstations were involved including, in particular, the neurosurgical, maxillofacial surgical and ENT departments, which require a very large number of axial image series for surgical planning. The hardware configurations of the ten stations involved were extended accordingly.

To avoid delays in image transfer to the clinical departments, marked series are sent overnight by ‘scheduler’.

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In our initial concept, we envisaged that the images would simply be retrieved by the clinical physicians. We assumed that the user would have an overview of the situation on his own local hard disc, and would take care of the storage administration himself. This concept has been changed in recent months, so that the radiology department now actively sends images to the ICU, operating room and other selected users. Distribution lists are provided at the individual diagnostic workstations which serve for electronic transmission of the images directly after assessment.

Assessment of purely electronic images, without hard copies, was a new experience for all the physicians in the hospital, and led to a very intensive dialogue between everyone involved. On one hand, the radiology department and the industrial suppliers had to make a major effort with respect to the technology, in order to ensure smooth operation of the various transfer processes.

On the other hand, the new working procedure was the subject of innumerable discussions in the clinical departments and the various examination areas. People had to accept that, even with the latest networking and data processing technology, it is still not possible for every image to be available at every location in the hospital within seconds. Many of the procedures in the clinical operation had to be reorganized. However, the assistant physicians wanted preparations for minor X-ray examinations to remain unchanged. The generally very constructive and collegial atmosphere, particularly with respect to the acceptance of the new procedures within the newly opened hospital, made a very favourable impression.

A complex system of this type can only be successfully brought into operation if all parties involved are prepared for dialogue, have clear tasks set by the medical management, and share a common goal. The multifaceted problems associated with the introduction can only be solved if all these requirements are met. Flexible allocation of responsibilities between radiologists, radiographic technicians, IT specialists and technicians, as well as a co-operative partnership with the various firms involved, are essential requirements for success.

The concept and realization of the image demonstration facilities was also not without complications. Particularly during the start-up phase in September 1997, the high image requirements of the individual clinics could only be met by a properly functioning demonstration of the images, together with interdisciplinary discussions. A small network for this purpose was soon installed within the radiology department, consisting of three specially configured computers, and a modified version of the PC viewing software. This network communicates directly with the image archive via a 100 Mbit link, and receives images from the individual diagnostic workstations in virtual ‘demonstration files’. Two computers outside the demonstration room prepare the radiological discussions by creating individual ‘patient files’, combining images from all the various imaging modalities.

The most powerful computer is in the demonstration room itself. It is connected to a ‘video beamer’ for large-screen projection. The demonstration software has a range of specific features for optimum display of conventional radiographs, axial images and angiographic series. Preset window levels, variable magnification, multiplanar reformatting, cine mode and widely variable viewer functions allow fast, elegant and optimum demonstration of clinical images with excellent visibility for everyone present.

These demonstrations of clinical images were very much in demand from the individual clinical departments. They allowed, and continue to allow, us to meet the information requirements of our clinical partners with images of the highest quality. The conception and realization of this demonstration system arose from the practical working procedure, and had to be done
very quickly. A range of specific aspects of the hospital, and the internal logistic procedures in the radiology department, had to be taken into account. The configuration that has now been arrived at reflects both the working procedure within the radiology department, as well as the central position of radiology within the hospital.

Safety back-up

The most important provision for equipment failure in an emergency hospital is sufficient redundancy of systems. In the Berlin-M arzhn Casualty Hospital all major imaging modalities, such as CT and read-out units for storage phosphor screens, are at least duplicated. Even the best maintenance plan cannot ensure the uninterrupted availability of all imaging systems, which is essential when examining so many patients with multiple injuries.

Each individual imaging modality is directly connected with one of the two laser printers, independently of the central hospital network. This ensures that, if the central data processing fails, hard copies can be produced immediately. Appropriate protocols are also available at the individual examination systems for use in the case of a breakdown of the RIS. These protocols are filled out, and immediately entered with the patient data in the examination system. They can be retrieved later for fast entry in the information system.

A breakdown in the archiving system can be compensated for by the storage capacity in the individual examination systems for up to 24 hours. If the functionality were not restored within this time, we would have to resort to external storage media (M O D), or make hard copies which could then be scanned in later. We have no practical experience of this breakdown contingency, as the technical faults that have occurred have always been of short duration, so that there has only been a brief interruption in the working procedure.

Practical experience, shared problems

When the digital radiology department became operational at the Berlin-M arzhn Casualty Hospital, it was obvious to the total radiology team, the clinical partners within the hospital and the responsible commercial companies that the concept that had been planned and worked out had to become a reality. Unlike most of the systems installed so far, the Berlin-M arzhn system had no practicable alternative for clinical routine operation, apart from the contingency plan for technical failure. The system configuration, the high degree of motivation of the staff, and the excellent technical facilities available in the hospital, met the requirements for successful introduction of our RIS/PACS installation.

Registration, entry and listing of patients can be done with acceptable speed, particularly since the introduction of the new Rados R software release in December 1997. The system can be operated without difficulty by the radiological assistants. The transfer of all patient data to the imaging modalities is generally regarded as a positive benefit.

In general, assessment of projection radiographs from preloaded worklists on the diagnostic workstation appears to be a practical procedure. All radiologists agreed that reporting from the 2K monitors was regarded very favourably with respect to image quality. However, appropriate fine adjustment of the post-processing protocols was necessary for each of the individual imaging techniques. The possibilities for magnification and centre-window postprocessing increased the diagnostic scope for the reporting physician.

Operation of the diagnostic workstation became more complicated as the number of examinations per patient increased. This is due on one hand to the limited speed at which the images are built up, and on the other hand to an insuffi-
Virtual demonstration and patient portfolios save time in preparing the X-ray discussions. The selected PACS concept has proved itself in principle; the optimization process still continues.

Ciently optimized logistic procedure of the operating menus. In general, the functionality of the diagnostic workstation is not satisfactory for evaluating axial images. This can lead to bottlenecks, particularly in assessing MR images. For this reason, reporting has so far been mainly done on the appropriate EasyVision workstations. This requires urgent attention from the manufacturers.

An important factor appears to be the central positioning of the diagnostic workstation in an evaluation area, where the diagnoses are checked by the specialists and/or senior physicians. This is unavoidable at the present state of the art, as images that have already been called up together with previous images cannot be arbitrarily blocked via the diagnostic workstation. Calling up the complete image series for a second time for confirmation does not appear to be really practicable.

The use of address lists, which make it possible to transmit individual images or image series to the various departments and operating rooms, as well as combining the images in demonstration files, has proved to be very useful. In contrast with the experience of others, we have had no problems with the noise or heat produced by the diagnostic workstations.

After solution of the teething troubles in September 1997, and correction of some short-duration technical faults in connection with the software release, our configuration consisting of a computer network with large-screen video projection in a demonstration can be regarded as more or less optimal. The compilation of virtual demonstration files, which can be accessed from various diagnostic workstations throughout the day, as well as the variable and uncomplicated compilation of virtual patient files, makes it possible to prepare a radiological demonstration of about 25 patients with images from different modalities in some 15–20 minutes. Our method of image presentation has been generally favourably received by our clinical colleagues.

Meanwhile, the PC viewing software in the clinical workstations has now become stable and is running satisfactorily. The operating menus in the latest software version are clearly arranged and easy to use. There have been occasional complaints of long access times of several minutes for the image archive, at times when there is a high load on the network. This problem has now been largely eliminated by the introduction of schedulers, with the possibilities of retrieving images overnight. The mutual learning process between the clinical partners and the radiologists with respect to image access is certainly not yet concluded. From time to time, it is still necessary to consider changes in the hardware.

The procedures for writing and transmitting reports within the RIS are practical. It is expected that these functions will be further optimized when the HL7 link is brought into use, together with the integration of the speech-recognition system, leading to a rationalization of the amount of work involved.

Over the last half year, the Berlin-Marzahn Casualty Hospital has had an average image data volume of 2.5 Gigabyte per day, with peaks of up to 4.5 Gigabyte per day. The installed system has proved to be easily capable of handling this throughput. In view of the complexity of the initial assignment, this result in itself can be regarded as a success. There are, of course, still many details to be improved, and new approaches to be worked out. However, the first and most difficult step of making the system operational is behind us. Now we can concentrate on optimizing our system in routine operation.