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Digital radiography with an electronic flat-panel detector: First clinical experience in skeletal diagnostics

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X-ray examinations of the skeleton are, after chest exposures, the most frequently performed type of radiological examination, representing about 30 % of the total. With a few exceptions, projection radiography forms the basis for the diagnosis of skeletal disorders and, in most cases, provides the information for the definitive diagnosis. In traumatology, rheumatology and oncology, projection radiography is still indispensable, even when non-radiological examination methods, (e.g. clinico-chemical and immunological) examination methods are taken into account.

Digital radiography

The continuing development in computer technology has made it possible to rationalize the working procedures in radiological practices and hospital departments with the aid of Radiology Information Systems (RIS) and digital archiving systems (PACS). The possibility of digital post-processing of the acquired images offers further advantages. Radiological reporting from the display screen spares the costs of film material and X-ray film archiving. Access to these systems is only possible with digital imaging technology.

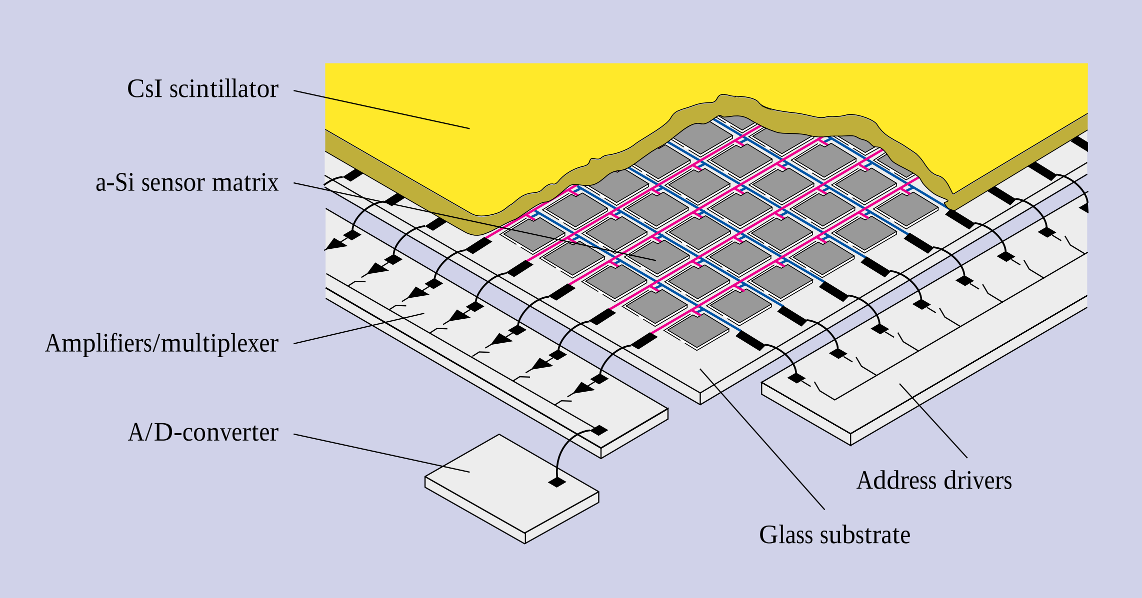

Fig. 1. Construction of the flat-panel detector. The X-ray sensitive convertor layer consists of caesium iodide (CsI). The amorphous silicon sensor array comprises 3000 x 3000 pixels.

A prerequisite for reliable diagnosis is the availability of technically satisfactory exposures. This not only includes accurate imaging of the object but also, and in particular, the choice of a suitable image carrier. New imaging systems must be measured against the conventional screen-film combinations, which have been optimized in the course of the years with respect to detail and contrast rendition, exposure latitude and, of course, the radiation dose required.

Computed radiography

Computed radiography, introduced at the beginning of the 1980's, has had its widest application in digital projection radiography. The image receptor is a storage screen, coated with europium-activated barium halide crystals. Radiation increases the energy of some of the electrons in the crystal lattice, which are held in 'traps'. This creates a latent image that can be read out

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later in a read-out unit by scanning it line-by-line with a laser beam. The resulting luminescence is detected by a photomultiplier, amplified electronically and converted into a digital value.

In addition to the qualities of a digital exposure system, as mentioned above, the major advantage of computed radiography is its wide dynamic range. The response curve is linear over a dose range of more than 1:10000, so that the chance of incorrect exposure is practically excluded, even when exposures are made without automatic exposure control. This technique has proved its value, particularly in applications in which precise exposure cannot be achieved, such as bed exposures of the lungs.

In skeletal diagnostics, computed radiography is suitable for obtaining surgical and orthopaedic information, and for follow-up control in oncology. It has limitations in applications where the highest detail resolution is required, such as analysis of the fine structure of bones.

The electronic flat-panel detector

The electronic flat-panel detector allows direct digital recording of X-ray images, without the intermediate step of optical or mechanical scanning (Fig.1). The essential part is a semiconductor layer of amorphous silicon, divided into a matrix of individual sensors, each with a width of 0.143 mm. However, silicon on its own is not sufficiently sensitive to the X-ray energies used in diagnostics. For this reason, the layer of amorphous silicon is coated with an image-conversion layer, which absorbs the X-ray photons and emits photons of visible light. These can be detected extremely well in the silicon layer. In general, caesium iodide (CsI) is used as the image-conversion layer, just as it is used as the input screen of X-ray image intensifiers. The needle-like crystal structure of CsI works as a set of lightguides, avoiding the scatter effect that reduces the resolution of other phosphors.

The pixel size in the X-ray image is determined by the size of the sensors. In the detector described here, it is 0.143 mm. This allows a resolution of more than 3 lp/mm to be achieved. With a detector size of 43 x 43 cm, a matrix of 3000 x 3000 pixels is created on the flat-panel detector. As a comparison, conventional storage screens with a cassette of 35 x 43 cm have a pixel matrix of 1760 x 2140 with a pixel size of 0.2 mm.

First clinical experience

In May 1998 the first prototype of a digital flat-panel detector (Trixell Pixium 4600), integrated in the Philips Bucky Diagnost TH table, was installed in our clinic. The detector had the technical specifications described above. If required, a moving grid (36 lines/cm; ratio 12) can be used. A Philips Optimus 65 Generator with a Philips SRO 33100 X-ray tube was used as the standard combination for X-ray generation.

In our first study, we compared the image quality of the new flat-panel detector with that of a conventional screen-film combination. In 23 selected patients, who had been referred to us for routine diagnostics, we made a total of 30 comparative X-ray exposures of the skeleton.

Fig. 2. Digital Diagnost system with integrated flat-panel detector.

The flat detector allows direct digital recording.

First, conventional exposures were made using a standardized technique. The digital exposures were made with the same exposure parameters and, as far as possible, identical projections. Examples of such exposure pairs are shown in Figures 3–7.

The exposure pairs were assessed by six different experienced radiologists with respect to the image latitude, the detail rendition in the struc-

Fig. 3. Lateral skull exposures. Fig. 3 a. Screen-film combination (speed 400). Fig. 3 b. Flat-panel detector exposure. Polyostotic Pagets Disease.

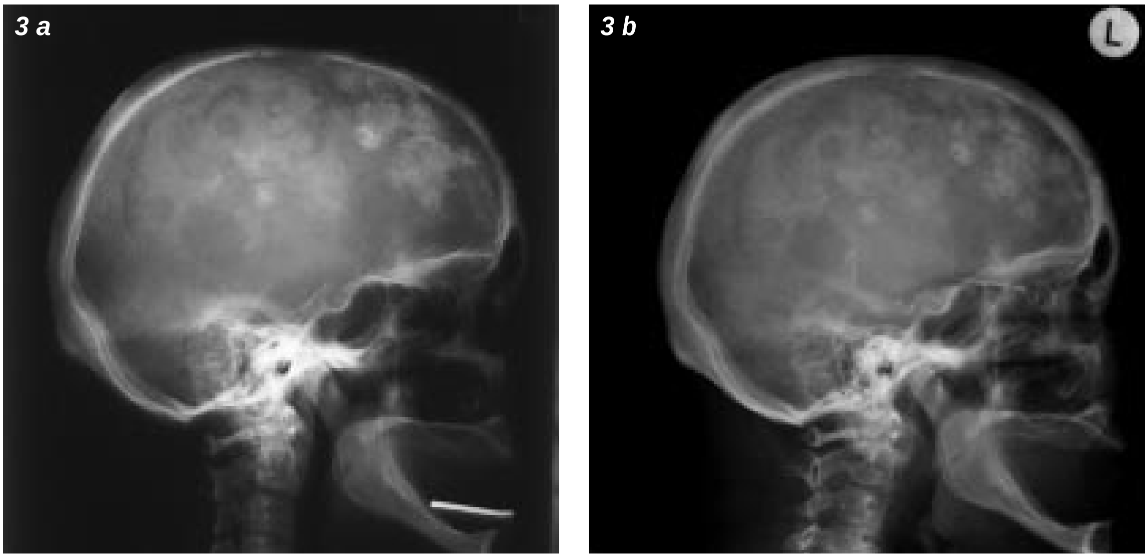

Fig. 4. Lauenstein exposure of the hip joint. Fig. 4 a. Screen-film combination (speed 400). Fig. 4 b. Flat-panel detector exposure. The fine bony structures can be easily assessed, and there is very good soft-tissue visualization.

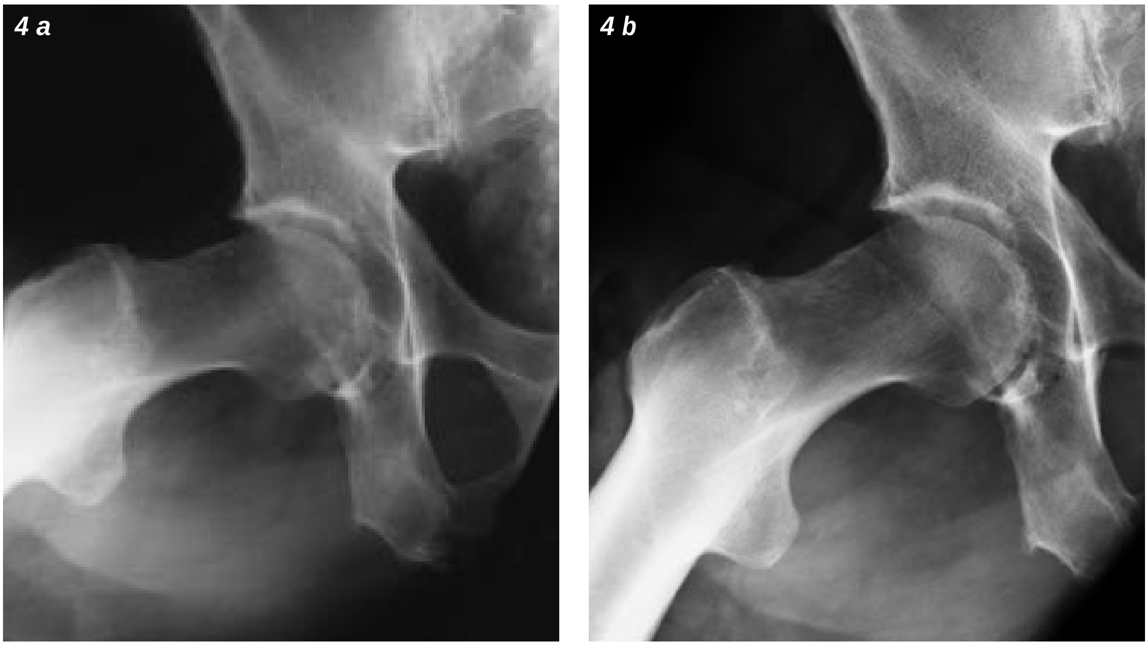

Fig. 5. Lateral exposure of the knee. Fig. 5 a. Screen-film combination (speed 250). Fig. 5 b. Flat-panel detector exposure. There is very good delineation of the object with excellent soft-tissue rendition. The fine bony structures can be easily assessed.

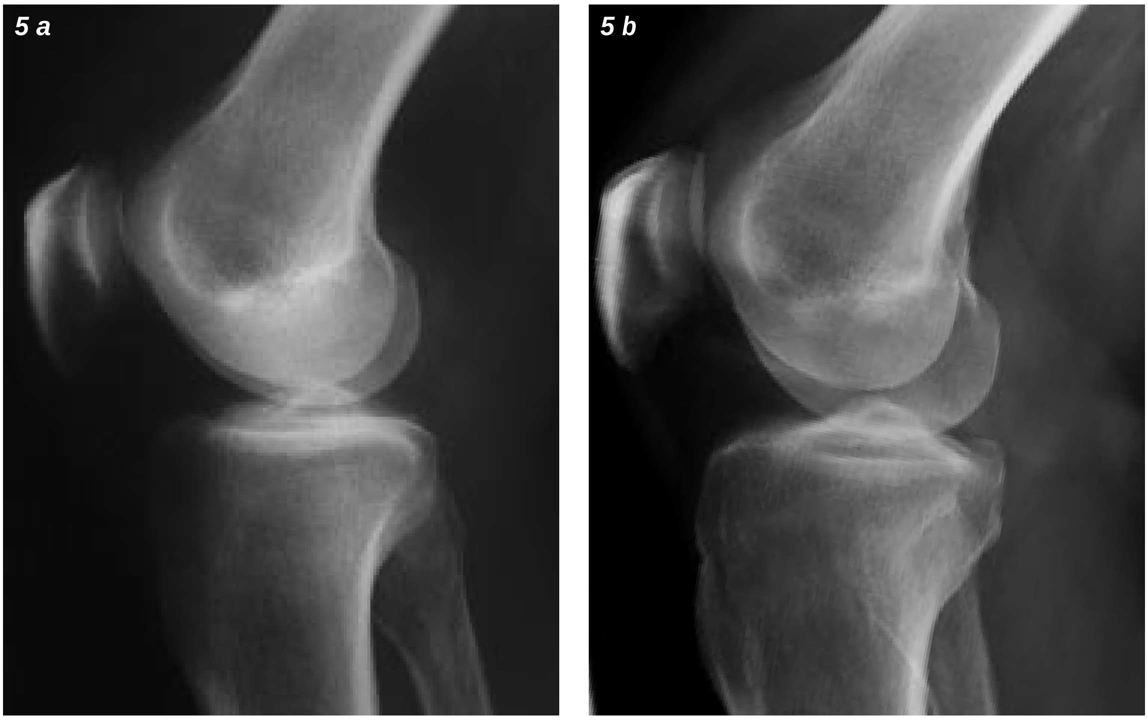

Fig. 6.
AP exposure of the hand.
Fig. 6 a. Screen-film combination (speed 250).
Fig. 6 b. Exposure using mammography technique.
Fig. 6 c. Flat-panel detector exposure. The image has a very good latitude, with better detail rendition than the screen-film combination. The exposure using the mammography technique is superior to both, but with a significantly higher dose.

Fig. 7.
Lateral exposure of the lumbar spine.
Fig. 7 a. Screen-film combination (speed 400).
Fig. 7 b. Flat-panel detector. The image latitude is clearly better. The increased sclerosis, particularly of L2, following irradiation of a vertebral metastasis of a mammary carcinoma is shown better in the conventional exposure.

Image latitude and soft-tissue rendition are significantly better than with screen-film combinations.

ture of the cancellous bone, the structure of the endosteal and periosteal compact bone, the soft tissue rendition, and the recognizability of any pathological changes that might be present. The results were assessed according to a 5-step evaluation scale. In general, all observers showed a significant preference for the digital exposures with respect to all criteria that could be evaluated in all images. The image latitude and the soft-tissue rendition in particular were assessed as being better in the digital exposures.

With respect to the display of diagnostically relevant pathological changes, three observers preferred the digital images, while for the other three there was no significant difference from the conventional image.

The flat detector has excellent detail resolution and allows an optimized working procedure.

One exception was the presence of sclerotic changes in bone, principally in a single plane, encountered in two patients (vertebral metastases of a mammary carcinoma; fractured vertebrae in osteoporosis). These tended to be regarded as poorer in the digital exposures (Fig. 7). This effect is already known from computed radiography, and is probably the consequence of less than optimal post-processing of the exposures, rather than a detection error in the flat a-Si detector.

Conclusion and future prospects

The flat-panel detector represents a new technology in the direct digital acquisition of radiographic images. It is likely to find widespread application in the coming years. In comparison with digital radiography using storage phosphor screens, it has the advantages of a theoretical improvement in detail resolution, as well as an optimized working procedure due to elimination of the use of cassettes. Both digital systems make it possible to rationalize the working procedure by integration in a Radiological Information System (RIS) and a digital archiving system (PACS).

In a first clinical comparative study, the flat detector exposures were assessed as being significantly better than those of conventional screen-film combinations, particularly with respect to image latitude and the soft-tissue rendition. The detail resolution was at least equal to that of the screen-film combinations used. Only the visualization of single-plane sclerotic changes was poorer than in the conventional exposures.

In the future, further comparative studies with larger numbers of cases will be needed for more accurate evaluation of the imaging properties of the new flat-panel detector. These studies will have to be made in comparison with conventional screen-film combinations, and digital radiography using storage screens. In addition to the spatial and contrast resolution, particular attention will have to be paid to investigating the visualization of osteolytic and osteosclerotic lesions in bone. Furthermore, it will be necessary to find the optimum digital post-processing parameters for each anatomical region.

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