Urol Radiol 14:56–58 (1992)

Urologic Radiology

Digital Radiography in Urologic Imaging: Radiation Dose Reduction on Urethrocystography

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Abstract. Digital luminescent radiography (DLR) is a new form of digital radiographic technology which can be used as an alternative to conventional radiologic systems; it replaces conventional screen-film systems by photostimulable phosphorus. Due to the linear dynamic range of photostimulable phosphorus, x-ray examinations can be performed with significantly lower radiation exposure. In this study radiation dose was reduced by about 90% using DLR for urethrocystography.

Key words: Digital radiography — Urethrocystography — Dose reduction.

Digital imaging systems are of increasing importance in radiology. Besides computed tomography, digital subtraction angiography, and magnetic resonance imaging, digital radiographic techniques are also becoming more frequently used in conventional x-ray examinations. Today, different digital imaging systems are available, either based on imaging plates with different photostimulable substances like phosphorus [1] and barium-fluorohalide europium doped crystals [2], or based on digital image amplification techniques of conventional x-ray fluoroscopy [3]. Due to the linear dynamic range of photostimulable phosphorus, digital luminescent radiography (DLR) is possible with significantly reduced radiation exposure, a fact of specific importance in x-ray examinations of the genitourinary tract where it is difficult to avoid a high gonadal radiation dose. The aim of our study was to determine the extent of radiation dose reduction possible in radiology of the lower urinary tract.

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Materials and Methods

Urethrocystography was regarded as a representative x-ray examination of the lower urinary tract. Urethrocystography was done preoperatively as a routine procedure in male patients prior to open surgery or transurethral resection of obstructive benign prostatic hyperplasia. The examination was performed in an oblique position and included an oblique plain film of the pelvis, a retrograde urethrography, and a voiding urethrocystogram after the bladder had been filled with 400 ml of contrast medium. The image plate sizes were 24 × 30 cm in all examinations.

We used a Siemens Urograph for screen-film exposures, in both conventional screen-film systems and DLR. Conventional screen-film exposures were produced using a medium-speed system and a Siemens Tridoros Optimatic 1000 phototimer with an exposure setting of 77 kV. In DLR screen-film exposures were produced with an exposure setting of 81 kV and 6.4 mAs, applying Philips Computed Radiography (PCR, Version 1.0) as the image reader and image processor for DLR imaging. These exposure settings provided a sufficient signal-to-noise ratio adequate for reliable diagnostic accuracy.

Measurements of radiation exposure were taken as a Diamentor measurement, recording the total exposure–area product ($mGy \cdot cm^2$) for each patient along with each x-ray examination [4]. For this purpose a PTW-Diamentor-D (Physikalisch-Technische Werkstätten, Dr. Pychlau, Freiburg, Germany) was fitted to the x-ray device.

The study was carried out using the conventional radiologic system in 10 patients and DLR technology in nine patients. According to the study design described above, three radiographs were performed in each patient, and the radiation dose was then calculated from the 30 radiographs taken with the conventional screen-film system and from the 27 radiographs with DLR.

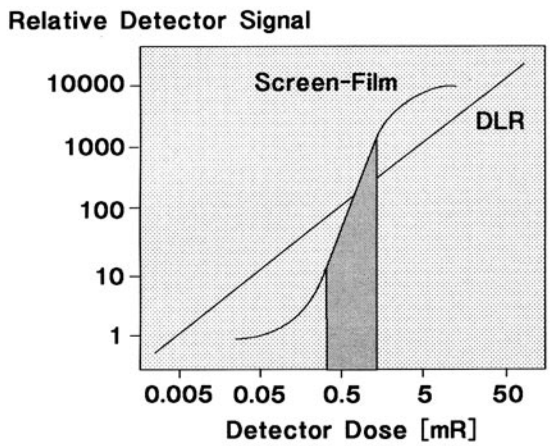

Fig. 1. Dynamic range with conventional screen-film combinations and the DLR technique [1]. With conventional screen-film combinations, x-ray imaging is only possible within the short, dark-gray radiation dose area representing a linear dynamic range.

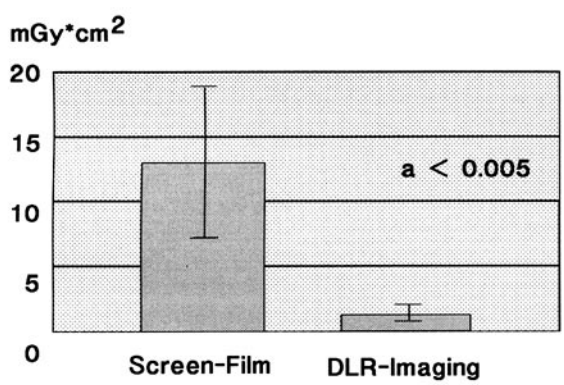

Fig. 2. Average radiation dose and standard deviation in excretory urethrography with screen-film combinations and DLR imaging.

The radiation dose for urethrocystography with the conventional screen-film system ranged from 5–30 mGy·cm², with an average dose of 12.9 mGy·cm² [standard deviation (SD) 6.13 mGy·cm²]. However, the radiation dose for urethrocystography with DLR ranged from 1–2 mGy·cm², with an average dose of only 1.33 mGy·cm² (SD 0.55 mGy·cm²). Thus, the radiation dose was significantly reduced with DLR compared to conventional screen-film combinations for x-ray examination of the lower genitourinary tract (Fig. 2).

Discussion

In DLR a resuable luminescent image plate consisting of photostimulable phosphorus is used instead of conventional screen-film combinations. These photostimulable phosphorus crystals are raised to a higher energy state by exposure to x-rays, and they are capable of storing this energy until being scanned with a 633-nm helium–neon laser beam. When x-ray-exposed image plates are scanned, luminescent radiation is emitted, corresponding to the absorbed x-ray energy, a phenomenon known as photostimulable luminescence. When a photodetector is applied along with a photomultiplier, this luminescent radiation can be converted into electric signals, used for digital image processing. When the processed digital signals are reconverted back into analog signals they can be used for generating a photographic film comparable to those of the conventional screen-film systems [2, 5] (Fig. 3).

As a rule, a linear correlation between imaging-plate x-ray exposure and imaging-plate density is necessary for accurate radiography. As the dynamic range of the conventional screen-film combination generally forms an S-shaped configuration, this linear correlation can only be achieved within a limited definite energy range (Fig. 1). Unlike conventional screen-film systems, imaging plates consisting of photostimulable phosphorus have an extremely wide linear dynamic range, allowing x-ray imaging at a significantly lower radiation dose level (Fig. 1). In addition, the use of imaging plates consisting of photostimulable crystals avoids exposure errors [1].

Using an image plate size of 24 × 30 cm with a scanning matrix of 1576 × 1975 at a laser dose size of 100 μm, spatial resolution is decreased to 2.5–3.5 line pairs/mm in DLR, compared to a spatial resolution of 4–6 line pairs/mm in conventional screen-film combinations [1, 6]. However, this decrease in spatial resolution does not affect diagnostic accuracy, as is shown when DLR and conventional x-ray examinations are compared in several studies including x-ray examinations of the chest and bones as well as angiography and excretory urography [2, 3, 6, 7]. With regard to excretory urography and contrast examinations of the gastrointestinal tract, radiation dose exposure could be reduced by 50% without affecting diagnostic accuracy [6].

Any further reduction in the radiation dose leads to a deterioration of the signal-to-noise ratio, resulting in a loss of image quality. Nevertheless, it is the question of gonadal radiation protection which must determine the extent to which a loss of image quality can be accepted in radiography of the lower urinary tract. It is our experience that, even when the radiation dose is reduced by up to 90%, the signal-to-noise ratio and spatial resolution in urethrocystography are sufficient to allow an adequate image interpretation in all patients.

Thus, DLR offers the opportunity for a significant radiation dose reduction in radiography. Further studies will have to be done in order to define

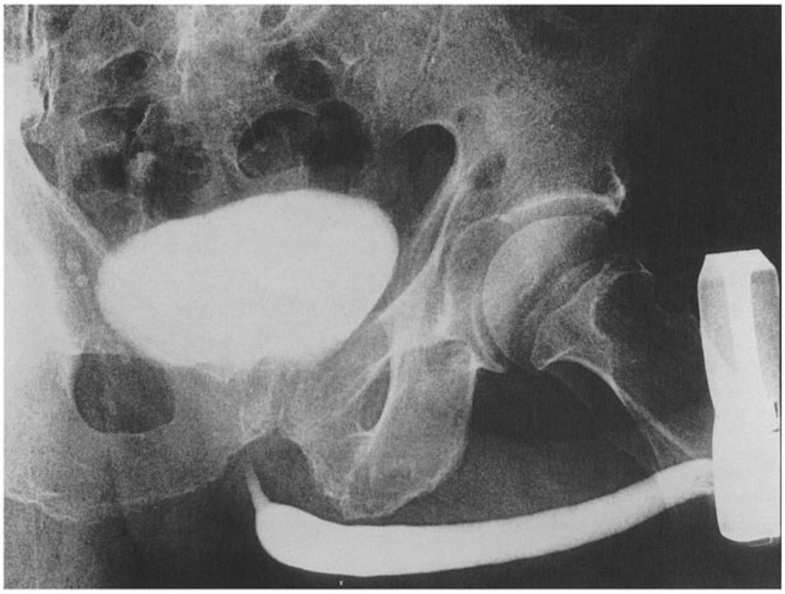

Fig. 3. Retrograde urethrography using the DLR technique.

the minimal radiation dose necessary for diagnostic accuracy in digital radiography with regard to different organs and different radiologic examinations.

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