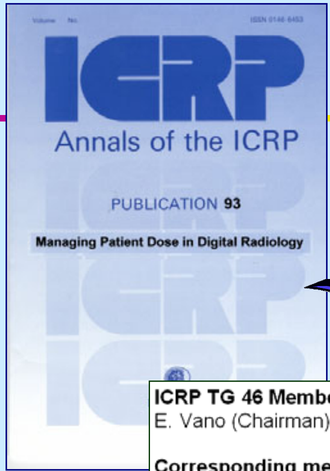

In press 2004

ELSEVIER

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ICRP Publication 93

Annals of the ICRP

Managing patient dose in digital radiology

ICRP Publication 93

Approved by the Commission in November 2003

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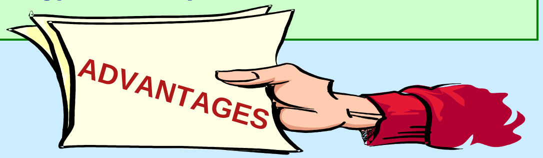
ICRP Publication 93

Guest Editorial

Guest Editorial (F. Mettler, H. Ringertz and E. Vano)

- **Digital radiology … An appropriate analogy that is easy for most people to understand is the replacement of typical film cameras with digital cameras: Images can be taken, immediately examined, deleted, corrected, and cropped, and subsequently sent to a network of computers.**
- **Digital technology has the potential to reduce patient doses.**



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ICRP Publication 93

Guest Editorial

Guest Editorial (F. Mettler, H. Ringertz and E. Vano)

- **What then is the problem and why did ICRP Committee 3 request a Task Group to write this document?.**

While digital techniques have the potential to reduce patient doses, they also have the potential to significantly increase them.

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ICRP Publication 93

Guest Editorial

Guest Editorial (F. Mettler, H. Ringertz and E. Vano)

- This is a technology that is advancing rapidly and which will soon affect hundreds of millions of patients.
- If careful attention is not paid to the radiation protection issues of digital radiology, medical exposure of patients will increase significantly and without concurrent benefit.

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ICRP 93 CONTENTS

- Introduction and purpose.
- Patient dose and image quality in digital radiology.
- Regulatory aspects and quality management.
- ICRP recommendations.
- Appendices:
  - Fundamentals of digital radiology.
  - Patient dosimetry: quantities and units.
  - Training outline.
- Glossary and acronyms.

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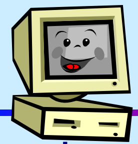
Main points (introduction)



- The diagnostic information provided by modern digital detectors can be equal or superior to conventional film-screen systems, with comparable patient doses.
- Digital imaging has practical technical advantages compared with film techniques, e.g. wide contrast dynamic range, postprocessing functionality, multiple image viewing options, and electronic transfer and archiving possibilities.

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Main points (introduction)

- With digital systems, an overexposure can occur without an adverse impact on image quality. Overexposure may not be recognised by the radiologist or radiographer. In conventional radiography, excessive exposure produces a “black” film and inadequate exposure produces a “white” film, both with reduced contrast. In digital systems, image brightness can be adjusted post processing independent of exposure level.

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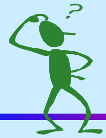
Main points (chapter 2)



- **Different medical imaging tasks require different levels of image quality. The objective is to avoid unnecessary patient doses; doses which have no additional benefit for the clinical purpose intended.**

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CLINICAL PROBLEM	IMAGE QUALITY CLASS	COMMENT
Primary bone tumour	High	Image may characterise the lesion.
Chronic back pain with no pointers to infection or neoplasm	Medium	Degenerative changes are common and non-specific. Mainly used for younger patients (e.g. less than 20 years of age, spondylolisthesis etc.) or older patients e.g. greater than 55 years of age.
Pneumonia adults: follow-up	Low	To confirm clearing, etc. Also, not useful to re-examine patient at less than 10-day intervals as clearing can be slow (especially in the elderly).

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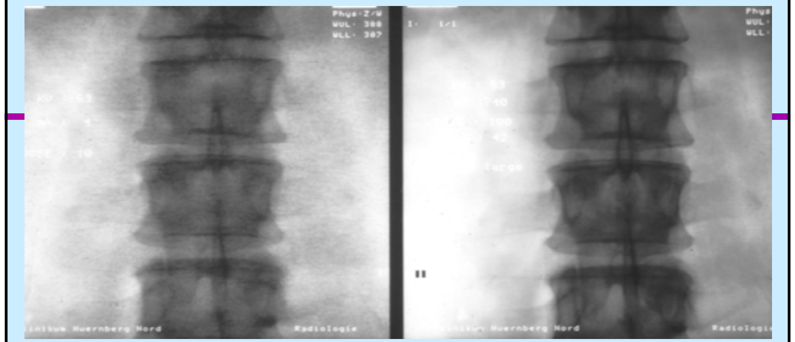

Digital image of lumbar spine. Fluoroscopy system: 10% dose (left); 100% dose (right) (relative values of dose). Courtesy of R. Loose.

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Present and desired situation for the different digital technologies for data on patient doses

Digital Technology	Available now	Desired in the future
CR	Dose or exposure index	Link with radiographic technique, patient dose estimation and patient data. Archive in the RIS
DR	Radiographic technique, Patient data and patient dose estimation	Automatic extraction of the information from the DICOM header. Archive in the RIS
Fluoroscopy	Radiographic technique, radiation field geometry and dose parameters per series	Fluoroscopy information. On-line skin dose maps and automatic extraction of information from DICOM header. Archive in the RIS

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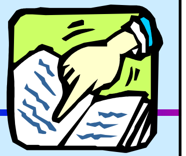
Main points (chapter 2)



- Image quality can be compromised by inappropriate levels of data compression and/or post-processing techniques.
- Data compression and post-processing requirements should be defined by modality and the medical imaging task.

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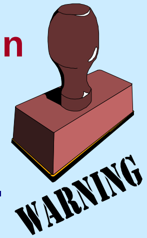
Main points (chapter 2)

- With digital fluoroscopy systems it is very easy to obtain (and delete) images.
- There may be a tendency to obtain more images than necessary.
- This would irradiate the patient more than is clinically necessary.



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With digital fluoroscopy systems may be a tendency to obtain more images than necessary …

Axelsson et al. have demonstrated that in upper gastrointestinal examinations, some centres with digital fluoroscopy use a mean number of 68 exposures per examination in comparison with 16 exposures used in other centres with conventional systems.

Axelsson et al. Eur Radiol 2000;10(8):1351-4.

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Examples of dose reduction

- Portable flat-panel evaluated for neonatal imaging requiring one quarter of the patient dose compared with conventional radiography. Samei et al. Med Phys 2003;30(4):601-7
- A dose reduction of 33-50% in chest radiography using a flat-panel detector

Strotzer et al. AJR 2002;178(1):169-71; Fink et al. AJR 2002;178:481-6; Herrmann et al. Eur Radiol 2002;12(2):385-90.

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Actions that affect patient doses	Influence on patient dose	Influence on image quality or diagnostic information
Reduction of noise perception in the image (i.e. the perception of the signal-to-noise ratio)	Increase	Improvement
Lost of images in the network or in the PACS due to improper identification or other reasons (Smith et al, AJR 2001;176:1381-4).	Increase	Retakes
Deletion of image files at the viewing or workstation of apparently non useful images	Increase	Loss of (perhaps) some useful information. Difficult to control repeated exposures

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Main points (chapter 3)

- **Commissioning of digital systems, or introduction of new techniques, should ensure that imaging capability and radiation dose management are integrated to achieve acceptable clinical image production using appropriate patient doses.**

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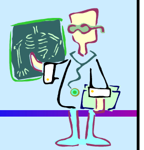
Main points (chapter 3)



- **Justification criteria should be one of the key components considered in the update of a quality assurance programme when a facility converts to digital imaging.**
- **Increases in the number of examinations could occur because of the relative ease of obtaining and archiving images with digital**

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Increase in the number of examinations with digital …

In several U.S. hospitals the number of examinations per in - patient day increased by 82% after a transition to film-less operation.

Outpatient utilization (i.e. the number of examinations per visit) increased by 21% compared with a net decrease of 19% nationally at film-based hospitals.

Reiner et al. Radiology. 2000 Apr;215(1):163-7.

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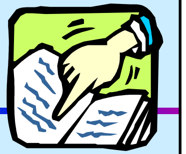
Main points (chapter 3)



- Once digital systems are in use, **comprehensive quality control programmes** are required to ensure image quality and patient dose management are maintained.
- Quality control programmes should detect any significant changes in image quality or patient dose management and therefore **prevent upward "drift" in doses**, without additional clinical benefit.

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ICRP-93 RECOMMENDATIONS

1. Appropriate **training,** particularly in the aspects of patient dose management, should be undertaken by radiologists, medical physicists and radiographers **before the clinical use of digital techniques.**

2. Local **diagnostic reference levels should be reviewed** when new digital systems are introduced in an operational facility.

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Chest image. Only a printing mistake … but exposure was repeated …. lack of training?

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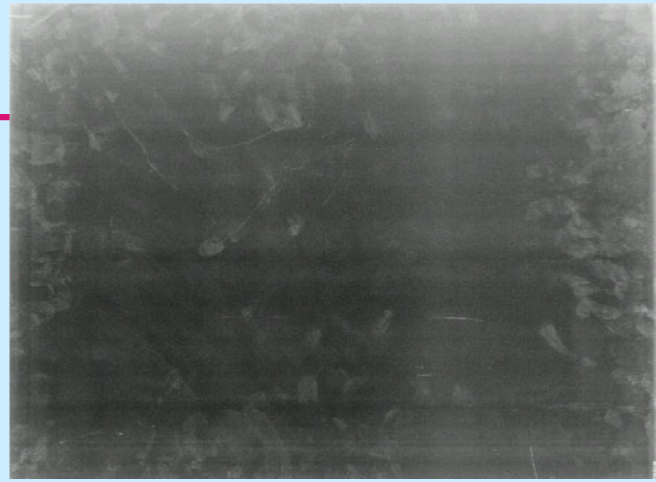

Phosphor plate misused. Impossible to clean. Lack of training?

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ICRP-93 RECOMMENDATIONS

3. Frequent **patient dose audits** should occur when digital techniques are introduced in an operational facility.

4. The **original image data should be made available to the user** not only for objective testing in a rigorous quality assurance program but also for other types of independent tests of the performance of digital-imaging systems.

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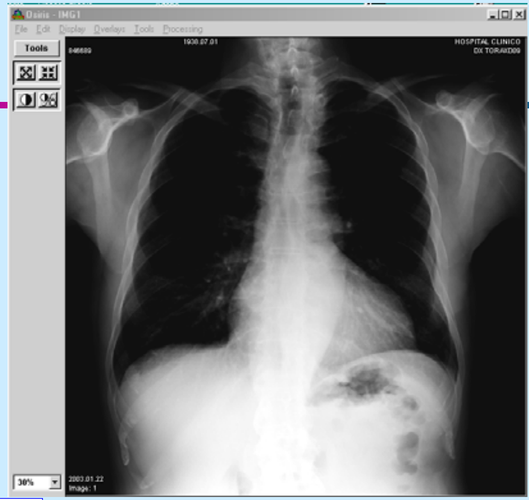

Chest PA obtained as chest LL (flat panel detector); 125 kV; 6.2 mAs; 0.54 mGy (entrance patient dose 4 times higher than necessary); AEC center cell used. Saturated image at the lung area. (Courtesy of E. Vano and J.M. Fernandez)

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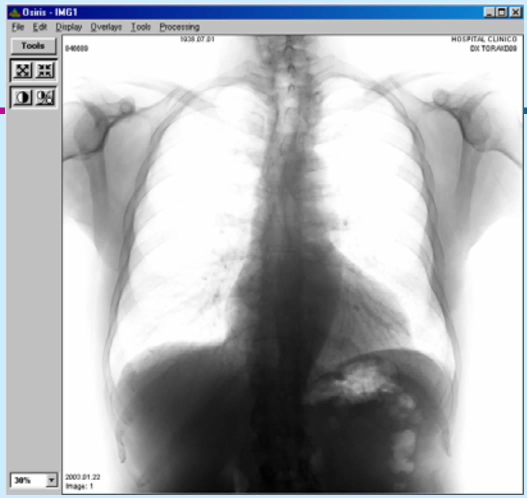

Same image. Inverted gray scale.

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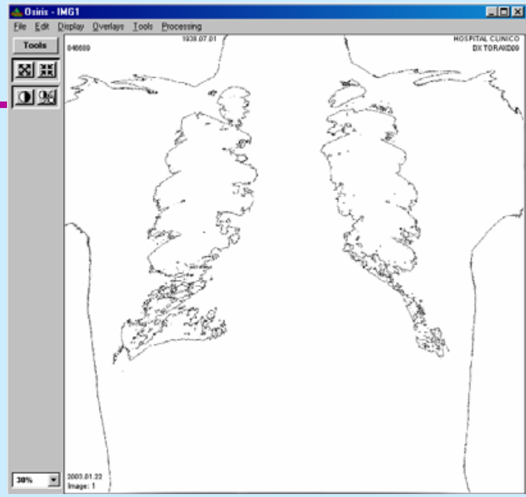
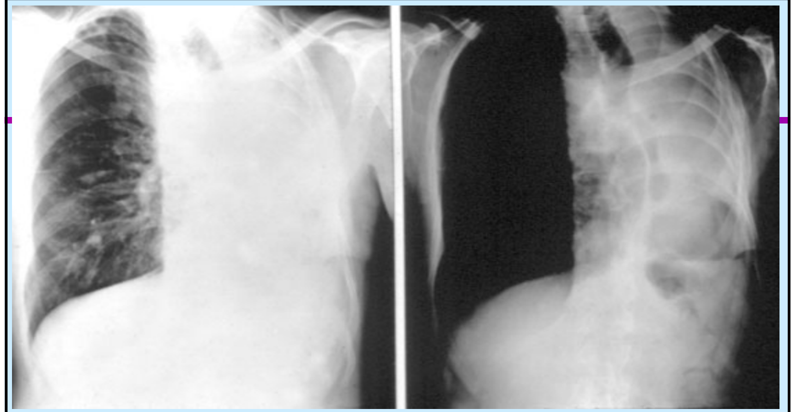


Same image. Isocontour 99% of pixel content. Some lung areas are saturated without any diagnostic information. The image was repeated.



Two postprocessings of a patient after pneumonectomy from raw (original) image: Postprocessing for lung tissue (left) postprocessing for mediastinum (right). Courtesy of R. Loose.

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ICRP-93 RECOMMENDATIONS

5. When a new digital system or new post-processing software is introduced, an optimisation programme and continuing training should be conducted in parallel.

6. Quality control in digital radiology requires new procedures and protocols. Acceptance and constancy tests should include aspects concerning visualization, transmission and archiving of the images.

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Relative exposure index 1.15
Image too noisy

Relative exposure index 1.87
Image with enough quality

From the Glossary. Exposure Index = Term usually used in relation to the absorbed dose to the phosphor plate (courtesy of E. Vano and J.M. Fernandez).

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ICRP-93 RECOMMENDATIONS

7. As digital-radiology images are easier to obtain and to transmit in modern communication networks, referring physicians should be fully conversant with the justification criteria for requesting medical x-ray imaging procedures.

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ICRP-93 RECOMMENDATIONS

8. Industry should promote tools to inform radiologists, radiographers and medical physicists about the exposure parameters and the resultant patient doses. The exposure parameters and the resultant patient doses should be standardized, displayed and recorded.

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Glossary (examples)

- Raw image (read-out signal of flat-panel detector or storage-phosphor system);
- Original image (after all device-specific corrections);
- Processed image (for display).
- Image conditioning consists of all processing steps necessary to transform the raw image into the original image.

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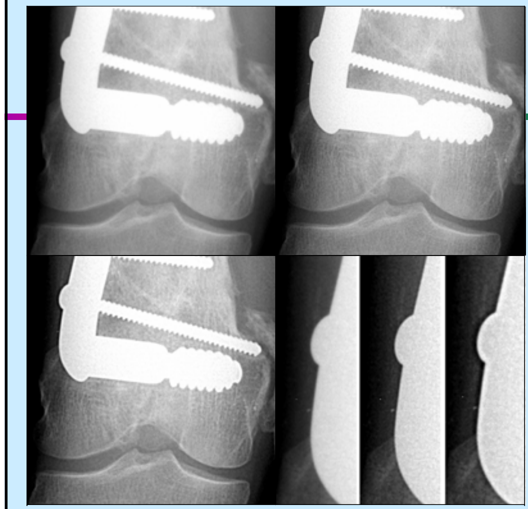

ANNEX 1: Digital systems. Fundamentals (examples)

Illustration of overshoot artefacts at high-contrast implant borders:
a) Without edge enhancement (upper left),
b) Kernel size 7x7 pixels (upper right),
c) Kernel size 15x15 pixels (lower left),
d) Zoomed display of critical border showing black and white halos for sample c).

(Courtesy of B. Geiger)

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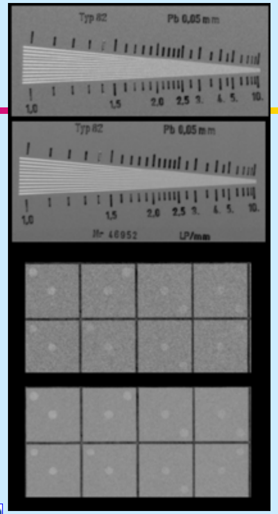

ANNEX 1: Digital systems. Fundamentals (examples)

Comparison of high contrast and low contrast phantom.

Upper row: relative dose 100%
Lower row: relative dose 400%
(theoretical improvement of S/N by a factor of two)
Significant change of low-contrast resolution can be observed, which would also be expected in clinical practice.

(Courtesy of B. Geiger)

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