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Effective use of X rays in Diagnostic Radiology: Guidance on the optimisation of image quality and' absorbed dose in the patient by use of a Monte Carlo computational model of the imaging chain

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X-ray examinations play an important role in modern health care. However, Diagnostic Radiology are the largest man-made source contributing to the radiation burden to the population. One of the current general principles of radiological protection clearly states that the protection of patient should be optimised.

The primary objective of this work is to give guidance on the reduction of absorbed dose in the patient and the improvement of image quality by the optimisation of the various parameters which control the performance of the radiographic imaging system. The methodology involves using a Monte Carlo computational model of the radiological imaging chain by simulating the X-ray photon transport from the X-ray tube, through a soft tissue phantom (patient), an anti-scatter grid and into the image receptor. Optimisation by using a theoretical model of the imaging system is an attractive choice because it allows the analysis of the effect of any factor without the constraints of the experimental set-up. The optimisation criteria can be expressed as: for a given diagnostic task, the optimal imaging conditions can be defined as the one that results in the lowest patient absorbed dose and simultaneously maintains the image quality that is required for an accurate diagnosis. Quantitative results are derived of image quality (contrast, SNR) and radiation risk (mean absorbed dose), both which are required for an optimisation of the radiological procedure and for scientific justification for actions taken to improve the imaging conditions.

An analysis is made of the influence of X-ray spectra, contrasting detail and image receptor on the signal-to-noise ratio (SNR). It is shown that the composition of the contrasting detail influences the SNR due to the different modulations of the photon energy spectra of primary photons passing beside and through the contrasting detail and that it is favourable to match the atomic composition of the detail and the image receptor.

The influence on the mean absorbed dose in the patient of the selection of photon energy spectra is studied and examples of suitable tube potentials and added filtrations are given. Different added filters are compared at equal contrast in conventional, screen-film imaging. Filters of copper can be generally recommended but the use of K-edge filters should be restricted to examinations where the need for substantial variation in tube potential from patient to patient is small. The optimal tube potential varies between 50-70 kV for an iodine contrasting detail and depends on patient thickness and image receptor atomic composition.

Scattered radiation impair image quality. In a series of papers, guidance on appropriate measures to reduce their influence are given by the proper selection of anti-scatter grids in relation to the imaging situation. It is shown that fibre materials in the grid interspaces can provide a significant dose reduction compared to using conventional ones of aluminium. The dose reduction varies·with irradiation conditions and is generally larger at low tube potential, higher grid ratios and at lower lead strip densities. It was found that grids of different strip density and ratio can have good performance provided that they are used with appropriate strip width and tube potential. Increasing the strip density generally requires the use of thinner lead strips and higher grid ratios. Commercial grids are better suited for examinations of adults than for children where an air gap could be considered instead of a grid.