Effective dose of intraoperative 3D imaging in spine surgery

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Introduction

3D-imaging was introduced in 1999. The first publications described the image quality of the 3D-images as comparable to a CT in small joints and sufficient for intraoperative control at the spine and the pelvis. It was initially not possible to visualize the shoulder region. The quality was insufficient for diagnostic purposes at spine and pelvis [1, 2]. The image quality of the CT is still the gold standard in postoperative control and diagnosis of fractures. The first publications dealing with clinical impact of the image modality showed revision rates based on the findings in the obtained images between 2.7% and 39%. In a cost-benefit-analysis, Hüfner et al. determined annual and average costs and estimated a positive economic effect by reducing the revision rate, if the overall revision rate is lower than 5% a deficit may result [3]. Since its introduction, 3D images are used more frequently in the orthopaedic operating room. Especially in spine surgery they allow immediate intraoperative control of pedicle screws and may be able to avoid a postoperative CT and the need of revision surgery due to implant malpositioning. The medical exposure to radiation is increasing, a threshold below which exposure is safe does not exist. Therefore, knowledge on the emission of radiation of these new technologies is essential to protect patients and staff alike.

In this study, we determined the effective dose of patients undergoing different types of imaging. On the one side, we measured the effective dose of a 3D scan with a flat-panel detector image intensifier using different settings. Since the CT is the gold standard, we also measured the effective dose of this imaging modality.

Material and Methods

The below described protocols were being used on a Rando-Alderson-Phantom, which was equipped with thermoluminescense dosimeters (TLD) representing the different organs and tissues. After each scan, the dosimeters were analysed and the phantom reequipped. Two different regions of the spine were examined, the thoracolumbar junction (focus: L1, collimation Th12-L2) and the middle thoracic spine (focus Th6, collimation Th5-7).

The following protocols were being examined:

- Flat-panel detector (Artis zeego®, Siemens, Forchheim, Germany)
    - Standard protocol high definition imaging, collimators off (5sDR Body, Artis VC21/XWP VB21)
    - Standard protocol high definition imaging, collimators on (5sDR Body, Artis VC21/XWP VB21)
    - Low dose protocol, collimators on (5sDR Body Care, Artis VC21/XWP VB21)
- CT (Somatom Definition Flash®, Siemens, Forchheim, Germany)
    - Standard spine protocol (120 kV, tube current-time product 160 mAs, gantry rotation time 1.0s, spiral scanning mode at a pitch of 0.8, automated attenuation-based tube current modulation (CAREDose4D, Siemens), and detector collimation 128x0.6 mm with the flying focal spot technique in radial (φ) direction)

- Low dose protocol (Sinogram Affirmed Iterative Reconstruction or SAFIRE; Siemens Healthcare, tube voltage 100 kV, tube current-time product 80 mAs, gantry rotation time 1.0s, spiral scanning mode at a pitch of 0.8, automated attenuation-based tube current modulation (CAREDose4D, Siemens), and detector collimation 128x0.6 mm with the flying focal spot technique in radial (φ) direction)

Results

At the thoracolumbar junction, the effective dose was comparable for images of the 3D fluoroscope without collimation (4.4 mSv), with collimation (4.3 mSv) and the routine CT protocol (5 mSv). A relevant reduction was achieved with the 3D low dose protocol (1.0 mSv) as well as with the low dose CT protocol (2.9 mSv). The most exposed organs at the thoracolumbar junction were the stomach and the liver.

Focusing on the middle thoracic spine (centre Th 6), the effective dose of 3D fluoroscopic images was lower in comparison to the CT protocols. For 3D images without collimation, the effective dose was 1.1 mSv, with collimation 0.8 mSv; the low dose 3D images required only 0.2 mSv. The routine CT images caused an effective does of 2.3 mSv, the low dose CT required 1.8 mSv. At the middle thoracic spine the most exposed organs were the lung and the oesophagus. In general, the effective dose was higher for all images at the thoracolumbar junction in comparison to the thoracic spine. However, the sensitive thyroid gland was more exposed in imaging of the thoracic spine.

Discussion

In the US, medical procedures represents the largest source of ionizing radiation and nearly all patients seeking help are affected [4]. Because there is no safe dose and any amount of ionizing radiation is potentially dangerous to human health, studies on human beings on direct carcinogenic and teratogenic effect of ionizing radiation do not exist. Animal studies support the view that a dose-dependent relationship exists between radiation dose and damages in the DNA of cells. Calculated dose-responses are most commonly derived from studies on cancer development of atomic bomb survivors. This studies support the no-threshold theory in cancer development due to exposure to ionizing radiation [5].

Radiation protection laws enforce the ALARA-principle: medical imaging must be as low as reasonably achievable. With our study, we analyzed a flat panel system, which performs a rotation around the object of interest and creates CT like data sets intraoperatively. Since many years, these technologies allow immediate intraoperative control and serve as basis for intraoperative navigation. Therefore it is essential, to determine standard operating procedures and routines for best clinical use. We were able to determine the resulting effective dose for patients undergoing intraoperative imaging. With this study we were able to show that the new flat panel 3D systems are able to reduce the radiation in comparison to CT, which is the gold standard in spine imaging. In future clinical studies, the image quality needs to be examined especially for the low dose protocols, which are to be preferred due to the very low effective dose. However, the clinical usability of this new image technology has to be determined before a new standard and new operating procedures can be established.

Reference List

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