Early feasibility studies of radiation dose reduction in cervical spine multidetector CT: Study 1 with test phantom

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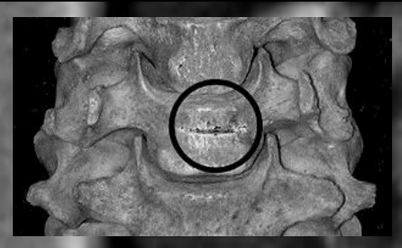
	C3	C5	C6
Photograph			
Anatomy	*Vertebral body*	*Vertebral body*	*Pedicle*
Cut position	*RHS*	*Middle*	*LHS*
Cut width (± 0.25mm)	*1.0*	*0.5*	*0.5*
Limiting mA	*60-80*	*N/A*	*20*

Table 1. Locations and sizes of vertebral osteotomies (C = cervical, LHS = left hand side, RHS = right hand side, mA = tube current).

Background and Purpose

Helical multidetector CT (MDCT) is the preferred primary imaging modality for cervical spine trauma. There appears to be a growing trend for complete cervical spine examination in suspected injury patients rather than level-specific examination leading to higher doses to the thyroid, lens and breast.

Approaches to dose reduction need to be considered and one is to adjust scanning parameters such as tube current (mA). Any dose reduction studies in patient examinations are limited by risk of reducing sensitivity to the point that pathology may be obscured, but phantom studies do not share this risk.

We have performed two studies that avoided unnecessary patient exposures and concentrated on visualising bony changes that simulate fracture lines in the first instance:

1. A cervical spine phantom with simulated cortical lesions (refer to background image)
2. Archived Low-dose CT series from existing PET/CT examinations

Methods

1.Test phantom design

- A series of cervical vertebrae was used, surrounded by rubber balloons containing tissue equivalent material, in a water filled bath.
- The vertebrae were modified by making small osteotomies to simulate bony changes, detailed in Table 1.
- The water bath was a 9lt polypropylene box, approximating a stocky neck at the shoulder junction.
- The vertebrae were surrounded by rubber balloons containing tissue equivalent solutions that would provide mean radiodensities of 45 HU anteriorly and 20 HU posteriorly.

2.Test phantom study

- A 64-slice LightSpeed VCT MDCT scanner was employed throughout using the standard clinical CT protocol (CT spine cervical) settings (1.0 second rotation time, detector coverage of 20 mm, slice thickness of 0.625 mm, pitch 0.531 and standard kV of 120). The automatic exposure control using tube current modulation (TCM) was employed when required ("Auto mA" scout view system with a "noise index" of 28 HU).
- A series of exposures of the phantom was undertaken with the tube current increasing in steps of 10 mA from 10 to 160 mA. All other parameters were kept constant. Standard TCM (TCMs) and Modified TCM (TCMm; with a reduced lower limit) exposures were performed afterwards.
- Three experienced image reviewers were recruited. Before assessment, the reviewers were shown a training sets of similar images. Reviewers reported if a fracture or other feature was seen, its location, orientation, description, confidence level and suitability of scan for reporting.
- The confidence levels were later scored from 1 to 5 (fracture: free, unlikely, possible, probable, definite) and summed.
- Dose survey parameters recorded were the dose–length product (DLP) and volume CT dose index (CTDIvol). Visual image noise was the standard deviation of pixel values in the spinal canal.

Results

Three different simulated cortical lesions were created:

- **C6** – the C6 pedicle feature (refer to Table 1) could be seen from very low tube currents (20 mA).
- **C5** – the osteotomy across the front of the vertebral body (refer to Table 1), in the middle and in the scan plane, was not detected throughout the visual grading analysis using any of the axial, sagital or coronal views. (MPR were not suitable for the phantom with this scanner due to its size.)
- **C3** – An axial view of the feature recorded using a tube current of 60 mA, with the feature visible clearly, is included in Table 2. Images suitable for assessment were generated by tube currents of 60-80 mA. This is confirmed by the convergence of the image quality scores which reached an asymptote at 80 mA. Spearman's rank correlations found strong positive correlations between the total confidence scores and the tube current (mA) used in the phantom tests for all three reviewers (0.90, 0.91 and 0.82). A generalised kappa for inter-review agreement of 0.70 confirmed substantial agreement between reviewers.
- **C3 with TCM** – Comparing standard and modified TCM CT images (refer to Table 2), the C3 vertebral body feature is clearly visible in both images for tube currents of 121 and 51 mA respectively. The DLP for a fixed mA of 60, together with the two TCMs are included in Table 2. DLP was used for relative comparisons between examinations. Using the standard TCM's DLP as the normal scan exposure and reference value, there is clear latitude for reducing dose while preserving image quality since bony features could be visualised suitably at 60 mA which would lead to a halving of the total DLP, with a 28% reduction at 80 mA. Just reducing the lower limit of the automatic tube current selection range to 50 mA, as done for the modified TCM, led to a more than 58% reduction in DLP.

Conclusions

Preliminary indications are that image assessments of bony changes with a high degree of confidence can be achieved with the radiation dose reduced by up to a factor of two. Images suitable for assessment were generated by tube currents of 60-80 mA. There was adequate image quality for identifying artificial bony features, but follow-up studies are required to explore more subtle features. The ability to detect features is determined by conspicuity, and is related to both the size of the feature and the feature to background contrast. However, ensuring that the tube current range that the TCM can select from is set appropriately has already been shown to lead to a valuable level of dose saving.

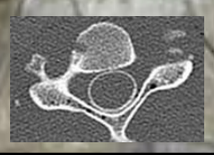
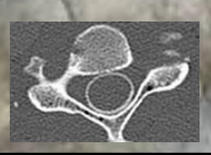
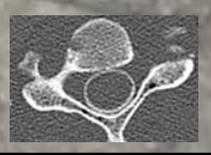
	60 mA	Standard TCM (120-600 mA)	Modified TCM (50-600 mA)
CTDIvol (mGy)	8.8	18.2	7.6
DLP (mGy.cm)	130	270	112
Noise (HU)	115.9	73.0	120.6
CT Image			

Table 2. The volume CT dose index (CTDIvol), dose–length product (DLP) and noise for fixed and automatically selected tube currents.