Radiation Protection of the Eye Lens During Brain CT Imaging Using a Barium Sulphate Vinyl Shield

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Introduction

Head CT examinations may result in significant and unnecessary exposure to the lens of the eye. The International Commission of Radiological Protection (ICRP) has estimated the threshold for detectable opacities in the lens from a single brief exposure to be 0.5 - 2Gy[1] and the threshold for visual impairment (cataract) to be 5Gy. The lens dose for sequential CT scanning of the brain with the orbit in the primary beam has been reported to be approximately 50mGy[2] which is significantly lower than these dose thresholds. However, the ICRP have recently suggested that the lens of the eye may be more radiosensitive than previously considered and that, because of the uncertainty concerning this risk, recommend particular emphasis on optimisation.

Optimisation of lens exposure through the use of bismuth and lead shielding materials has been widely investigated[3,4]. The aim of this study was to investigate the use of a new shielding material, barium sulphate vinyl (Kemmetech Ltd, Kent, UK), with respect to eye lens dose reduction and significance of generated image artefacts during computed tomography (CT) of the brain. The vinyl is stated to be an inexpensive, latex free and inert material. These properties enable the shield to be totally disposable and avoid the need for decontamination between patients.

Method

Two barium sulphate vinyl shields were considered; a large shield and slightly smaller shield both of 0.07mm lead equivalence and shaped to provide superficial anterior coverage of the eye (Fig. 1b and 1c). The larger shield was shaped to provide greater superficial lateral coverage. The effect of positioning each shield further away from the phantom surface using a 4.5mm thick foam “stand-off” material (Fig. 1a) was also considered.

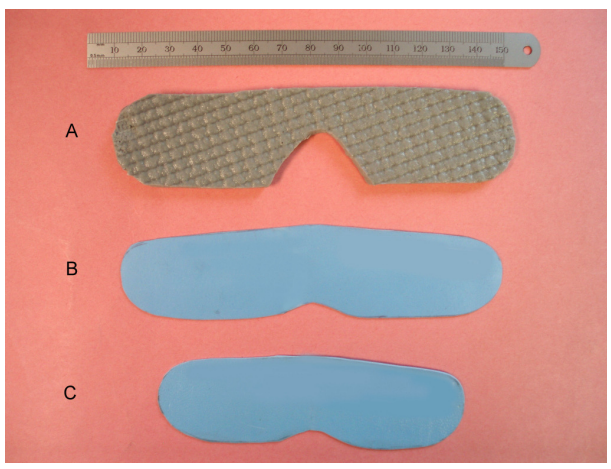

Figure 1. *Foam “stand-off” (A) large barium vinyl shield (B) and small barium vinyl shield (C)*

Imaging was performed using a Brilliance Big Bore Oncology CT scanner (Philips Medical Systems) at Singleton Hospital together with a Rando Average-Man head phantom (Alderson Research Laboratories, USA[5])

A standard sequential brain imaging protocol was employed throughout the study (120kV, 580mAs per rotation, 8 x 3mm collimation) with the X-ray beam passing through the orbit. No X-ray beam angulation was employed in keeping with the local protocol for radiotherapy treatment planning (Fig. 2).

Dosimetry was performed using LiF thermoluminescent dosimeters (TLD-100H, Harshaw, Bicron, USA) with a Harshaw 5500 TLD reader. Five identical scans of the phantom were initially performed without an eye shield. For each scan, two unexposed TLDs were positioned over the centre of each eye of the phantom. This process was repeated for each shield with stand-off material positioned above the TLDs in order to obtain the shielded lens doses (Fig. 3). The minimum detectable dose was 2μGy and the uncertainty in each individual TLD was estimated to be ±9.9% (95% confidence level).

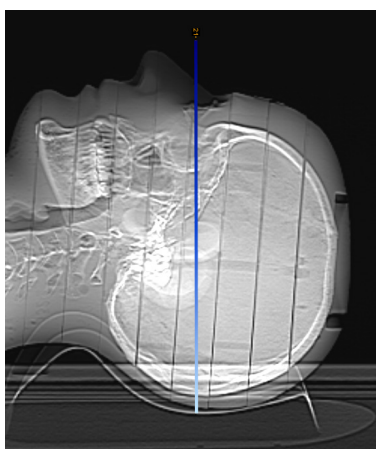

Figure 2. *Scout view showing X-ray beam angle (blue line) through phantom orbit*

Figure 3. *Rando head phantom with small shield in-situ*

Results

Significant image artefacts were generated from the use of the large shield. Streak artefacts were found to emanate from the shield edges and photon starvation was present in the anterior region of the head immediately beneath the shield (Fig 4a). Despite not being projected into the brain region, the presence of such artefacts could potentially affect clinical diagnosis during imaging of structural diseases of the orbits and orbital content, sinuses and facial trauma.

The use of the large shield with a foam “stand-off” resulted in a reduction in image artefacts (Fig 4b). Further reduction was achieved with the use of the smaller shield with “stand-off”. Since the edges of the small shield were located above the anterior region of the orbits the streak artefacts were significantly reduced in this region (Fig 4c). However, the presence of artefacts remained evident in the sinus region.

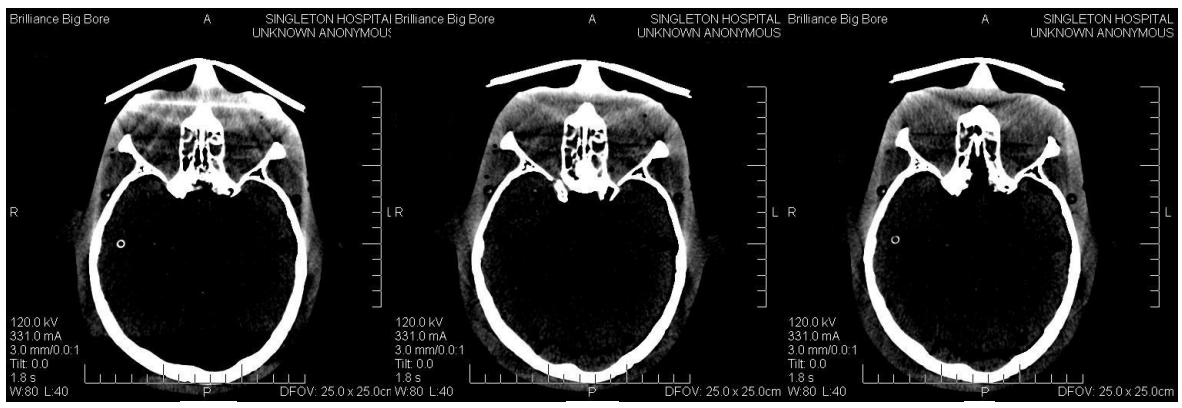

Figure 4. *CT images showing image artefacts in the anterior region of the Rando head phantom with the use of large shield (a) large shield with foam “stand-off” (b) and small shield with foam “stand-off” (c).*

The results of the eye lens dose measurements are presented in Table 1. The use of the large and small barium vinyl shields resulted in a reduction in lens dose of 29.6% and 27.7% respectively. The difference in lens dose between unshielded and shielded with the large and small barium shields were statistically significant (p<0.0001, n=10). The difference in lens dose between the large and small barium shield was not statistically significant (p= 0.4716, n=10).

Shield*	Eye	Mean	SD	Max	Min	Lens dose reduction (%)
None	Left	62.6	5.5	68.7	56.1	-
	Right	59.3	6.6	68.8	50.5	-
	Combined	61.0	6.0	68.8	50.5	-
Large barium vinyl	Left	42.8	1.1	44.1	41.5	-
	Right	43.1	3.8	46.8	37.9	-
	Combined	42.9	2.6	46.8	37.9	29.6
Small barium vinyl	Left	44.8	3.9	49.7	40.4	-
	Right	43.4	2.1	45.9	41.2	-
	Combined	44.1	3.0	49.7	40.4	27.7

Table 1. Eye lens dose (mGy) and level of reduction in eye lens dose with barium vinyl shields

**Results for both barium vinyl shields include the use of 4.5mm foam stand-off material*

Conclusion

Phantom studies have demonstrated that the radiation dose to the eye lens may be significantly reduced with the use of a barium sulphate vinyl shield during CT examinations involving direct exposure of the orbit.

Generated image artefacts did not appear to be significant in the brain region of the phantom but were evident in the anterior region of the head. The location of the artefacts could potentially affect clinical diagnosis during imaging of structural diseases of the orbits and orbital content, sinuses and facial trauma. Artefacts were reduced in extent, but not completely removed, following the introduction of a modified shield and foam “stand-off” material.

An approved patient study is required to confirm the absence of generated image artefacts in the brain during brain CT imaging. Further investigation of artefact reduction in the anterior region of the head through the use of lower lead equivalent barium vinyl together with a greater thickness of foam “stand-off” material is proposed in order for the shield to be recommended for use during general head CT imaging.

References:

1 The 2007 Recommendations of the International Commission On Radiological Protection. *ICRP 103*. 2007

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5 P C Shrimpton, B F Wall and E S Fisher. The tissue-equivalence of the Alderson Rando anthropomorphic phantom for X-rays of diagnostic qualities. *Phys. Med. Biol*. 1981; 26: 133-139.