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Evaluation of Eye Shielding on Radiation Dose Saving and Image Quality during Brain Computed Tomography

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The authors declare no conflict of interest

Introduction

- The lens of the eye is one of the most sensitive organs to radiation injury, especially in adult patients undergoing repeated brain computed tomography (CT) and pediatric patients, which can lead to lens opacity and visual impairment. CT eye shields hence have been developed for protecting the lens of the eye.

- Preclinical studies showed that the application of barium sulfate shields can reduce eye lens dose while the size of shields strongly affected image artifacts generated in the orbital regions but not the brain areas.

Evans CS, 2017;
www.kemmetech.co.uk/media/52c60e61ae253.pdf

- By placing bismuth shields over the eyelids of children who underwent head CT, researchers found that 1-cm eye-lens-to-shield distance can avoid the occurrence of artifacts and allow orbital pathology to be addressed.

Raissaki M et al, Pediatr Radiol 2010 Nov;40(11):1748-54.

Aims

- To evaluate the protective effects of non-latex barium sulfate eye shields during head CT scans while maintaining image quality;
- To estimate the radiation dose saving efficiency of different type/layer of eye shields and the resultant effect on image quality in clinical settings for head CT scans;
- To optimize image quality while applying eye shields for radiation dose reduction

Materials and Methods

- An adult head phantom (PBU-50) was implemented with a water-based noise indicator for CT image quality assessment using ROIs in the nasal bone and extraorbital soft tissue (Fig. 1A).
- We applied CT-specified ionization chamber (RaySafe Xi CT detector) for detecting the amount of air dose close to the eyes of the phantom head (Fig. 1B).
- Barium and bismuth shield equipped with unique 7 mm and 5 mm foams was attached to the phantom (Fig. 1A).
- A human head phantom with a water-based marker was scanned using a 256-slice dual-source CT scanner with automatic tube current modulation at various tube voltages.
- Starting from the central point of bilateral articular tubercles to the top of the head, CT brain scan was proceeded with different x-ray flux output (Table 1).
- Statistic analysis was expressed as mean $\pm$ SD using bar charts. Statistical significance was tested with ANOVA ($p < 0.05$) and Turkey Kramer test (absolute difference $>$ critical range) or post-hoc t-tests (with Bonferroni correction) for their significance.

Materials and Methods

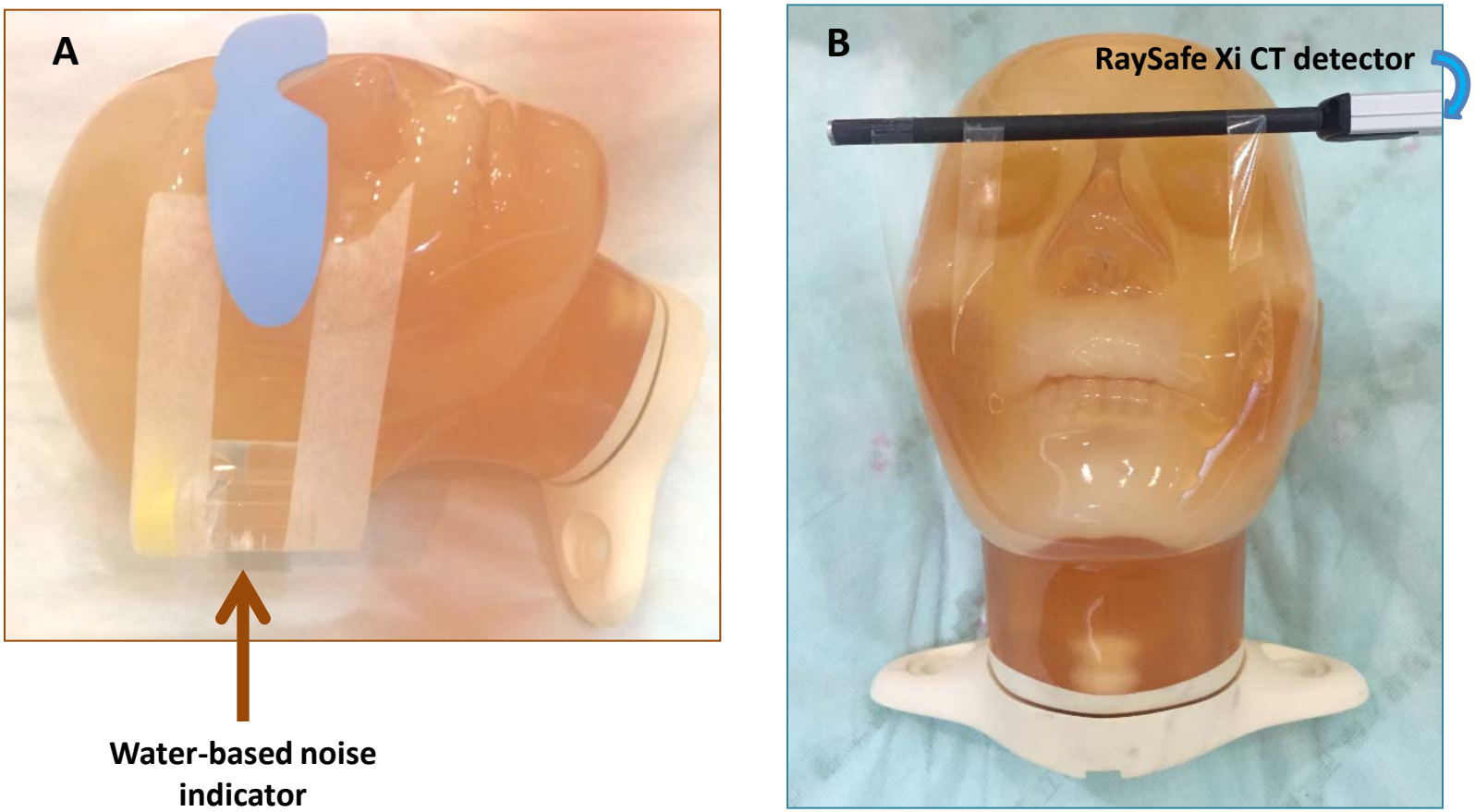


Figure 1: Phantom settings for evaluating the image quality and radiation exposure.

Materials and Methods

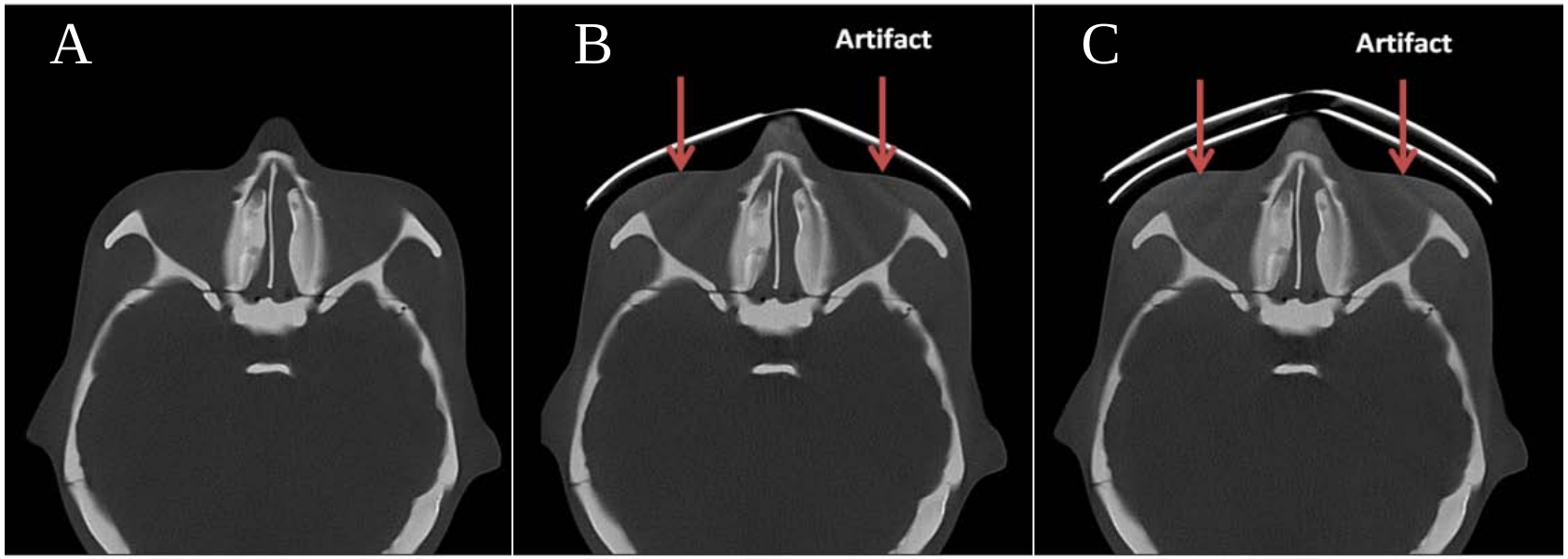


Figure 2: Phantom imaging at 80 kVp. (A) Image without any eye shield; (B) A single layer of barium sulfate shield was added; (C) Two layers of barium sulfate shields were added.

Results

Table 1: Protection Effect of the Barium Sulfate Shield.

Tube Voltage (Modulated tube current-time setting)	Dose Reduction Rate (Decreased amount of air dose)	
	Single Layer of Eye Shield	Two Layers of Eye Shield
140 kVp (116 mAs)	21% (17.49 mGy)	26% (16.33 mGy)
120 kVp (118 mAs)	19% (12.40 mGy)	33% (10.26 mGy)
100 kVp (121 mAs)	24% (7.00 mGy)	34% (6.11 mGy)
80 kVp (126 mAs)	30% (3.55 mGy)	44% (2.83 mGy)

Results

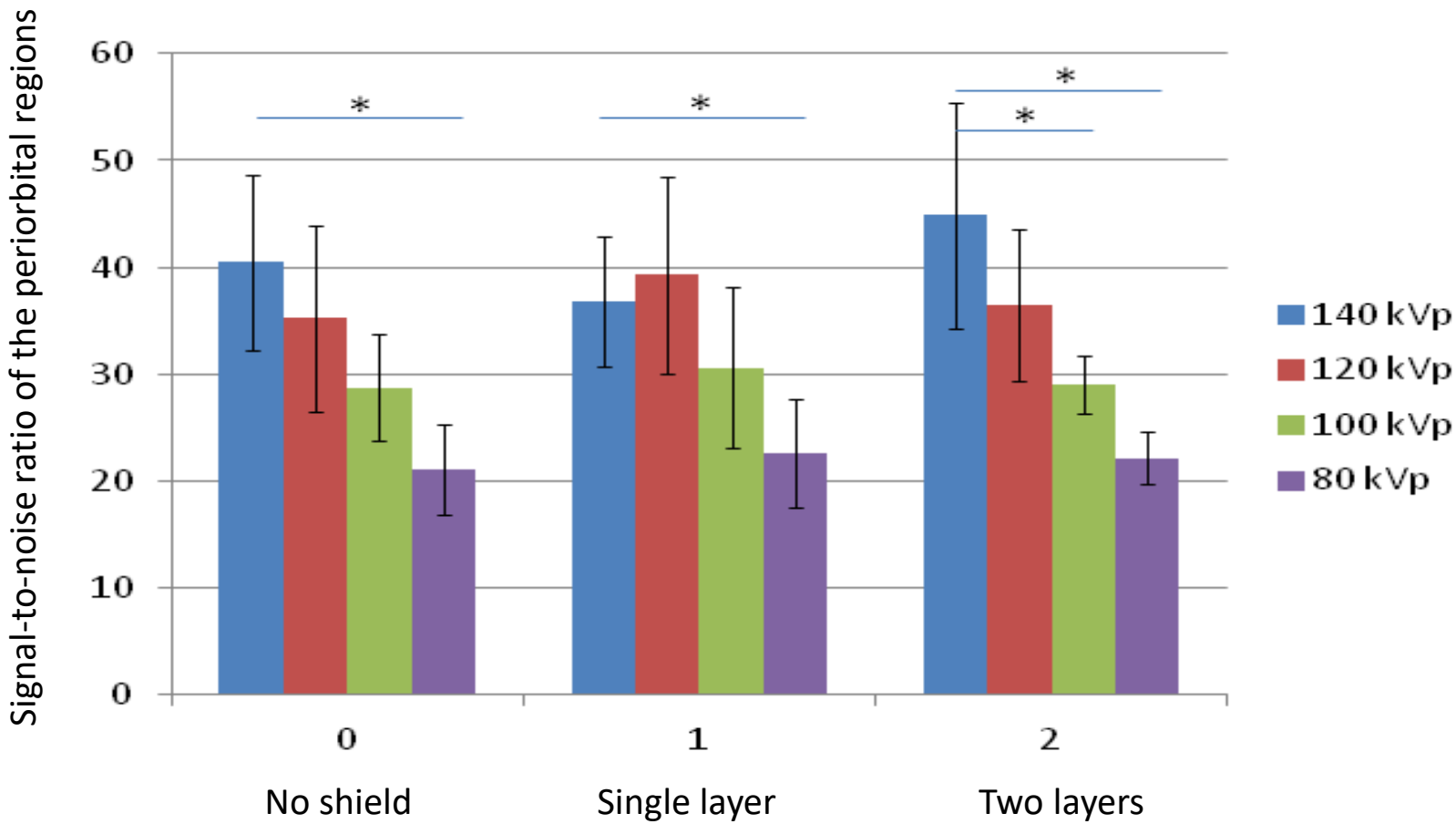


Figure 3: Image Quality Assessment. Decreased SNRs with decreasing tube voltage but were eye shield-independent. The SNR at tube voltage of 140 kVp was significant difference with that of 80 kVp ($p = 0.036$, 0.023 and 0.022 for none, one and two shields, respectively); and 120 kVp vs. 80 kVp ($p = 0.030$) as well as 100 kVp vs. 80 kVp ($p = 0.030$) for two shields.

Materials and Methods

Table 2

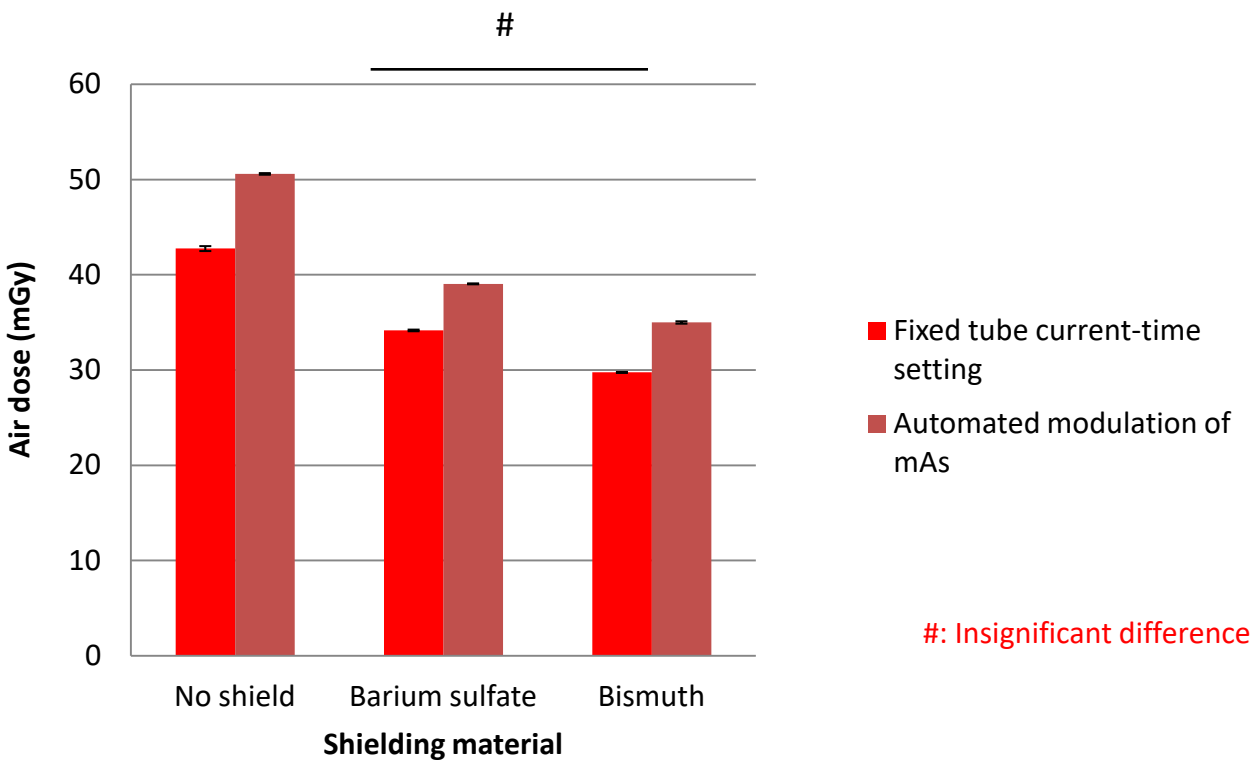
Parameters of the fixed tube current-time setting and the automated tube current modulation via CARE Dose4D method

Tube voltage (kVp)	Fixed tube current (mAs)	Modulated tube current (mAs/ quality reference mAs)		
	All	No shield	Bismuth-impregnated Shield	BS shield
120	300	306/300	322/300	324/300

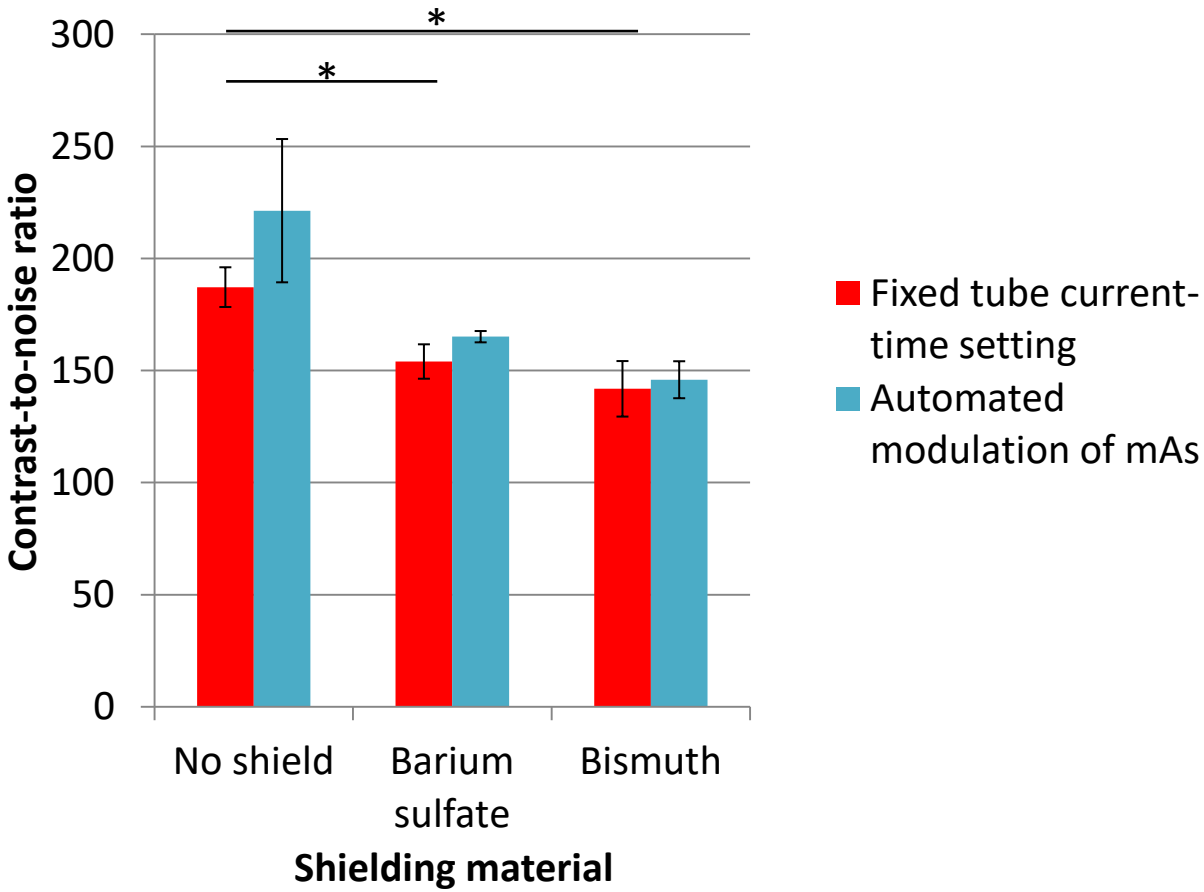
BS: Barium sulfate

Eye exposure

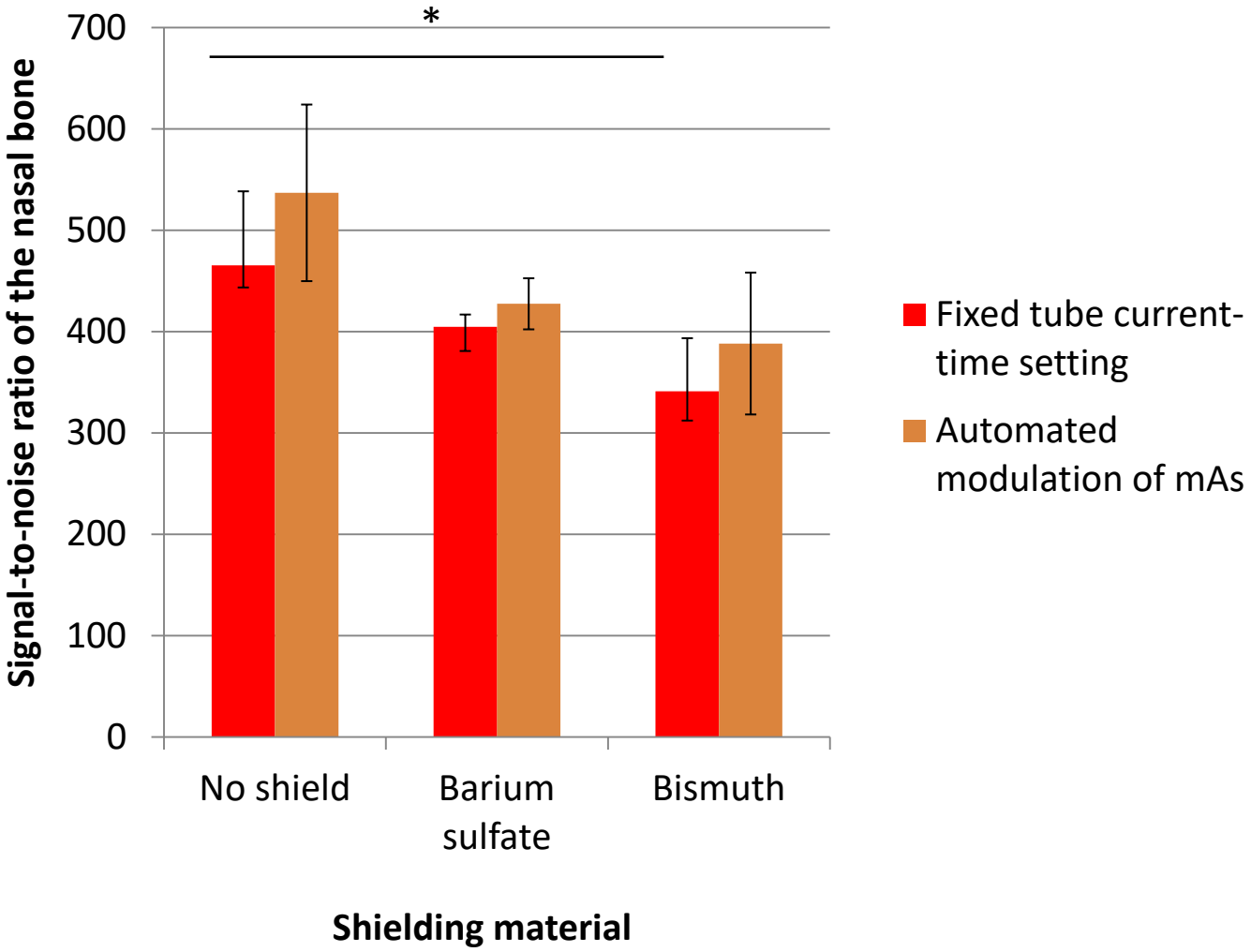
The dose differences among all groups in a particular experimental condition were significant, except for that between "Fixed mAs with BS shield" and "CARE Dose/kV with bismuth shield" is insignificant difference.



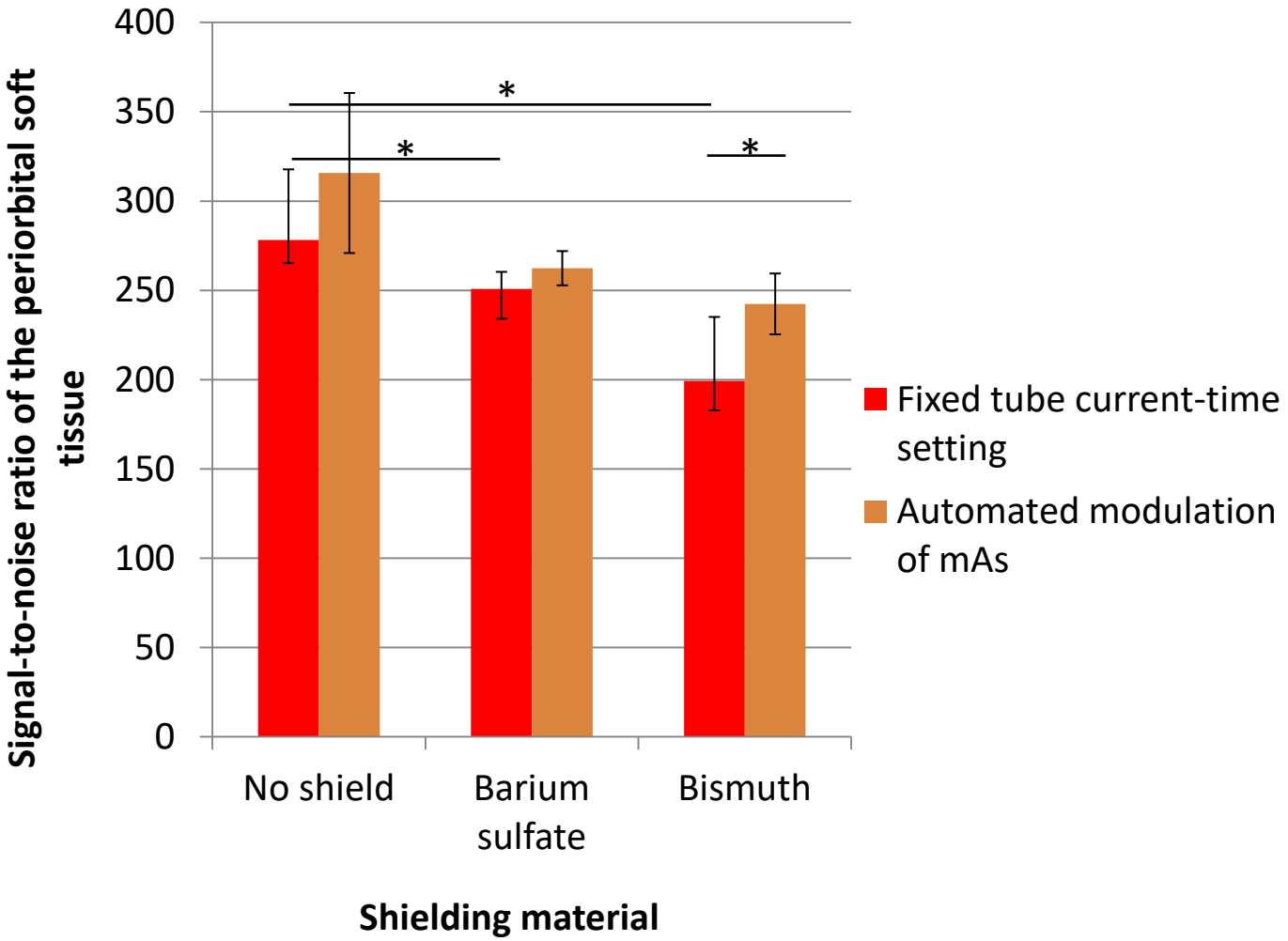
Contrast between nasal bone and extraorbital soft tissue



CT number of the bone compartment



CT number of the soft tissue compartment



Conclusions

- Application of barium sulfate shields in combination with automated tube current modulation led to acceptable image artifacts and up to 44% of reduction in the radiation exposure of the eye.
- Eye shields added attenuation artifacts close to the anterolateral corner of the eyes. The artifacts did not affect brain CT interpretation.
- Compared with barium sulfate shield, bismuth shield is better to be used in combination with the current modulation program, CARE Dose4 D, for eliminating image artifacts.