The efficacy of bismuth shield and BOLUS in reducing eye dose during CT brain examinations: A phantom study

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Learning objectives

Problem identified

- The appropriateness of in-plane bismuth shield use during CT brain examination is debatable.
- Problems related to image quality degradation and incidence of artefacts with the use of an in-plane bismuth shield during CT examination were found mostly at an area "several cm just beneath the bismuth shield".

Hypothesis

Can we use of a layer of material "equivalent to the attenuation of soft tissue and sandwiched between the bismuth shield and the surface of the superficial organs", so that the aforementioned problems will not be easily projected into the patient?

Background

An in-plane bismuth shield reduces radiation exposure to radiosensitive superficial organ structures during CT examinations. The application of a bismuth or lead shield of different thicknesses reduces the radiation dose to many superficial organs, including the eye lens (1), thyroid gland (2) and breast tissue (3). However, concerns regarding degradations in image quality and the incidence of streak artefacts have been raised, particularly when the shield is placed in direct close contact with the patient's surface over the orbits, the neck and the breast (4-8). These concerns and problems related to hygiene and extra running costs have limited the extensive use of bismuth shields.

One practical technique to reduce the eye dose during CT brain examinations is the angling of the gantry along the patient's supra-orbital meatal line (SOM method) instead of the routine inter-orbital meatal line (OM method) (7, 9, 10). However, concerns were raised previously about the subsequent high incidence of streak artefacts over the posterior cranial fossa that resulted from a beam hardening effect and partial volume averaging and a noticeable degradation in temporal lobe visualisation using the SOM method (7, 11).

BOLUS has been widely been used in ultrasound examinations to improve shield conformation to body surfaces and provide build-up, energy reduction/attenuation or
extra scattering in radiation therapy. The intrinsic property of BOLUS favours its application during CT brain examinations because it does not flow, creep or sag out of shape during the examination. BOLUS can also be cut with scissors to fit the patient, and it is easily layered when needed. Moreover, BOLUS is a tissue-equivalent material that exhibits 8% less attenuation than water in energy ranges less than 125 keV. The application of BOLUS in the present study served as a low energy X-ray photon-absorbing and scatter source.

**Imaging findings OR Procedure details**

**Methodology**

**Bismuth eye shield, face shield and BOLUS**

- Dedicated commercial face shields were used to achieve a 4-cm air gap above the phantom's eye surface.

- Commercial bismuth-impregnated shields (0.5 cm thick and 3.4 g/cm$^2$ of bismuth, AttenuRad, F&L Medical Products) were used as the eye shields.

- Eight pieces of commercial BOLUS (BOLX-II, Action Product INC, USA), 0.5-cm thick, were cut to the same size of the bismuth shield before use.

**CT system and RANDO® phantom**

- Discovery$^\text{TM}$ CT750 HD with Adaptive Statistical Iterative Reconstruction (ASiR) and a carbon fibre flat tabletop (GE Medical Systems, LLC) were used in the present study.

- Slices No.1 to No.13 of an anthropomorphic phantom (RANDO® Woman) were selected and packed tightly to simulate the head and neck region of a patient.

- Thermoluminescent dosimeters (TLDs) were annealed and calibrated according to the manufacturer's recommended protocol, and 5 TLDs measured background radiation.

- The CT scout view was obtained, and 10 TLDs (5 TLDs on each eye) were placed along the eye surface of the RANDO phantom before acquisition.
• The degree of gantry tilt was set to either 0# or 30# for the OM and SOM methods, respectively.

• The acquisitions were repeated using SEVEN different techniques:

A. OM method: no bismuth shield was applied
B. OM method: a bismuth shield was placed on top of a face shield
C. OM method: a bismuth shield and 4-cm-thick BOLUS (i.e., 8 pieces of BOLUS stacked together) were placed directly on top of the orbits
D. OM method: a bismuth shield was placed directly on top of the orbits.
E. OM method: a bismuth shield and a 0.5-cm-thick BOLUS were placed directly on top of the orbits.
F. OM method: a bismuth shield and 1-cm-thick BOLUS were placed on top of a face shield
G. SOM method: no bismuth shield was applied.

Data analysis

• A TLD reader read the exposed TLDs, and the net counts of each TLD were obtained by subtracting the residual and background counts. The counts were converted, and the overall eye doses in the different techniques were determined in mean equivalent doses (mSv).

• All collected images using the OM method were analysed using a Centricity Radiology RA 600 workstation (GE Medical Systems, LLC).

• Image quality, including the correctness of mean CT number and its standard deviations, of techniques A-F was assessed at four pre-defined regions of interests: 274 mm$^2$ in the intracranial regions and 86 mm$^2$ in the orbits.

Major Findings

1. The best strategy to reduce radiation dose to the eyes remains using a cranial gantry tilting, so that the eye lenses can spare from the direct x-ray beam.

2. The present study also identified an innovative technique that can effective reduce eye dose during CT brain examination:
simply using a 1-cm-thick BOLUS and a bismuth shield placed on top of a dedicated face shield (technique F in the present study), we can achieve the greatest amount of radiation dose reduction when compared to other mentioned techniques in this study.

Images for this section:

Figure 1a: CT Brain in lateral scout view using the OM Method (No gantry-tilt).

Fig. 1: CT Brain in lateral scout view using the OM Method (No gantry-tilt)
Figure 1b: CT Brain in lateral scout view using the SOM Method (30° gantry-tilt)

Fig. 2: CT Brain in lateral scout view using the SOM Method (30° gantry-tilt)
Figure 2a: The setup of the technique B: Using the OM method: With one-ply of Bismuth shield placed on top of a face shield (frontal view)

Fig. 3: The setup of the technique B: Using the OM method: With one-ply of Bismuth shield placed on top of a face shield (frontal view)
Figure 2b: The setup of the technique B: Using the OM method: With one-ply of Bismuth shield placed on top of a face shield (side view)

Fig. 4: The setup of the technique B: Using the OM method: With one-ply of Bismuth shield placed on top of a face shield (side view)
Figure 3a: The setup of the Technique F: Using the OM method: With one-ply of Bismuth shield and a 1cm thick of BOLX placed on top of a face shield. (frontal view)

**Fig. 5:** The setup of the Technique F: Using the OM method: With one-ply of Bismuth shield and a 1cm thick of BOLX placed on top of a face shield. (frontal view)
Figure 3b: The setup of the Technique F: Using the OM method: With one-ply of Bismuth shield and a 1cm thick of BOLX placed on top of a face shield. (Side view)
Fig. 7: Illustration of the 8 ROIs used to measure CT number and image noise. A sample image using technique C: OM method with a bismuth shield and 4-cm-thick BOLUS
**Fig. 8:** A sample image using technique A: OM method with no bismuth shield was applied
Figure 9: A sample image using technique B: OM method with a bismuth shield was placed on top of a face shield
Figure 5c: An image sample of technique D

Fig. 10: A sample image using technique D: OM method with a bismuth shield and 4-cm-thick BOLUS
**Fig. 11:** A sample image using technique E: OM method with a bismuth shield and a 0.5-cm-thick BOLUS ---- The best result achieved!
**Fig. 12:** A sample image using technique F: OM method with a bismuth shield and 1-cm-thick BOLUS were placed on top of a face shield
Conclusion

- A bismuth shield and a 0.5-cm-thick BOLUS that placed directly on top of the orbits can effectively reduced the incidence of streak artefacts, maintained good image quality and reduced the eye dose to patients.

- The application of this innovative new technique should interest radiographers aiming for good radiation protection practices.

References


**Personal Information**

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