

## Nordic position statement on the use of bismuth shielding for the purpose of dose reduction in CT scanning

### The Nordic Radiation Protection co-operation

Based on the position statement from the American Association of Physicists in Medicine

**Bismuth shields have the potential to reduce dose to anterior organs in patients during CT scanning, if used properly. Unfortunately, there are several disadvantages associated with the use of bismuth shields, especially when used with automatic exposure control or tube current modulation. Other techniques exist that can provide the same level of anterior dose reduction at equivalent or superior image quality that do not have these disadvantages. The Nordic radiation protection authorities therefore do not recommend the use of bismuth shielding in CT scanning on a regular basis. The use of bismuth shielding should only be considered if the behaviour of the CT-scanner is fully known. In those situations where the behaviour of the CT-scanners is not fully known, we recommend that alternatives to bismuth shielding should be carefully considered and implemented when possible.**

### Introduction

Bismuth shielding has been used to reduce the dose from CT to anterior radiosensitive organs, such as the breast, lens of the eye, and thyroid [1]. These bismuth-impregnated latex shields are placed over the organ of interest to attenuate the X-ray beam entering the patient. While bismuth shielding appears easy to use and studies confirm a reduction in anterior surface dose [2-5], there are several disadvantages associated with their use that could result in increased patient dose and/or degraded image quality [6]. Other methods for reducing anterior dose exist that do not suffer from these drawbacks. These methods may additionally offer improved image quality and/or additional dose reduction relative to the use of bismuth shielding, and should be carefully considered by users seeking to reduce dose to the lens of the eye, thyroid and breast.

### Disadvantages associated with the use of bismuth shields:

- 1) Applying bismuth shielding together with automatic exposure controls(AEC) systems, such as tube current modulation (TCM), leads to unpredictable and potentially undesirable levels of dose and image quality.**

AEC systems adjust scanner output based on patient attenuation to deliver a user-specified level of image noise. They take into account system characteristics, patient anatomy and user-specified requirements for image quality [7]. Localizer CT radiographs (e.g. anterior-posterior and/or lateral) are used to estimate patient attenuation, and system behaviour is programmed according to the measured attenuation. However, when bismuth shielding is used, the dose delivered to the patient and the image quality achieved depends on whether the shield was placed before or after acquisition of the CT radiograph.

Placing a bismuth shield on the patient prior to acquiring the CT radiograph will lead to measuring higher “patient” attenuation and the tube current will be increased accordingly [4, 8]. The effect of dose reduction to the anterior surface by bismuth shielding will be countered, and dose to other surfaces will be increased, which is clearly undesirable.

Placing a bismuth shield on the patient after the CT radiograph has been acquired avoids having the AEC algorithm increase the tube current [4, 8] on some systems. However, the image quality delivered will not be what the user prescribed due to the additional attenuation of the shield, which the system did not anticipate (as it was placed after the CT radiograph was acquired).

On other systems, the AEC algorithm responds to increases in patient attenuation that occur after the CT radiograph has been acquired, resulting in differences in both image quality and dose relative to what was planned using the CT radiograph.

## **2) The shields can degrade image quality and accuracy.**

The shields can cause streak and beam hardening artifacts. They artifactually increase CT numbers below the shield [9] and adversely affect the accuracy of CT numbers. Because these would affect the accuracy of coronary calcification measurements, the Society of Cardiac CT clearly states that breast shields are not recommended in cardiovascular CT [10]. Additionally, if the inferior aspect of the shield lies over the upper portion of the liver, unacceptable image quality in the liver can occur.

## **3) The shields waste some of the patient’s radiation exposure.**

In CT scanning, the x-ray tube rotates 360 degrees around the patient and irradiates the patient from all directions. When the x-ray tube is above the patient, the shield absorbs x-rays before they strike the patient and reduces the dose to peripheral organs. However, when the x-ray tube is beneath the patient, the shield does not reduce dose to the patient, but rather absorbs many of the photons exiting the patient before they can reach the CT detector. Those photons would have contributed to forming the CT image. Similarly, photons from lateral directions are partially attenuated by the shield upon exiting the patient. Therefore, during more than half of each 360-degree rotation of the x-ray tube, the shield attenuates useful photons, thus wasting radiation dose. This leads to a noise increase across the entire image, not just in the region near the shield [4, 9, 11, 12].

## **Alternative methods for reducing dose to peripheral organs in CT scanning:**

For equivalent levels of image noise, the percent dose reduction to the anterior surface from bismuth shielding can be achieved by reducing the x-ray tube current by that same percentage [11-14]. This has the added benefit of reducing dose to the lateral and posterior surfaces. No additional materials (i.e. the shields) or special scanner features are required, and technologists do not need to spend additional time positioning the shields on patients or disinfecting the shields between patients. Furthermore, streak and beam hardening artifacts are avoided and CT number accuracy is maintained. Other methods for reducing dose to specific peripheral organs include adjusting AEC parameters to more aggressively decrease the tube current in regions of lower attenuation (e.g. in the thorax) and use of organ-based tube current modulation techniques. Since AEC systems on CT scanners can be complex and involve adjustments of several parameters, users are urged to consult with a medical physicist and/or applications specialist when making changes to the AEC parameters.

## References

1. Hopper KD, King SH, Lobell ME, TenHave TR, Weaver JS: The breast: inplane x-ray protection during diagnostic thoracic CT--shielding with bismuth radioprotective garments. *Radiology* 1997, 205(3):853-858.
2. Hopper KD, Neuman JD, King SH, Kunselman AR: Radioprotection to the eye during CT scanning. *AJNR Am J Neuroradiol* 2001, 22(6):1194-1198.
3. Mukundan S, Wang PI, Frush DP, Yoshizumi T, Marcus J, Kloebler E, Moore M: MOSFET Dosimetry for Radiation Dose Assessment of Bismuth Shielding of the Eye in Children. *American Journal of Roentgenology* 2007, 188(6):1648-1650.
4. Leswick DA, Hunt MM, Webster ST, Fladeland DA: Thyroid shields versus z-axis automatic tube current modulation for dose reduction at neck CT. *Radiology* 2008, 249(2):572-580.
5. Hohl C, Wildberger JE, Süß C, Thomas C, Mühlenbruch G, Schmidt T, Honnef D, Günther RW, Mahnken AH: Radiation Dose Reduction to Breast and Thyroid During MDCT: Effectiveness of an In-Plane Bismuth Shield. *Acta Radiologica* 2006, 47(6):562-567.
6. McCollough CH, Wang J, Berland LL: Bismuth Shields for CT Dose Reduction: Do They Help or Hurt? *Journal of the American College of Radiology* 2011, 8(12):878-879.
7. McCollough CH, Bruesewitz MR, Kofler JM, Jr.: CT dose reduction and dose management tools: overview of available options. *Radiographics* 2006, 26(2):503-512.
8. Coursey C, Frush DP, Yoshizumi T, Toncheva G, Nguyen G, Greenberg SB: Pediatric chest MDCT using tube current modulation: effect on radiation dose with breast shielding. *AJR Am J Roentgenol* 2008, 190(1):W54-61.
9. Kalra MK, Dang P, Singh S, Saini S, Shepard JA: In-plane shielding for CT: effect of off-centering, automatic exposure control and shield-to-surface distance. *Korean J Radiol* 2009, 10(2):156-163.
10. Halliburton SS, Abbara S, Chen MY, Gentry R, Mahesh M, Raff GL, Shaw LJ, Hausleiter J: SCCT guidelines on radiation dose and dose-optimization strategies in cardiovascular CT. *J Cardiovasc Comput Tomogr* 2011, 5(4):198-224.
11. Geleijns J, Salvado Artells M, Veldkamp WJ, Lopez Tortosa M, Calzado Cantera A: Quantitative assessment of selective in-plane shielding of tissues in computed tomography through evaluation of absorbed dose and image quality. *Eur Radiol* 2006, 16(10):2334-2340.
12. Vollmar SV, Kalender WA: Reduction of dose to the female breast in thoracic CT: a comparison of standard-protocol, bismuth-shielded, partial and tube-current-modulated CT examinations. *Eur Radiol* 2008, 18(8):1674-1682.
13. Wang J, Duan X, Christner JA, Leng S, Grant KL, McCollough CH: Bismuth Shielding, Organ-based Tube Current Modulation and Global Reduction of Tube Current for Dose Reduction to the Eye in Head CT. *Radiology* 2012, 262(1):191-8.
14. Wang J, Duan X, Christner JA, Leng S, Yu L, McCollough CH: Radiation Dose Reduction to the Breast in Thoracic CT: Comparison of Bismuth Shielding, Organ-based Tube Current Modulation and Use of a Globally Decreased Tube Current. *Med Phys* 2011, 38(11):6084-6092.