

AAPM Position Statement on the Use of Bismuth Shielding for the Purpose of Dose Reduction in CT scanning

Policy Text: Bismuth shields are easy to use and have been shown to reduce dose to anterior radiosensitive organs in CT scanning. However, several disadvantages exist, including wasted radiation, reduced image quality, and unpredictable results when combined with automatic exposure control, tube current modulation or dual-energy acquisitions. Alternative techniques exist that can provide equivalent anterior dose reduction at the same or superior image quality without the limitations of bismuth shields. The AAPM recommends that these alternatives to bismuth shielding be carefully considered, and implemented when possible.

Rationale for policy:

Bismuth shielding has been used to reduce the dose from CT to anterior radiosensitive organs, such as the breast, lens of the eye, thyroid, and gonads [1,2]. 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 [3-6], there are several disadvantages associated with their use that could result in increased patient dose and/or degraded image quality [7]. 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, breast or gonads.

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 [8]. Localizer CT radiographs (e.g. anterior-posterior and/or lateral) are used to estimate patient attenuation, and system behavior 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 [5,9]. 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 [5,9] 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 [10] 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 [11]. Similarly, because the shields alter the energy spectrum, inaccurate results would be expected if used with dual-energy CT. Finally, 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 [5,10,12,13].

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 [12-15]. 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. In conjunction with global reduction of the x-ray tube current, iterative reconstruction algorithms can provide reduced image noise at globally reduced dose settings [16-19]. Alternatively, many CT scanners are now equipped with organ dose modulation schemes that reduce dose to the anterior portion of the scan field without the negative consequences of bismuth shields [14,15,19]. 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, especially before using bismuth shields in conjunction with AEC systems.

References

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