Letter to the Editor

Response to ''Comment on 'Real-time *B*-mode ultrasound quality control test procedures' '' [Med Phys. 25, 1547–1551 (1998)]

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To the Editor,

Before addressing Dr. Goldstein's criticisms of our task group report, we believe it would be useful to review the history of the report. We began writing this report about seven years ago. It has undergone many revisions in response to innumerable reviews, including two very thorough internal reviews and the AAPM Science Council review. A member of the General Ultrasound committee had one of his graduate students use the document to perform all of the tests and provide us with feedback. An earlier version of the abbreviated test instructions (Appendix A) was employed in an ultrasound QC hands-on refresher course at last year's AAPM meeting. Many individuals including Dr. Goldstein have had ample opportunity to critique the manuscript (see the acknowledgment section of the report). The report has been the major topic of discussion for the past four years at every one of our task group meetings at both the AAPM and RSNA conferences. These meetings are open to all who wish to participate. Although Dr. Goldstein assisted the task group during the initial development of the report, he has not been involved the past few years. It is unfortunate that Dr. Goldstein preferred to interact with the committee with a letter to the editor rather than making his suggestions during the evolution of this report. He might then have understood the care with which it was written and revised (and revised and revised).

Since some readers may be confused by the points raised by Dr. Goldstein, we would like to clarify and, in some cases, correct his criticisms of our report.

(1) TEST OBJECT (PHANTOM) DESIGN AND REQUIREMENTS PLUS DISTANCE ACCURACY

Dr. Goldstein has presented a thorough explanation of a specific error regarding the use of phantoms having speeds of sound that differ from 1540 m/s. Dr. Goldstein is correct that the different speed of sound can result in substantial errors in measurements of horizontal distances when imaging with sector probes. However, phantoms can be designed to compensate for these errors at specific distances. In fact, the manufacturer of such a phantom includes a specific set of fibers with the corrected horizontal spacing for testing only sector probes. As long as this set is used only for sector probes and others for linear probes, and the vertical column of fibers with velocity compensated spacing are scanned near the center of the image, both horizontal and vertical distance accuracy can be adequately tested with such a phantom.

Our task group report did cite many problems associated with the use of phantoms with low speeds of sound, including a statement that ''non-tissue mimicking phantoms can not very accurately assess any property of a system that is related to focusing or pulse length such as lateral and axial resolution and cyst fill-in.'' In his criticism, Dr. Goldstein failed to acknowledge this statement as well as our first sentence in this section, which declared that the ideal phantom should have a speed of sound of 1540 ± 10 m/s. There was much debate in our committee about the use of urethane-type phantoms that are much more stable over time, but have slower speeds of sound. It was concluded by consensus that such phantoms might be used for consistency checks. We state in the manuscript that ''the phantoms can still be used to test for consistency (i.e., precision rather than accuracy).'' We stand by this statement. We would like to add that it is important that medical physicists not use such phantoms to compare lateral and axial resolution and cyst fill-in properties of different systems or transducers since the results may be misleading.

(2) IMAGE UNIFORMITY

Dr. Goldstein excuses nonuniformity, in particular, horizontal bands, as often being associated with proper equipment performance or due to a design flaw that cannot be corrected. We do not agree that significant banding may be acceptable, and believe notification of the manufacturer that nonuniformity problems with their equipment have been detected by medical physicists may prompt the development of solutions. This will especially be true if the ACR or some other accrediting body establishes performance criteria for this important parameter.

(3) FAILURE TO MENTION THE PAPER CLIP TEST

The paper clip test that Dr. Goldstein refers to was included in an early version of the manuscript. In particular, we described its use in estimating the aperture size of the transducer. Our reference to this technique was deleted in response to a reviewer's comment that the test has limited applicability because it works only for linear arrays, and these typically do not have a single aperture, but rather have apertures that vary with depth. In hindsight, we should have included reference to this test for detecting bad elements or associated bad circuits and estimating aperture size in linear array transducers. However, the uniformity and penetration tests described in the report are sufficient for discovering

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missing elements that become significant clinically. It is interesting to note that in his letter Dr. Goldstein states that the paper clip test can locate bad elements or circuits in ''all types of multielement array transducers.'' This statement contradicts the following statement that appears in his paper describing this test.[1] ''The test tool cannot be used with phased arrays or mechanical sector scanners with annular array transducers. Phased arrays use all of their elements in the generation of each image line so the test tool will not present any significant information. Mechanical sector scanners encase the transducer inside a liquid-filled chamber so that the rod cannot be placed in contact with the individual elements of an annular array transducer. Even if the rod could be placed in contact with an annular array, it has the wrong shape to contact only one of the annular ring elements on this transducer.''

(4) ANECHOIC OBJECT IMAGING

We agree with Dr. Goldstein that displayed dynamic range affects fill-in. In fact, we specifically state in the setup section for this test ''Be sure to record the gray-level map and dynamic range used since these parameters affect cyst fill-in.''

(5) AXIAL AND LATERAL RESOLUTION

Dr. Goldstein makes an interesting point regarding the independence of measurements of axial and lateral resolution on gain and power settings when the filament targets are imaged in tissue equivalent phantoms. His argument is based on the assumption that our eye–brain system always compares the echoes from the filaments with the average background echo level to determine the apparent sizes of the filament echoes. Since the filament echoes are a fixed dB above the background, the results should be independent of gain or power. This may, in general, be true; however, it is probably a desirable feature only for very simple measurements, since the beam degrading effects of side lobes and clutter are hidden in the background speckle pattern. In our report, we state that the preferred method for measuring axial and lateral resolution is to measure the FWHM or FWTM of profiles of the echo amplitudes in an image of a single filament in a low scatter medium. Such measurements do depend on the gain and power settings of the instrument, as stated in our report and acknowledged by Dr. Goldstein. When sufficient sensitivity levels are employed in imaging the filament in the low scatter medium, plots of the resulting profiles permit visualization and/or quantification of the pulse-echo response widths as well as the side lobes and clutter.

The ''suggested action level'' for a lateral response width of $2.5\times$ focal length/(frequency in MHz$\times D$ in mm) is a level that was judged to be a balance between detecting poor performance and causing too many concerns. The D in this equation is the manufacturer specified aperture width, which in the case of apodization could be the effective aperture width. Hence, when apodization is employed, D could be smaller, increasing the action level. Further experience will indicate whether the factor of 2.5 in the formula should be increased to reduce unnecessary numbers of negative assessments, as suggested by Dr. Goldstein. Caution should be exercised when applying the formula and action level because the transmit and receive aperture sizes can differ, only the transmit aperture size may be provided by the manufacturers, and this size may be provided only at one or a limited number of settings. Also, the frequency to employ in the equation might need to be adjusted to account for beam hardening as a function of depth.

(6) RECOMMENDED TESTS

Many of the tests recommended in the letter are identical to those in our report. However, several of the basic tests, such as those for the display monitor, hard copy device, and film processor are missing. Our experience has shown that often these basic tests are the ones that are the most valuable.

(7) FINDING FAULT WITH A PROPERLY FUNCTIONING SCANNER

Finally, we take issue with the implied suggestion that a medical physicist using this report has a strong probability of finding fault with a properly functioning scanner, especially with respect to distance accuracy and lateral resolution. The distance accuracy issue involves the possible use of urethane phantoms, the pros and cons of which are adequately discussed in the report. We did not ''recommend'' these phantoms, as implied by Dr. Goldstein. We stated ''for consistency checks over several years, it may be effective to employ a phantom made of a more stable material that doesn't necessarily have the speed of sound or attenuation properties of soft tissue.''

We reiterate: lateral resolution is not recommended as a routine test. The report only suggests finding fault if the beamwidth changes by more than 1 mm for two successive test periods or if it is greater than the value computed with the formula discussed earlier. Because, as mentioned above, there are many difficulties associated with the use of this formula, it is highly unlikely that a medical physicist will use this formula as a basis for determining a fault in the lateral resolution of a system. Instead, they will use the table of recommended values that is also provided.

Performance of any test including the paper clip test by a novice can result in unnecessary service calls. To help avoid this problem, we tried to be as thorough as possible in describing the test procedures and in providing additional notes regarding the tests. Admittedly, in a few instances we may have failed to include some useful information. It is difficult

to include everything without making the document inordinately long. Good calibration of US equipment must rest on an understanding of the expectations of the radiologist as well as reasonable expectations of equipment performance. The Ultrasound Task Group's report emphasizes this approach to QC.

We believe Dr. Goldstein was mistaken in his vigorous condemnation of the Ultrasound Task Group's report and the AAPM Scientific Council's review of that report.

[1]A. Goldstein, D. Ranney, and R. D. McLeary, ''Linear array test tool,'' J. Ultrasound Med. **8**, 385–397 (1989).

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