Commentary on "Whole-Body Clinical Applications of Digital Tomosynthesis," with Response from Dr Machida and Colleagues

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There was a common board question in the 1990s that asked, "Which body imaging system has the best spatial resolution: computed tomography, magnetic resonance imaging, ultrasound, or linear tomography?" Residents would get caught trying to compare the most recent systems from the various manufacturers, when the answer was that linear tomography had the highest spatial resolution due to the detector that was used in those days—film. Today, in the digital era, the equivalent question would replace "linear tomography" with "digital tomosynthesis," but the answer would be the same; DT is routinely capable of the highest in-plane spatial resolution of any modality, even superior to projection radiography in some instances (1).

A second benefit of DT is the low radiation dose. In DT, the entire tomographic volume is acquired with a single sweep of low-dose projections, theoretically requiring a dose nearly equivalent to that of the matching projection radiograph. In practice, current breast DT systems operate close to this dose limit due to extensive work to optimize image acquisition and advanced detector designs (2,3); body DT systems operate at higher doses today (4), although research into optimized acquisition techniques and novel detector designs should result in sizable dose reductions. Regardless, DT doses are a fraction of the equivalent CT doses (4).

Despite the obvious benefits, breast DT is the only procedure widely performed today. In the preceding article, Machida and colleagues provide compelling evidence to support broader use of DT. They give a succinct overview of DT to introduce the technique and provide excellent clinical examples and important take-home points. Notably, they have chosen to present both breast and body imaging in the same article, emphasizing the commonalities of these two DT modalities. This should encourage body imagers to look more closely at the innovations of breast DT to identify potential improvements, and vice versa.

For example, common to all DT applications, sweep angle, sweep direction, and radiation dose are the primary determinants of image quality, in which the common goal is to minimize the artifacts from out-of-plane anatomy. Yet certain techniques, such as digitally reconstructed maximum intensity projection (MIP) images, remain solely within the purview of breast imaging today; a simple dose-reduction strategy for body imaging would be to eliminate the scout view, as has occurred in breast DT. One shortcoming of the article by Machida and colleagues is that the issues of dose are not covered in more detail. One should never compare the benefits of various imaging methods without comparing their dose.

The most common criticism of DT is that the images are not fully three-dimensional (3D). It is true that when compared with CT, the spatial resolution of DT is anisotropic (meaning that resolution is

dependent on orientation); thus, in DT, the in-plane resolution is high and the out-of-plane resolution is poor. Yet this does not change the fact that DT is a 3D tomographic imaging modality with all the associated benefits. Thus, while anisotropy may limit some applications of tomosynthesis because out-of-plane artifacts can dominate the reconstructed image, Machida and colleagues have demonstrated that this is rarely the case. Moreover, as the authors clearly illustrate, DT is less prone to metal artifacts than CT, one of the key advantages of the technique.

Admittedly, DT has poorer contrast resolution than CT; however, as Machida and colleagues show, DT is excellent for imaging high-contrast structures such as air-filled cavities, bony structures, and foreign objects. Thus, DT has a compelling role in detection of pulmonary disease, evaluation of the sinuses, and diagnosis of subtle fractures. Bony structures that are best imaged in the coronal plane, such as the odontoid process, are clear candidates for DT; even with isotropic voxels, the image quality of coronal CT is reduced in comparison with that of axial CT.

The authors' example of foreign object detection is also illustrative. DT has a potentially important role in pediatric imaging, something not covered in sufficient detail in their article. There are a number of factors supporting the role of DT in pediatric imaging. The low dose, together with the high incidence of certain indications in pediatrics (eg, fractures, sinusitis, and ingestion of foreign objects), makes DT an obvious choice over CT.

Naysayers of DT claim that the dose reductions achieved with modern iterative CT reconstructions make DT unnecessary, as the gap between CT and DT doses is being reduced. However, this argument is disingenuous, as the same technologies that are propelling CT doses downward have equal applicability in DT. We have yet to see substantive model-based DT reconstruction methods become clinically available.

DT can also support oblique reconstructions with moderate degrees of obliquity. As illustrated by the authors' work in breast imaging, oblique or multiplanar reconstructions (MPRs) can be created (5,6). Although only recently available commercially in breast and body DT, this ability should further reduce the radiation dose of DT in comparison with that of projection imaging, as certain oblique views should be rendered unnecessary. DT MPR will also increase the number of imaging studies that are suited to DT. For example, Uchida (7) has demonstrated the role of oblique reconstructions to generate planar images of the clavicles and lateral oblique views of the hip.

Drawing an analogy to breast imaging, the idea of contrast-enhanced DT is intriguing. Early work on contrast-enhanced breast DT demonstrated elucidation of subtle tumors based on iodine uptake (8). Initial results indicate concordance with breast MR imaging, without the associated expense, and DT enables contrast-enhanced imaging of patients otherwise excluded from MR imaging, including patients with pacemakers, metallic implants, and claustrophobia. Machida and colleagues provide several examples of contrast-enhanced DT, including arthrography and biliary ductography, highlighting the benefits of DT with exogenous contrast agents.

DT has another advantage compared with CT—cost. Many clinics in rural or remote areas, which are unable to afford CT, could easily configure their radiography systems to offer DT. Outside the United States, where access to CT can be limited, DT provides an excellent alternative.

Ultimately, we must decide on the preferred clinical role of tomosynthesis. Machida and colleagues, while showing excellent clinical examples, do not touch on this issue. Quaia et al (9) have demonstrated that DT can significantly reduce the need for CT in screening for pulmonary lesions. Yet, I believe their workflow example is shortsighted and unlikely to lead to extensive use of DT. Instead, I believe that we should be asking whether DT could replace general radiography, just as has occurred in breast imaging. It is possible today to perform an anteroposterior chest DT for the same radiation dose as anteroposterior and lateral chest radiographs, with greater sensitivity for pulmonary nodule detection, but we have yet to take this step.

Perhaps we need to follow the lead of Machida and colleagues by thinking of breast DT and body DT in the same way. Breast DT seems destined to replace mammography. Would the addition of optimized acquisition techniques, MIP views, and other advanced acquisition and display methods lead to broader use of body DT? More than likely, the same reimbursement issues that plague breast DT will need to be addressed before we see use of body DT increase greatly. However, ultimately it should be possible to replace radiography largely with DT without an increase in radiation dose.

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Dr Machida and colleagues respond:

We thank Dr Maidment for his perceptive comments and insights on our article. It is interesting that Dr Maidment raised the comparison with linear tomography. As he pointed out, in a number of ways, including high resolution, DT is the modern replacement for linear tomography; however, it differs in a number of key aspects. Unlike linear tomography, DT can reconstruct planes throughout the volume of interest with a single sweep of the x-ray source, whereas in linear tomography only one plane of the patient is in focus for each acquisition. Thus, DT requires less dose to acquire multiple tomographic planes, has a more efficient workflow for the technologists acquiring the images, and provides the opportunity for postprocessing and patient-specific reconstructions.

Dose from ionizing radiation is of high concern, and understanding the dosimetry of DT is important for determining the appropriate use of this imaging technique. As Dr Maidment described, for mammographic applications tomosynthesis images are acquired at a dose level similar to the dose used for projection imaging. An American Association of Physicists in Medicine (AAPM) task group recently described and characterized the dose of commercially available systems and a generic breast tomosynthesis geometry (1). Dose assessment for radiographic DT applications is more complex as a result of the number of different examinations, the number of views per examination (some of which may be 2D projection and others DT), and the appropriate reference comparison (2D projection or CT). A number of investigators have characterized the dose of individual examinations including chest (2,3), sinus (4), spine (5), and abdomen (6,7). Complete characterization of DT dose will require accurate characterization of DT dosimetry (8) and understanding of how DT will be used as part of clinical protocols; as such, it was beyond the scope of our article.

Dr Maidment is correct in pointing out that DT may play a significant role in pediatric imaging, in large part due to the dose advantages. Although currently underused and underresearched in this population, there have been preliminary assessments of the dose advantages of DT in pediatric skeletal imaging (9) and thoracic imaging for cystic fibrosis (10). Vult von Steyern et al (11) have commented on the significance of using DT as a lower-dose alternative to CT for repeated assessments of pediatric cystic fibrosis patients. We agree that this is a worthy area for further basic and applied clinical research.

We also agree that skeletal structures such as the odontoid process are excellent candidates for visualization with DT. However, DT is useful for imaging not only in the coronal plane, but for any plane of the patient that can be positioned parallel to the detector plane. For example, a sagittal view of the cervical spine (acquired with a cross-table or lateral DT acquisition) provides much better visualization of the spine than a traditional lateral or swimmer's view.

Dr Maidment notes that DT has cost and accessibility advantages compared with CT. In addition to use in underserved regions, the increasing use of bundled payment models and accountable care organizations further motivates use of lower-cost techniques, like DT.

Finally, we strongly agree that there is much research to be done to determine the preferred clinical roles for DT in various clinical care pathways. In our article, we referred to some of the published studies that are beginning to define roles for DT for specific indications; however, there is still much work to be done to determine the clinical effectiveness and overall efficacy of DT, including whether it will ultimately supplant 2D radiography.

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