References

[1] Tepper OM, Small K, Rudolph L, et al. Virtual 3-dimensional modeling as a valuable adjunct to aesthetic and reconstructive breast surgery. Am J Surg 2006;192:548–51.
[2] Kovacs L, Eder M, Hollweck R, et al. New aspects of breast volume measurement using 3D surface imaging. Ann Plast Surg 2006;57:602–10.
[3] Kovacs L, Zimmermann A, Papadopulos NA, et al. Re: factors determining shape and symmetry in immediate breast reconstruction. Ann Plast Surg 2004;53:192–4.
[4] Kovacs L, Yassouridis A, Zimmermann A, et al. Optimisation of the three-dimensional imaging of the breast region with 3D laser scanners. Ann Plast Surg 2006;56:229–36.
[5] Kovacs L, Eder M, Papadopulos NA, et al. Re: validating three-dimensional imaging of the breast. Ann Plast Surg 2005;55:695–6.
[6] Kovacs L, Eder M, Hollweck R, et al. Comparison between the breast volume measurement using 3D surface imaging and classical techniques. Breast 2007;16:137–45.
[7] Lee HY, Hong K, Kim EA. Measurement protocol of women's nude breasts using a 3D scanning technique. Appl Ergon 2004;35:353–9.
[8] Isogai N, Sai K, Kamiishi H, et al. Quantitative analysis of the reconstructed breast using a 3-dimensional laser light scanner. Ann Plast Surg 2006;56:237–42.
[9] Losken A, Fishman I, Denson DD, et al. An objective evaluation of breast symmetry and shape differences using 3-dimensional images. Ann Plast Surg 2005;55:571–5.
[10] Eder M, Papadopulos NA, Kovacs L. Re: breast volume determination in breast hypertrophy: an accurate method using two anthropomorphic measurements. Plast Reconstr Surg 2007 (in press).

In search of an accurate and practical approach to 3-dimensional photography of the breast: reply

To the Editor:

We appreciate the invitation to provide a commentary on the Letter to the Editor by Eder et al [1]. In their Letter to the Editor, the authors' provide their perspectives on our recent publication in *The American Journal of Surgery*, titled "Virtual 3-dimensional modeling as a valuable adjunct to aesthetic and reconstructive breast surgery" [2]. This group previously reported on 3-dimensional (3-D) imaging of the breast, and thus has a wealth of experience that offers unique viewpoints on this exciting new modality.

Over recent years, 3-D photography has emerged as a potential clinical tool in various medical specialties [3–7]. As ongoing studies explore the possibilities of 3-D imaging, the clinical success of this technology will depend on a number of factors including accuracy, reproducibility, cost, and technical feasibility. Our experience with 3-D imaging suggests that this technology may offer a practical method for measuring breast volume, shape, and contour. This approach may help to improve the planning and assessment of procedures such as breast reduction, augmentation, and reconstruction (summarized in our earlier report) [2]. However, despite encouraging preliminary results with 3-D imaging, further optimization of this technique is required for it to be applicable clinically. Some of these key aspects are raised by Eder et al, and therefore we believe warrant further discussion.

In regards to scanning protocol, the authors point out that to optimize the accuracy of 3-D scans one must try to minimize "[scanning] time, patient moving, and number of scans." In our experiences of scanning hundreds of patients with varying height, weight, body habitus, and breast size, we strongly agree with this viewpoint. When performing 3-D breast scanning, key variables to address include scanner position, patient position, number of scans, and volume calculations.

Scan Number

Eder et al raised concerns regarding the accuracy and reproducibility of 3-D images created by merging images from various angles. The authors have made significant progress in this area, having published their experiences with 2 connected cameras [8]. In this study, the authors reported their method of accurate scans obtained with 2 cameras (30° left and 30° right of the sagittal plane) that were tilted 10° upward. However, in our experience we have found that this minimal degree of tilt is inadequate to capture the undersurface of the breast with women with large or ptotic breasts. Furthermore, although a 2-camera system such as the one previously described by the authors does help limit the total number of scans, it should be noted that even this type of system fails to consistently obtain a complete circumferential view of both breasts. In such cases in which holes persist, two options remain to complete the breast: (1) to fill the hole with an artificial, or mathematically based surface, or (2) to obtain an additional view that can be merged into a single model using 3-D computer software. For our studies, we chose the latter to better reflect the patient's true anatomy, at the risk of sacrificing some accuracy when merging the image. It is worth noting that we have repeatedly scanned individual patients using this multiple-scan approach, and have not found significant variation in volumetric measurements (unpublished data).

Clearly, an ideal 3-D system would consist of multiple cameras placed at various positions, such that the entire breast could be obtained in a single shot. The future of 3-D imaging likely will not use a single or 2-viewpoint system, but rather multiple cameras positioned at various angles such that a circumferential view can be obtained in just one scan. Excitedly, newer systems currently are being developed to achieve this for breast surgery and other clinical scenarios. However, their costs remain high, and thus current applications in 3-D scanning may require establishing scanning protocols with individual systems that are both clinically useful and affordable.

Patient and Scanner Position

Eder et al described their preference to move the scanner "around the patient" rather than move the patient around the scanner because this may represent a more reliable approach. Although we do believe patient and scanner position are important variables, we do not agree with the suggestion that one approach is superior to the other. We have tested both approaches in our system and have concluded that reproducible scans can be achieved by asking the patient to turn relative to the camera. Some key points to highlight include the following: (1) having the patient maintain a comfortable and steady hand position on her hips, (2) asking the patient to turn according to prelabeled foot markings on the floor, and (3) having the camera mounted on a

stand that can be raised quickly and easily. In our experience, this technique has led to a more rapid scanning protocol (on the order of minutes) compared with trying to maneuver a camera system around a stationary patient.

We also welcome the authors' statement on the importance of "placing landmarks before shooting." Although we did not highlight this point in our initial article, we also routinely place markings on the breast before scanning. These marks have proven not only to be essential for merging multiple images (by identifying identical points), but also can serve as important landmarks for preoperative and postoperative analysis. For instance, measurements of the sternal notch–to–nipple distance or breast width (lateral-to-medial inframammary fold distance) are important clinical values that can be measured appropriately from 3-D scans with prior markings.

Volume Calculations

Ultimately, the usefulness of 3-D imaging of the breast will depend on its ability to provide valuable clinical data. Although 3-D imaging has a number of clinical applications, the measurement of breast volume is among one of the most exciting possibilities of 3-D imaging. For volume measurements to be obtained from 3-D images, a posterior border (or the chest wall) must be created to achieve a closed object. Our approach mimics that described by Eder et al, which involves a computer-based algorithm to interpolate the chest wall curvature. We are excited to learn that this group has compared this technique with magnetic resonance imaging data and found that the chest wall and resulting breast volume match. We too have found strong correlation between volumes from 3-D images and magnetic resonance image data in cancer patients, and thus look forward to publication of their work.

3-D breast imaging has unique potential in plastic and reconstructive surgery by providing previously unattainable breast measurements. Further work is required to validate this technology and its application to surgical planning and assessment. Drs. Eder, Papadopulos, and Kovacs should be commended on their continued efforts to advance the field, and hopefully optimize patient care.

Oren M. Tepper, M.D.
Mihye Choi, M.D.
Nolan S. Karp, M.D.
Institute of Reconstructive Plastic Surgery
New York University Medical Center
550 First Ave., TH-169
New York, NY 10016, USA

doi:10.1016/j.amjsurg.2006.12.039

References

[1] Eder M, Papadopulos NA, Kovacs L. Re: virtual 3-dimensional modeling as a valuable adjunct to aesthetic and reconstructive breast surgery [letter]. Am J Surg 2007;194:563–5.
[2] Tepper OM, Small K, Rudolph L, et al. Virtual 3-dimensional modeling as a valuable adjunct to aesthetic and reconstructive breast surgery. Am J Surg 2006;192:548–51.
[3] Lee S. Three-dimensional photography and its application to facial plastic surgery. Arch Facial Plast Surg 2004;6:410–4.
[4] Ciocca L, Scotti R. CAD-CAM generated ear cast by means of a laser scanner and rapid prototyping machine. J Prosthet Dent 2004;92:591–5.
[5] Seibert JP. Human body 3D imaging by specke texture projection photogrammetry. Sensor Rev 2000;3:218–26.
[6] Avis NJ, Briggs NM, Kleinermann F, et al. Anatomical and physiological models for surgical simulation. Stud Health Technol Inform 1999;62:23–9.
[7] Avis NJ, McClure J, Kleinermann F. Surface scanning soft tissues. Stud Health Technol Inform 2005;111:29–32.
[8] Kovacs L, Yassouridis A, Zimmermann A, et al. Optimization of 3-dimensional imaging of the breast region with 3-dimensional laser scanners. Ann Plast Surg 2006;56:229–36.