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ORIGINAL ARTICLE

Breast

Estimation of Mastectomy Volume Using Preoperative Mastectomy Simulation Images Acquired by the Vectra H2 System

Jiwoo Kim, MD
Hajime Matsumine, MD, PhD
Yosuke Niimi, MD, PhD
Atsuyoshi Osada, MD, PhD
Hiroyuki Sakurai, MD, PhD

Background: Preoperative prediction of breast volume is very important in planning breast reconstruction. In this study, we assessed the usefulness of a novel method for preoperative estimation of mastectomy volume by comparing the weight of actual mastectomy specimens with the values predicted by the developed method using the Vectra H2.

Methods: All patients underwent skin-sparing mastectomy and immediate autologous breast reconstruction. Preoperatively, the patient's breast was scanned using the Vectra H2 and a postmastectomy simulation image was constructed on a personal computer. The estimated mastectomy volume was calculated by comparing the preoperative and postmastectomy three-dimensional simulation images. Correlation coefficients with the estimated mastectomy volume were calculated for the actual mastectomy weight and the transplanted flap weight.

Results: Forty-five breasts of 42 patients were prospectively analyzed. The correlations with the estimated mastectomy volume were $r = 0.95$ ($P < 0.0001$) for actual mastectomy weight and $r = 0.84$ ($P < 0.0001$) for transplanted free-flap weight. The mastectomy weight estimation formula obtained by linear regression analysis using the estimated mastectomy volume was 0.98 × estimated mastectomy volume + 5.4 (coefficient of determination $R^2 = 0.90$, $P < 0.0001$). The root-mean-square error for the mastectomy weight estimation formula was 38 g.

Conclusions: We used the Vectra H2 system to predict mastectomy volume. The predictions provided by this method were highly accurate. Three-dimensional imaging is a noncontact, noninvasive measurement method that is both accurate and simple to perform. Use of this effective tool for volume prediction is expected to increase in the future. *(Plast Reconstr Surg Glob Open 2023; 11:e5180; doi: 10.1097/GOX.0000000000005180; Published online 11 August 2023.)*

INTRODUCTION

Preoperative prediction of breast volume is very important in planning breast reconstruction. It aids in selecting the best flap procedure for autologous tissue reconstruction and the most appropriate expander/implant for reconstruction, and determining the injection volume for fat transfer. Although many estimation methods have been reported, they all require measurement-related costs, time, and human resources, and have unwanted effects such as radiation exposure. There is currently no standardized measurement method.[1,2] Therefore, a simple and highly accurate method is needed for the measurement of breast volume. Previously reported methods include anthropometric measurements, casting, computed tomography, magnetic resonance imaging, and mammography; methods utilizing three-dimensional (3D) imaging devices have also been described.[3,4] The amount of water displaced by the excised breast tissue is regarded as the gold standard measurement method.[5] However, recent studies have described the value of 3D imaging in the assessment of breast volume.[1,6–11]

The Vectra H2 (Canfield Scientific, Parsippany, N.J.; Fig. 1) is an easy-to-use handheld 3D camera that can construct 3D data for both breasts with a personal computer

From the Department of Plastic and Reconstructive Surgery, School of Medicine, Tokyo Women's Medical University, Tokyo, Japan.
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Fig. 1. Appearance of the Vectra H2.

(PC) application after taking images in three directions. The constructed 3D data can be used to simulate mastopexy and breast augmentation by using various functions in the application. We have used the Vectra H2 system to construct a postmastectomy simulation image from preoperative 3D images and compared this image with the preoperative image to infer the volume of the mastectomy specimen.

In this study, we assessed the usefulness of this novel method for preoperative estimation of mastectomy volume in cases with nonptotic breasts by comparing the weight of actual mastectomy specimens with the values predicted using the developed method.

PATIENTS AND METHODS

The study was approved by the ethics committee of Tokyo Women's Medical University (approval number 2020-0088). All patients provided written informed consent to be included in the study. All women who underwent skin-sparing mastectomy (SSM) and immediate autologous breast reconstruction with a deep inferior epigastric perforator or profunda artery perforator (PAP) flap at Tokyo Women's Medical University Yachiyo Medical Center or Tokyo Women's Medical University Hospital between 2018 and 2023 were retrospectively reviewed. Four breast surgeons were involved in the mastectomy procedures in this study and were blinded to the study.

Takeaways

Question: Development of estimation of mastectomy volume using preoperative mastectomy simulation images.

Findings: The estimated mastectomy volume was calculated by comparing the preoperative and postmastectomy images constructed by the Vectra H2 system. The predicted values were highly accurate compared with the actual mastectomy specimens.

Meaning: Preoperative prediction of mastectomy volume aids in selecting the best flap procedure for autologous tissue reconstruction and the most appropriate expander/implant for reconstruction.

The following exclusion criteria were applied: SSM type IV (inverted T-design) performed; a history of partial mastectomy; severe breast ptosis or breast size too large for construction of a 3D image of the mammary gland area; reconstruction performed with a pedicle flap; risk-reducing mastectomy performed for hereditary breast and ovarian cancer syndrome; and body mass index (BMI) less than 18.5 or greater than or equal to 25. The SSM type IV procedure, which is considered for patients with ptotic breasts who desire breast reduction after reconstruction, was excluded to focus on simple SSM cases in this study. Cases of pedicled flap reconstruction were also excluded because the weight of the transplanted tissue could not be accurately measured.

PREOPERATIVE SCANNING WITH THE 3D CAMERA

First, skin marking was performed using ultrasonography to show the extent of the mammary glands in the affected breast (Fig. 2). Measurements were then obtained using the Vectra H2 system. Scanning was performed while the patient stood with arms crossed behind the back. The camera lens was positioned at the height of the inframammary fold; three stereo images were scanned at 45 degrees to the left and right of the patient and from straight ahead. Two green circular pointers were directed at the patient, and the point at which they were both in focus was scanned to equalize the distance between the camera and the patient. The scanning data were imported into the application software (Vectra Breast Sculptor; Canfield Scientific) for measurement.

CONSTRUCTION OF MASTECTOMY SIMULATION IMAGE WITH PC APPLICATION

The Vectra Breast Sculptor program was opened on a computer, and the images scanned with the 3D camera were selected from the "import files." The imported images were converted to 3D image data using the "stitch images" mode. This application can automatically measure the volume of the breast using these 3D image data, and this volume was used as the "automatically measured volume" in this study. Next, the body color of the converted 3D image

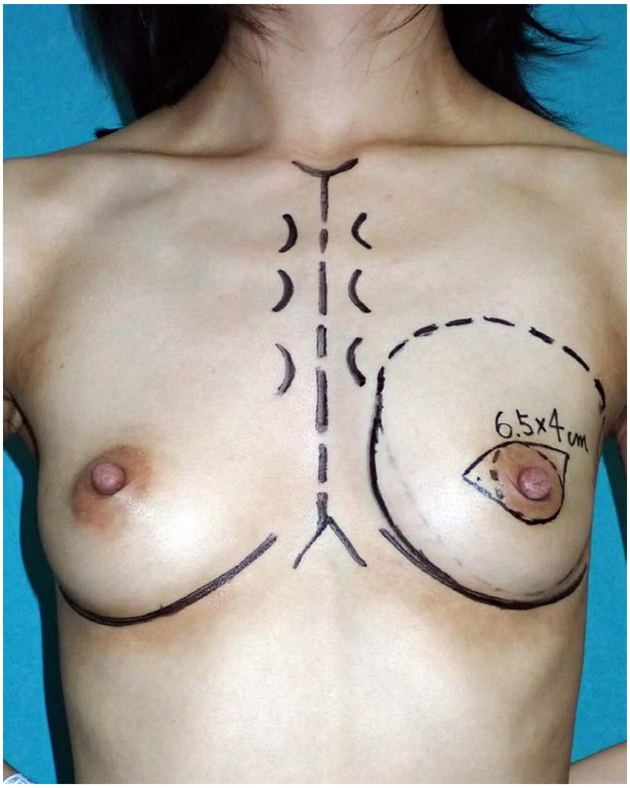

Fig. 2. Instructions for estimation of mastectomy volume using the Vectra H2 system. Skin marking was performed based on ultrasonography showing the extent of mammary gland tissue in the affected breast.

data was set to monochrome view. The "warp" button was selected from the contouring system tag, and the breast region marked preoperatively by ultrasound was traced manually using a mouse (Fig. 3A). We then depressed the projection of the breast to the estimated level of the chest wall while observing it in lateral, cranial, and caudal views, reproducing the flat shape of the chest without breast tissue using the warp function (Fig. 3B). To adjust the color of the data for the missing breast, we switched to color view mode, after which the "clone" button was used, and the coloring of the nipple, inframammary fold, and other shadows around the breast was removed (Fig. 3C).

ESTIMATION OF MASTECTOMY VOLUME

We then selected the preoperative 3D image and mastectomy simulation image and used the "open in comparison" function to visualize them simultaneously (Fig. 3D, E). Next, the merge button was used to merge these two 3D image files and visualize them as a single 3D image. On this merged image, the areas in which the volume data had differed between the preprocessed 3D image and mastectomy simulation image data were marked, similar to contour lines on a map; areas where the volume had decreased and increased were highlighted in red and blue, respectively. The measure button was then selected, and the area of the missing breast was traced to select it, after which the difference in volume between the preprocessed and processed images was automatically displayed. This volume was recorded as the estimated mastectomy volume. (**See Video [online],** which displays instructions

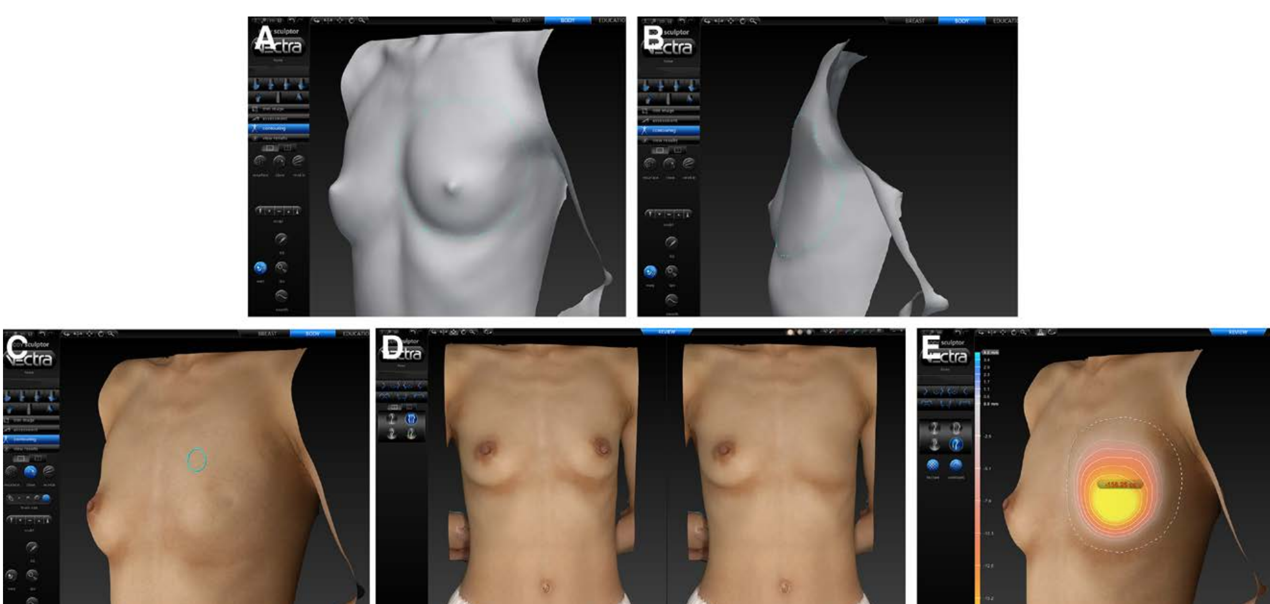

Fig. 3. Instructions for estimation of mastectomy volume using the Vectra H2 system. A, The breast region marked by preoperative ultrasound is traced manually on the preoperative 3D image using the Vectra Breast Sculptor application. B, The projection of the breast is then depressed to the estimated level of the chest wall using the "warp" function. C, The coloring of the nipple, inframammary fold, and other features is removed using the "clone" button. D, The preoperative 3D image and the mastectomy simulation image are displayed side by side. E, The two 3D images are merged, and the differences between the two are measured automatically.

for estimation of mastectomy volume using the Vectra H2 system.)

The preoperative volume measurements were mainly used for flap selection. If the estimated mastectomy weight was smaller than the predicted weight of the PAP flap, which we reported in our previous study,[12] the PAP flap was selected. If it was larger, we chose the deep inferior epigastric perforator flap or stacked flap with multiple flaps.

STATISTICAL ANALYSIS

Correlation coefficients were calculated among the estimated mastectomy volume, the automatically measured volume and actual mastectomy weight, and the transplanted flap weight by Pearson correlation analysis. Linear regression analysis was performed with the estimated mastectomy volume as the explanatory variable and the actual mastectomy weight as the objective variable to obtain an estimation formula for mastectomy weight. Finally, linear regression analysis was performed for the estimated mastectomy volume and the actual mastectomy weight to calculate the R^2 and root-mean-square error of the mastectomy weight estimation formula. The results are expressed as the mean ± SD. All analyses were performed using GraphPad Prism version 7.02 for Windows (GraphPad Software Inc., La Jolla, Calif.). Values of *P* less than 0.05 were considered statistically significant.

RESULTS

Forty-five breasts of 42 patients were prospectively analyzed. The mean age was 47 years (range, 32–79) and the mean BMI was 20.9 (range, 18.6–24.2). The mean estimated mastectomy volume was 290 ± 141 mL and the mean automatically measured volume was 184 ± 111 mL. The mean actual mastectomy weight was 288 ± 145 g. The mean transplanted free-flap weight was 326 ± 121 g (Table 1). The correlations with the estimated mastectomy volume for the actual mastectomy weight and transplanted free-flap weight were r = 0.95 ($P < 0.0001$) for actual mastectomy weight and r = 0.84 ($P < 0.0001$) for transplanted free-flap weight (Fig. 4A, B). The correlations with the automatically measured volume of each weight were r = 0.88 ($P < 0.0001$) for actual mastectomy weight and r = 0.79 ($P < 0.0001$) for transplanted free-flap weight (Fig. 4C, D).

The mastectomy weight estimation formula obtained by linear regression analysis using estimated mastectomy volume was as follows: 0.98 × estimated mastectomy volume + 5.4 (coefficient of determination R^2 = 0.90, $P < 0.0001$). The estimated mastectomy weight calculated using this formula was very similar to the estimated mastectomy volume. The mean estimated mastectomy weight was 289 ± 138 g. In linear regression analysis of the estimated mastectomy weight and actual mastectomy weight, the root-mean-square error for the mastectomy weight estimation formula was 38 g.

CLINICAL CASE

A 36-year-old woman with cancer of the left breast underwent SSM and sentinel lymph node biopsy (Fig. 5A). The preoperative estimated mastectomy volume was 153 mL, and the automatically measured volume was 107 mL (Fig. 5B). The area of resected skin (including the nipple-areolar complex) was 7 cm × 3.5 cm, and the actual mastectomy specimen weighed 164 g (Fig. 5C). A PAP flap (20 cm × 10 cm) consisting of a PAP arising from the right deep femoral artery as a vascular pedicle was harvested from the right thigh, and autologous breast reconstruction was performed immediately (Fig. 5D). The appearance of the breast after the reconstruction procedure was excellent, resulting in a high level of patient satisfaction (Fig. 5E).

Table 1. Patient Demographic and Clinical Characteristics

Variable	Summary Statistic (Range or %)
Total no. patients	41
Total no. flaps	45
Mean age, years	47.4 (32–79)
Mean BMI, kg/m^2	20.8 (18.6–24.2)
Mean mastectomy specimen weight, g	286.6 (83–620)
Breast laterality	
Right	32 (71%)
Left	13 (29%)
ASA score	
I	15 (37%)
II	26 (63%)
Smoking history	13 (32%)
Hypertension	4 (0.1%)
Diabetes	1 (0.02%)
Reconstruction laterality	
Unilateral	37 (90%)
Bilateral	4 (10%)
Reconstruction procedure	
DIEP flap	17 (38%)
PAP flap	28 (62%)
Lymphadenectomy	
SLB	37 (82%)
ALND	8 (18%)

ALND, axillary lymph node dissection; ASA, American Society of Anesthesiologists physical status; BMI, body mass index; DIEP, deep inferior epigastric perforator; SLB, sentinel lymph node; PAP, profunda artery perforator.

DISCUSSION

In this study, the predicted mastectomy volume measured by preoperative mastectomy simulation images using the Vectra H2 system showed a strong positive correlation with the actual mastectomy weight. Furthermore, the predicted mastectomy volume was strongly correlated with the final weight of the implanted skin flap. This measurement method makes it possible to predict the necessary skin flap weight before surgery and is very useful for surgical planning, including selection of type of flap and its size. In cases where a stacked flap combining multiple free flaps is planned based on preoperative estimated mastectomy weight, multiple skin flaps can be harvested simultaneously during surgery, making it possible to shorten the operation time. Mastectomy simulation by this method had a stronger correlation with the actual mastectomy volume than the automatic breast measurement

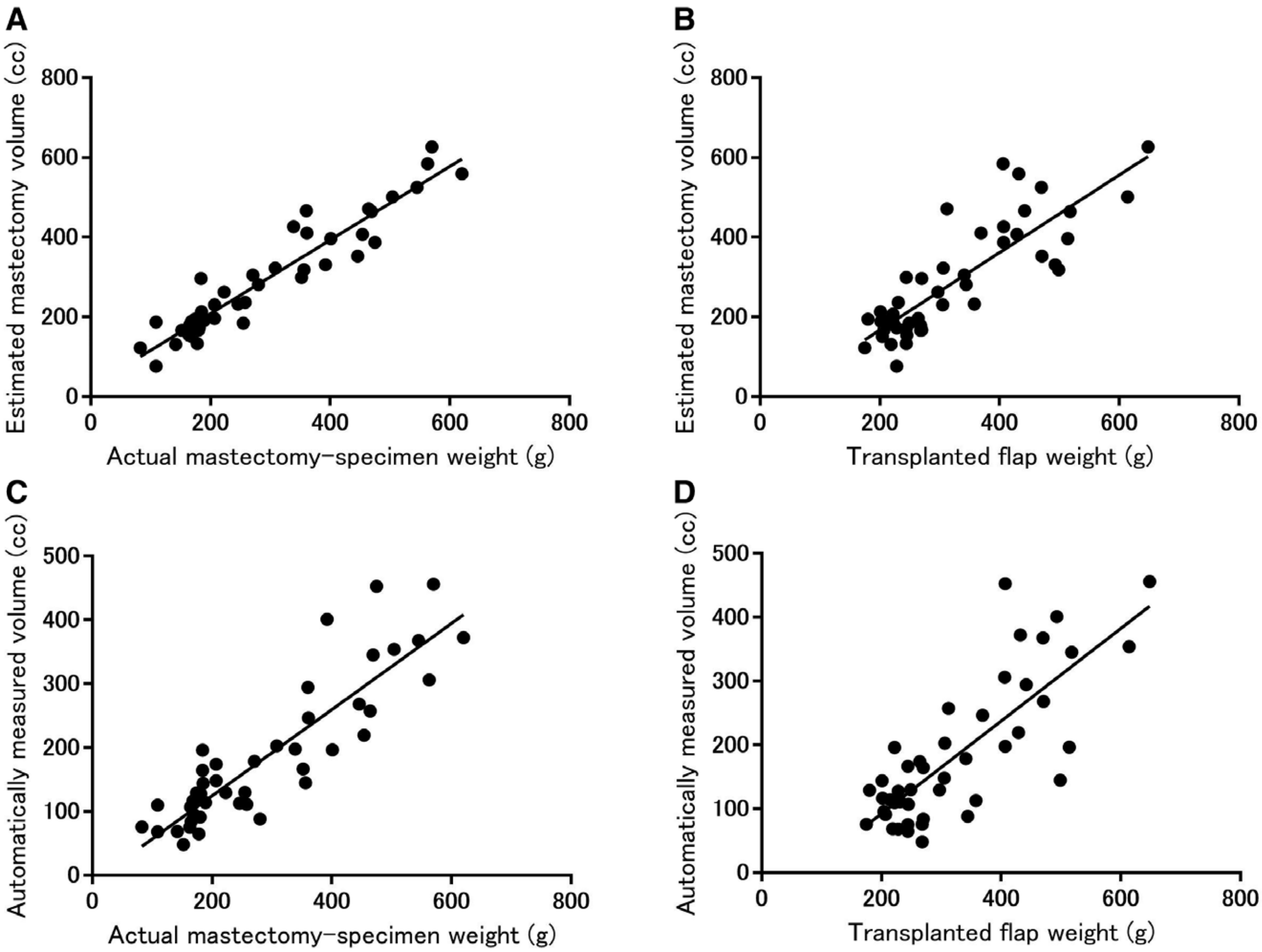

Fig. 4. Correlation analysis. Correlations with the estimated mastectomy volume of each weight were as follows: A, r = 0.95 ($P < 0.0001$) for actual mastectomy weight; B, r = 0.84 ($P < 0.0001$) for transplanted free-flap weight. Correlations with the automatically measured volume for the actual mastectomy weight and transplanted free-flap weight were as follows: C, r = 0.88 ($P < 0.0001$) for actual mastectomy weight; D, r = 0.79 ($P < 0.0001$) for transplanted free-flap weight.

in the application, likely because preoperative ultrasound-guided skin marking enabled selective measurement of only the areas containing the mammary glands. Our estimation method has the following four main advantages.

First, the measurement time is short. The marking of breast borders using ultrasound took approximately 5 minutes; the actual scanning time when using the Vectra H2 is only a few minutes; and the time interval between image import and completion of measurements is around 5 minutes. This means that the time taken to obtain the results is shorter than that with other measurement methods.

Second, the breast volume measurements obtained are accurate. Kayar et al[3] summarized the studies that have compared different breast specimen volume measurement methods and found that mammography and 3D imaging provided the most accurate results. Moreover, Kovacs et al[13] found 3D imaging to be more accurate than magnetic resonance imaging for measurement of breast volume. O'Connell et al[14] evaluated the volumes of plasticine phantoms using the Vectra XT imaging system and found that the accuracy was approximately 2.2% lower than that for the true volume. Utsunomiya et al[15] compared the breast volumes predicted using a Kinect 3D scanner with those of mastectomy specimens and found a strong correlation, reporting that the predicted value was useful for implant selection. Our study found that the values obtained by 3D imaging were extremely close to the actual amount resected, suggesting that the measurements obtained by a 3D imaging device are highly accurate.

Third, like computed tomography and magnetic resonance imaging, 3D imaging using the Vector H2 system is a noncontact measurement method, whereas anthropometric measurements, mammography, the Archimedes procedure, and casting all involve contact. The ability to obtain measurements without bodily contact means that patient discomfort can be avoided, which is an important factor when caring for patients.

Fourth, there are no measurement-associated costs. The initial cost of installing the Vectra H2 is approximately 20,000 dollars, but basically no maintenance costs or consumables are required, and there is no cost incurred when a measurement is taken. Therefore, this measurement method is more affordable than any other.

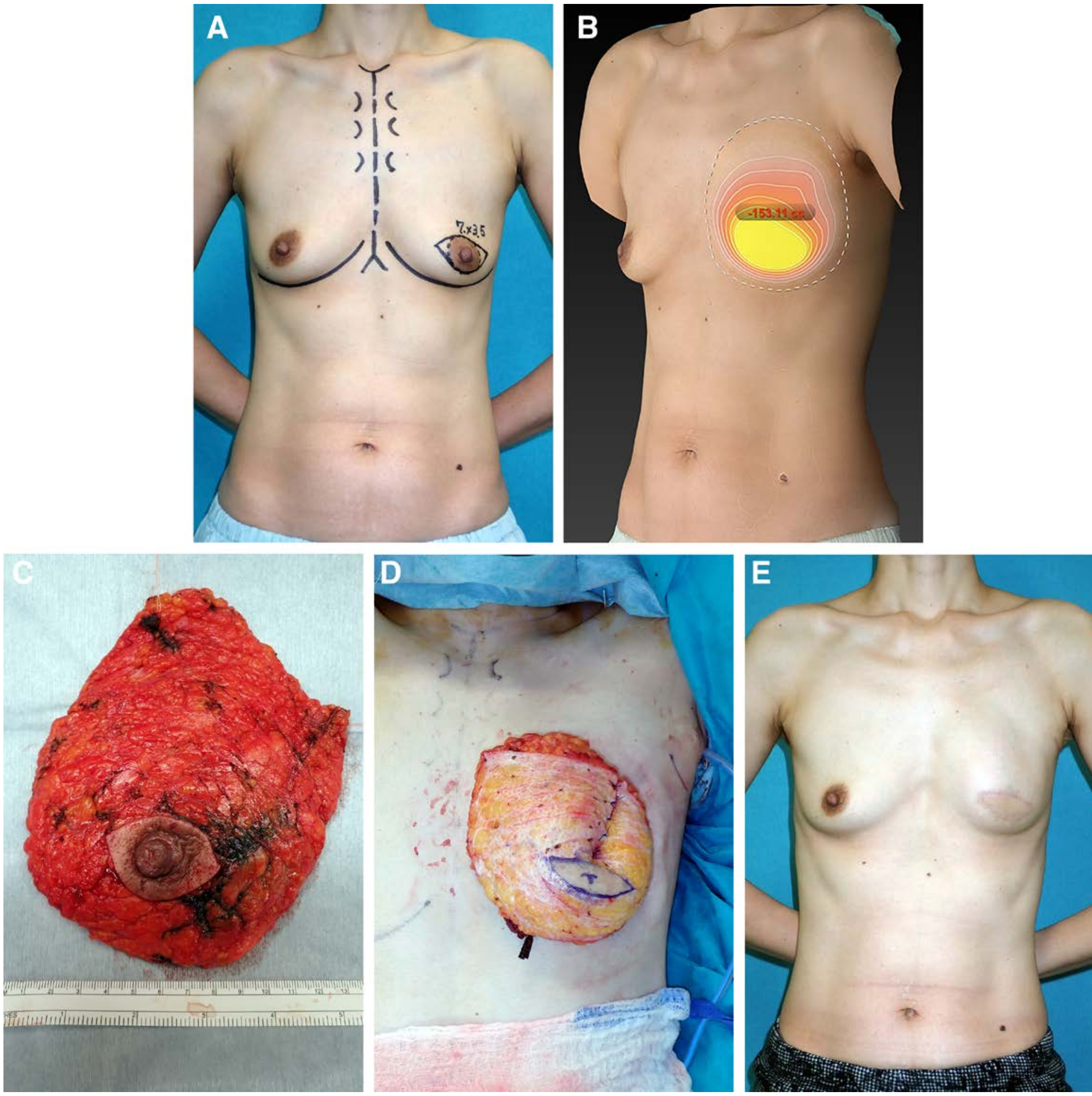

Fig. 5. Clinical case. A, A 36-year-old woman with cancer of the left breast underwent skin-sparing mastectomy and sentinel lymph node biopsy. B, The preoperative estimated mastectomy volume was 153 mL. C, The actual mastectomy specimen weighed 164 g. D, A PAP flap (20 cm × 10 cm) was harvested from the right thigh, and autologous breast reconstruction was performed immediately. E, Appearance at 12 months after breast reconstruction.

In terms of image processing, the possibility that the maneuvers involved in pushing the breast down to the chest wall may change the values measured is of concern. However, because a single image is used and the amount of change is displayed in different colors when the processed image is merged, if the thorax is excessively reduced, then the abnormal value can be distinguished during image merging because the color of the chest appears to be different from that of the breasts. Errors are easily detected and have little effect on measurements. This enables the correct chest morphology to be reproduced by any operator without variation. However, caution is required when treating patients with pectus excavatum or other preexisting thoracic deformities.

This study has some limitations. First, in cases where breast borders, such as the inframammary fold and axillary area, are unclear, it is technically difficult to create simulated images on a PC. Therefore, this method has a limitation in predicting mastectomy weight for patients with high BMI or ptosis. In the future, we would like to modify this method to make it applicable for a wider range of patients. It may be possible to predict mastectomy volume by performing Vectra scanning in a position where the breasts do not fold at the inframammary fold due to gravity, such as the pushup position. However, further investigation is required to determine the feasibility of Vectra scanning in such a position. Second, it is possible that the specimen weight may be biased because of differences between operators in how mastectomy is performed. Third, our study did not include non-SSM and nipple-sparing mastectomy cases. Therefore, additional investigations are required to determine whether our measurement method can be applied in these cases. Finally, only normal-sized patients were included in this case series, and further investigation is needed in the future to determine whether the method can be applied to patients with lean or obese body types. In addition, patients with high BMI are expected to have thick skin and subcutaneous tissue remaining after SSM, so the estimated mastectomy weight obtained by the present method needs to be multiplied by a coefficient considering subcutaneous fat thickness measured by ultrasound.

CONCLUSIONS

We used the Vectra H2 system to predict mastectomy volume. The predictions provided by this method were highly accurate. 3D imaging is a noncontact, noninvasive measurement method that is both simple to perform and accurate. Use of this effective tool for volume prediction is expected to increase in the future.

Hajime Matsumine, MD, PhD
Department of Plastic and Reconstructive Surgery
Tokyo Women's Medical University
8-1 Kawada-cho
Shinjuku-ku, Tokyo 162-8666, Japan
E-mail: matsumine.hajime@twmu.ac.jp

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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