



# Three-dimensional visualization technique in endoscopic breast-conserving surgery and pedicled omentum for immediate breast reconstruction

Pusheng Zhang<sup>a,1</sup>, Linyun He<sup>b,1</sup>, Fujun Shi<sup>a</sup>, Jianwen Deng<sup>a</sup>, Chihua Fang<sup>b</sup>, Yunfeng Luo<sup>a,\*</sup>

<sup>a</sup> Department of General Surgery, Zhujiang Hospital, Southern Medical University, Guangzhou, 510282, China

<sup>b</sup> Department of Hepatobiliary Surgery, Zhujiang Hospital, Southern Medical University, Guangzhou, 510282, China

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## ABSTRACT

**Purpose:** To evaluate the three-dimensional visualization technique (3DVT) in endoscopic breast-conserving surgery (EBCS) and pedicled omentum for immediate breast reconstruction.

**Methods:** Clinical data of 256-slice multi-detector CT scanning from 52 patients (group A) were introduced into self-developed Medical Imaging 3D Visualization Systems (MI-3DVS) for individualized segmentation, 3D reconstruction and volume calculation. The surgical process was designed according to the 3D model. Next, the EBCS and pedicled omentum breast reconstruction were performed according to the preoperative design. Finally, the operating time, blood loss, length of postoperative hospital stay, complications and cosmetic outcomes in group A were compared to 44 patients in group B, who underwent the same operation without 3DVT.

**Results:** The 3DVT can be used to analyze the location of the breast tumors and determine the excision extension of the breast precisely. Compared to group B, group A had the advantage of less bleeding, shortened operating time and earlier discharge ( $p < 0.05$ ). The cosmetic results of group A were more satisfactory than those of group B ( $p < 0.05$ ). After a postoperative follow-up of 6–30 months, none of the patients in either group showed any signs of recurrence.

**Conclusions:** 3DVT can be used to design the surgical process preoperatively and results in positive therapeutic and cosmetic outcomes in EBCS and pedicled omentum for immediate breast reconstruction.

## 1. Introduction

Breast cancer is the most common cancer in women and the second most common malignancy worldwide [1]. Breast-conserving surgery (BCS) has become a standard surgical modality for treating early breast cancer as it enhances the quality of patients' life without influencing the long-term mortality [2]. If the resected portion is  $\geq 70 \text{ cm}^3$  or  $\geq 25\%$  of the total breast volume, breast reconstruction is required to prevent deformity [3]. Omentum is rather suitable for breast reconstruction as it is soft, highly vascularized and can be shaped in any way [4]. Zaha et al. have applied the pedicled omentum for breast reconstruction in more than 200 patients with breast cancer, which is the largest series reported to date [5].

The critical process for omentum breast reconstruction is method for accurately determining the range of excision of the breast. The conventional imaging methods, such as ultrasonography, mammography, computed tomography (CT) and magnetic resonance imaging (MRI), only partially unravel the intricate architecture of the breast and

do not meet the surgeons' need of preoperative evaluation [6,7]. Therefore, it is important to find an advanced technique to assist the surgeon in the preoperative process. Three-dimensional visualization technique (3DVT) has become extremely useful in many fields such as trauma and reconstructive surgeries [8] due to the advantages in optimizing the surgical plans, shortening the duration of operation and minimizing the surgical trauma. In this study, we used the 3DVT based on the 256-slice spiral CT scanning data from patients with breast cancer to help the surgeon to design the process before surgery and calculate the excision volume of the mammary gland in EBCS and pedicled omentum for immediate breast reconstruction. The aim of this study is to determine the therapeutic effects and cosmetic outcomes of surgery guided by the 3DVT.

## 2. Methods and materials

The study was approved by the Ethics Committee of the Zhujiang Hospital. All patients were informed of all available surgical therapy

\* Corresponding author. Department of General surgery, Zhujiang Hospital, Southern Medical University, Guangzhou 510282, Guangdong Province, China.  
E-mail address: [drluoyf@126.com](mailto:drluoyf@126.com) (Y. Luo).

<sup>1</sup> Pusheng Zhang and Linyun He contributed equally to this work.

**Abbreviations**

BCS	Breast-conserving surgery
EBCS	Endoscopic breast-conserving surgery
CT	Computed tomography
MRI	Magnetic resonance imaging
3DVT	Three-dimensional visualization technique

MI-3DVS	Medical Imaging 3D Visualization Systems
NCCN	National Comprehensive Cancer Network
BMI	Body mass index
TNM	Tumor, node, metastasis
DIAP	Deep inferior epigastric perforator flap
LOS	Length of hospital stay

and the risks of each operation. All patients chose to receive the EBBS and pedicled omentum for immediate breast reconstruction and signed the informed consent preoperatively.

**2.1. Patients**

From March 2015 to May 2017, 96 breast cancer patients newly diagnosed through preoperative biopsy were recruited for this study at Zhujiang Hospital. The characteristics of the patients are listed in Table 1. A total of 52 patients, randomly assigned to group A, accepted the 256-slice CT scan in prone position. The CT data of 52 cases were introduced into self-developed Medical Imaging 3D Visualization Systems (MI-3DVS) for individualized segmentation, volume calculation and 3D reconstruction. The remaining 44 patients in group B underwent surgeries without 3DVT.

The inclusion criteria for the patients were as follows: (1) stage 0, I, II, breast cancer with a single tumor; (2) maximum tumor diameter  $\leq 30$  mm; distance between the tumor and the skin  $\geq 20$  mm; distance between the tumor margin and the nipple  $\geq 20$  mm; (3) the volume of the resected breast is  $\leq 1/2$  of the total breast since the omentum is not enough for the total mastectomy; (4) strong desire to undergo BCS and breast reconstruction and (5) no history of abdominal laparotomy or intra-abdominal malignancy. However, the patients with a history of laparoscopic appendectomy, laparoscopic ovariectomy and cesarean section were not required to be excluded.

**2.2. Surgical process was designed by 3DVT in group A**

The CT data of group A were introduced into the MI-3DVS for preoperative evaluation (Fig. 1). First, we set the regional growth point of interest through the analysis of threshold for segmentation (Fig. 2) and the data were reconstructed as a 3D model based on the automatic regional growth coupled with the manual threshold segmentation (Fig. 3). The 3D model was able to be transparent and could be rotated freely for observation (Fig. 4). Then we began to determine the range of excision of the breast (Fig. 5). The distance between the tumor and each margin was measured to make sure each margin was  $\geq 20$  mm (Fig. 6). The volume of the total breast and the excised breast were calculated accurately to make sure the volume of the excised mammary gland was  $\leq 1/2$  of the total breast due to the limited amount of omentum (Figs. 7 and 8). If the volume of the excised mammary gland was  $> 1/2$  of the total breast, this case may not be suitable for pedicled omentum breast reconstruction.

**2.3. The surgical procedures and evaluation of therapeutic effects**

According to the preoperative design, we marked the tumor location, contour of the breast and the incisions on the skin and performed the EBBS and immediate pedicled omentum reconstruction. During the operation, firstly, the endoscopic sentinel lymph node biopsy was performed, and then the nodes were sent to rapid frozen pathological examination. If the sentinel node was negative, the axillary surgery was terminated. Otherwise the endoscopic axillary lymph node dissection was continued. Secondly, the endoscopically assisted quadrantectomy was done according to the preoperative planning, ensuring the safe margin is not less than 20 mm. Then the laparoscopically harvested

pedicled omentum was obtained and finally the pedicled omentum was transferred to the residual breast cavity through the subcutaneous tunnel to reconstruct the breast (Fig. 9) [9].

All patients were treated with systemic postoperative chemotherapy and radiation therapy postoperatively according to the standard institutional protocols (National Comprehensive Cancer Network [NCCN] Breast Cancer Practice Guideline). The patients with Her-2 (+ + +) were treated with Herceptin for 1 year. All patients were evaluated for operating time, blood loss, postoperative length of hospital stay (LOS), complications, etc. (Table 2). Cosmetic outcomes were evaluated 6 months after the surgery, according to the Harris criteria [10] as follows: (1) Excellent: size and shape of the reconstructed breast are almost the same as those of the original breast; (2) Good: deformity of the reconstructed breast involves  $\leq 1/4$  of the original breast; (3) Fair: deformity of the reconstructed breast involves  $> 1/4$  and  $\leq 1/2$  of the original breast; (4) Poor: breast deformity involves  $> 1/2$  of the original breast.

**2.4. Statistical analysis**

The operating time, blood loss, LOS, complications and cosmetic outcomes in group A were compared to 44 patients in group B, who underwent the same operation without 3DVT. Student's t-test and  $\chi^2$  test were performed for continuous data and categorical data, respectively. The Mann – Whitney U test was used for analyzing the ranked data. All statistical analyses were performed by SPSS 20.0 (SPSS Inc., IL, USA). *P*-value  $< 0.05$  was considered statistically significant.

**Table 1**  
Patients' characteristics in the two groups.

	Group A (%) <sup>a</sup>	Group B (%) <sup>a</sup>	<i>p</i> -value
Age (years) <sup>b</sup>	40.3 (28–53)	39.1 (26–52)	0.320
BMI (kg/m <sup>2</sup> ) <sup>b</sup>	21.8 (16.7–32.1)	22.6 (16.2–32.3)	0.956
< 18.5	8 (15.4)	7 (15.9)	
18.5–23.9	30 (57.7)	27 (61.4)	
24.0–31.9	12 (23.1)	9 (20.4)	
> 31.9	2 (3.8)	1 (2.3)	
Prior abdominal surgery			0.717
Cesarean section	1 (1.9)	2 (4.6)	
Laparoscopic falcetomy	1 (1.9)	1 (2.3)	
Laparoscopic appendectomy	2 (3.8)	1 (2.3)	
The maximum diameter of tumor (cm) <sup>b</sup>	1.8 (0.9–2.8)	1.9 (0.8–3.0)	0.535
Location of the tumor			0.995
Outer upper quadrant	12 (23.1)	10 (22.7)	
Outer lower quadrant	18 (34.6)	16 (36.4)	
Inner upper quadrant	8 (15.4)	6 (13.6)	
Inner lower quadrant	14 (26.9)	12 (27.3)	
Tumor Stage			0.606
Stage I	28 (53.8)	26 (59.1)	
Stage II	24 (46.2)	18 (40.9)	
Pathologic type			0.918
Invasive ductal carcinoma	34 (65.4)	29 (65.9)	
Ductal carcinoma in situ	12 (23)	9 (20.5)	
Pleomorphic carcinoma	3 (5.8)	2 (4.5)	
Invasive lobular carcinoma	3 (5.8)	4 (9.1)	

<sup>a</sup> Values in parentheses are percentages unless indicated otherwise.

<sup>b</sup> Values are mean (range).

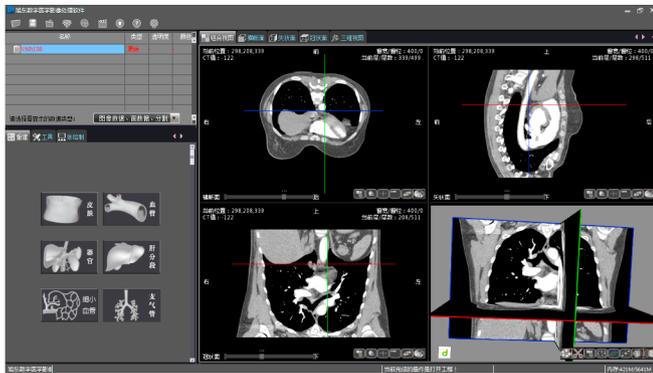


Fig. 1. The image data were imported into the MI-3DVS.

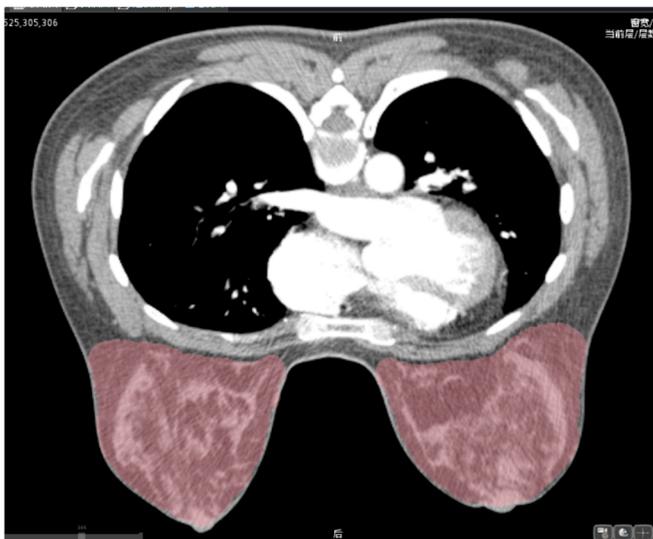


Fig. 2. The segmentation of breast image by digital 3DVT.



Fig. 3. The reconstruction of breast image by digital 3DVT.

### 3. Results

#### 3.1. Operative results

After a careful preoperative evaluation, a total of 93 patients underwent EBCS and pedicled omentum reconstruction. No significant differences in patients' characteristics were detected between both groups ( $p > 0.05$ ). (Table 1).

In addition, 49 patients in group A were recommended for the

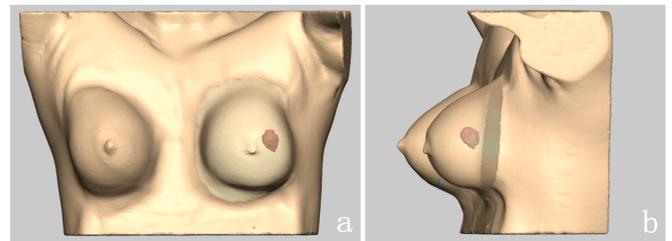


Fig. 4. The reconstruction of breast image by digital 3DVT before surgery. The location, size and shape of the tumor are clear in the transparent view of the breast (a: front; b: side).

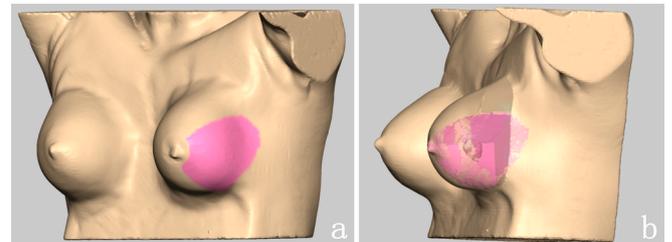


Fig. 5. Determine the range of excision of the breast preoperatively (a: the range of excision of the breast; b: Evaluated the distance between the tumor and the surgical margins in the transparent view of the breast).

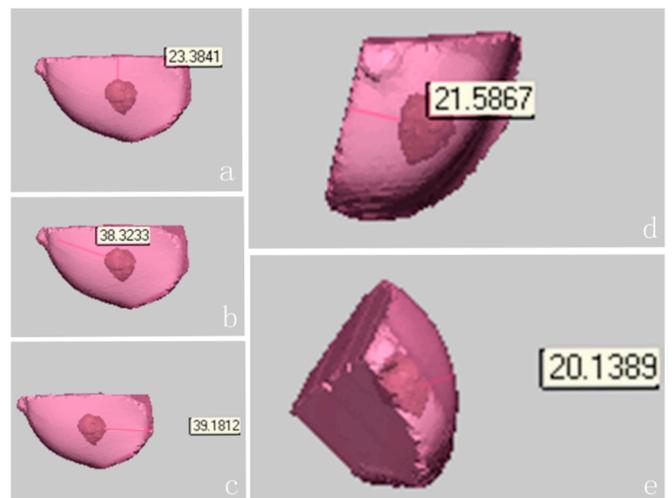


Fig. 6. The distance between the tumor and the surgical margins were measured (a: The distance between the tumor and the superior margin; b: The distance between the tumor and the nipple; c: The distance between the tumor and the posterior margin; d: The distance between the tumor and the inferior margin; e: The distance between the tumor and the skin).

omentum breast reconstruction. Two patients in group A were recommended for prosthetic breast reconstruction because the volume of the excised mammary gland calculated by 3DVT was more than 1/2 of the total breast, while another patient was recommended for a mastectomy as the distance between the tumor and nipple was less than 20 mm.

After the surgery, the median operation time, blood loss and LOS in 49 cases of group A were collected and were significantly lower than that in group B ( $p < 0.05$ ). After a postoperative follow-up of 6–30 months, none of the patients in either group showed any signs of recurrence (Table 2).

#### 3.2. Cosmetic results

The cosmetic results were mostly satisfactory at 6 months after the

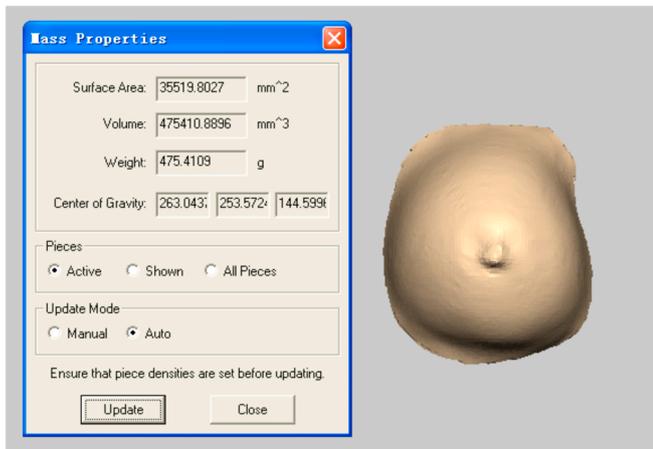


Fig. 7. The volume of the total breast was calculated as 475.4 cm<sup>3</sup>.

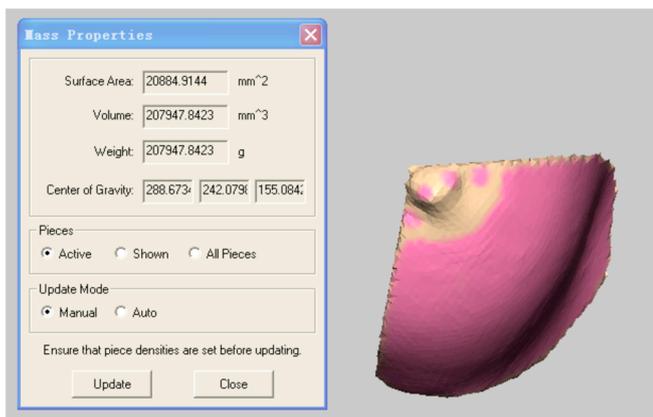


Fig. 8. The volume of the proposed removal of the breast was calculated as 207.9 cm<sup>3</sup>, lower than 1/2 total breast, according with the indication of omentum breast reconstruction.

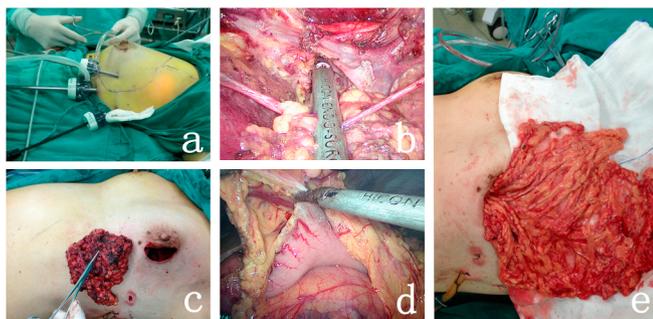


Fig. 9. EBCS and pedicled omentum for immediate breast reconstruction. (a, b: EBCS/endoscopic axillary lymph node dissection was performed; c: The endoscopically assisted quadrantectomy was done; d: The laparoscopically harvested pedicled omentum was obtained; e: The pedicled omentum was transferred to the residual breast cavity through the subcutaneous tunnel to reconstruct the breast.)

surgery in group A. The incision scars on the patients’ areola, lateral chest wall and abdomen were not obvious. The axillary appearance was natural without distortion. No partial graft necrosis occurred. The size and the characters of the reconstructed breast were consistent with the original breast (Fig. 10). The cosmetic results of group A were much more satisfactory than those of group B ( $p < 0.05$ ). (Table 3).

Table 2  
Operative data and complications.

	Group A (%) <sup>a</sup>	Group B (%) <sup>a</sup>	p-value
Total operating time (min) <sup>c</sup>	258 (191–320)	303 (205–410)	< 0.001*
Operating time for BCS (min) <sup>c</sup>	39 (31–55)	49 (41–65)	< 0.001*
Operating time for omentum reconstruction (min) <sup>c</sup>	55 (38–65)	61 (45–83)	< 0.001*
Blood loss (mL) <sup>c</sup>	62 (45–85)	70 (50–90)	0.009*
Postoperative hospital stay (days) <sup>c</sup>	8.1 (5–15)	9.5 (6–17)	0.003*
Complications			
Partial skin flap necrosis	0 (0)	0 (0)	
Partial graft necrosis	0 (0)	2 (3.8)	
Local recurrence	0 (0)	0 (0)	
Distant metastasis	0 (0)	0 (0)	

<sup>a</sup> Values in parentheses are percentages unless indicated otherwise.

<sup>c</sup> Values are median (range).

\* $p < 0.05$ .

#### 4. Discussion

The successful outcomes in breast reconstruction are dependent on breast accurate evaluation preoperatively. Hitherto, several imaging modalities have been used to assess the size of the breast tumor and determine the optimal breast reconstruction. Although mammography and ultrasonography are preferred for the detection of breast cancer, mammography is limited in premenopausal women with dense breasts and ultrasonography is not sufficiently reliable to visualize tumor extensions in an extensive intraductal spread [11]. Although MRI is highly sensitive in the detection of breast lesions, it tends to overestimate the tumor size and is limited by a relatively high false-positive rate, thereby resulting in additional biopsies and increasing the patients’ anxiety, diagnosis time and cost [12–14]. Therefore, mammography, ultrasonography and MRI cannot be operated by the clinical doctor to design the process of the surgery and provide surgical navigation. Thus, the surgeons urgently require a new method to assist in the preoperative evaluation and design of the surgery.

Several scholars reported that the digital 3DVT based on spiral CT images allows for viewing of the shape and features of the breast tumor as well as defining the tumor margin and surroundings in transversal, sagittal-coronal planes or other angles [15,16]. So according to previous study, the 3DVT based on spiral CT has the potential to provide not only the precise evaluation before the surgery but also surgical navigation required in BCS [17–19]. In this study, we used the 3DVT to reconstruct the 3D models of patients in group A in order to facilitate the localization of breast tumors and the assurance of safe margins  $\geq 20$  mm. The reason we chose 20 mm as a safe margin for resection is



Fig. 10. The cosmetic outcome was evaluated as “good” in 1 case after 6 months post-surgery. (a: Marking the location of the tumor and the range of excision of the breast according to the design preoperatively; b: The patient’s breasts appearance after 6 months of omentum breast reconstruction).

**Table 3**  
Cosmetic results of the patients in 2 groups after surgery.

	Group A (%) <sup>a</sup>	Group B (%) <sup>a</sup>	p-value
Excellent	47 (95.92)	35 (79.55)	0.047
Good	2 (4.08)	8 (18.18)	
Fair	0 (0)	1 (2.27)	
Poor	0 (0)	0 (0)	

<sup>a</sup> Values in parentheses are percentages unless indicated otherwise.

that our research began in March 2015, the guidelines for breast-conserving surgery for breast cancer in China [20] at that time recommended 1–2 cm as a safe margin for resection. In order to carry out this research on the premise of safety, as well as promoting the development of breast-conserving surgery in China smoothly, we had defined 20 mm as the safe margin. In our cases, the 3DVT showed that the distance between the tumor and nipple < 20 mm in 1 case of group A, which is at a high risk of recurrence if the nipple was retained. After understanding the risks of BCS, the patient chose to undergo the total mastectomy.

The breast volume calculation has been identified as a key process in breast reconstruction [21]. An adequate estimation of breast volume could be helpful in improving the planning of breast reconstruction after BCS, including the determination of the implant size and correction of the breast asymmetry [22–24]. Since the breast is various in shapes and it is difficult to identify the boundaries, many of the measurement methods cannot calculate the volume of the breast accurately [25]. In our study, we used the 3DVT based on 256-slice CT to perform the automatic segmentation based on volume rendering, adopted the manual segmentation layer-by-layer in case of irregular area and determined the boundaries and the bottom of the breast precisely. Next, the regional growth patterns were used to divide the figures' pixels in the region of interest (ROI). Finally we acquired the volume data of the breast exactly.

In comparison to westerners', Chinese women's breasts are relatively small in size whose average volume is about  $325.36 \pm 12.66$  ml [26]. So even if the diameter of breast tumors is less than 20 mm, the excision extension has reached 20–30% of the breast volume including tumor and a 20 mm safe margin. Due to the limited amount of omentum, the pedicled omentum breast reconstruction can only meet the maximum needs of reconstructing no more than 50% of the total volume of the breast. If the tumor is large or the disease is extensive, the volume of the mammary gland to be removed (including the safe margin of 20 mm) will exceed 50% of the total volume of the breast. Then we do not recommend omentum breast reconstruction, while the total mastectomy and prosthesis/latissimus dorsi muscle breast reconstruction are recommended. Besides, due to the small body size of Asians, the majority of the population has a Body mass index (BMI)  $\leq 31.9$ , especially for Chinese women included in this study, and very few patients have a BMI > 31.9, so the laparoscopic pedicled omentum breast reconstruction is suitable for patients in this study [27]. If the obese patients have BMI > 40, they usually have big breasts and are often accompanied by mastoptosis. So we consider that partial mastectomy with contralateral reduction mammoplasty or deep inferior epigastric perforator flap (DIEP) breast reconstruction after total mastectomy is more appropriate for these patients. After measuring the breast volume of patients in group A by the 3DVT, 2 patients were recommended for the total mastectomy and prosthetic reconstruction because the excision volume was more than 1/2 of the total mammary. The 3DVT provided an efficient and accurate method for breast volume measurement and laparoscopic pedicled omentum breast reconstruction, avoiding the condition of filler volume that fails to match the cavity of mammary gland resection intraoperatively.

In addition, the 3DVT could show the blood vessels of omentum in some patients, which aided the preoperative evaluation of laparoscopic

omentum harvesting, avoiding the accidental injury of the pedicle vascular and postoperative necrosis of omentum. The 3DVT also provided navigation to clinical operation intraoperatively, such that the total operation time, blood loss and the LOS in group A were significantly less than that in group B ( $p < 0.05$ ). Although the LOS in group A is significantly shortened, it's still much longer than that in Western countries, whose patients receiving breast cancer surgery (including breast reconstruction) were discharged from hospital for about 2–3 days or even the same day of surgery. This difference reflects the special situation of Chinese healthcare: Most medical insurance in China only covers the cost of hospitalization, while the outpatient treatment does not, such as wound care and therapy; On the other hand, the LOS was unrestricted by Chinese medical insurance; In addition, when Chinese people are getting sick, they like to be hospitalized for treatment rather than stay at home because of more considerate care and feeling safe. Therefore, the LOS for breast cancer patients in China is longer than that in Western countries. However, our results also shows a shorter average LOS (8.1 days) than that in other Chinese studies (12.1 days) [28], which due to the application of 3DVT for preoperative evaluation and surgical guidance.

Forty-nine patients in group A underwent EBCS and pedicled omentum breast reconstruction successfully which resulted in a soft, shapely breast postoperatively. The cosmetic results of group A were much more satisfactory than those in group B ( $p < 0.05$ ). Neither the local recurrence in the breast nor distant metastasis appeared in the two groups during the follow-up of 6–30 months. Therefore, the 3DVT plays a major role in characterizing the morphology of breast tumors and the adjacent tissues from multiple angles, assisting to design the process of the breast reconstruction.

Nevertheless, the present study had some limitations. This study was susceptible to selection bias as it was conducted in only one hospital and the sample size was relatively small. Besides, the data were obtained from patients within the same race and in a relatively local region. Thus, future studies in this field could provide deeper insight into the Medical Imaging 3D Visualization Systems and make the preoperative evaluation for patients easier and more accurate.

## 5. Conclusion

In conclusion, the 3DVT based on 256-slice spiral CT scanning data can be used to design the surgical process preoperatively and results in positive therapeutic and cosmetic outcomes in EBCS and pedicled omentum for immediate breast reconstruction.

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## Disclosure of interest

All authors declare that they have no conflicts of interest.

## Authors' contributions

Pusheng Zhang and Linyun He drafted the article and revised it critically for important intellectual content. Fujun Shi, Jianwen Deng and Chihua-Fang analyzed the data. Yunfeng Luo designed of the study and made final approval of the version to be submitted. All authors read and approved the final manuscript.

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