



# Modified Keystone a Versatile Flap Reconstruction for Mastectomy Defects: Our Clinical Experience

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## Abstract

**Introduction** The closure of extensive defects in reconstructive surgery is a common challenge. The keystone flap technique has gained popularity due to its adaptability and reliance on fascia, providing a reliable blood supply and offering a better match for skin color compared with skin grafts. However, keystone flap necrosis can occur due to tension and inadequate tissue perfusion. To address this, a modified keystone flap technique called the “doubled-handle saucepan” was developed, resulting in improved flap vitality and reduced tissue necrosis, particularly in mastectomy defects.

**Materials and Method** We assessed 16 female patients who underwent “doubled-handle saucepan” keystone flaps after modified radical mastectomy (MRM). The average dimensions of wounds in this study were  $23.1 \pm 3.8 \text{ cm} \times 16.9 \pm 2.9 \text{ cm}$ , with the largest defect measuring  $28.0 \text{ cm} \times 21.5 \text{ cm}$ . The average size of the modified keystone flap was  $36.3 \pm 3.8 \text{ cm} \times 21.2 \pm 2.2 \text{ cm}$ .

**Results** Modified keystone flap demonstrated effective performance in managing extensive defects without any complication. The average operation time in our study was  $124.3 \pm 11.2$  minutes.

**Conclusion** The “double-handled saucepan” keystone flap technique is a unique and dependable method derived from the original keystone flap, which effectively covers defects and maintains flap vitality without tension by ensuring vascularization at the skin bridge. This modified keystone flap technique proves highly effective for reconstruction after MRM, offering time efficiency and no need for a secondary donor site, making it an appealing alternative to free flaps or other local flap techniques in many cases.

## Keywords

- ▶ keystone
- ▶ saucepan
- ▶ mastectomy

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## Introduction

The issue of closure of extensive defect is a commonly encountered hurdle in the field of reconstructive surgery.<sup>1-5</sup> However, there is a relatively new technique gaining traction called the keystone flap. This method, consisting of two joined V-Y flaps that rely on fascia, is becoming increasingly popular because of its adaptability in addressing a variety of defects.<sup>2,5-8</sup> This flap builds on various fasciocutaneous perforators, ensuring dependable blood supply comparable to other perforator flaps, but with the added benefit of being able to rearrange local tissue quickly and easily.<sup>4-10</sup> Local flaps, like the keystone flap, have an advantage over skin grafts due to their ability to provide a closer match in skin texture and color. The preparation and surgical procedure for the keystone flap are also simpler than those for free flaps.<sup>11,12</sup> However, we often find that in the case of covering extensive defects with a keystone flap, partial flap necrosis frequently occurs, which may be attributed to flap tension and inadequate tissue perfusion.<sup>13-15</sup>

We developed an innovative modification to the keystone flap technique, designed to provide effective skin coverage for extensive surgical defects, such as mastectomy defect. This adaptation represents a significant departure from the traditional keystone island flap design, introducing a unique and effective approach to reconstructive surgery. In certain cases, the size of these defects is so substantial that reconstructive techniques, such as free flaps and skin grafts, are the only viable solutions. However, planning and implementing free flap procedures present significant challenges, particularly when dealing with patients who have multiple comorbidities, such as diabetes or cardiovascular disease, which can lead to morphological changes in vessels that might contribute to flap failure and was significantly linked to flap loss. Diabetes, in particular, is associated with an increase in vessel wall thickness, impeding successful anastomosis. Furthermore, many health care facilities in our country are not equipped with the necessary microsurgical tools and expertise required for free flap reconstruction, creating additional logistical hurdles.<sup>16,17</sup> Therefore, we created a modification that we call the “doubled-handle saucepan” keystone flap as an option for defect closure, especially for mastectomy defects. From all of our cases, the application of this technique consistently yields a flap with enhanced vitality, resulting in the minimization of tissue necrosis. The implementation of this modified keystone flap has been highly successful in achieving robust coverage over large surgical defects.

## Materials and Methods

### Data Collection

We gathered data of all patients who underwent “doubled-handle saucepan” keystone flap after modified radical mastectomy (MRM) between 2021 and 2024, including basic demographic data, medical histories, wound locations, sizes,

depths, and postoperative complications. The data was statistically analyzed using univariate analysis, and means  $\pm$  standard deviation was provided for the continuous variables.

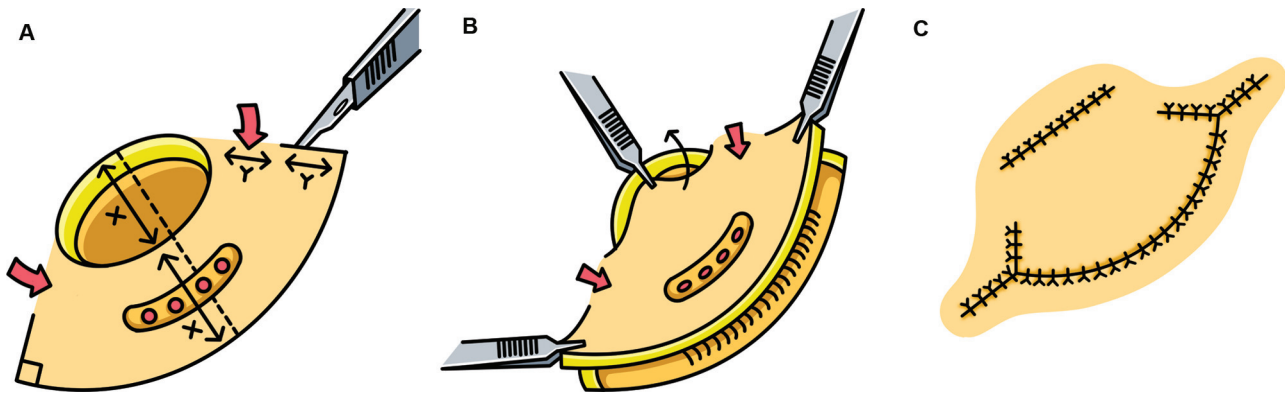
### Operation Technique

For our study, we opted for an innovative technique, the “doubled-handle saucepan” keystone flap. Our aim was to close extensive defects following a MRM procedure, which were referred to us by the oncology surgical team because the defects could not be closed primarily. All patients were initially positioned in the supine position. In cases where the flap extended to the back region, the position was adjusted to a semilateral decubitus. This adjustment allowed for simultaneous flap harvesting and defect closure without requiring additional repositioning during the procedure. The surgery involved measuring the wound from two different angles—the longer side was the length and the perpendicular one became the width. Once we had the measurements, the Doppler ultrasound was used to locate the perforators “O” and the flap was designed. We used **►Fig. 1(A)** as a guide and found that the width of the defect “X” matched up perfectly with the keystone arc. The flap was incised according to the design. Every patient then underwent immediate reconstruction, with the fasciocutaneous pedicle preserved carefully during flap elevation, and skin bridge “Y” left intact around 30 to 50% from total tangent line. The random perforators were included in this preservation process (**►Fig. 1B**). To achieve the desired laxity, we performed undermining or degloving without damaging the perforators. This technique allows for adequate tissue mobilization, enabling the flap to cover the defect effectively. For a more innovative solution, we maintained the skin bridge at the side of the defect. The resulting coverage of the wound is displayed in **►Fig. 1(C)**.

Utilizing this technique, a suture line was extended from this shaped flap, and we made sure to avoid any tension during the suturing process. Additionally, we inserted drains to help with the aftermath.

## Result

We assessed 16 female patients who underwent “doubled-handle saucepan” keystone flaps after MRM surgery. The demographic details are summarized in **►Table 1**. The mean age was  $42 \pm 10.3$ . The mean body mass index was  $22.9 \pm 3.8$ . Among the patients, 10 (62.5%) have a familial background of breast cancer, while 7 (43.8%) have breastfed their children. Four (25%) patients have history of smoking, and 11 (68.8%) patients have a record of using hormonal contraception. **►Table 1** also outlines the wound characteristics, with nine (56.3%) patients had defect on the left hemithorax while seven (43.7%) on the right side. The average wound dimensions were  $23.1 \pm 3.8$  cm  $\times$   $16.9 \pm 2.9$  cm, with the largest defect measuring  $28.0$  cm  $\times$   $21.5$  cm. The average size of the modified keystone flap was  $36.3 \pm 3.8$  cm  $\times$   $21.2 \pm 2.2$  cm. The mean operation time, from the flap



**Fig. 1** Illustration of the “double-handled saucepan” keystone flap design. (A) The width of the wound denoted as “X” matches the width of the keystone arc, and the skin bridge “Y” was preserved at half the width of the edge. “O” was the perforators. (B) Entire flap design was incised, and the flap was raised while preserving the central perforators “o.” Thorough undermining and fasciotomy were performed. The flap was then advanced and expanded, following the principles of traditional keystone flaps, with the skin bridge at the edge remaining intact preserving the subdermal plexus “red arrow.” (C) The flap was sutured, giving the shape of double-handled saucepan in result.

incision to the complete closure of the defect, was  $124.3 \pm 11.2$  minutes. The duration for each surgery remained consistently similar.

There were no postoperative complications, as outlined in **Table 2**. None of the patients experienced minor wound dehiscence, infection, or partial or total flap losses, and no additional operations were required. A surgical correction might involve trimming the “dog ear” formation and reconfiguring the closure to achieve a smoother and more aesthetically

pleasing result. This procedure can be performed approximately 6 months after the initial defect closure surgery.

## Case Report

### Case I

A 36-year-old female who had previously undergone a MRM and consulted by oncology regarding defect closure. The defect measured  $24 \times 15$  cm on the left hemithorax through

**Table 1** Patient demographics, wound descriptions, and flap description

Patient demographics	Value
Total patient	16
Age	$42.4 \pm 10.3$
BMI	$22.9 \pm 3.8$
Family history	10 (62.5%)
Breastfeeding history	7 (43.8%)
Smoking	4 (25%)
Type-2 diabetes	2 (12.5%)
Hormonal contraception	11 (68.8%)
Wound description	Value
Defect location	
Left hemithorax	9 (56.3%)
Right hemithorax	7 (43.7%)
Defect length (cm)	$23.1 \pm 3.1$
Defect width (cm)	$16.9 \pm 2.9$
Flap description	Value
Flap length (cm)	$36.3 \pm 3.8$
Flap width (cm)	$21.2 \pm 2.2$
Operation time (min)	$124.3 \pm 11.2$
Length of stay (d)	$4.5 \pm 0.6$

Abbreviation: BMI, body mass index.

**Table 2** Complications

Complications	Quantity (%)
Hematoma	0 (0)
Seroma	0 (0)
Dehiscence	0 (0)
Infection	0 (0)
Partial flap loss	0 (0)
Total flap loss	0 (0)

midaxillary, and she had been diagnosed with breast carcinoma. To close the wound, we harvested flap from the axillary through the abdominal area, with no immediate complications observed during the postoperative period. Over the course of 20 days long follow-up, there was no evidence of wound dehiscence, and we observed seamless integration of the flap with the surrounding tissues.

### Case II

A 34-year-old female diagnosed with malignant phyllodes on the right breast underwent a MRM. The defect was 26 × 21 cm on the right hemithorax. The flap harvested from the axilla through the abdomen successfully covered the defect without any postoperative complications. Throughout a month-long observation period, there were no signs of dehiscence, and we observed that the flap had smoothly merged with the adjacent tissues.

### Case III

A 37-year-old female was referred by the oncology surgery team with carcinoma of the right breast and underwent a MRM. The resulting defect measured 25 × 19 cm on the right hemithorax. A flap was harvested from the axilla through the abdomen and successfully used to cover the defect without any postoperative complications. At the 15-day follow-up, no complications were observed.

### Case IV

A 45-year-old female patient with carcinoma mammae, underwent a MRM. The resulting defect, measuring 27 × 17 cm with vertical direction, was successfully covered using a flap harvested from the thorax and abdomen with minimal tension. No complications were observed at the 30-day follow-up.

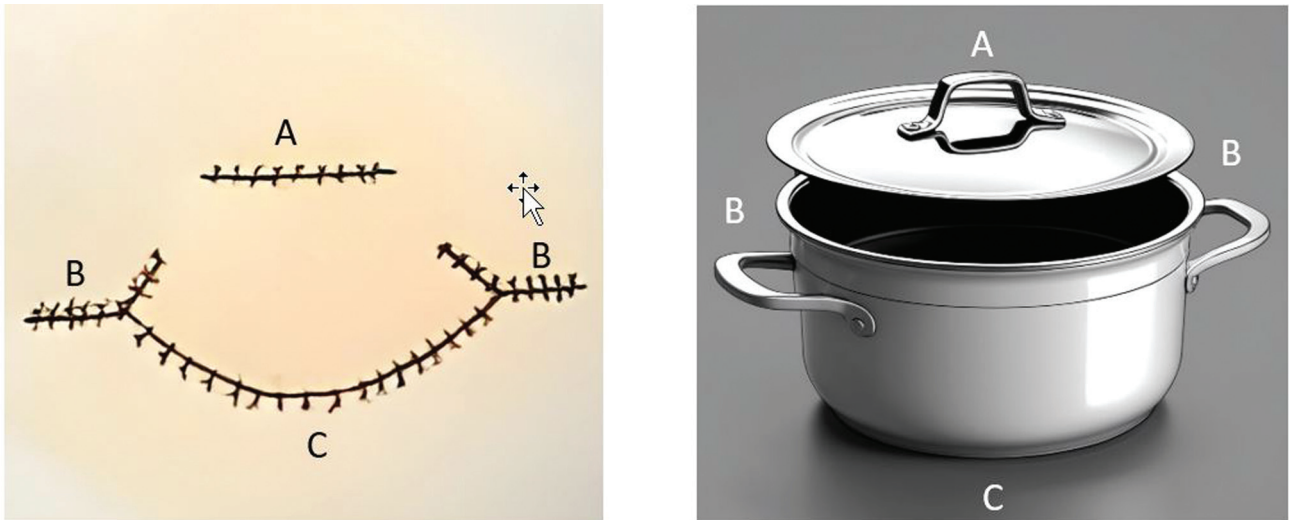
## Discussion

In case of mammary tumors that significantly exceed the size of the breast, the need for intricate reconstructive techniques becomes apparent. Some experts propose preserving healthy-looking overlying skin to facilitate primary wound closure and avoid more intricate reconstructive methods.<sup>18,19</sup> However, it is important to note that this approach may compromise surgical margins, and in a disease where positive excision margins correlate with local tumor recurrence, such compromises may carry significant implica-

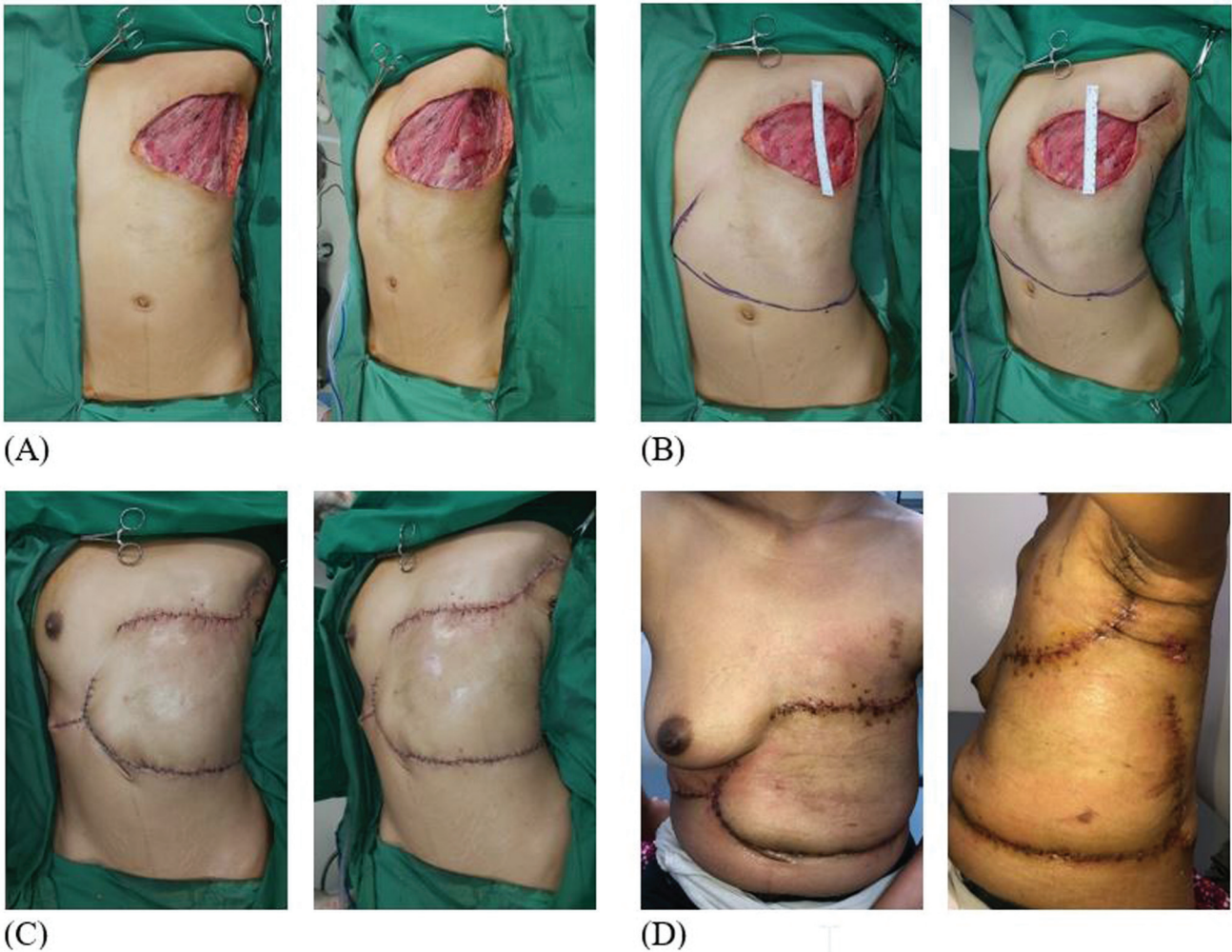
tions.<sup>20,21</sup> The typical closure of such defects involves the utilization of skin grafts, local skin flaps, or myocutaneous flaps, with the latissimus myocutaneous pedicle flap being the most commonly employed method. The latissimus dorsi (LD) flap is an effective choice for achieving adequate skin coverage, particularly for defects within its manageable size range due to its robust vascularity and reliable tissue characteristics. It is particularly advantageous for patients who have undergone previous radiotherapy, as it provides well-vascularized tissue that can help overcome compromised local tissue quality. The LD flap can also be used in conjunction with other reconstructive techniques, such as free tissue transfer or additional local flaps, to augment coverage in complex cases. Additionally, for patients with contraindications for microvascular surgery or those not optimal candidates for free flaps, the LD flap offers a simpler alternative with lower complexity and reduced operative time. However, in our cases, it was not feasible to close the defects with an LD flap due to the extensive size of the mastectomy defects. Therefore, we developed this modified keystone flap technique to address these larger defects effectively.

The keystone flap is acknowledged for its versatility and effectiveness; however, certain debates and limitations surround its application. One extensively discussed concern is that the keystone paddle's expansion is not significantly superior to that of a V-Y advancement flap.<sup>22-24</sup> Another limitation highlighted is the ideal coverage range; although the flap can consistently address defects up to 6 cm in length, challenges may emerge when dealing with larger wounds.<sup>25</sup> Both traditional and modified keystone flap techniques often require an elliptical-shaped wound to achieve the desired design outcome. Moreover, the removal of surrounding normal tissues is often necessary to optimize the results.<sup>3,6,26</sup> To overcome these challenges and at the same time reduce the defect size, we implemented primary suturing on the nontension side of the wound to attain the desired outcome. Lastly, the excision of the skin paddle from the elevated flap is a critical step in accommodating and covering the defect. However, it can be challenging as excessive excision may lead to flap loss complications.<sup>26,27</sup> To prevent flap loss, we enhance vascularization to the flap via the subdermal plexus at the skin bridge, and this has been effectively proven in all our cases.

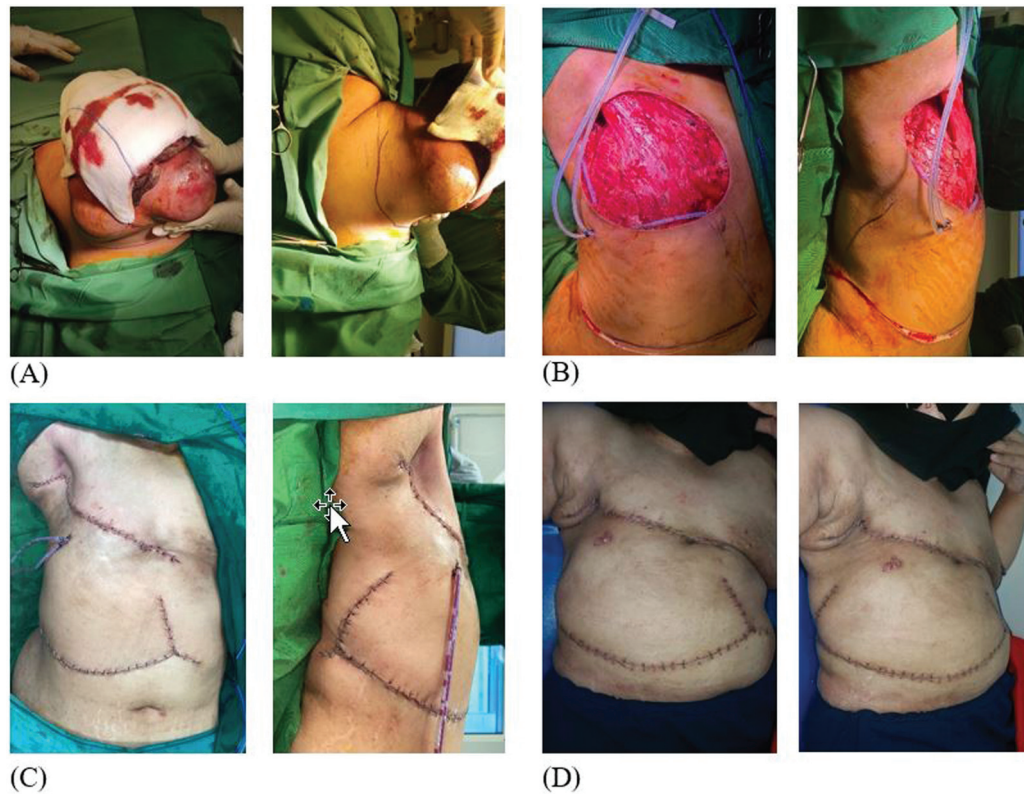
The modified keystone flap appears to be more versatile, showing no apparent restriction to specific wound



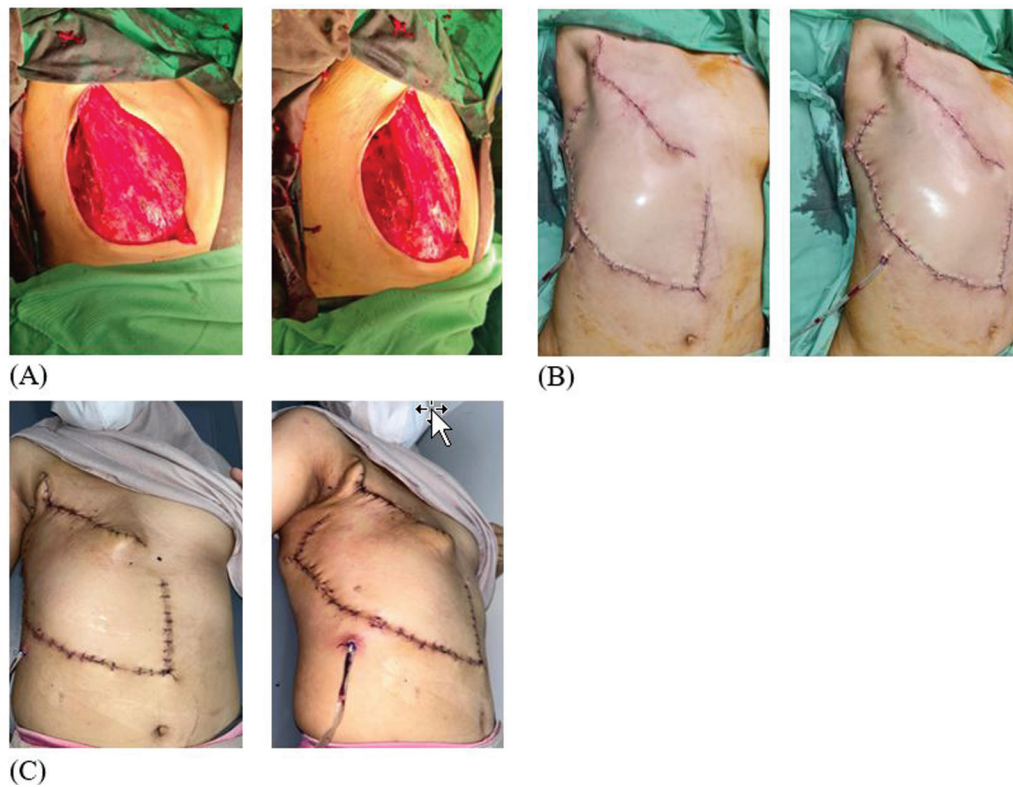
**Fig. 2** Diagram of “double-handled saucepan” keystone flap design. (A) The advanced part of the flap as the lid of the pan. (B) The V-Y part as the handle. (C) The arc as the pan bottom.



**Fig. 3** Case 1. (A) Preoperative view. (B) Intraoperative view. Flap design, modified keystone flap was harvested from the axilla and abdominal region, then the defect was successfully covered. (C) Postoperative day (POD) 0. The defect was successfully closed without any tension, and a drain was placed to ensure proper drainage. (D) POD 20, completely healed without complications.



**Fig. 4** Case II. (A) Preoperative view. (B) Intraoperative view, “doubled-handle saucepan” keystone flap design from the abdominal and axilla regions. (C) Postoperative view. The defect was successfully closed without any tension, and a drain was placed to ensure proper drainage. (D) Postoperative day (POD) 30, completely healed without complications.



**Fig. 5** Case IV. (A) Preoperative view. (B) Postoperative view, the defect was successfully covered by “doubled-handle saucepan” keystone flap. The defect was successfully closed without any tension, and a drain was placed to ensure proper drainage. (C) Postoperative day (POD) 15, completely healed without complications.



**Fig. 6** Case IV. (A) Preoperative view. (B) Intraoperative view, the “doubled-handle saucepan” keystone flap design from the abdominal and thorax region. (C) Postoperative. The defect was successfully closed with minimal tension in the advancement area, and a drain was placed to ensure proper drainage. (D) Postoperative day (POD) 30, completely healed without complications.

dimensions contrary to the previously suggested limitations on the optimal coverage size of the keystone flap.

In comparison to free flaps, modified keystone flaps offer the advantage of eliminating the need for microvascular flap monitoring and skin grafting. This simplifies postoperative care and reduces the risk of complications associated with microvascular anastomosis. Furthermore, local flaps generally yield better aesthetic matching with surrounding tissues than skin grafts.<sup>11,12,28</sup>

This modified keystone flap is primarily indicated for breast cancer patients who will subsequently undergo radiotherapy. The advantage of this flap is that it is not as thin as a skin graft, which could cause issues with radiotherapy-induced wounds, nor is it as thick as a myocutaneous flap, making residual tumors easier to detect. Additionally, this flap is easier to perform, particularly for less experienced plastic surgeons, and is beneficial for patients requiring extensive resections. This flap is not indicated for patients who will undergo breast reconstruction because the drawback of this technique is that it can result in scarring on the abdomen and may preclude the use of the abdomen as a potential donor site for future procedures, such as breast

mound creation. This modification was developed as an alternative for defect closure in hospitals without microsurgery and Doppler facilities.

This modified keystone technique is essentially a modification of the type 4 keystone flap. Before performing the undermining, Doppler ultrasound was used to identify the perforator. We performed undermining up to 50% to enhance the flap’s flexibility while preserving 30 to 50% of the skin bridge on both sides of the tangent line (►Figs. 4–5 and 6). This strategy aims to improve vascularization from the subdermal plexus, following the angiosome concept, with the vascularization spreading centrifugally.<sup>29</sup> This, in turn, increases flap viability for larger flaps compared to the standard type 4 keystone flap.

This modified keystone flap demonstrated effective performance in managing extensive defects without any complication, as outlined in ►Table 2. However, further data collection is necessary for a more comprehensive evaluation. Excising skin from the harvested modified keystone flap was unnecessary, showing the efficient utilization of all surrounding tissues (►Figs. 2 and 3). With such optimal tissue efficiency, there was no requirement for skin grafts in any of

the cases. Further research is essential to investigate factors such as perforator size and perfusion pressure, which could be critical for assessing flap viability more accurately.

## Limitations

This study was a retrospective and uncontrolled study, and the sample size is relatively small, consisting of only 16 cases, and a larger sample size would be beneficial in revealing additional strengths or limitations. Our experience has primarily focused on mastectomy defects. However, we are actively collecting more cases for reconstruction using this approach, including instances such as pressure injuries. This expansion of our experience will further enhance our understanding and application of the technique in various scenarios.

## Conclusion

Derived from the original keystone flap, this “double-handled saucepan” keystone flap stands out as an innovative and dependable method. It has unique approach to ensure vascularization at the skin bridge while elongating the outer arc margin. This method has effectively covered the defect and maintained flap vitality without inducing tension. The modified keystone flap has proven to be a highly effective option for mastectomy reconstruction, offering notable time efficiency regardless of the size of the defect. Additionally, its ability to eliminate the need for a secondary donor site further enhances its appeal. With such advantages, it may emerge as a compelling alternative to free flaps or other local flap techniques in numerous cases.

### Conflict of Interest

None declared.

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