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Original research

THE KEYSTONE ISLAND PERFORATOR FLAPS: A NEW OPTION IN SOFT TISSUE MANAGEMENT OF PLASTIC SURGERY

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ABSTRACT

Background: *The keystone flap is an effective technique for reconstructive surgery that restores the natural contour of the affected area and provides superior aesthetic results. This technique involves taking healthy skin and subcutaneous tissue from a nearby area and transplanting it to the site of the defect, creating a new skin area that meets the patient's ideal outcome. We conducted a research project to objectively examine and evaluate the effectiveness and practicality of keystone flaps in clinical settings. Our two objectives were to analyze the characteristics of skin abnormalities on the body and to assess the surgical outcomes of using keystone flaps to repair defects.*

Methods: *40 patients with soft tissue defects throughout the body who underwent surgical treatment using keystone flap coverage at the Orthopedic and Plastic Surgery Center, Hue Central Hospital - Viet Nam.*

Results: *The most common causes of soft tissue defects are infectious necrosis (35.0%), chronic ulcerative lesions (32.5%), trauma (17.5%), scar excision (12.5%), and other factors (2.5%). Flaps are primarily designed in Type I and Type III fashion. Our follow-up evaluation of the flaps after 3 - 6 months showed that the majority of cases achieved good results, with 37 out of 40 cases (92.5%) and 3 out of 40 cases (7.5%) categorized as fair. No significant complications were reported.*

Conclusion: *The keystone island perforator flap is a modern method in plastic surgery that has proven to be a useful tool. The authors strongly recommend the use of the keystone technique as a safe, reliable, and feasible approach to covering soft tissue defects that vary in clinical characteristics.*

Keywords: *Keystone island perforator flaps, plasstic surgery, soft tissue defects.*

I. INTRODUCTION

According to Oswaldo et al [1], plastic surgeons have come a long way to find a reconstructive strategy that provides living tissue in order to restore both form and function following a wide range of congenital or acquired defects [2]; is versatile for any reconstructive requirement [3]; provokes minimal or no aesthetic or functional morbidity of donor areas [4]; entails short surgical times; and is replicable, with short learning curves and without large infrastructure requirements [5].

Closure of the skin defect following excision of skin cancers is ideally achieved by transposing local tissues of similar qualities. In this regard, flaps are generally preferable to skin grafts because they have better color and contour and are associated with the reduction of donor site morbidity. Whereas small defects have never been a problematic issue, larger ones often pose a unique challenge to reconstructive surgery, requiring knowledge, experience, and time. Searching for a better solution for bigger defects closure, more than 30 years of research and operative experience by its originator Felix C Behan, the concept of Keystone Design Perforator Island Flap was invented based on the most contemporary knowledge of the vascularization of the skin and soft tissue overlying bones [3, 6]. The keystone flap properly restores the contour of the

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defect and produces superior aesthetic outcomes through the use of nearby skin and soft tissue, giving patients who need reconstructive surgery the ideal outcome. The keystone perforator flap offers a single fasciocutaneous flap for use in nearly every region of the body to achieve rapid and reliable fasciocutaneous coverage with minimal morbidity to the patient, good cosmetic, and good quality of life. As such, it is well suited to meet the needs of reconstructive surgeons in the future and should appropriately limit the use of free flap reconstruction to defects unsuitable for loco-regional reconstruction and assist in the management of free flap morbidity by assisting donor site closure [7]. To the best of our knowledge, this paper is the first one focused on this flap and aims to evaluate the outcome of keystone flaps to cover the soft tissue defects with the various clinical traits of wounds.

II. PATIENTS AND METHODS

2.1. Patients

Between January 2021 and May 2023, a total of 40 patients (11 men and 6 women), with an average age of 56.1 ± 21.8 years (range: 12 - 95 years) underwent KDPIF reconstructions to cover defects at various locations on the body in the Plastic and Orthopedic Center, Hue Central Hospital.

We conducted a retrospective review of the assessment of various factors, including demographic data, pre-operative clinical examinations (such as causes, locations, and sizes), intra-operative conditions (including the state of the underlying soft tissue defect, the type of flap according to Behan's classification (figures 1, 2, 3, 4), and the flaps' survivals), hospitalization time, complications, post-operative outcomes, and follow-up examinations. This information was gathered over a period of 3 - 6 months and used to create a research questionnaire. No colostomy was done for all pressure ulcer patients; patients with acute local infections or who refused to participate in the study were excluded.

The types of keystone flaps used are based on Behan's classification [3]: Type I: Primary defect less than 2 cm width; Lateral deep fascia remains intact. Type IIa: Defects greater than 2 cm (< 2cm - ≤ 5cm) and Division of deep fascia required to facilitate tissue mobilization. Type IIb: Defects greater than 2 cm (< 2cm - ≤ 5cm) but concomitant use of split-skin graft, reduces tension on flap margin. Type III: Large primary defect (5 - 10 cm) and two keystone flaps on each border of the defect. Type IV: Rotational keystone flap, useful in joint contracture or open fractures, and Flap is raised with up to 50% sub-facial undermining.

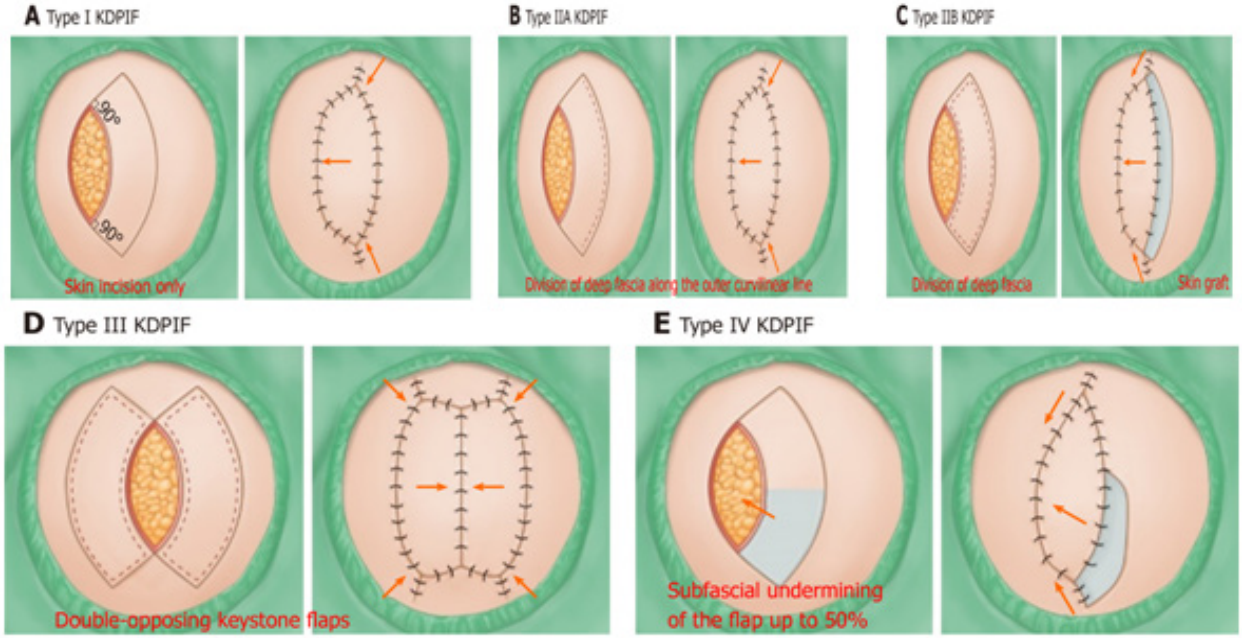

Figure 1: Keystone flaps according to Behan's classification

2.2. Surgical technique

- A handheld Doppler ultrasound machine, Model 811-B, with an 8.2 MHz probe, a measuring tape, and a marker pen to determine the course of adjacent perforator vessels and design the shape of the flap.

(A)

(B)

Figure 2: Identification of adjacent perforator vessels flap using a handheld Doppler ultrasound (A); measurement flap dimensions (B).

- Selecting the flap design based on the location, size, and characteristics of the defect, the following considerations can be made:

+ For small defects (width ranging from 2cm - ≤ 5cm), a simple keystone flap (Type I) is sufficient for coverage. Draw a line at a 90-degree angle at both ends of the defect and extend it in a manner that the length of the line is equal to the width of the defect in a 1:1 ratio. Connect the two endpoints with a curved line parallel to the edge of the defect. The width of the flap should be drawn in a 1:1 ratio to the width of the defect. The length of the flap is determined by the length of the elliptical-shaped cut.

Figure 3: Drawing a keystone flap design

Figure 4: Drawing two keystone flap designs for back injury regions

+ For larger defects (width > 5cm), it may be necessary to design flaps using two keystone flaps (Type III and beyond) to achieve sufficient coverage. In this case, the second flap is designed symmetrically to the first flap, covering the remaining portion of the defect edge. The size of the second flap is designed similarly to the first flap.

- The operations were performed with the patients under general or local anesthesia.

- The surgical procedure consists of 4 steps:

Step 1: Preparation of the recipient site: Clear the inflamed, necrotic soft tissue and poorly perfused areas; Debride any inflamed or necrotic bone (if present); Measure the size of the defect and determine the desired reconstruction requirements.

Step 2: Harvesting the perforator flap: Skin incision according to the predetermined design; Deepen the incision by blunt dissection, protecting the perforator vessels and blood supply to the flap. In some cases, for small defects ranging from 2 - 5cm, it may not be necessary to dissect down to the subcutaneous layer.

Figure 5: Elevation of the flap by following the marked keystone flap design

Step 3: Transferring and covering the defect with the flap: Depending on the initial design, whether it is a single flap or two keystone flaps, slide or advance the flap(s) to cover the recipient site; The first step is to suture the 'V' closure at the two distant corners (relative to the defect) of the keystone flap, transforming it into a 'Y' shape. This creates laxity of the tissue at the center of the flap, forming a right angle with the 'Y' shape and narrowing the secondary defect; Secure the flap using 3.0 or 4.0 nylon sutures with interrupted stitches. The distance between the stitches should be around 3 - 5 mm, avoiding overly thick sutures that may cause fluid or blood to pool under the flap; Place a drainage tube beneath the flap if necessary and maintain drainage for 48 to 72 hours (if applicable).

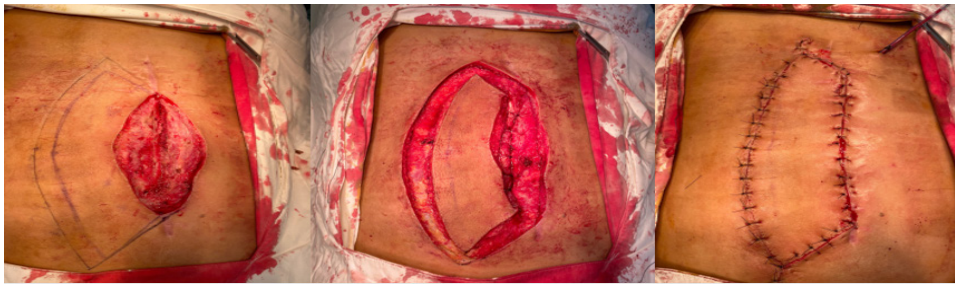

Figure 6: Flap sliding, V-Y closure, and closure of the flap.

Step 4: Assess coverage and perform skin grafting if needed: In cases where the flap cannot completely cover the defect, additional skin grafting may be performed using moist gauze dressings; In cases where the flap completely covers the defect, clean the surface of the flap and sutured incision, and then dress the surgical wound.

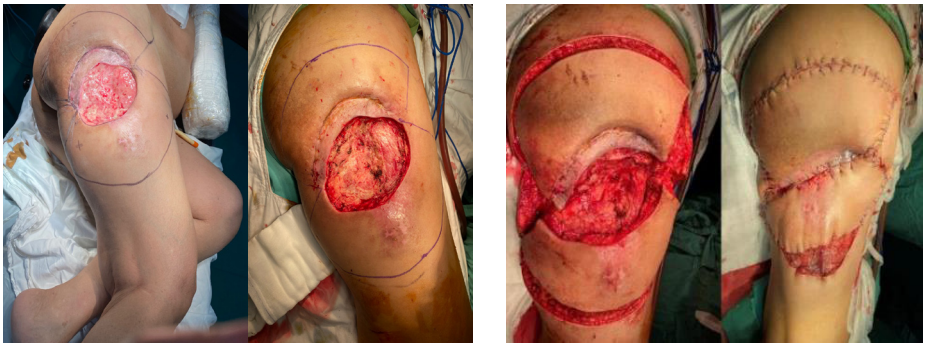

Figure 7: Additional skin grafting in Keystone flap type III

2.3. Statistical analysis

Data is recorded on a standardized research form and entered into Microsoft Excel 2016 software. Statistical analysis of the research data is performed using SPSS 20.0 software. Results are presented as means, percentages, and other relevant statistical parameters: percentage, mean, and variance calculations are used. Significance level: $p < 0.05$ with 95% confidence interval.

III. RESULTS

The results indicate infectious necrosis (35.0%), followed by chronic ulcerative lesions (32.5%), trauma (17.5%), scar excision (12.5%), and others (2.5%). Among the 40 cases, soft tissue defects vary in size depending on the extent of the injury. The smallest defect square measures 1.5 x 1.5 cm on the face, while the largest defect measures 18 x 10 cm in the buttock/pelvic region. The average area square is 59.5 cm^2.

The study sample recorded 3 cases (7.5%) with diabetes mellitus as a comorbidity. No cases of vascular diseases were reported, while the remaining cases either had unrelated comorbidities or had no associated diseases (92.5%).

There were 6 cases of large soft tissue defects located in the gluteal/pelvic and trunk regions, which required the use of 2 keystone flaps for coverage. The average flap area was 62.4 cm^2.

All the defects were reconstructed in a single-stage procedure by applying the keystone island perforator flap; the most frequently applied flap was the Type II A, B (n = 9), followed by Type III (n = 7), Type I (n = 3) and Type IV (n = 1) respectively.

The average hospital stay was 26.1 ± 14.4 days, with a minimum of 9 days and a maximum of 75 days.

All 40 patients had been followed up to evaluate the outcome over a three-month period after their discharge. The shortest follow-up time was three months, and the longest was 24 months. Out of the 40 cases, 37 (92.5%) showed stable healed scars and soft, pliable flaps, categorized as good results. There were 3 cases (7.5%) with fair results, including 3 cases with flap hypertrophy. Injuries in the head-face-neck region, lower extremities, and trunk achieved good results (100%). Injuries in the buttock/pelvic region showed good results (75.0%), fair results (25.0%), and no poor results.

IV. DISCUSSION

Evaluating the results of the keystone flap technique, based on clinical application in treating soft tissue defects, we have clinically identified several outstanding points of view:

The keystone flap has a high survival rate of 100%, providing favorable aesthetic outcomes, lower technical complexity, and reduced morbidity at the donor site. Based on the criteria of Oberlin C and Duparc J to evaluate the flap outcome, we obtained the following results: 38/40 (95.0%) flaps had good color and vitality; 2/40 (5.0%) flaps were hypotrophic, of which 1 case had water blister formation on the surface and required skin grafting, and 1 case had partial necrosis at the flap edge (< 1/3 of the flap area) without the need for second surgery; no complete flap necrosis observed.

The keystone flap method can be applied to large defects on the trunk and extremities without the need for complex surgical techniques or prolonged surgery while still achieving effective initial wound healing. It does not require sacrificing muscles or major blood vessels in the donor area, helping to preserve the integrity of muscles, blood vessels, and reduce the risk of complications. In this study, the defects varied in size, ranging from the smallest of 1.5 x 1.5 cm resulting from scar excision on the facial area, to the largest software defect of 18 x 10 cm caused by a chronic ulcer with tissue loss. The average surface area of the software defects was 59.1 ± 77.5 cm^2. Specifically, in our study, there were four large software defects in the amputation region and 2 in the trunk area with a size of 100 cm^2, resulting in an average defect area of 110 cm^2. Large and moderate software defects can be addressed by designing two keystone flaps on both sides of the defect, allowing for a sufficiently large skin flap to cover the wound and protect the underlying structures, including nerves, muscles, and penetrating vessels. This design has the advantage of completely closing the software defect without affecting the surrounding tissue, thereby enhancing aesthetics, reducing postoperative pain, and facilitating rapid patient recovery. Our study successfully covered six cases of large surface area defects using two keystone flaps.

In our study, the average hospital stay after surgery was 26.1 ± 14.4 days, with the shortest duration being nine days and the longest 75 days. Prolonged hospital stays were due to preoperative processes requiring infection control measures, such as VAC (Vacuum-Assisted Closure) therapy, to optimize the wound bed for flap surgery, or patients with underlying diabetes requiring intensified care, or patients with poor general condition and multiple comorbidities, necessitating a longer recovery time after surgery.

The evaluation of the flaps over three months with criteria such as vitality, mobility, softness, and the presence of complications like hypertrophic scars or recurrent inflammation showed that the majority of cases achieved good results, with 37 out of 40 cases (92.5%) categorized as Good, and 3 out of 40 cases (7.5%) categorized as Fair. There were no cases with Poor outcomes. Comparing our results to some findings by other authors worldwide: According to a retrospective evaluation conducted by Aravind L. Rao and Rakesh K. Janna, who studied 20 patients undergoing Keystone flap reconstruction for various defects from 2012 to 2014, the overall success rate of the flaps was 95% [8]. Another study by Joseph Khouri and colleagues assessed Keystone flaps for reconstruction of large trunks and upper limb defects in 28 patients, achieving a successful reconstruction rate of 97% [9]. The overall survival rate of the flaps was recorded as 100% in our experience.

V. CONCLUSION

In summary, the keystone surgical technique is a valuable tool for surgeons to create future aesthetic figures with various keystone variations. The authors encourage the use of the keystone method as a safe, reliable, and feasible approach in the treatment of soft tissue defects. However, the keystone flap also has some limitations: Performing keystone flap surgery requires a Doppler ultrasound device to determine the location of perforating vessels on the skin in the donor area. But, not all surgical facilities are equipped with this tool. Therefore, performing keystone flap surgery may encounter difficulties in accurately orienting the surgery. In addition, to the best of our knowledge, we take the liberty of making recommendations: this technique should be performed at specialized plastic surgery centers or large hospitals equipped with complete facilities and staffed by well-trained surgeons who have a high level of expertise and a thorough understanding of vascular and nerve anatomy, as well as soft tissue; Good coordination among the surgical team, anesthesiologists, surgical assistants, and physical therapy staff is necessary to enhance the quality and effectiveness of the surgery, minimize complications and adverse events, and ensure the safety and satisfaction of the patients.

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