

The keystone flap, a versatile reconstructive solution: surgical options and a long-term experience

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ABSTRACT

Background The keystone island flap allows quick reconstruction of skin losses in different areas, as an alternative to skin grafts or free flaps.

Hypotesis The described keystone island flap is shaped as two V-to-Y advancing flaps that are supplied by musculocutaneous and fascio-cutaneous perforator vessels.

Methods For the patients enrolled in the present study, keystone island flap was chosen as a surgical strategy after oncologic resections for the reconstruction of defects of the trunk or extremities derived from of tumors. The study involved 20 patients, from 2015 to 2021. After tumor removal, all patients underwent an immediate reconstruction; margins were cleared on the first resection in all cases.

Results There were no flap losses. The complication rate was 10.9%, and there were no major complications. Minor complications included two cases of dehiscence and one of the two cases needed another refinement surgery.

Conclusions This study shows that the keystone island flap can be a useful reconstruction option even in large defects of the trunk and extremities.

Implications for clinical practice The described keystone island flap can be used to easily cover wounds of the trunk or extremities.

Keywords keystone island flap, reconstructive surgery, oncologic surgery, plastic surgery, flaps

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KEY MESSAGE

- Wounds can be surgically treated by plastic surgeons with the pedicled keystone island flap. Authors depict the surgical technique. For the patients enrolled by the present study, keystone island flap was chosen as surgical strategy after oncologic resections for the reconstruction of defects of the trunk or extremities. This study shows that the keystone island flap can be considered useful reconstruction option even in large defects of the trunk and extremities

INTRODUCTION

Based on fasciocutaneous perforator vessels, the keystone island flap (KF), first described by Behan,¹ offers both reliable vascularity typical of perforator flaps and enables efficient and expedient local tissue rearrangement. This technique is particularly useful in cases where skin grafts or free flaps are not feasible, as it reduces complications linked to donor site harvest, vascular viability, and cosmetic outcomes.^{2,3} The KF approach provides distinctive benefits such as shorter operative times, high reproducibility, and a natural aesthetic result due to tissue similarity. The flap is designed in a curvilinear, trapezoidal shape that shares one margin with the original wound, mimicking the structural integrity of an architectural keystone. The KF relies on

both musculocutaneous and fasciocutaneous perforators, minimising the need for invasive exposure, and does not involve surgical undermining. According to Cormack and Lamberty's classification,^{4,5} the keystone island flap is classified as a type A advancing flap, consisting of dual V-to-Y flaps that longitudinally receive vascular supply from perforators. Several studies^{6,7} have documented the versatility and vascular stability of KF in covering various post-surgical skin defects. Despite its advantages, the technique has received less emphasis due to the development of microsurgical and more complex reconstruction options.^{8,9} This study presents the application of KF in addressing substance losses across different anatomical regions, supported by comprehensive long-term clinical experience.

MATERIALS AND METHODS

Authors used the KF for the reconstruction of defects of the trunk or extremities derived from oncologic resections of skin tumors from 2015 to 2021. A total of 20 flaps were performed in 20 patients (12 men and eight women), seven of whom were diabetic and nine smokers. Of the 20 flaps, 11 (55%) were adopted as surgical solution to correct lesions of the chest; three (15%) were facial; three (15%) were to correct defects of the upper limb; two (10%) were to reconstruct defects of the lower limb and one (5%) to cover a defect of the perineum.

Informed consent was obtained for each patient and the local ethics committee approved the study in compliance with human rights.

After tumor extirpation, each of the patients underwent an immediate reconstruction (Figures 1 and 2); in this study, margins were cleared on the first resection in all cases. Patients were hospitalised for an average of 4–5 days; the first post-operative follow-up was after one week, the second 20–25 days after hospital discharge.

The surgical harvesting of the flap was described by Behan and Jovic.^{1,2} When it was possible the surgical excision was made shaped as an ellipsis with its major axis parallel to the one of the limbs, the spine or major known vessel in the area (Figures 3 and 4). The flap was designed on the area with more skin laxity, as the posterior compartment in lower limbs or the proximal extensor and flexor areas in the forearm. It was shaped as a curvilinear trapezoid with the minor base coinciding with one side of elliptical excision. The flap width is the same or barely bigger than the width of the skin defect, its curvature depends on skin laxity and the body area treated.



Figure 1. Case 1: Flap design, voluminous neoformation of the thigh.



Figure 2a. Case 1: Intraoperative view, preparation of the flap.



Figure 2b. Case 1: Intraoperative view final result.

We applied this flap design using the long axis of the wound as a guideline, the wound is then estimated into a 3:1 ellipse. One side of this ellipse serves as the inner arc of the keystone — the inferior edge of an architectural keystone. A second, parallel arc is then drawn at a distance away from the ellipse equal to its short axis—this is the upper edge of the keystone. The 'height' of the keystone is equal to the short axis of the defect ellipse, and again parallel to the maximal resulting tension vector. Next, the inferior limb of the defect ellipse is continued on both ends, as if a much larger ellipse is being marked. This line will intersect with the continuation of the upper keystone arc. Next, the flap is incised along its entire length; is not undermined, but care is taken to ensure the full thickness incision to the underlying muscular or deep fascia. The perforators supplying the flap emerge from deeper tissues at an axis usually almost perpendicular to the skin and are, therefore, not at risk during the incising of the flap. Once incised, the skin surrounding the flap is traditionally dissected bluntly at its deep margin, in order to free it from the underlying deep fascia. Likewise, the deep fascia can be incised, allowing additional advancement. The completely incised flap is now ready for inset. Our first stitch is typically with 2-0 monofilament nylon in the skin at the line of greatest tension—across the short side of the elliptical defect. If the tension here is tight, we may alternatively start peripherally and advance the skin to the line of greatest tension. As the closure goes on, the keystone island flap will gently distort by shortening along its long axis. Often, the inner corners of the flap become redundant and can be trimmed to prevent closure length discrepancies or cutaneous deformities.

Postoperative outcomes were assessed both subjectively and objectively. Patients completed the Scar-Q questionnaire at the six month follow-up to evaluate satisfaction with the



Figure 3a. Case 2: Surgical radicalisation of a melanoma of the back



Figure 3b. Case 2: 2 KS-Flap are designed.

scar's appearance, symptoms, and psychosocial impact. Additionally, a panel of five independent reconstructive surgeons conducted a blinded review of postoperative photographs taken at three and six months post-surgery. The surgeons rated the aesthetic and functional outcomes of each reconstruction on a five-point Likert scale, providing an external assessment of the flap's effectiveness.

RESULTS

In this study, a total of 20 KFs were used to reconstruct defects in 20 patients following oncologic resection. The mean age of the patients was 65 years, ranging from 45 to 82 years. Of these patients, seven were diabetic and nine were smokers, these were recorded as potential risk factors for postoperative complications. The average defect size treated with the KF was 15.5cm × 13.5cm (209.25cm²), with individual defect areas ranging from 4cm² to 615cm². Hospitalisation time averaged 4.5 days, with minor variations based on patient comorbidities and defect location.



Figure 4a. Case 2: Intraoperative view showing skin defect



Figure 4b. Case 2: Intraoperative view showing flap harvesting.

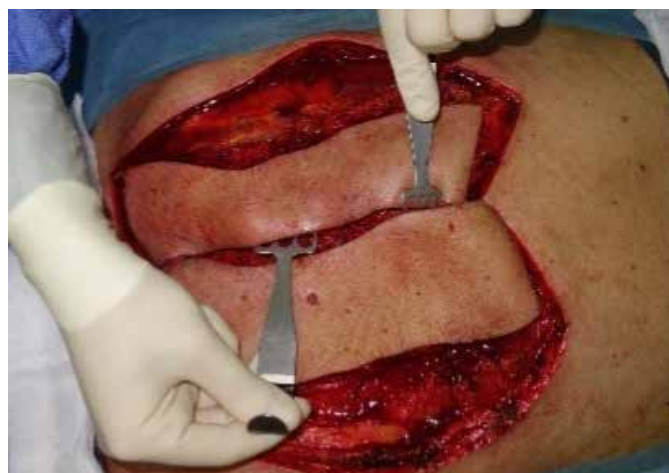


Figure 4c. Case 2: Intraoperative view showing flap mobilisation.

No major complications, such as partial or total flap loss, were observed across the cohort, confirming the high reliability of KF for such reconstructions. However, the overall complication rate was 10.9%, with two cases of minor complications, specifically wound dehiscence, in patients with risk factors such as diabetes and smoking.^{6,7} One case of dehiscence was managed conservatively with closure by secondary intention, while the other required a delayed primary closure. Postoperative healing occurred without further intervention, and no infections were reported during the follow-up.

In subgroup analyses, complications appeared slightly higher for reconstructions involving the trunk (three of 11 cases), as compared to extremities and the face, suggesting that areas with greater muscle-cutaneous tension present unique challenges for flap stabilisation.^{8,9} Smoking and diabetes were associated with a higher rate of delayed wound healing, with diabetic patients showing an average of two additional days of hospital stay compared to non-diabetic patients.

Long-term outcomes were assessed at six months post-operation using the Scar-Q evaluation tool, where patient satisfaction scores averaged 4.5 out of 5 for aspects including appearance, symptoms, and psychosocial impact. The results from Scar-Q assessments indicated high patient satisfaction, particularly for reconstructions of the face and chest, where the keystone flap provided superior aesthetic integration with the surrounding tissues.

Additionally, a team of five independent reconstructive surgeons conducted a blind review of postoperative photographs at three and six months, evaluating functional and aesthetic outcomes on a five-point Likert scale. The average rating from the external team was 4.7 out of five, indicating a strong consensus on the effectiveness and appearance of the KF reconstructions.^{10,11}

Patients reported high satisfaction levels, especially for chest and facial reconstructions, where the KF design provided a near-native aesthetic result. These findings support the keystone flap as a reliable technique, delivering favorable functional and cosmetic outcomes across various anatomical sites.

DISCUSSION

For decades, thanks to the presence of rich subcutaneous vascular networks, the use of advancement random V-Y flaps has been adopted as a valid surgical solution for covering small and medium-sized substance losses in different regions of the body.^{10,11,12} Modern plastic reconstructive surgery, thanks to studies conducted by Taylor and Palmer¹³ which identified a rich network of vessels in all body districts, has allowed an evolution of the V-Y flaps of random advancement, transforming them into skin bundles with the possibility of setting up bundle-cutaneous flaps with preservation of muscles and nerves, even after trunk/mammary procedures.^{10,14}

The KF has demonstrated its utility for the reconstruction of complex defects with a high degree of success: this flap is faster to execute, does not present the risk of complete flap necrosis, and has favorable cosmesis with minimal donor-site morbidity compared with free flap or flaps isolated on a single perforator. Modern software technology allowed authors to check the success of the flap as well as the prognosis.^{15,16}

Traditional techniques such as the random V-Y advancement flap and axial flaps are frequently employed for smaller or moderate defects. While these approaches offer reliable coverage, they are often limited by their range of movement and may not provide sufficient vascular support for larger reconstructions. Microsurgical free flaps, by contrast, have become the gold standard for extensive and complex reconstructions due to their versatility in shaping and their ability to transfer large tissue volumes with primary vascular anastomosis. However, free flaps are associated with significant technical demands, increased operative time, and a risk of donor-site morbidity, which may not be ideal for patients with multiple comorbidities or in cases where microsurgical expertise is unavailable.

The KF stands as an innovative intermediate option, combining the advantages of local flaps with elements of perforator-based design, offering both robust perfusion and relatively straightforward execution. Unlike axial flaps, which rely on a single named artery, the KF is based on fasciocutaneous perforators distributed across the flap base, enhancing its vascular safety while eliminating the need for an isolated vessel. This unique vascular support is a significant advantage in the context of larger defects, as it reduces the risk of ischemia and allows for extensive coverage without necessitating microvascular anastomosis. The KF's reliance on local perforators not only preserves the donor site integrity but also ensures the flap is nourished through multiple, small-caliber vessels, providing a natural gradient of vascularisation that promotes healing and reduces the potential for flap necrosis.

The vascular supply may come from few large fasciocutaneous perforators or from a collection of smaller, randomly distributed vessels, this concept highlights even more the importance of a correct pre-operative design. In our common practice we identify them by means of a portable Doppler device that allows us to quickly identify dominant vessels near the defect to be reconstructed.

Compared with free-tissue transfer or even simple skin grafting alone, there is no secondary donor-site deformity other than an incision slightly longer than the defect itself. This eliminates a secondary donor site, vascular monitoring, skin grafting, and the associated issues that may arise in such a setting.

In our experience, we found the flap to be more difficult to get a definitive closure on the trunk than in other anatomical areas due to the greater muscle-cutaneous traction and tension present in that part of the body. As with many other reconstructive techniques, we found also that the lower extremity presents challenges in wound closure due to less tissue elasticity.

CONCLUSIONS

The KF can be considered useful for losses of substance of the trunk and extremities: even in large defects, the flap can achieve primary closure without the need for axial flap mobilisation or microsurgical techniques, including avoidance of such technical overhead. It is a reliably effective and uncomplicated surgical technique.

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All authors contributed equally to the manuscript and read and approved the final version of the manuscript

STATEMENT

Informed consent was obtained for each patient and the local ethics committee approved the study in compliance with human rights

CONFLICT OF INTEREST

The authors certify that there is no conflict of interest with any financial organisation regarding the material discussed in the manuscript.

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