

V-Y Hemi-keystone Advancement Flap: A Novel and Simplified Reconstructive Modification

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Background: The keystone perforator flap design has been gaining popularity for reconstruction of cutaneous defects due to its robust vascular supply and high rates of flap survival. However, the design requires significant tissue mobilization relative to the defect and is consequently technically demanding, time intensive, and has associated morbidity. We present a novel, simplified modification of the keystone flap that may increase its reconstructive applications.

Methods: A retrospective chart review was conducted of patients who underwent V-Y hemi-keystone advancement flap reconstruction of cutaneous defects by a single surgeon. Outcomes of interest included wound healing complications.

Results: Eighty-six consecutive V-Y hemi-keystone advancement flaps were performed with an overall complication rate of 7% (6/86). Reconstruction sites included lower extremities (75/86, 87.2%), upper extremities (9/86, 10.5%), and the trunk (2/86, 2.3%). Mean follow-up time was 26.3 weeks. Four out of 5 surgical site infections occurred on lower extremity wounds. There were no cases of complete or partial flap loss.

Conclusions: The current series presents a simplification of the traditional keystone flap that decreases surgical complexity and time required for successful reconstruction of cutaneous defects, especially in challenging wounds on the lower extremities. The complication rates were similar, or lower, than previously reported series of keystone flap reconstructions. The consistently favorable outcome of this technique supports the integration of the V-Y hemi-keystone advancement flap into reconstructive surgery. (*Plast Reconstr Surg Glob Open* 2020;8:e2654; doi: [10.1097/GOX.0000000000002654](https://doi.org/10.1097/GOX.0000000000002654); Published online 6 February 2020.)

INTRODUCTION

Originally described by Behan,¹ the keystone flap is a curvilinear trapezoidal advancement flap with a robust vascular supply indicated for anatomical sites within perforator vascular zones. The technique has garnered particular favor with reconstructive surgeons for repair of lower extremity defects, where there is limited tissue mobility and poor vascularity. In such areas, harnessing vertically oriented subcutaneous, musculocutaneous, and fasciocutaneous perforators increases flap survival compared with other reconstructive techniques that may confer a higher risk of tension necrosis, prolonged healing time, or worse esthetic outcome.² For tight closures, modifications of the

keystone flap have been described for greater tissue mobilization, including deep fascial release (type II), adjacent bilateral advancement (type III), and subfascial rotation and advancement (type IV).³

Following skin cancer resection, especially with Mohs micrographic surgery, the defects are relatively small and infrequently cross the facial plane. Although a repair technique with durable vascular supply is favored, the keystone flap requires a significant area of incision and tissue mobilization relative to defect size (>4:1).³ Arguably, for some wounds, keystone flap variations may be technically excessive in incision area and time commitment.

In a novel modification of the design by Behan,¹ we present a simplified V-Y hemi-keystone advancement flap customized for minimal tissue incision. The technique involves incising the curvilinear portion of the flap unilaterally, as needed, until the defect is closed. In this stepwise approach to flap advancement, wounds can be closed with low tension, utilizing only a portion of the traditional

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keystone design. This technique minimizes the incision area and morbidity associated with reconstruction, while increasing efficiency and allowing for easy incorporation into clinical practice. (See [Video 1 \[online\]](#), which displays a V-Y hemi-keystone advancement flap reconstruction.)

METHODS

From 2016 to 2018, 73 patients presented for skin cancer surgery and underwent reconstruction with a simplified V-Y hemi-keystone advancement flap. A retrospective review was conducted with approval from the Weill Cornell Medicine Institutional Review Board.

Surgical Technique

After tumor extirpation, each defect is converted to a fusiform shape ([Fig. 1](#)). A traditional keystone flap is designed at 90 degrees from each apex with the longitudinal curvilinear flap having width equal to defect diameter. A partial incision is made extending along one apex

allowing for a portion of the flap to be approximated. The incision is extended vertically through the subcutaneous plane, preserving the perforators. The outside margin away from the flap is then undermined. The unilateral incised portion is advanced and closed in a “V-Y” fashion, allowing for enough tissue mobilization into the center of the defect under minimal tension. If needed, more of the curvilinear flap can be gradually incised and mobilized. If the defect is able to close with a partial incision, then the flap is trimmed and sewn into place with a V-Y hemi-keystone flap configuration ([Fig. 2](#)).

RESULTS

A total 86 V-Y hemi-keystone advancement flaps were performed in 73 patients by one surgeon (K.M.). The average patient age was 71.1 years, and 49% of the patients were male ([Table 1](#)).

The majority of reconstructions were for soft tissue defects from Mohs micrographic surgery or excisions of

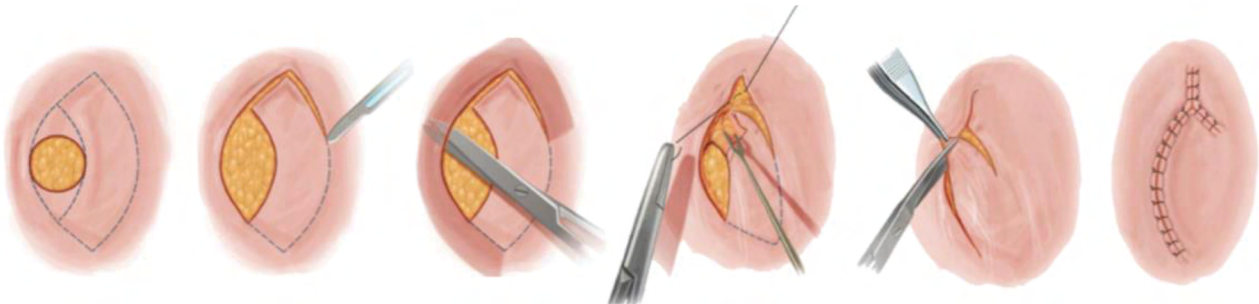


Fig. 1. Illustration of the V-Y hemi-keystone advancement flap technique. Illustration by Anatomy By Design, Inc.



Fig. 2. Representative outcome of the V-Y hemi-keystone advancement flap reconstruction in an 80-year-old woman who presented for excision of malignant melanoma on the right lower leg, with final defect measuring $4.5 \times 3.6 \text{ cm}^2$ extending to the fascial plane, and reconstructed with a V-Y hemi-keystone advancement flap measuring $12.0 \times 8.5 \text{ cm}^2$. All surgical wounds were dressed with a pressure dressing for 48 hours with suture removal at 2–3 weeks; with the exception of below-the-knee reconstructions, which were wrapped in a weekly zinc oxide compression dressing to decrease swelling.

Table 1. Patient Demographics and Clinical Characteristics

| Characteristics | Value |
|-----------------------|------------|
| Total participants, n | 73 |
| Male sex, n (%) | 36 (49.3) |
| Age, y, mean (SEM) | 71.1 (1.5) |
| Comorbidities, n (%) | |
| Diabetes | 5 (6.9) |
| Smoking | 5 (6.9) |
| Anticoagulants | 30 (41.1) |

Table 2. Characteristics and Outcomes Following Reconstruction with the V-Y Hemi-keystone Advancement Flap

| Characteristics | Value |
|--------------------------------------------------|------------|
| Total cases | 86 |
| Diagnosis, n (%) | |
| SCC | 39 (45.3) |
| BCC | 33 (38.4) |
| Melanoma | 8 (9.3) |
| Atypical nevus | 3 (3.5) |
| Others | 3 (3.5) |
| Tumor location, n (%) | |
| Trunk | 2 (2.3) |
| Upper extremity | 9 (10.5) |
| Lower extremity | 75 (87.2) |
| Defect area cm ² , mean (SEM) | 5.8 (0.6) |
| Reconstruction area cm ² , mean (SEM) | 53.5 (4.2) |
| Follow-up time, weeks, mean (SEM) | 26.3 (2.5) |
| Complications, n (%) | 6 (7.0) |
| Infection | 2 (2.3) |
| Dehiscence | 1 (1.2) |
| Infection + dehiscence | 3 (3.5) |
| Hematoma | 0 (0) |
| Flap failure | 0 (0) |

BCC, basal cell carcinoma; SCC, squamous cell carcinoma.

cutaneous tumors, including basal cell carcinoma (38.4%), squamous cell carcinoma (45.3%), melanoma (9.3%), atypical nevi (3.5%), and others (3.5%). Defect locations included the lower extremity (87.2%), upper extremity (10.5%), and trunk (2.3%). The average defect size was 5.8 cm² and reconstruction area averaged 53.5 cm². The mean follow-up time was 26.3 weeks (Table 2).

Associated patient comorbidities included diabetes mellitus (6.9%), tobacco use (6.9%), and anticoagulant use (41.1%). Recorded complications included 5 surgical site infections (SSIs), based on clinical examination and positive culture (5.8%), and 4 incidents of partial dehiscence (4.7%). Three out of 4 wound dehiscences, all <2 cm, occurred in patients who had concomitant SSI. The remaining partial dehiscence occurred in a patient who had a lower extremity reconstruction but could not tolerate a compression dressing due to pain.

There were no cases of major complications such as bleeding, hematoma formation, partial or complete flap loss.

DISCUSSION

The current series of 86 cases demonstrates a novel modification of the traditional keystone advancement flap with a simplified V-Y hemi-keystone approach for successful closure of cutaneous surgical defects (see figure, Supplemental Digital Content 1, which shows the representative outcome of the V-Y

hemi-keystone advancement flap reconstruction on the shin, <http://links.lww.com/PRSGO/B312>) (see figure, Supplemental Digital Content 2, which shows the representative outcome of the V-Y hemi-keystone advancement flap reconstruction on the foot, <http://links.lww.com/PRSGO/B313>) (see figure, Supplemental Digital Content 3, which shows the representative outcome of the V-Y hemi-keystone advancement flap reconstruction on the leg, <http://links.lww.com/PRSGO/B314>) (see figure, Supplemental Digital Content 4, which shows the representative outcome of the V-Y hemi-keystone advancement flap reconstruction on the trunk, <http://links.lww.com/PRSGO/B315>). The technique minimizes incision area, decreases morbidity, and increases efficiency, while maintaining a robust vascular pedicle with high rates of flap survival, especially on difficult areas for closure on the lower extremities.

The overall complication rate of 7% is less than the 9.6% rate reported in a systematic review of keystone flaps.² The SSI rate in our cohort was 5.8%, where 80% of infections occurred on lower extremities, highlighting the difficulty in healing of lower extremity wounds, mainly due to decreased vascular supply, skin fragility, and minimal skin laxity. In a previous series of lower extremity keystone flap reconstructions, SSI rate was as high as 20%.⁴ All patients in our cohort with SSI improved with a course of oral antibiotics. One of the 5 patients with SSI had also received preoperative antibiotics due to a previous history of joint replacement. There was no statistically significant difference in rates of infection among patients who received prophylactic antibiotics and those who did not ($P > 0.9999$).

Notably, there were no bleeding complications, despite 41% of patients being on anticoagulants, including 5 patients taking newer classes of anticoagulants (apixaban, dabigatran, and rivaroxaban) that have been previously associated with increased rates of bleeding in dermatologic surgery.⁵

All patients experienced complete wound healing with excellent contour, color, and texture match, without limitations in range of motion.

Due to the retrospective design, limitations of the study include lack of prospective data or comparison control group of other reconstructive methods. The generalizability of the results is limited by data collection from a single surgeon. Further prospective investigation to validate the effectiveness of our modification compared with grafting, linear closure, and other locoregional flap designs with defects of various sizes may be prudent to confirm the observed favorable outcome of the V-Y hemi-keystone advancement flap. However, the current series of reconstructions resulting in no major complications and 100% flap survival, supports the reconstructive advantage of the V-Y hemi-keystone advancement flap design in reconstructive surgery.

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REFERENCES

1. Behan FC. The keystone design perforator island flap in reconstructive surgery. *ANZ J Surg.* 2003;73:112–120.
2. Huang J, Yu N, Long X, et al. A systematic review of the keystone design perforator island flap in lower extremity defects. *Medicine (Baltimore).* 2017;96:e6842.
3. Abraham JT, Saint-Cyr M. Keystone and pedicle perforator flaps in reconstructive surgery: new modifications and applications. *Clin Plast Surg.* 2017;44:385–402.
4. Lanni MA, Van Kouwenberg E, Yan A, et al. Applying the keystone design perforator island flap concept in a variety of anatomic locations: a review of 60 consecutive cases by a single surgeon. *Ann Plast Surg.* 2017;79:60–67.
5. Eilers RE Jr, Goldenberg A, Cowan NL, et al. A retrospective assessment of postoperative bleeding complications in anticoagulated patients following Mohs micrographic surgery. *Dermatol Surg.* 2018;44:504–511.