Keystone perforator island flap: a clinical summary of 28 melanoma cases

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Abstract
Background: The keystone perforator island flap (KPIF) and its design variations developed as a clinical necessity for reconstructing large surgical defects. This article focuses on melanoma management in 28 cases taken from a series of up to 3,000 established over 20+ years of clinical experience.

Method: The dermatome is the basis of the keystone success where vessels accompany nerves. Keystone perforator island flaps are fascial lined, supporting vascular integrity. The design resembles two conjoined VY island flaps facilitating closure under tension as the perforator zones (perforazones) are oriented vertically with a stronger hydrostatic supply than the horizontally aligned subdermal plexus. Tissue match is important and contributes to a sound aesthetic outcome.

Results: KPIF reconstructions are pain free even though tension is noted. KPIF reconstructions are almost anaesthetic for the complete dimension of the wound. This is explained by the simple fact that temporary interruption of somatic innervation in this design recovers over a few months in the same way as any longitudinal incision regains its nerve supply. Oedema in the KPIF is rarely observed and could possibly be a sympathetic affect. Reactive hyperaemia is evident in irradiated tissue, breaking another rule in plastic and reconstructive surgery in irradiated tissue where loco–regional reconstruction is contraindicated.

Conclusion: With an intact vascular system associated with autonomic and somatic support—including lymphatic drainage, the Gillies principles of replacing ‘like for like’ and the ‘next best tissue is the next best tissue’—reconstructive design principles are maintained.

Keywords: perforator flap, islands, hyperemia, fascia, pain
Introduction

The clinical use of the keystone perforator island flap (KPIF) in surgical reconstruction continues to be re-evaluated from its initial concept for use in small mitotic lesions to major reconstructions all over the body. The KPIF’s arch-like shape is architectural in design based on the concept that it provides structural support for construction. Metaphorically, the arch is the basis of the KPIF technique which allows extensive applications for reconstruction all over the body.

The composition of the KPIF

Structurally, the KPIF consists of skin, fat and facia, all designed with the dermatomal markouts of the body, ensuring an embryological basis for the design. It has VY triangular apices at the extremes having a close resemblance to the original VY island flaps designed by Friedrich Dieffenbach, a German surgeon of the University of Königsberg of the 1840s. Schematically, when one joins the diagonal extremes across the centre of the keystone arch this creates two apparently conjoined VY islands. This is the basis of the vascular integrity and clinical success of the KPIF which is based randomly, avoiding specific exploration of perforated sources (perforasomes) which may skeletonise the sources of autonomic and lymphatic support.

The vascular and neural basis

The KPIF is complemented by the work of Michel Saint–Cyr, who delineated specific perforasomes, and is designed within the dermatomes. In human development, the generation of neural strands—future nerves—from the notochord around the coelom stimulated vessels to accompany these radially developing neural structures. Therefore if there is a nerve supply there must be a blood supply and if flaps have a design within neural specificity (KPIF within the dermatomes) the neurovascular support must have an integral base. However, in the process of skeletonising vascular axes, as one sees in perforator propeller flaps, kinking is a common occurrence accounting for a 47 percent complication rate. In KPIF, and as long as the undermining of the fascial lined KPIF retains one third of deep attachment, perforasomes are not skeletonised. All the following illustrated clinical cases have been designed and executed in this manner without Doppler localisation. Reactive hyperaemia illustrated implies that the sympathectomy effect has been created. This usually develops within 15 minutes of raising the fascial lined KPIF. The red dot sign is a regular clinical finding where the suture sites in the flap bleed more on the flap side than the surrounding insert area. Reflecting this hypervascularity means that the flaps can be closed under surgical tension and the initial white stress lines across the flap are only fleeting because the perforator circulation (perforasomes) are vertically orientated. This bypasses the subdermal plexus which is unable to handle closure under tension and thus is the basis of flap necrosis seen when tension on reconstruction is developed. Associated with this presumed autonomic supply, lymphatic integrity could also be retained as postoperative oedema is a rare phenomenon in KPIF reconstructions. Another important aspect in this reconstructive technique is that, where possible, all venous tributaries are retained and repaired should they be inadvertently or surgically damaged. Also, we must not forget McGregor’s famous comment years ago that ‘more flaps die of venous stasis than arterial insufficiency’.

Clinical perspectives

The KPIF has undergone a clinical metamorphosis in design and shape over the last 20 years and is governed by the design of the surgical defect creating rectangular and even omega variants since its initial concept and use from 1995. The initial case of vertically keloid scar repair across the cubital fossa meant that an island flap with VY design apices allowed rotation and transverse alignment and closure completed with VY apposition at either extreme. Needless to say, the satisfactory improvement of elbow function became the basis for ongoing applications throughout the body using the elementary principle that fascial lined flaps must be within the dermatomal presence.
The easiest places to gain confidence in the use of this KPIF technique is over the limbs where the muscle bulk allows compressional closure of the keystone arch even under tension—for example, the muscle substances of the forearm, then the upper limb between shoulder joint and elbow. The muscles of the thigh and the calf are other sites where KPIF closure is relatively easy. However, circumferential KPIFs are contraindicated as closure in a vertical axis results in tensional disintegration, yet when biopsy excisions are done with this alignment it can be a difficult KPIF closure.

Where major defects are involved and closure under tension over joints, KPIF closure is still possible and undermining at the fascial level—with or without grafting—can achieve wound closure. However, the principle of one third (1/3) attachment must be obtained. In the head and neck region, major parotid defects can be closed with relative ease with direct apposition over the cheek including the superficial muscular aponeurotic system (SMAS) layer. For larger head and neck defects, the cervical submental dermatome c2/c3 allows the island flap to be rotated from the loose neck tissue into the pre-auricular cheek defect, even as high as the zygomatic arch. In the back, especially over the scapula region, the u–shaped horseshoe variant design allows closure of the defect when designed along the intercostal perforator input ~ t4–t8. To repeat, the KPIF is designed along the intercostal perforators undermined in its proximal and distal thirds and closed into a u-shape to achieve closure of large scapular defects as illustrated in the video.

Scientific evaluation

Throughout my extensive 20 year experience with over 3,000 cases, clinical observation and reproducible data has been the basis of the scientific evaluation of the KPIF technique.² Reconstructions using this techniques have been performed all over the body (limited over the scalp where reconstructions using axial island flaps can be applied). The success of the KPIF technique has been documented photographically and in the two text books and 14 articles as summarised on the Mayo Clinic publication, co–authored with Saint–Cyr.³ It is hoped that future text books will adopt this teaching format that combines visual presentation supplemented with video. The clinical success of the KPIF is the foundation of this evidence-based process which simplifies reconstruction.

Complications

Complication with this single layer wound closure technique are rare. Tight closures on any region with premature removal of sutures can be a clinical setback. My working rule is that the continuous everting nylon epidermal sutures are clipped at seven days, some mattress sutures can be removed at 14 days (providing they are not tension points) and the locking mattress sutures can be discretely removed at 21 days. The locking mattress sutures are usually located along the mid–points of the arch of the KPIF (convex and concave sides). If bleeding occurs using this staged wound closure technique, suture removal should cease and the patient brought back in seven days to allow for further healing. To avoid wound breakdown issues, details of wound dressings must be part of any discharge summary instructions. This applies particularly when wounds are dressed at outside clinics and the suture removal pattern needs to be cautiously supervised to avoid wound breakdown, a complication for those not conversant with the technique of single layer tension closure.

Complications have arisen with vascular impedance on the dorsum of the foot and therefore grafting of any secondary defect is mandatory. Patients with diabetes should be handled with absolute caution. Again, split skin grafts help to relieve any tensional alignments.

Summary of KPIF characteristics

- The fascial line dermatome creates a pattern ensuring vascular integrity from a specific or a non–specific random perforator source. The suprafascial and infrafascial vascular support have been verified scientifically in the angiographic experiment by Saint–Cyr.⁴
- The transverse dimensions of the flap with perforator support permit closure under tension of the central area.
- VY apposition proximally and distally permit closure around the apices to create an aesthetic outcome.
The initial appearance of a cyanotic phase is replaced as the flap becomes slowly vascularised; the perfusion of arterialised blood throughout the subdermal plexus eliminates the white lines of tension, reflecting a possible sympathectomy effect of creating island flap reconstructions.

◊ The hypothesis of the increase in vascular perfusion is based on the clinical findings established years ago when a lumbar sympathectomy resulted in a pink foot within a few hours.

◊ In the KPIF, these vascular effects are documented photographically and the timeframe of its development is usually within 15 minutes.

◊ Increased vascular perfusion aids healing with minimal evidence of flap necrosis. KPIF reconstructions on the dorsum of the foot and in particular in diabetics and such cases are to be taken as a warning of potential complications. The issue of smoking is also a contraindication when one observes this traditional restriction in any form of flap reconstruction.

• The dermatomal mark out with non–specific neural connections provides a pain free recovery with the patient’s only assessment: ‘the tissues feel tight.’ Following recovery, normal somatic supply with protective sensation is a characteristic of the KPIF.

• The KPIF’s likewise avoid pin–cushioning oedema, a former criticism of island flaps. Could this be a reflection of a sympathectomy effect on the lymphatic drainage facilitating removal of oedema fluid? It is hypothesised that the dilation of the lymphatic bed, thus minimising oedema, may well be a similar effect as the vascular hyperaemic changes and red dot sign characteristics of the KPIF.

The acronym PACE crystallises the above:

- **Pain**: reconstructions are tight but pain free, which the patient appreciates but does not complain.
- **Aesthetics**: the aesthetic appearance of using Gillie’s principle of ‘like with like’ in reconstruction, gives an acceptable outcome.
- **Complications**: are fairly unusual from a vascular point of view (diabetics and the dorsum of the foot are treacherous areas to be avoided).
- **Economics**: the timeframe for operations may last 60–90 minutes compared with the different timeframes for microsurgery. As Benjamin Franklin said two centuries ago: time is money.

Illustrated case studies

Introduction videos

Case studies

Felix Behan introduction to the design principle and its architectural variations

Keystone overview and its design variations

A clinical synopsis acronym covering:
- pain level
- aesthetic outcome
- complications
- efficiency from time perspective

Cases videos

Case 1: Introduction to using KPIF with melanoma posterior neck.

Case 2: Neck melanoma and the KPIF design within the c2 c3 dermatomes undermining leaving a third attachment along sternocleidomastoid muscle: no Doppler localisation.

Case 3: Neck, anterior infraclavicular random perforators for the KPIF.

Case 4: Scalp—vertex melanoma of the scalp, secondary disseminated into the right neck—following clearance the cyanotic flap is hypervascularised by creating an island leaving a third deep attachment. Full survival.

Case 5: Melanoma—lower limb over posterior calf above the tendo achilles.

Case 6: Face—preauricular region melanoma closure with a cervico submental KPIF. Base rotated on random sternocleidomastoid perforator.

Case 7: Hand—first dorsal intersosseus region melanoma—poor biopsy orientation closure with a circumferential KPIF with hand in ulna deviation.

Case 8: Right cheek melanoma—closure with a submandibular KPIF closure.

Case 9: Right cheek melanoma—parodid melanoma defect 10 x 9 cm closure by supraclavicular KPIF with a third attached beyond the block dissection.

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Case 10: Right cheek melanoma in an irradiated field—KPIF can be used in irradiated field reflecting the hyperaemic phase in spite of subdermal fibrosis caused by the xrt, the vertical orientated perforators bypass this fibrosis to ensure healing.

Case 11: Right parotid melanoma—direct closure smas layer KPIF.

Cases 12 and 13: Groin—recurrent melanoma following failed xrt. Primary acral lentiginous melanoma on the sole of the foot. The quadrangular l2 KPIF of the anterior thigh closes the defect after division tensor fascia and medial deep fascia KPIF.

Case 14: Lateral calf—melanoma—grafting of the secondary defect in along the peroneal compartment because of tension.

Case 15: Left calf upper third—peroneal KPIF creating a horse shoe variant—u shape—and preservation of the superficial peroneal nerve and split skin graft of secondary defect.

Case 16: Angle of the jaw—large melanoma over the parotid. Closure of the defect with a cervico submental KPIF.

Case 17: Angle of the jaw—melanoma of the parotid in an 80–year–old, closure by creating island KPIF by delineating the v2 dermatome to hypervascularise it. The whole wound is closed directly including tensional apposition over the parotid.

Case 18: HMF l 1mm of the left cheek—drape procedure, delayed reconstruction after pathology evaluation. Clearance and closure of the cervico submental KPIF based on random sternocleidomastoid perforators.

Case 19: Calf melanoma—the standard for learning the art of the KPIF closure over muscles. Calf, thigh, forearm and biceps region are the easiest places to learn this KPIF technique (deep fascia must be divided to create a bridge flap).

Case 20: Right malar melanoma—superior orientation of the KPIF along the v2 division delineation allows direct apposition as an alternative to a cheek rotation flap in a young patient.

Case 21: Right calf—standard KPIF in a young female—orientated according to the biopsy orientation—single redvac drain tube covering both sites is folded on itself—draining both defects.

Case 22: Heel acral lentiginous melanoma in an 80–year–old patient, planta fascia KPIF. Based on medial planta neurovascular circuit leaving the medial third attachment for the KPIF, no secondary defect graft needed, although planned.

Case 23: Scapula region melanoma—sarcamo of the scapula with auxiliary clearance—omega KPIF fascial lined variant leaving the middle third attached to t6–t8 intercostal perforators orientation. Patient walked the himalayas 4–5 weeks post–op.

Case 24: Recurrent melanoma of the parotid—sacrificing the facial nerve. KPIF principle and v2 dermatome is the mark out for the island flap reconstruction to hyper vascularise the cyanotic tip. Delayed tarsorrhaphy 12months.

Case 25: Forehead melanoma and reconstruction with v2 dermatome islanded flap to hyper vascularise the tip, to reach the medial eyebrow region for a defect 10 x 6 cm.

Case 26: Left forehead desmoplastic melanoma. KPIF of the superficial temporal artery in a smoker. The sarcoma clearance was achieved, but this may contributed to the distal flat necrosis which took 4 weeks to heal.

Case 26: Complication.

Case 27: Complications of the calf—delayed healing in a KPIF for recurrent melanoma following xrt, then groin dissection and peripheral oedema.

Case 28: Forehead melanoma—slow healing KPIF in a patient with chronic lymphatic leukaemia.

Keystone (KPIF) reconstructive concept for major melanoma defects—an aesthetic perspective.

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Further reading

References