

THE KEYSTONE PERFORATOR FLAP CONCEPT – A USEFUL TOOL IN THE ARMAMENTARIUM OF PLASTIC SURGERY

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Summary. Closure of skins and soft tissue defects is a mainstream procedure in the field of reconstructive plastic surgery. Nowadays plenty of reconstructive options exists in the armamentarium of the specialty. The "keystone island perforator flap" is a relatively new conception which consists of taking skin and superficial fascia in a keystone pattern adjacent to the defect that needs to be covered. This technique is based on the most contemporary knowledge of the vascularization and three-dimensional vascular architecture of the skin and soft tissue overlying the bones – the so called angiosomes and perforasomes concepts. In the present article a brief review of the main keystone flap types and on their predecessor – the Bezier flap, was made. Two clinical cases with difficult defects on the limbs are presented and discussed in order to illustrate the application of that approach. The keystone perforator island flaps is a sophisticated and relatively easy option for defect closure. However, this surgical concept still remains unpopular in the Bulgarian practice and science of plastic surgery. To the best of our knowledge this paper is the first one focused on the topic.

Key words: keystone perforator island flap, Bezier flap, perforasomes, local plasty

INTRODUCTION

Closure of skin defects following excision of skin cancers or traumatic injuries is a mainstream procedure in the field of reconstructive plastic surgery. Nowadays a plenty of reconstructive options exists [1] and one of the golden rules in reconstructive surgery which is always taken into consideration

at the time of choosing the most appropriate one is: "The plastic surgeon should consider using the simplest procedure that effectively solves the problem" [2]. Speaking about effectiveness, the local flaps have shown to be a preferable option because they have better colour and contour and are associated with significant reduction of the donor site morbidity [3]. And whereas small defects have never been problematic issue, larger ones often poses a unique challenge to the reconstructive surgeon requiring knowledge, experience and time. Searching for better solution for bigger defects closure, 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.

The keystone perforator island flap was initially described by Behan as a trapezoidal-shaped flap that is essentially two conjoined V-Y island flaps [3-6]. This is a relatively new conception which consists of taking skin and superficial fascia in a keystone pattern adjacent to the defect that needs to be covered. The vascular supply is supported by the subcutaneous vascular network and is dependent on fascial and muscular perforators [7].

Keystone perforator flap subtypes (4)

- **Type I**

The standard flap design and closure is suitable for defects of different types over most areas of the human body up to 2 cm in width (Fig. 1).

- **Type IIA**

For larger areas of reconstruction, located over the muscular compartments, the deep fascia over the muscular compartment is divided along the outer curvature of the flap to permit further mobilization of the keystone flap (Fig. 2A).

- **Type IIB**

Where excessive tension is present, the secondary defect may be closed by using a skin graft (Fig. 2B). This retains the advantage, however, of allowing the flap to cover vital structures while the graft allows wound healing. This technique is especially indicated where tissue has limited elastic stretch, for example on the lower one-third of the lower limb and the lower one-third of the forearm.

- **Type III**

For considerably larger defects (5-10 cm) a double keystone design can be done to exploit maximum laxity of the surrounding tissues. This is suitable for large defects in the calf or sacral regions (Fig. 3).

- **Type IV**

Occasionally to facilitate rotation across a joint contractures or compound fractures with exposed bone, the keystone flap is raised with undermining up to 50% of the flap subfascially. The undermined fasciocutaneous part of the flap that could be either proximal or distally based can then be transposed across large joint contrac-

tures of the elbow and knee or to cover the exposed bone in compound fractures. The perforator support is derived from the attached part of the flap (Fig. 4).

In order to illustrate our initial experience with the keystone conception, we report on two clinical cases – one of application of the Bezier flap as a predecessor and the other representing the typical keystone perforator flap; both of them for closure of difficult defects on the limbs.

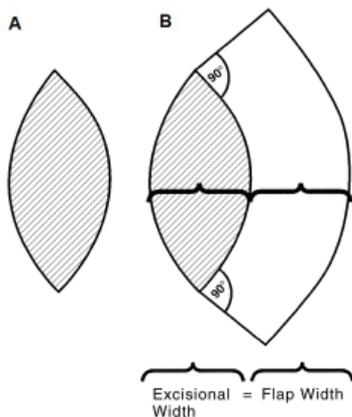


Fig. 1. Keystone flap type I. (A) Fusiform defect to be closed; (B) Design of the flap: the trapezoidal shaped flap is contoured along the side of the excisional defect with 90° angle at the limits of the island flap

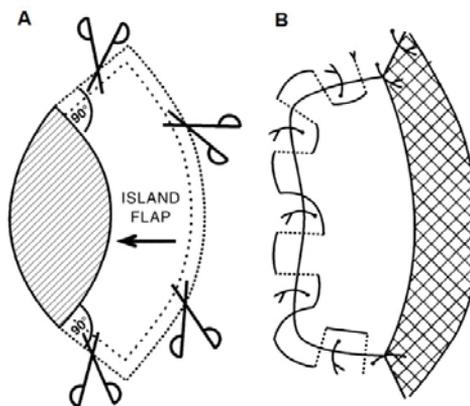


Fig. 2. Keystone flap type II. (A) Type IIA: Division of the deep fascia along the outer curvilinear line to facilitate closure; (B) Type IIB: Skin graft used to cover to the secondary defect when excessive tension is present

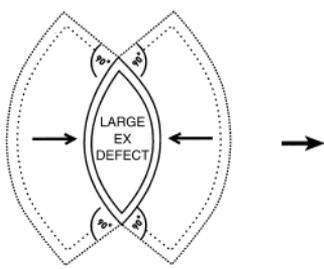


Fig. 3. Keystone flap type III. Two identical opposing keystone flaps are designed to create a double keystone flap

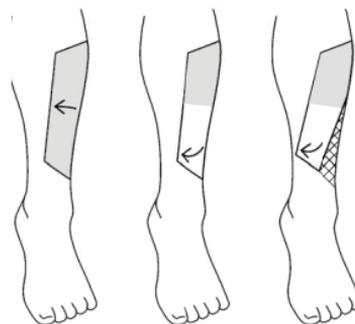


Fig. 4. Keystone flap type IV. It is a rotational keystone flap. A skin graft is applied for closure of the secondary defect after flap harvest

Clinical case 1

A 60 year-old female operated on because of advanced breast cancer presented with a cubital fossa ulcer. The defect was present for more than 3 months after an extravasation of a cytostatic medication and subsequent necrosis of the overlying skin. The defect was circular in shape with measuring about 4cm in diameter (Fig. 5A). A wide excision of the chronic ulcer was performed taking out all the scar tissue. Bezier flap was designed (Fig. 5B) and a sophisticated closure was achieved (Fig. 5C). The postoperative period was uneventful and good anatomic, functional and aesthetic outcome was obtained (Fig. 5D).



Fig. 5. Clinical case 1: (A) Chronic wound after skin necrosis; (B) Bezier flap designed and harvested; (C) Immediately post-op result; (D) Outcome at 6 weeks post-op.

Clinical case 2

An 84-year-old otherwise healthy man presented with posttraumatic injury of the middle third of the left lower leg. The accident happened 4 weeks ago and two consecutive attempts to close the defect by direct closure were made but failed. The plastic surgery team was requested to review the patient. On a clinical examination a nearly circular pretibial defect with minimal bone exposure with periosteal strip-

ping was found (Fig. 6A). No discharge or signs of local inflammatory reaction were observed at the time of clinical examination. Conventional microbiology testing was performed and the obtained results were negative for bacterial growth. Upon debridement, the resulting defect to be reconstructed measured about 4cm x 7cm and a type I keystone perforator flap was dissected (Fig. 6B). When advancement of the flap was intended, it could not reach the opposite border of the defect and closure was impossible. That's why a second flap was designed according to the classical conception of the type III keystone perforator flap (Fig. 3). Thus, the reconstruction aim was achieved and the defect was closed (Fig. 6C). At 6 months follow up good anatomic and aesthetic result was obtained (Fig. 6D).



Fig. 6. Clinical case 2: (A) Post-traumatic wound after 2 intentions for direct closure; (B) Post-excisional defect and design of a keystone flap type I; (C) Immediately post-op result. Two opposing keystone flaps are used – this is so called type III technique; (D) Outcome at 6 months post-op.

DISCUSSION

The angiosome concept was introduced by Taylor and Palmer in 1987 [8-10]. After total body studies of the blood supply to the skin and the underlying deep tissues, they divided the body anatomically into three-dimensional vascular territories, “angiosomes”, supplied by a source artery and its accompanying vein(s) that span between the skin and the bone. Each angiosome is linked to its neighbor, in each tissue, by a fringe of either true anastomotic arteries without change in caliber or by reduced-caliber choke (retiform) anastomotic vessels. Each angiosome therefore defines the safe anatomic boundary of tissue that can be transferred separately or combined together on the underlying source vessels as a composite flap [8]. The perforasome concept is an advancement of the angiosome concept [11]. A perforasome is the vascular territory of a single perforator. Each perforasome is connected

to its neighbor both by direct and indirect linking vessels. These two conceptions help us to understand the nature of the perforator flaps in general but also the Bezier flap and its successor – the keystone perforator island flap, in particular.

The Bezier or French curve flap was published in 1995 by Behan et al [12, 13]. It was introduced to deal with elliptical defects that are not closable by direct apposition. Developed from similar underlying principles to the keystone island flap, the Bezier flap is an elegant extension of the V-Y advancement principle (i.e. limited in terms of advancement). The gentle curve of the Bezier flap uses Langer's lines to minimize the visibility of scars and to maximize the aesthetic result.

In subsequent years, the design of the Bezier flap evolved. The gentle curve of this design was retained at the wound margin, but it was identified that having two regions for V-Y advancement and these areas further away from the long axis of the wound would provide improved tissue laxity and greatly aid the primary close of larger defects. This resulted in an arch of tissue being raised on underlying perforators; hence, it was initially coined the "arch" flap. It was renamed a keystone flap due to its resemblance to the keystone of archways [4-7].

The keystone flap design is considered to be a relatively simple and at the same time excellent solution for defects over the total body surface area. We have applied successfully this concept in closing defects on the limbs. Especially the second clinical case was a particularly difficult solution as the pretibial area is not a good indication for applying the keystone perforator flap concept because of the tibial ridge which makes difficult the advancement of the tissue and its closure in a tension-free manner [13]. That's why in the cited case a second flap was necessary to be dissected in order to achieve a good closure under minimal tension. Despite the difficulty that we have, that was a good solution considering the age of the patient and his personal refusal more complicated techniques such as loco-regional muscle flaps and microsurgery to be applied.

CONCLUSION

The keystone perforator island flaps seem to be a sophisticated and relatively easy option for defect closure. The knowledge of the vascular supply of the skin and soft tissue is of paramount importance for the proper design and execution of this technique. Thus, it could be applied even in difficult at first sight areas of the human body.

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