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Research Article

Application of Modified Keystone Flap After Mohs Surgery

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Abstract

Background: The modified keystone flap is a type of fasciocutaneous island flap, whose vascularization comes from the muscular perforating arterioles. There are several techniques, Behan described the original one and Moncrieff et al. Introduced a variation in the flap in 2008. Currently, a new modification to the technique is proposed, the boated-shape form, which consists of the addition of a new V-shaped design in the outer bow, improving the distribution of closure tension.

We present our clinical experience and surgical results in the Dermatological Surgery Unit with these different techniques.

Methods: A retrospective collected series of cutaneous carcinomas treated by MMS and repaired with the modified keystone flap was studied during the years 2013-2021 in our department.

Results: Twenty seven reconstructions were made for the modified keystone flap. Twenty four were made using the Behan technique, two using the Moncrieff technique, and one using the boat-shaped variant. The types of tumors treated were seventeen basal cell carcinomas, nine squamous cell carcinomas, and one keratoacanthoma. The location of the tumors was seventeen in the lower limbs, five in the upper limbs, four in the back and one in the face. Most of the patients did not present major complications.

Conclusions: The modified keystone flap is a good surgical repair option for use in areas of poor skin where repair of the surgical defect with a simple closure is not possible or when a graft does not have good aesthetic results.

INTRODUCTION

Skin cancer represents 20% of cancers in humans, ranking first in frequency within malignant neoplasms and with an incidence that continues to rise [1,2]. In the United States, more than two million cases of skin cancer are reported annuall [3].

Skin cancer is divided into two large groups: non-melanoma skin cancer and melanoma. The second group includes basal cell and squamous cell carcinoma, which are responsible for 80% of skin cancer cases, as well as less frequent cutaneous neoplasms such as cutaneous lymphomas, malignant tumors of annexes or Merkel cells [4,5].

The characteristics of the tumor, as well as the preference of the patient, will guide the therapy. Although there are several treatment modalities, Mohs micrographic surgery (MMS) is a staged surgical technique that allows a complete evaluation of the histological margin in lateral and depth, reducing the number of recurrences and limiting the resection of unaffected tissue, and therefore achieving faster healing and better aesthetic results [6,7].

When performing the MMS, 4 criteria are taken into account, the oncological being the cardinal objective, that is, the complete elimination of the tumor, followed by the functional criterion where the function of the organ will be preserved, the anatomical criterion through the conservation of the shape and by Lastly, the steric criterion, which will seek to preserve the aesthetics where the tumor is located, with the order of importance being the one previously described [8].

There is a wide variety of surgical techniques to repair primary defects due to skin cancer, which can be classified into 4 large groups: simple edge-to-edge closure, healing by secondary intention, grafts and hanging, ideally seeking to meet the criteria through them. Mentioned above, taking into account that it is currently not acceptable to cover only the primary defect [8].

The choice of the reconstructive technique will depend on factors related to the surgical defect of the tumor, such as its size and location, factors related to the patient, such as his history and the drugs consumed by him, as well as according to the experience of the surgeon [8].

Reconstruction of postoperative defects larger than 15mm, located in areas with limited mobility or skin, such as the knees, legs, feet, shoulders, forearms, and hands, can be very challenging. In these cases, primary closure may not be recommended or possible, which establishes the need to apply flaps or grafts, the latter with unfavorable cosmetic results. The keystone fasciocutaneous (CK) flap is a relatively easy option to repair defects in these regions, with a rapid postoperative recovery period and highly acceptable cosmetic results [9]. In this article we will focus on exposing a series of clinical cases in which the surgical defect performed with CMM is reconstructed using the modified keystone flap.

MATERIALS AND METHODS

We carried on a retrospective descriptive study in patients with cutaneous carcinomas. The patients received surgical treatment with MMS, and the defect was repaired with the modified keystone flap, during the years 2013-2021 in the Dermatologic Surgery Unit, Department of Dermatology, Hospital de Clínicas «Dr. Manuel Quintela». Through a revision of medical registries and a thorough analysis of the iconographic documentation, the following surgical and demographic data were evaluated: age, gender, type of tumor, size of the defect, anatomic localization, and the number of Mohs phases. After surgery, the patients were controlled 24 hours, 1 month, 3 months, 6 months, and 12 months after. In each control, any possible complications were evaluated, as well as the aesthetic result of the scarring.

Before the surgical intervention, all patients signed a consent form for the MMS and authorized the use of photographs in scientific publications.

Surgery was performed on an outpatient basis for both the micrographic surgery and reconstruction. In each case, local anesthesia was used, and antibiotic treatment was indicated at the end of the surgery.

Surgical Technique

In this study, we adopted three types of modified keystone flaps, included two Moncrieff and cols (type I and II), and one from fang and cols. Called a boated-shaped flap.

Moncrieff and cols. Suggested that the design of the classic Keystone flap as an entire island may not always be necessary [10]. Thus, three modifications to the keystone flap were proposed (Figure 1):

Type I Modified Keystone Flap (Figure 1 A-C)

Mainly, this modification of the Keystone flap consists of two lateral extremities and a larger arch that runs in a curve parallel to one side of the excision defect. However, unlike the original description, a skin bridge is left intact along the external arch of the flap, which provides additional vascularization to the flap and significantly reduces the operative time. Besides, it is recommended that when the laxity of the tissue is not enough, a fasciotomy could be performed along the external arch. However, in many cases performing a fasciotomy may not be necessary. Later, the V-side flaps are advanced. The closure is done following a design in VY, which produces enough laxity of the skin in the center, allowing the mobilization of the flap and favoring

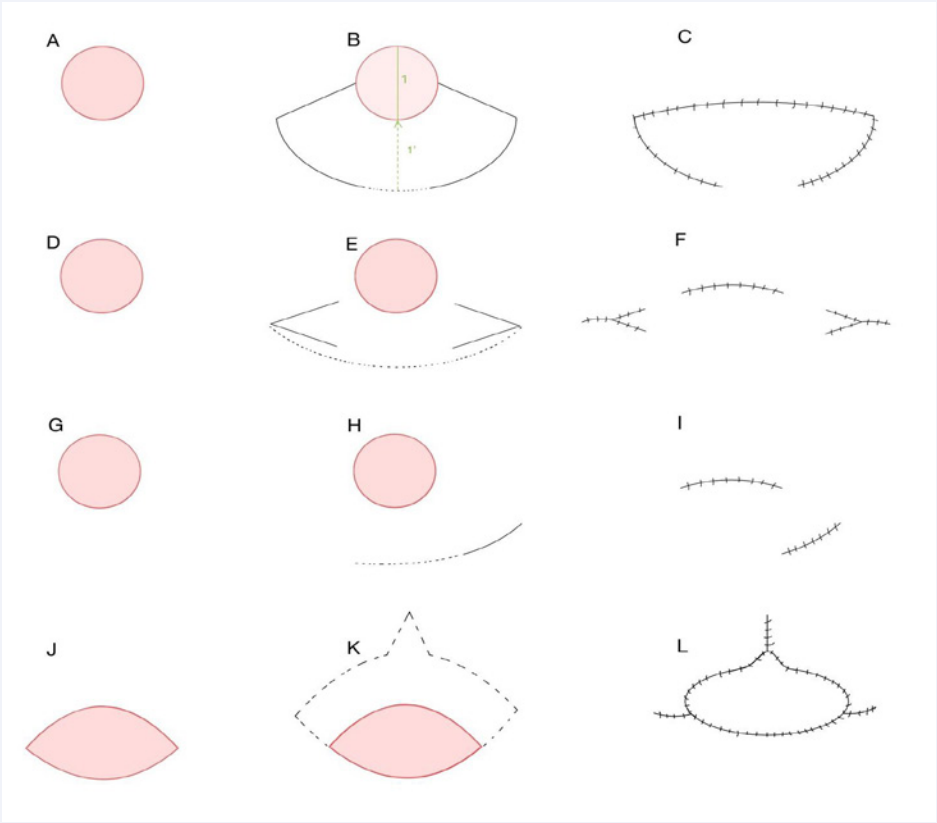

Figure 1 Schematic diagram of type I modified keystone flap (A-C), type II modified keystone flap (D-F), type III modified keystone flap (G-I) y Boated- shaped modified keystone flap design (J-L).
A, D, G & J: Surgical defect to be reconstructed. B: An arch parallel to the defect is drawn (1), giving the flap a width (1') of 1–1.5 times the width of the defect. Lateral borders joining the arch with approximately a 90 angle from the surgical defect. Arch's external thirds and lateral borders are incised. Remaining uncut central part of the arch is undermined carefully. Flap is placed into the surgical defect and redundant skin (dog ears) are repaired. E, H & K: Incision planning, fasciotomy perform along the external arch (black dotted line). C, F, I & L: After suturing, final result.

Figure 2 Case 1: (A) Mohs defect of the right lower leg, with diagram of typ
at 6 months follow-up. Case 2: (D) Mohs defect of the right leg, with diagra
(F) postoperative appearance at 6 months. Case 3: (G) Mohs defect of the right lower leg, with Boated- shaped modified keystone flap design; (H)
after closure with keystone flap; (I) result at 6 months follow-up.

the closure of the primary defect. The final result is shown after the surgical defect's closure with interrupted non-absorbable sutures [5,10-12].

Type Ii Modified Keystone Flap (Figure 1 D-F)

This modification of the Keystone flap is quite similar to the previous one. However, the main difference is that a complete lateral incision of the skin is not made between the two "V" flaps and the defect. In the same way as in the Keystone flap type I, it is recommended that when the tissue's laxity is not enough, a fasciotomy could be performed along the external arch [5,10-12].

Type Iii Modified Keystone Flap (Figure 1 G-I)

In some cases, the tissue's laxity may be so good that it is only necessary to release the subcutaneous tissue along the major arch, omitting the lateral V-Y flaps [5,10-12].

Recently, a novel variant of the keystone flap was proposed by Fang and cols., that could decrease the tension of the flap and the surrounding soft tissues: Boated-shaped modified keystone flap could decrease the tension of the flap and the surrounding soft tissues (Figure 1). At first, two perpendicular straight lines, AA1 and BB1, are designed on both ends of the arc-shaped surgical defect: "bottom of the boat (A1B1)". On the other hand, the arc that is located far from the wound and parallel to the bottom of the boat is the "deck (AB)". At the midpoint of AB is designed the "head of the sail", and the height is the same as the maximum diameter of the defect [13,14].

The flap is advanced to the wound, and if the tension is too much, the deep fascia could be incised. A blunt separation of the flap with a scissor should be performed under the fascia, increasing the flap's degree of movement. During this process, the vessels that perforate upward from the muscle and muscle septum need to be protected [10-14].

RESULTS

Twenty seven modified keystone flaps were performed in total. Demographic and surgical data are shown in Table 1. The average age of the patients was 70,4 years. Twenty four were made by the type I, two by the type II, and one by the boated-shaped flap. The types of tumors treated were 17 basal cell carcinomas (BCC), 9 squamous cell carcinomas (SCC), and 1 keratoacanthoma (KA). The location of the tumors was 17 in the lower limbs, 5 in the upper limbs, 4 in the back, and 1 in the face.

Only three patients present complications, one case had a wound infection with good improvement without major complications, other case had wound dehiscence and another case had hemorrhage. Most of the patients did not present complications.

Tumor's size varied between 1.4 cm and 12 cm, with an average size of 2.8 cm. Mohs stages needed to obtain free margins in most patients was one, with two stages for two patients and three stages for one.

The wound defect's average size was 3.7 cm (range: 2.0–15 cm). The procedure was well tolerated in all patients. In 12 months of follow-up, no recurrence was observed.

DISCUSSION

The keystone flap was described by Behan in 2003 and consists of a local fasciocutaneous island advancement flap in a trapezoidal V-Y shape, supplied by perforating arteries. This allows closure in a single surgical act of both the defect and the donor area without generally requiring skin autograft, making it an interesting option to be used in extremities and defects where simple closure is not possible or when a graft will not present good aesthetic results [15-19].

Behan's original description of the keystone flap included a

Table 1: Demographic and surgical data of six patients that underwent reconstruction surgery with the modified keystone flap.

Patient no.	Gender	Age (year)	Phototype	Location	Tumor type	Mohs stages	Tumor size (cm)	Defect size (cm)	KYM Type	Complications
1	F	58	III	Right leg	SCC	1	1,5	2,2	I	None
2	M	85	II	Right leg	BCC	1	2	2,8	I	None
3	M	61	III	Left thigh	SCC	1	3,5	4	I	None
4	F	74	III	Left leg	SCC	1	2,4	3,2	I	None
5	M	80	II	Right thigh	BCC	1	1,5	2,2	I	None
6	M	49	III	Right forearm	SCC	2	2,5	4,5	I	None
7	M	61	III	Left thigh	SCC	1	3,6	4,1	I	None
8	M	49	III	Right forearm	SCC	1	2.4	4.4	I	None
9	M	77	III	Right thigh	SCC	1	1.6	3.0	I	None
10	M	73	II	Right leg	BCC	1	3.5	5.8	I	None
11	M	54	III	Left arm	KA	1	3.0	3.8	I	None
12	M	74	II	Left leg	BCC	1	2.0	2.6	I	None
13	M	67	II	Back	BCC	2	12	15	I	None
14	F	80	III	Left leg	SCC	1	2.5	4.0	I	None
15	M	68	II	Back	BCC	1	3.5	5.6	I	Wound infection
16	F	91	II	Right leg	BCC	3	2.2	3.5	I	None
17	M	51	III	Nose	BCC	1	1.8	2.1	I	None
18	M	89	II	Right leg	BCC	1	2.5	4.0	II	None
19	F	80	II	Left leg	BCC	1	1,8	2,5	BS	None
20	F	64	II	Left arm	BCC	1	1,4	2	II	None
21	M	71	III	Back	BCC	1	2	2,8	I	None
22	M	83	II	Left leg	BCC	1	2,1	3	I	Wound Dehiscence
23	M	52	II	Back	BCC	1	3,4	5	I	Hemorrhage
24	M	90	II	Right leg	BCC	1	2,5	2,8	I	None
25	F	78	II	Rigth hand	SCC	1	1,8	2,3	I	None
26	F	73	III	Left leg	BCC	1	2,3	3,5	I	None
27	F	69	III	Left leg	BCC	1	1,6	2	I	None

Abbreviations: BCC: Basal Cell Carcinoma; SCC: Squamous Cell Carcinoma; BS: Boated- shaped modified keystone flap design

classification system that organized the flap design into 4 distinct categories (types I-IV), with a further subdivision of the type II flap into type IIA and type IIB. The basic premise of trapezoidal flap design and performance is easily understood with the type I flap, while the remaining subtypes are extrapolated from the type I design [10,11].

In the type I keystone flap, after excision of the primary spindle-shaped lesion, a keystone flap is designed adjacent to the surgical defect with a 1:1 ratio between the width of the defect and the width of the flap. Once the circumferential dissection of the tissue is performed down to the level of the underlying deep fascia, the flap dissection is complete. This subtype of type I trapezoidal flap is characterized in that the entire deep fascia remains circumferentially intact. Regarding the closure, it begins with the terminal portions of the fin closing in a VY manner. This increases the laxity of the tissue in the central part of the flap and thus allows primary closure of the ablative defect and the donor site simultaneously (Figure 5) [15-22].

The type II trapezoidal flap is designed identically to the type I flap, with the difference that the deep fascia is incised along the external curvature in order to increase its displacement, allowing primary closure of the defect and the site. Donor, while the perforators located in the central part of the flap remain intact. It is indicated in defects that require greater mobility or for larger reconstruction areas. The type II trapezoidal flap is subclassified into IIA if the resulting secondary defect is closed primarily and IIB if the donor area is grafted. Donor site skin grafting is generally required in circumstances where excessive skin tension persists during closure despite typical flap mobilization and subsequent fascial release. Of note, an alternative method to eliminate the need for a skin graft is to increase the width of the trapezoidal flap to exceed the typical 1:1 ratio with the ablative defect (2:1, 3:1, 4:1, and so on) [15-22].

The type III keystone flap is composed of 2 opposing keystone flaps designed on either side of the central surgical defect. This subtype is particularly useful for reconstructing larger ablative

defects (5–10 cm), or defects found in areas of the body with low intrinsic soft tissue laxity, such as the sacral area. It should be noted that due to the natural laxity of the tissues within the face and neck, this specific type of trapezoidal flap configuration is not commonly used for reconstruction in these areas [15-22].

The type IV trapezoidal flap, as originally described by Behan, is a trapezoidal flap with up to one-half to two-thirds of one flap end to facilitate rotation and/or advancement into an adjacent surgical defect. The vascular supply to the type IV flap originates from the perforators arising within the nonelevated portion of the flap, which by design provide vascular supply to the elevated tip of the flap via both the subdermal plexus and the suprafascial adipose tissue plexus. It is indicated in cases of more complex surgery involving articular or open fracture [17-22].

In 2008, Moncrieff et al., He introduced several variations to the Keystone flap, which sought to reduce tension and improve the aesthetic result. Among these we highlight the type I modified Keystone, which consists of leaving an intact skin bridge (skin pedicle) along the long axis. Gentle dissection of the subcutaneous fibrous tracts avoids damaging the small capillary network and compromising the blood supply of the flap. Thus, injury to the underlying blood vessels is reduced, reducing the risk of postoperative venous and lymphatic congestion. It also distributes tension more evenly across the entire skin bridge, reducing scarring complications [5,8,10,11]. It is noteworthy that authors observed a low rate of complications with this type of flap.

Another modification was published in 2019 by Fang et al., calling it the modified boat-shaped Keystone flap, in which an additional V-shape is added to the outer curve of the flap, in order to reduce tension on the flap, especially that caused by the closure of the donor area, disperse the tension of the flap and achieve a lower rate of flap necrosis compared to the traditional method [13,14].

These modifications to the keystone flap described by Behan have sought greater laxity, less trauma, and less congestion in the venous and lymphatic plexus, thereby increasing the magnitude of soft tissue coverage of large defects [17-22].

Of note, a fundamental axiom of reconstructive surgery is that local tissue adjacent to a surgical defect almost invariably provides the best reconstructive match in terms of tissue quality, thickness, consistency, and color. In this sense, the use of locoregional flaps, such as the CK, not only has the potential to reduce surgical complexity, but also frequently provides better cosmetic results compared to other more complicated forms of reconstruction [12].

Behan's original keystone flap designs consolidate the vascular segment concept, obtaining blood supply from various vascular networks (muscular perforators, muscular septal perforators, vessels from deep fascia to subcutaneous tissue and dermis) [15-17].

Keystone flaps offer, in addition to the advantage of having a simple surgical design and technique with a high margin of safety and of being a convenient operation with perforating blood supply (reliable vascularization) without the need for Doppler marking, wide ranges of motion and less morbidity. of the donor area, which added to the decrease in surgical time and hospital stay, translates into lower costs for the health system. For all of the aforementioned, CK become an excellent alternative to skin grafts and a better option than other local or regional flaps [17-23].

CK have been widely applied to repair skin and soft tissue defects of different types and areas, whether caused by trauma, tumor resections and/or scars [7].

Although its main indication is the reconstruction of wounds in extremities, it can also be used to reconstruct tumor defects of the back, joints, and face, being a good alternative for more complex and larger surgical defects with excellent aesthetic results in experienced hands [5].

The authors have previously published a series of cases of limb defects after MMS, which were reconstructed with the modified keystone flap, obtaining excellent results with low complication rates, and therefore recommending it as a good option in the repair of large defects. located in areas of difficult closure, such as the extremities [5-7].

Keystone flaps can certainly be used in irradiated and traumatized tissue beds with high expectations of flap success; however, surgeons should be aware of the impacts of each of these scenarios on overall wound healing, regardless of the type of flap reconstruction selected [9,24,25].

Despite the great benefits of CK, they can have specific problems such as excessive tension, constriction of the donor area, and skin contractures due to straight-line scars that occur in the folds, especially in defects of the skin. Large size in the trunk, joints or other mobile areas. It must also be kept in mind that, as with all local soft tissue flaps, neglect of basic vascular physiology can lead to partial or even complete necrosis of the flap, which can greatly compromise the reconstructive outcome [9,24,25].

In addition, caution should be exercised in patients with a history of surgical skin involving the operative field, patients with irradiated tissue beds, or wounds currently in an inflammatory state, as each of these scenarios compromises flap vascularity and flap laxity soft tissues [9,24,25].

Patient selection plays an important role in determining the suitability of trapezoidal flaps for the reconstruction of surgical defects and, in conjunction with sound surgical technique, reduces major complication rates in less than 10% of cases (i.e., partial or total necrosis of the flap) [24-25].

The main concept to describe is that there is no single flap or modification for all circumstances. The surgeon should employ a systematic algorithm that separately utilizes each of the following details available in the trapezoidal design flap:

1) Intraoperative recruitment of skin and soft tissues

2) Subcutaneous soft tissue release under the larger arch

3) Breakthrough of skin, subcutaneous fat, and fascia at lateral apices

4) Fascial perforators

5) Longitudinal orientation to preserve lymphatic-venous flow, to minimize distal lymphedema and avoid cushion formation [10].

CONCLUSION

We presented a series of 27 patients where we performed a keystone flap modified for oncological skin defects. Based on our experience, we recommend the keystone flap modified for large defects located in difficult closure areas; it is mainly indicated for limbs but can also be used in other locations with good results. The functional and aesthetic results are excellent, with a low complication rate.

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