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Reconstructive

Achieving Direct Closure of the Anterolateral Thigh Flap Donor Site—An Algorithmic Approach

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Background: Minimizing donor-site morbidity after free flap harvest is of paramount importance. In this article, we share our experience with achieving primary closure of 58 anterolateral thigh (ALT) free flap donor sites using a simple algorithm in cases where primary closure would otherwise have not been possible.
Methods: Between 2004 and 2010, 58 patients who underwent free ALT flap reconstruction were included in the study. The inclusion criteria were those who had flap width requirements that were wider than 16% of the thigh circumference and had achieved direct primary closure of the donor site by the use of our technique.
Results: Primary closure of the donor sites was facilitated in all cases by the use of 3 distinct techniques. This included the use of the V-Y advancement technique in 13 patients, split skin paddle technique in 7 patients, and the tubed skin paddle design in 38 patients. No episodes of postoperative wound dehiscence at the donor site were encountered; however, 2 cases were complicated by superficial wound infections that settled with a course of antibiotics.
Conclusions: Direct primary closure of the ALT donor site can be facilitated by the use of our simple algorithm. Certain strategies need to be adopted at the design stage; however, the techniques used are simple and reliable, produce superior cosmetic results at the donor site, save time, and spare the patient the morbidity associated with the harvest of a skin graft. *(Plast Reconstr Surg Glob Open 2014;2:e232; doi: 10.1097/GOX.0000000000000205; Published online 14 October 2014.)*

The anterolateral thigh (ALT) flap is one of the most popular options used by reconstructive surgeons to reconstruct a myriad of complex defects caused by tumor ablation, trauma, and congenital malformations.[1] Achieving direct primary closure of the donor site results in better cosmesis and negates the need to harvest a skin graft. Several authors have described various techniques to achieve this. In 2001, Zhao et al[2] used a groin flap to facilitate direct ALT donor-site closure, and in 2002, Hallock[3] reported on the use of suprafascial preexpansion to aid in the subsequent closure of the ALT donor site. In 2006, Calderón et al[4] proposed the use of rectangular local advancement flaps, and more recently, in 2010, Marsh and Chana[5] reported on the successful use of harvesting 2 separate skin paddles from a long elliptical ALT design in 6 cases, thus doubling

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flap width while maintaining the ability to achieve direct primary closure of the donor sites. Moreover, Zhang et al[6] have recently published on the ability to harvest large skin paddles from the back using a split skin paddle approach that allows for direct donor-site closure that would not have been possible to achieve with conventional skin paddle designs. In addition to achieving direct donor-site closure, we also recommend only harvesting a strip of deep fascia around the perforators, as this allows for direct closure of the deep fascia and preservation of the iliotibial tract.

In a study previously performed at our institution, we demonstrated that it was possible to directly close those donor-site defects that were less than 16% of the thigh circumference.[7] With this in mind, we then sought to develop techniques to limit our flap width to within this figure, in situations where the defect size was such that conventional techniques would have resulted in a donor site too wide to close directly. In this article, we present our new algorithm and results from 58 such cases.

PATIENTS AND METHODS

Between 2004 and 2010, 58 ALT flaps were used to reconstruct a range of head and neck and lower limb defects in 58 patients. All donor sites were closed primarily using 1 of 3 techniques outlined below. The mean age of the patients included in our study was 54 years (range, 17–83), and all those included had flap width requirements that were greater than 16% of the thigh circumference. Details of the defect size, location, primary pathology, and means with which donor-site closure was achieved are outlined in Table 1.

Operating Procedure

Patients are positioned supine on the operating table before undergoing perforator mapping with handheld Doppler. After careful defect analysis, the required flap dimensions are then marked on the patient's thigh in accordance with perforator location. If the flap width exceeds 16% of the thigh circumference, then one of the following strategies will need to be adopted to facilitate primary donor-site closure and avoid a skin graft.

Tubed Skin Paddle Design

In cases where the ALT flap was used for reconstruction of circumferential defects (in all our cases, this represented hypopharyngeal reconstruction), we used the following technique. We consider the circumferential defect as a cylinder with a diameter of 3 cm and a length of 10 cm. Hence, if we unroll the cylinder, we are left with a rectangular skin paddle with a 100 cm^2 surface area. This represents the minimum surface area requirement that our elliptical design will need to meet. To achieve this, we simply use the equation for calculating the surface area of an ellipse.[8] This will normally result in a need to harvest a skin paddle with a width of 8 cm and a length of 16 cm,[9] as this will equate to a surface area of 100 cm^2. If, for instance, a second skin paddle is required to achieve outer coverage, then this can be incorporated into the elliptical design based upon a distal perforator. The portion of the ellipse due for tubing can then be split from the portion required for outer coverage. This allows for reconstruction of large complex hypopharyngeal defects while ensuring that primary closure of the donor site is achieved. In our series, we reconstructed 38 hypopharyngeal defects using this tubed design. Three of these involved outer skin defects, and in these cases, we therefore adopted the split tubing principle mentioned above (Fig. 1).

V-Y Advancement Technique

If the flap width is between 16% and 18% of the thigh circumference, then a V-Y antegrade or retrograde advancement flap can safely and reliably be used to achieve direct primary closure of the donor site. Indeed, in our series, we closed 13 ALT donor sites with both antegrade (3/13) and retrograde (10/13) V-Y advancement flaps. No wound breakdown was experienced; however, one episode of postoperative wound infection was encountered which settled with conservative measures. The mean flap width for this group was 8.0 cm (range, 6–10), and mean flap width as a percentage of thigh circumference was 16.4% (range, 16–18%).

If a V-Y advancement technique is selected, then a skin paddle based on a perforator of the transverse branch of the lateral circumflex femoral artery (LCFA) can be raised and advanced into the central portion of the donor site (antegrade advancement). Alternatively, a skin paddle based on a distal perforator of the descending branch of the LCFA can be raised and advanced in a similar fashion into the central portion of the donor site, that is, retrograde advancement (Fig. 2). Both techniques introduce new skin flaps into the central aspect of the donor region, thus reducing the effective width of the donor site and facilitating direct primary closure.

Split Skin Paddle Technique

With wider defects that require wide skin paddles greater than 18% of the thigh circumference, we recommend against using V-Y advancement flaps, as the amount of soft tissue introduced into

Table 1. Summary of Our Patient Series with Flap Dimensions, Primary Pathology, Complications, and Technique for Achieving Donor-site Closure

Case	Age	Pathology	Defect Size (cm)	ALT Skin Paddle (cm)	Thigh Circumference (at Midpoint, cm)	Donor-site Width as Percentage of Thigh Circumference	Technique Used to Facilitate Donor-site Closure	Complications
1	49	Hypopharyngeal cancer	10×8	15×8	50	16%	Tube	None
2	59	Tongue cancer	10×8	10×8	47	17%	V-Y retrograde	None
3	72	Hypopharyngeal cancer	10×6	20×7	41	16%	Tube	None
4	64	Right auricular cancer	10×7	9×7	39	18%	V-Y antegrade	None
5	49	Lower lip cancer	10×10	10×10	59	17%	V-Y retrograde	None
6	48	Left trigone cancer	12×7	13×8	46	17.5%	V-Y retrograde	None
7	63	Left tongue cancer	8×7	12×8	47	17%	V-Y retrograde	None
8	67	Left hypopharyngeal cancer	10×7	13×8	48.5	16.5%	Tube	None
9	57	Right tongue cancer	15×8	19×8	44.5	18%	V-Y retrograde	None
10	77	Right cheek skin cancer	10×10	18×10	55.5	18%	V-Y antegrade	Wound infection
11	67	Right hypopharyngeal cancer	8×8	20×8	49.5	16.2%	V-Y retrograde	None
12	65	Left supraglottic cancer	9×6	18×6	36. 5	16.4%	Tube	None
13	46	Right buccal cancer	10×12	19×10	55.5	18%	V-Y retrograde	None
14	24	Chronic traumatic right heel ulcer	10×10	20×8	46.5	17.2%	V-Y antegrade	None
15	47	Right buccal cancer	10×6	19×8	46.2	17.3%	V-Y retrograde	None
16	83	Right lower gum cancer	10×6	15×9	53	17%	V-Y retrograde	None
17	61	Left cheek sarcoma	12×10	22×8	44.5	18%	V-Y retrograde	None
18	70	Posterior pharyngeal cancer	12×8	20×7	43.7	16%	Tube	None
19	70	Left hypopharyngeal cancer	10×6	10×9	56.2	16%	Tube	None
20	50	Left hypopharyngeal cancer	10×6	13×8	50	16%	Tube	None
21	56	Left hypopharyngeal cancer	12×6	20×8	48	16.5%	Tube	None
22	34	Left hypopharyngeal cancer	8×7	10×8	50	16%	Tube	None
23	37	Right hypopharyngeal cancer	10×8	20×8	48.7	16.4%	Tube	None
24	49	Supraglottic cancer	10×6	13×8	50	16%	Tube	None
25	46	Right supraglottic cancer	10×7	14×8	50	16%	Tube	None
26	53	Right hypopharynx cancer	10×8	20×8	48.7	16.4%	tube	None
27	53	Left hypopharynx cancer	10×9	22×8	49	16.3%	Tube	None
28	66	Right hypopharyngeal cancer	10×5	22×8	48.5	16.5%	Tube	None
29	45	Left hypopharyngeal cancer	10×6	12×8	50	16%	Tube	None
30	59	Right hypopharyngeal cancer	9×8	12×8	49	16.3%	Tube	None
31	51	Supraglottic cancer with hypopharyngeal invasion	10×9	25×8	50	16%	Tube	None
32	41	Right hypopharyngeal cancer	10×6	15×8	49.6	16.1%	Tube	None
33	52	Left hypopharyngeal cancer	10×6	16×8	50	16%	Tube	None
34	61	Right hypopharyngeal cancer	12×7	20×8	49.3	16.2%	Tube	None
35	41	Hypopharyngeal and esophageal cancer	12×6	20×8	50	16%	Tube	None
36	51	Right hypopharyngeal cancer	12×7	21×8	49.3	16.2%	Tube	None
37	69	Right hypopharyngeal cancer	9×8	22×8	48.5	16.5%	Tube	None
38	65	Left hypopharyngeal cancer	8×8	13×8	50	16%	Tube	None
39	59	Right hypopharyngeal cancer	9×7	20×8	48.7	16.4%	Tube	None
40	46	Right hypopharyngeal cancer	10×6	18×8	49	16.3%	Tube	None
41	55	Supraglottic cancer	10×6	19×8	50	16%	Tube	None
42	49	Right hypopharyngeal cancer	9×7	15×8	50	16%	Tube	None
43	64	Posterior pharyngeal cancer	10×6	17×8	49.6	16.1%	Tube	None
44	52	Right tonsillar cancer	9×6	15×8	48.7	16.4%	Tube	None
45	55	Hypopharyngeal cancer	9×6	15×8	50	16%	Tube	None

(*Continued*)

Table 1. (*Continued*) Summary of Our Patient Series with Flap Dimensions, Primary Pathology, Complications, and Technique for Achieving Donor-site Closure

Case	Age	Pathology	Defect Size (cm)	ALT Skin Paddle (cm)	Thigh Circumference (at Midpoint, cm)	Donor-site Width as Percentage of Thigh Circumference	Technique Used to Facilitate Donor-site Closure	Complications
46	43	Hypopharyngeal cancer	10×7	19×8	49	16.3%	Tube	None
47	50	Right supraglottic cancer	10×6	18×8	49.3	16.2%	Tube	None
48	53	Right hypopharyngeal cancer	11×7	20×8	50	16%	Tube	None
49	56	Left hypopharyngeal cancer	12×6	20×8	48.7	16.4%	Tube	None
50	69	Left hypopharyngeal cancer	7×8	15×8	50	16%	Tube	None
51	50	Right hypopharyngeal cancer	9×8	16×8	49.3	16.2%	Tube	None
52	45	Degloved dorsum of foot (right)	14×16	20×8	50	16%	Split skin paddle design	None
53	50	Buccal cancer	12×14	22×7	50	16%	Split skin paddle design	Wound infection
54	74	Recurrent buccal cancer	18×16	32×9	50	16%	Split skin paddle design	None
55	51	Lower limb necrotizing fasciitis (right)	25×12	30×8.5	49.3	16.2%	Split skin paddle design	None
56	51	Left buccal cancer	20×13	22×7	48	16%	Split skin paddle design	None
57	17	Avulsed heel pad (right)	17×14	20×8	50	16%	Split skin paddle design	None
58	29	Dorsal crush wound right hand	18×13	25×7.5	50	16%	Split skin paddle design	None

the central portion of the donor region will not be sufficient to allow for direct primary closure. In these situations, the surgeon can consider adopting the policy of skin paddle splitting to reduce the effective width of the donor site. Two perforators of the LCFA system are mapped onto the anterior thigh, and the maximum width of the defect is then halved and marked as 2 separate skin paddles on the thigh in line with the mapped perforators. The ALT flap can now be raised as a single skin paddle based on these 2 perforators before being split into 2 separate flaps nourished by the same source vessel. The wide defect can now be covered by these 2 flaps based on one microvascular anastomosis, while the donor defect can be closed directly (Fig. 3). In our series, we raised 6 free ALT flaps using this spilt skin paddle technique. Three cases were for lower limb reconstruction, three for head and neck reconstruction, and one for upper limb reconstruction. Mean defect length for this group was 17.7 cm (range, 12–25), and mean width was 14 cm (range, 12–16). Mean flap length was 24.4 cm (range, 20–32), and mean flap width was 7.8 cm (range, 7–9). All the donor sites closed directly, with no episodes of postoperative dehiscence; however, one superficial wound infection was encountered. We would recommend measuring the maximum defect width preoperatively, if half of this figure is less than 16% of the thigh circumference, then adopting the split skin paddle design should allow for direct donor-site closure. If, however, the figure is more than this, then it is unadvisable to attempt primary closure as the option of raising V-Y advancement flaps from the same thigh will have been exhausted by the long skin paddle design used. Indeed, in this scenario, using a split skin paddle design will not lead to direct closure of the donor site.

DISCUSSION

Since its first report by Song et al[10] in 1984, the ALT flap has become the work-horse flap option for many reconstructive surgeons worldwide. Some of the reasons why the ALT has gained so much popularity is due to its long pedicle length and sizable vessels for microanastomosis, excellent location, and good donor-site outcomes.

Although it has been reported that more than 80% of donor sites of the ALT flap can be closed primarily,[9] a significant percentage of patients still suffer donor-site morbidities, mainly resulting from skin grafting. In this modern era of reconstructive surgery, however, we should strive to improve outcomes not only at the recipient site but also at the donor site.[4,11]

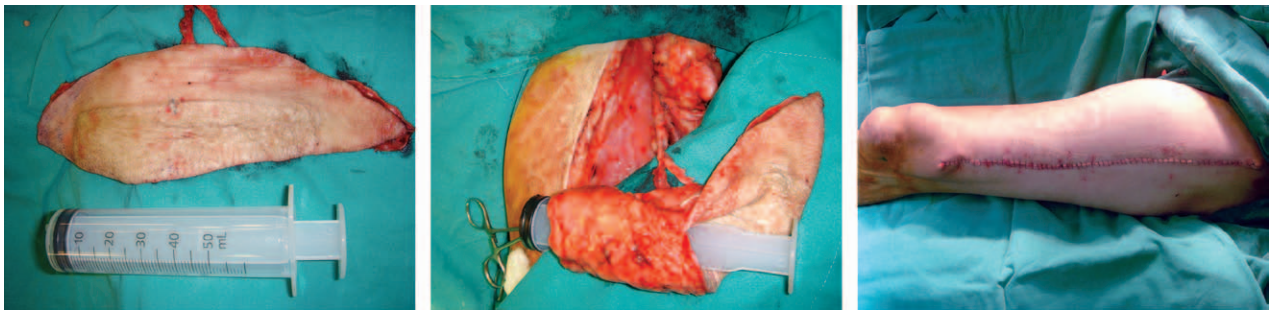

Fig. 1. A tubed ALT fabricated for circumferential hypopharyngeal reconstruction (case 46) while allowing for direct primary closure of the donor site.

In 2010, we demonstrated the importance of taking into consideration the flap width to thigh circumference ratio, when deciding whether or not an ALT donor site would close directly.[7] We showed that donor defects less than 16% of the thigh circumference were amenable to direct primary closure. This spurred an interest within our department to attempt to design our ALT skin paddles such that donor-site widths would fall within this figure. With regard to the reconstruction of circumferential defects, which in our institution we commonly encounter when reconstructing the hypopharynx, we have found that designing an elliptical skin paddle with a maximum width of 8 cm, which can then be tubed, results in a donor defect that is consistently less than 16% of the thigh circumference.[8] Indeed, the dimensions of the hypopharynx can consistently be taken as a tube that is 3 cm in diameter and 10 cm in length. The surface area of this tube equates to 100 cm^2 ($2\pi RH$). Our technique is to use an elliptical design to achieve this

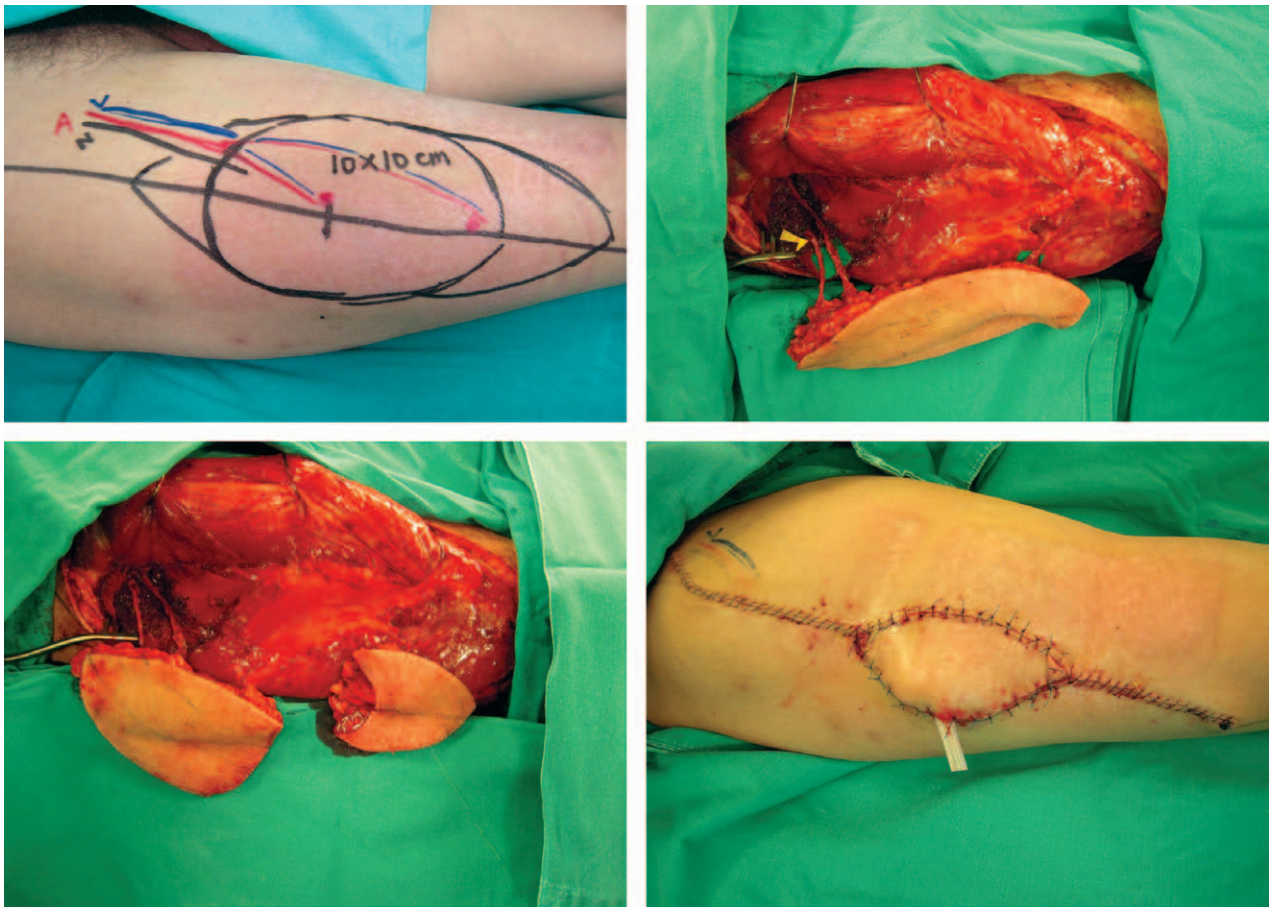

Fig. 2. ALT skin paddle design incorporating a retrograde V-Y advancement flap to facilitate primary closure of the donor site (case 14).

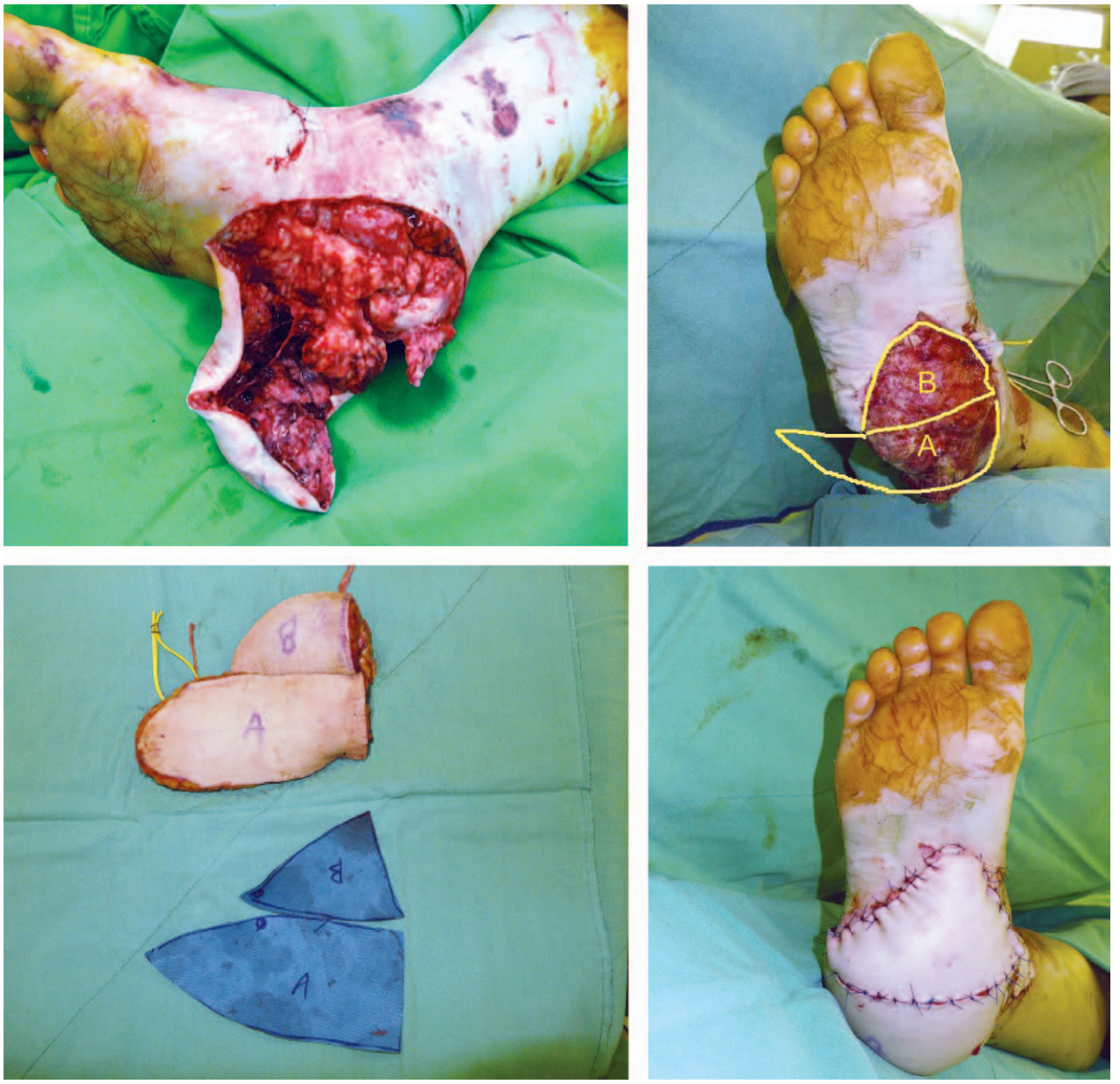

Fig. 3. Heel pad degloving injury reconstructed with a split neurotized ALT that allowed for direct primary closure of the donor site (case 52). The neurotized "A" flap was used to reconstruct the heel pad (lateral femoral cutaneous nerve to branch of medial plantar nerve) while the "B" flap was rotated to reconstruct the area just distal to the heel.

surface area requirement as opposed to a rectangular design, as this will keep the width below 16%. The formula to calculate the surface area of an ellipse is as follows: $2\pi RH = 100\,cm^2 = rh$ (r is flap width and h is flap length). By using this approach, we have managed to close all of our donor sites primarily when reconstructing hypopharyngeal defects. Indeed, by using this design, we have managed to maintain the large surface area requirements of the skin paddle while minimizing the flap width.

In situations where the flap width exceeds 16% but is less than 18%, we have found that the use of an antegrade or retrograde V-Y advancement flap can reliably introduce a new skin flap into the central aspect of the donor site where maximal tension exists. This reduces the effective width of the donor site, thus allowing for direct primary closure.[9] Indeed, the reliability of reverse flow to nourish an ALT skin paddle is well established,[12] and this can be used when planning retrograde V-Y advancement flaps.

In cases where a very wide skin paddle is required, as may be encountered when reconstructing large lower limb defects, the principle of splitting the skin paddle on 2 perforators, which can then be

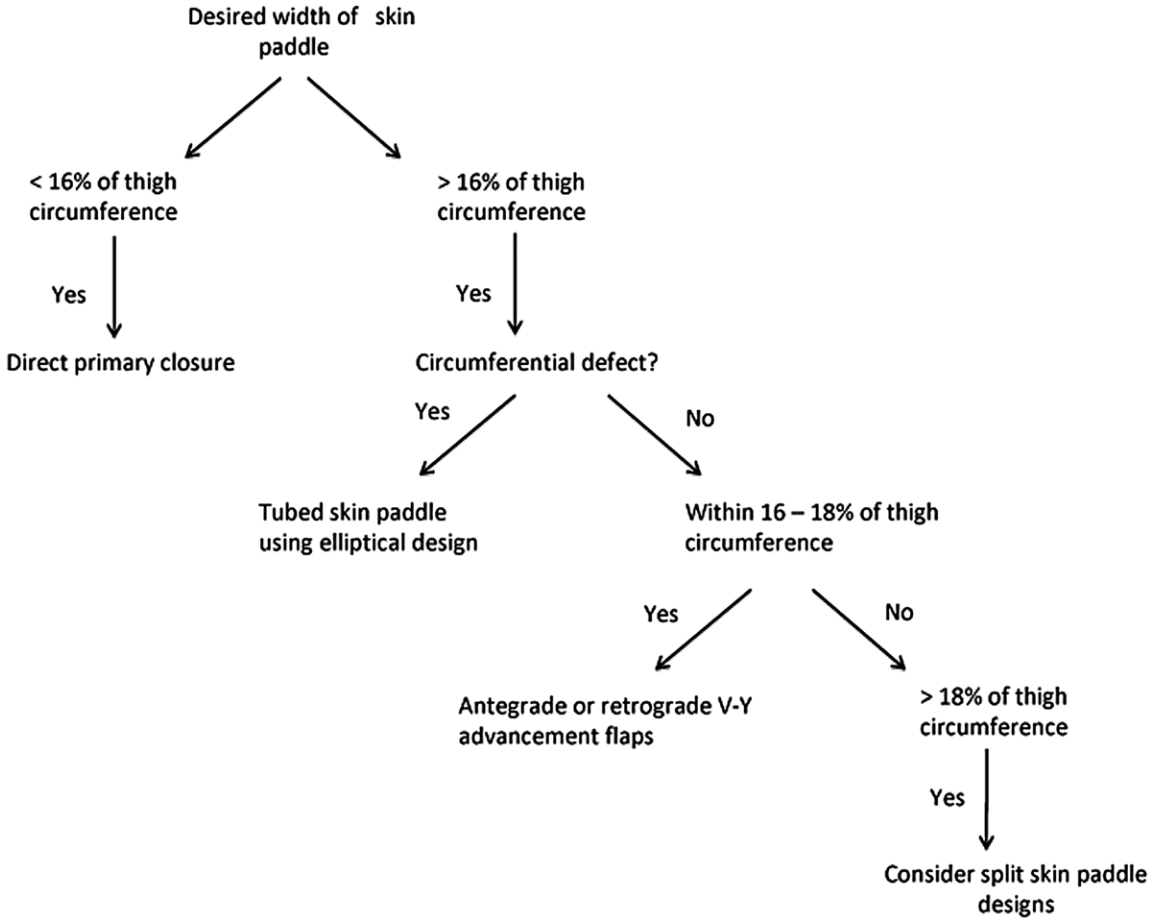

Fig. 4. Algorithm we use at our institution to facilitate direct primary closure of the ALT donor site.

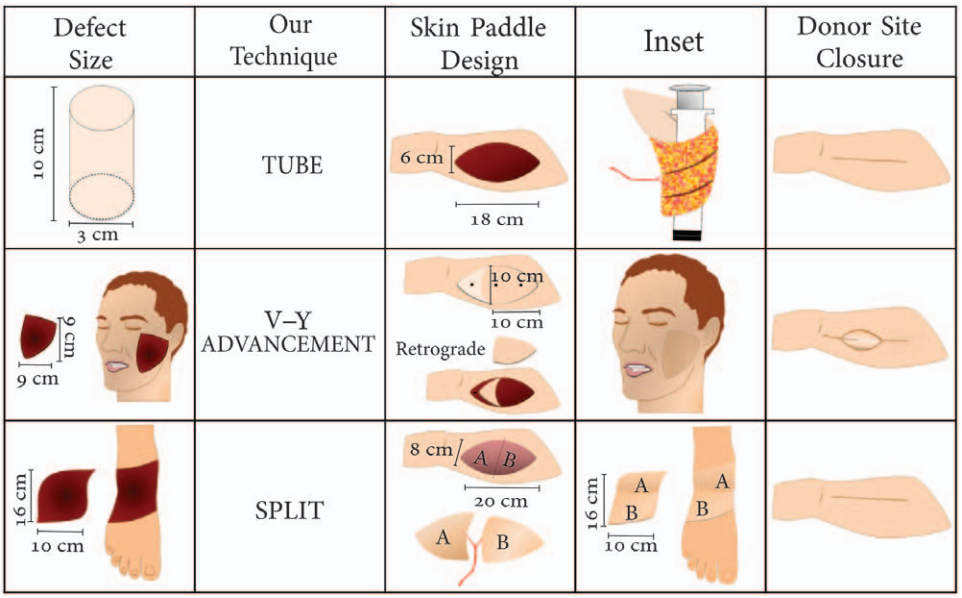

Fig. 5. Pictorial representation of the 3 techniques used in our algorithm to facilitate direct primary donor-site closure.

placed side by side into the defect, can be adopted. We have found this to be a reliable technique that can allow for direct primary closure of the donor site when the maximum width of the defect to be reconstructed is less than 32% of the thigh circumference. Indeed, if the width of the defect is greater than 32%, then it is unlikely that adopting a split skin paddle design will lead to direct closure of the donor site, as an ellipse greater than 16% of the thigh circumference will need to be harvested. Given the long skin paddle required with split designs, V-Y advancement flaps from either end of the ellipse are an unlikely option here. A defect width of 32% of thigh circumference therefore signifies the upper limit of this approach.

In our series, we were able to achieve direct primary closure of all 58 donor sites in cases where conventional techniques would otherwise have led to skin grafting. In all of our cases, primary closure was achieved without the need to raise additional flaps from outside of the ALT donor area, representing a distinct advantage over the use of local or regional flaps. Moreover, the techniques proposed are simple and reliable and did not lengthen the operative time in our series. We present our algorithmic approach in both Figures 4 and 5. It must be stressed that all of our patients were Taiwanese, and the thighs that were therefore included in this study were both thin and relatively lacking in adipose content. This produced a relatively uniform series of thigh dimensions from which we were able to make our observations. The figures of 16% and 18% may therefore vary with thighs of differing adipose content and shape. We see these figures as a guide that can help inform the surgeon as to how best to achieve direct closure of the donor site but acknowledge that interracial variability will undoubtedly exist.

CONCLUSIONS

In conclusion, by adopting the techniques laid out in our simple algorithm, achieving one stage direct primary closure of the ALT donor site is now a feasible option in situations where skin grafts were previously required.

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