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. 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 used a groin flap to facilitate direct ALT donor-site closure, and in 2002, Hallock reported on the use of suprafascial preexpansion to aid in the subsequent closure of the ALT donor site. In 2006, Calderón et al proposed the use of rectangular local advancement flaps, and more recently, in 2010, Marsh and Ghan reported on the successful use of harvesting 2 separate skin paddles from a long elliptical ALT design in 6 cases, thus doubling...
flap width while maintaining the ability to achieve direct primary closure of the donor sites. Moreover, Zhang et al. 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. 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 cm² 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. This will normally result in a need to harvest a skin paddle with a width of 8 cm and a length of 16 cm, as this will equate to a surface area of 100 cm². 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 retrograde                                   | 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 × 9           | 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             | 10 × 9           | 25 × 8               | 50                                     | 16%                                                  | Tube                                             | None                             |
|      |     | hypopharyngeal invasion             |                  |                      |                                        |                                                      |                                                  |                                  |
| 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)
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 split 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. The ALT flap can now be raised as a single skin paddle based on one microvascular anastomosis, while the effective width of the 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 anterior thigh. In this modern era of reconstructive surgery, we should strive to improve outcomes not only at the recipient site but also at the donor site.11

| 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          |

**DISCUSSION**

Since its first report by Song et al in 1984, the ALT flap has become the workhorse 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, a significant percentage of patients still suffer donor-site morbidities, mainly resulting from skin grafting. In this modern era of reconstructive surgery, we should strive to improve outcomes not only at the recipient site but also at the donor site.11

### Table 1. (Continued) Summary of Our Patient Series with Flap Dimensions, Primary Pathology, Complications, and Technique for Achieving Donor-site Closure
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. 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. 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 cm² ($2\pi RH$). Our technique is to use an elliptical design to achieve this.
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: $2\pi rh = 100 \text{ cm}^2 = rh$ ($r$ 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. Indeed, the reliability of reverse flow to nourish an ALT skin paddle is well established, 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

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

| Defect Size | Our Technique | Skin Paddle Design | Inset | Donor Site Closure |
|-------------|---------------|---------------------|-------|--------------------|
| ![Defect 1](image1.png) | TUBE          | ![Skin Paddle Design 1](image2.png) | ![Inset](image3.png) | ![Donor Site Closure 1](image4.png) |
| ![Defect 2](image5.png) | V-Y ADVANCEMENT | ![Skin Paddle Design 2](image6.png) | ![Inset](image7.png) | ![Donor Site Closure 2](image8.png) |
| ![Defect 3](image9.png) | SPLIT         | ![Skin Paddle Design 3](image10.png) | ![Inset](image11.png) | ![Donor Site Closure 3](image12.png) |

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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**REFERENCES**

1. Wei FC, Jain V, Celik N, et al. Have we found an ideal soft-tissue flap? An experience with 672 anterolateral thigh flaps. *Plast Reconstr Surg*. 2002;109:2219–2226; discussion 2227–2230.
2. Zhao Y, Qiao Q, Liu Z, et al. Alternative method to improve the repair of the donor site of the anterolateral thigh flap. *Ann Plast Surg*. 2002;49:593–598.
3. Hallock GG. The preexpanded anterolateral thigh free flap. *Ann Plast Surg*. 2004;53:170–173.
4. Calderón W, Borel C, Roco H, et al. Primary closure of donor site in anterolateral cutaneous thigh free flap. *Plast Reconstr Surg*. 2006;117:2528–2529.
5. Marsh DJ, Chana JS. Reconstruction of very large defects: a novel application of the double skin paddle anterolateral thigh flap design provides for primary donor-site closure. *J Plast Reconstr Aesthet Surg*. 2010;63:120–125.
6. Zhang YX, Messmer C, Pang FK, et al. A novel design of the multilobed latissimus dorsi myocutaneous flap to achieve primary donor-site closure in the reconstruction of large defects. *Plast Reconstr Surg*. 2013;131:752–758.
7. Boca R, Kuo YR, Hsieh CH, et al. A reliable parameter for primary closure of the free anterolateral thigh flap donor site. *Plast Reconstr Surg*. 2010;126:1558–1562.
8. Spyropoulou GA, Lin PY, Chien CY, et al. Reconstruction of the hypopharynx with the anterolateral thigh flap: defect classification, method, tips, and outcomes. *Plast Reconstr Surg*. 2011;127:161–172.
9. Jeng SF, Tan NC. Optimizing aesthetic and functional outcomes at donor sites. *Chang Gung Med J*. 2012;35:219–230.
10. Song YG, Chen GZ, Song YL. The free thigh flap: a new free flap concept based on the septocutaneous artery. *Br J Plast Surg*. 1984;37:149–159.
11. Kimata Y, Uchiyama K, Ebihara S, et al. Anterolateral thigh flap donor-site complications and morbidity. *Plast Reconstr Surg*. 2000;106:584–589.
12. Sadigh PL, Wu CJ, Shih HS, et al. Reverse anterolateral thigh flap to revise a below-knee amputation stump at the mid-tibial level. *Plast Reconstr Surg Glob Open*. 2013;1:e88.