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# The classification and treatment algorithm for post-burn cervical contractures reconstructed with free flaps

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**Abstract**

Neck contractures after burn produce restrictions in motion and unacceptable aesthetic outcomes. Proper planning and tissue selection is essential to minimize donor site morbidity while optimizing outcomes. A classification system and treatment algorithm aids in achieving this goal. Between December 1999 and January 2003, 40 burn patients underwent release and reconstruction with free perforator flaps. Neck extensibility and zone of injury were evaluated. Choice of reconstruction was based on available tissue, restriction degree and zones involved. Cervical territories were classified according to movement restrictions and amount of improvement. Reconstructive territories were classified as central above (CA), central below (CB), central above and below (CAB) and lateral (L). Single, split, double and preexpanded free flaps were used for the reconstructions. Maximal gain in motion was noted at 4 weeks and maintained for the average 11 months follow-up. Types of reconstructive territories showed significant effects on range of motion while etiology and time between injury and reconstruction showed no impact on the functional outcome.

Classification of neck territories aids in improving outcomes while minimizing donor morbidity. The central above territory, when reconstructed with free flaps, yielded the most rewarding improvement. A classification and treatment algorithm aids in achieving significant improvements in range of neck motion while taking into consideration the donor sites.


*Keywords:* Free flaps; Burns; Contracture; Microsurgery; Perforator flap

## 1. Introduction

Exposed regions such as the face and neck are commonly involved in severe burns especially in patients who did not have appropriate protective equipment in occupational accidents. Anterior cervical contractures are characterized by limitations in the range of neck motion, most noticeably extension. The scar may extend to or involve the face and the chest, thus, causing a synechia effect. Physical and aesthetic deformities resulting from this type of disfigurement in exposed areas, such as the face and the neck can cause significant depression [1], therefore affecting the patient's quality of life in ways other than just physical or functional disability. Aesthetic reasons alone would place cervicofacial contractures as a priority for reconstruction [2–7].

The principles of reconstructive surgery dictate that the defect should be replaced with donor tissues that have matching texture and color as well as pliability. Free flaps meet these criteria to replace scar tissues and repair the resulting defect post release, providing superior aesthetic and functional outcomes [8–15]. The color, however, is not always optimal. If the surgeon aims to completely release and reconstruct in one operation, a large defect in the neck

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that follows the scar release, the large surface area requirement may result in large donor site morbidity. Achieving a balance between minimizing donor site morbidity and complete scar resurfacing is a challenge that depends mainly on the size of the area involved, the region of involvement and the availability of non-scarred tissue for use as free flaps.

This paper will classify scarring of the anterior cervical region into specific zones and define associated reconstructive territories in relation to functional benefits and limitations of resurfacing with free flaps. By organizing anterior cervical scar reconstruction into distinct territories, an attempt can then be made to provide guidelines, or more specifically, an algorithm for prioritizing specific neck regions for reconstruction.

## 2. Patients and methods

Between December 1999 and January 2003, 40 patients with anterior cervical contractures underwent contracture release and reconstruction with free perforator flaps.

### 2.1. Data collection

A retrospective chart review was performed in search of the indication for surgery, the zones of scar involvement, the available tissue for reconstruction and the specific patient requests. All patients were preoperatively assessed in outpatient clinics followed by comprehensive discussions with the operating surgeon.

### 2.2. Patient profile (Table 1)

The group consisted of 33 males and 7 females with an average age of 41.1 ± 15.6 years (range: 8–62 years). The etiologies of the cervical contractures were flame burns in 30 patients, chemical burns in 6 patients and electrical burns in 4 patients.

Table 1
Demographic characteristics of all patients

| Variables | Data |
|---|---|
| Sex | 33 males; 7 females |
| Age: mean ± S.D. (range) | 41.1 ± 15.6-year-old (8–62) |
| Etiologies | 30 flame burns, 6 chemical burns, 4 electrical burns |
| TBSA of burns (range) | 29.8 ± 18.6% (8–69) |
| Source of referral | Other hospitals (18 patients); our own burns center (22 patients) |
| Time after initial injury: mean ± S.D. (range) | 1.6 ± 0.9 years (0.8–4) |
| Neck scar zone involvement | Zone I (64.3%); II (64.3%); III (71.4%); IV (71.4%) |
| Times of previous skin grafts: mean ± S.D. (range) | 1.9 ± 0.9 (1–4) |

The choice of free flaps included anterolateral thigh (ALT) perforator flaps ($n = 32$), lateral thigh perforator flaps ($n = 2$), medial thigh (MT) perforator flaps ($n = 3$), tensor fascia lata (TFL) perforator flaps ($n = 2$) and a thoracodorsal artery (TD) perforator flap ($n = 1$). The free flaps were split into two separate skin islands in six patients to allow for better geometric alignment (split free flaps), flaps in two patients were preexpanded at the donor site (preexpanded free flaps), and in two patients flaps were used in combination with another free flap (double free flaps). In the remainder of patients ($n = 30$) the free flap was harvested and conventionally used as a single skin paddle alone.

### 2.3. The classification system (Fig. 1)

Our purpose was to define the zones of scar contractures in burn patients with anterior cervical contractures, in association with their reconstructive territorial features, and to comment on their related microsurgical characteristics. Establishing the classification system was an evolving process, based on the clinical experience of our unit over the last 4 years, during which we learned about characteristics of these contractures and reconstruction with free flaps as well as their outcomes [1].

#### 2.3.1. Zones of anterior cervical scar involvement

The zones of scar involvement are divided into four quarters according to two lines: a horizontal line crossing the thyroid cartilage and a vertical line passing through the midpoint of the mandible. The anterior cervical region is divided into the upper right zone (zone I), the upper left zone (zone II), the lower left zone (zone III) and the lower right zone (zone IV).

#### 2.3.2. Reconstructive territories of the neck

This classification system is based on a large experience with neck contracture release and reconstruction using a variety of methods. It is used for planning reconstructions with free flaps. The reconstructive territories of the neck are classified into four regions based on the functional benefit that is achieved in range of motion improvement following scar release, partial excision and reconstruction with free flaps.

1. Central above (CA): the most commonly reconstructed territory. The flaps are placed on the upper zones above the thyroid cartilage (zones I + II).
2. Central below (CB): the flaps are placed on the low zones below the thyroid cartilage (zones III + IV).
3. Central above and below (CAB): this is synonymous with the near-total anterior cervical replacement where the flap replaces the neck scar across both upper and lower zones (zones I + II + III + IV).
4. Lateral (L): the flap is located on the lateral side of neck (zone I + IV or II + III).

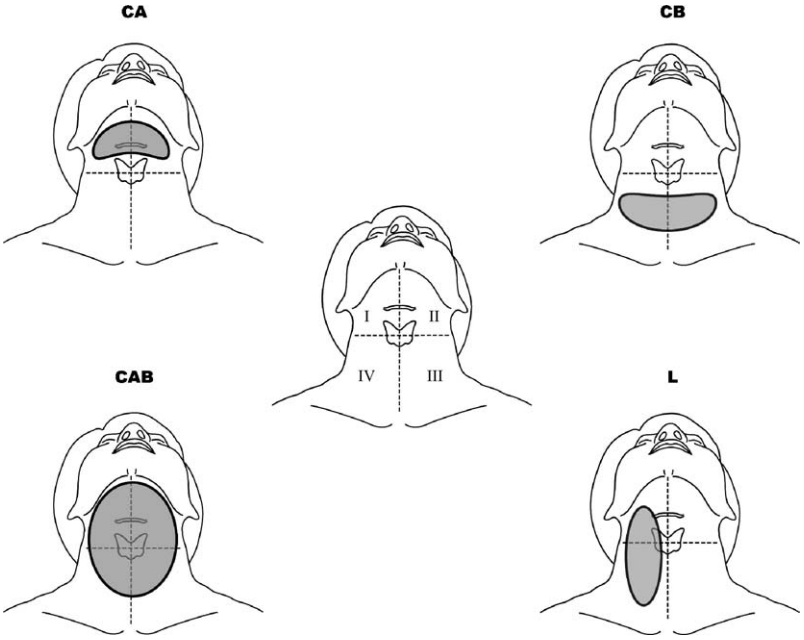


Fig. 1. Classification system: the zones of anterior cervical scar involvement (zones I–IV) and the reconstructive territories of the neck (CA, CB, CAB and L reconstructive territories).

*2.3.3. Grades of neck extension deficit*

Based on a previously proposed classification [8], the functional grading for neck extension was used for the evaluation of extension deficit severity. The grades include Normal (N): extension greater than 110°, E1: extension beyond the horizontal plane, parallel to the ground (95–110°), E2: extension and vision limited to the horizontal plane only (85–95°) and E3: mentosternal synechia (<85°) where patients only have a visual range below the horizontal plane. These grades are also useful for defining the indications for free-flap reconstructions as well as being used as a tool for reassessment of neck motion after reconstruction.

Improvement of function is based on measurements of neck motion, according to the following equation (all motion ranges in degrees of angles).

$$\text{Outcome of functional improvement}\,(\%) = \frac{\text{postoperative range} - \text{preoperative angles}}{\text{ideal range} - \text{preoperative range}}$$

(The ideal range for extension = 120°; ideal range for rotation = 90°; ideal range for lateral flexion = 50°).

*2.4. Indications for free-flap neck reconstruction*

The criteria for free-flap reconstruction of burn cervical contractures [8] included limited range of neck motion (equal or more severe than E2) for at least 6 months after an aggressive rehabilitation program with or without surgical release, skin grafting, local flaps or z-plasties.

*2.5. Postoperative care after reconstruction*

The patients were taught and advised to perform a set of motion exercises 1 week postoperatively in order to prevent neck stiffness; however, no aggressive rehabilitation and garments were required. All patients were evaluated at monthly intervals.

*2.6. Statistical analysis*

Statistical analyses were performed to determine the effects of different factors on functional outcome, including burn etiology, extent of scar release, time after initial injury and types of reconstructive territories. Analysis of variance with Fisher's protected least-significant difference post hoc test (SPSS 10.0, Taiwan) was used to determine whether there were significant differences between each group. The statistical significance was established at $p = 0.05$.

## 3. Results

All flaps survived and healed well. Two reexplorations were required within the first 24 h postoperatively due to venous thrombosis, but these healed uneventfully after thrombectomy. No major complications of the donor sites were seen. The average hospital stay was 10.2 days. Secondary thinning of the flaps was performed in 10 patients. The functional evaluation was done after an average of 6.3 months (Table 2). All cases had normal

Table 2
Neck movement pre and post surgery based on the zone of involvement

| Classification | Number of cases | Average percentage resurfaced | Average range of extension (°) | | Average range of lateral flexion (°) | |
|---|---|---|---|---|---|---|
| | | | Preop | Postop | Preop | Postop |
| CA | 26 | 55.5 | 89.1 | 114.5 | 26.3 | 34.4 |
| CB | 5 | 92.2 | 96.3 | 118.0 | 30.0 | 43.2 |
| CAB | 4 | 89.5 | 83.0 | 117.6 | 25.9 | 36.2 |
| L | 5 | 90.2 | 110.2 | 120.1 | 23.1 | 40.0 |

Preop: preoperative; Postop: postoperative.

Table 3
Univariate relationship between variables and outcomes

| Variables | Number of cases | Outcome of functional improvement (mean in %) | *p*-value |
|---|---|---|---|
| Etiologies | | | |
| Flame | 30 | 85.70 | 0.950 |
| Chemical | 6 | 85.76 | |
| Electrical | 4 | 84.42 | |
| Time after initial injury | | | |
| <1 year | 10 | 84.95 | 0.686 |
| 1–2 year | 17 | 84.81 | |
| >2 year | 13 | 87.09 | |
| Reconstructive territories | | | |
| CA | 26 | 82.46 | 0.001* |
| CB | 5 | 91.70 | |
| CAB | 4 | 93.52 | |

Outcome of functional improvement (%) = (postoperative range − preopera-preoperative range)/(ideal range − preoperative range).
The ideal range for extension = 120°; the ideal range for rotation = 90°.
* Statistically significant ($p$-value ≤0.05).

extension grade after free-flap reconstruction. The average follow-up period was 11 months.

The etiologies ($p = 0.950$) and time after initial injury (the time between the burn incident and the free tissue transfer, $p = 0.686$) showed no significant difference on the functional result; however, the reconstructive territories ($p = 0.001$) demonstrated significant influence on the outcome (Table 3). The average increase in flap width during cervical extension of free flaps in CA, CB and CAB reconstructive territories were 38.0% (2.85 cm), 18.5% (1.39 cm) and 14.6% (2.38 cm), respectively (Table 4). The average time required to reach the constant flap width, with adequate home rehabilitation program, was 4 weeks postoperatively (Fig. 2).

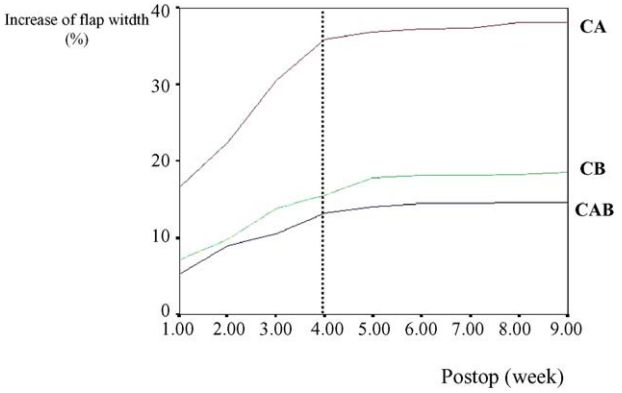


Fig. 2. The average increase in flap width (%), shown according to different free flap territories.

## 4. Discussion

The cervicofacial area is the most important aesthetic and functional region in burn patients. The natural neck posture places the head in the most optimal alignment for daily interactions. Overall body posture changes and eye movements can compensate for slight alignment alterations that may occur due to hyperflexion or hyperextension of the neck. Unlike other joints, which are normally in maximal extension (e.g. the knee), the neck is in a neutral contracted position during standing. Due to gravity and weight of the head on the neck, the chronic flexion contracture is often seen in deep extensive cervical burns despite improved acute burn care and treatment in recent years. In Taiwan, all burn victims receive well-planned multidisciplinary support from burn centers and community foundations which includes rehabilitation, psychological consultations, medical and paramedical advice, social assistance and many other services. However, severe scar contractures of the neck

Table 4
Change in flap width at different intervals related to the reconstruction

| | Average flap width intraoperatively (cm) | Average gain in flap width after rehabilitation (cm) | Average increase in flap width (%) |
|---|---|---|---|
| CA | 7.5 | 2.85 | 38.0 |
| CB | 7.5 | 1.39 | 18.5 |
| CAB | 16.3 | 2.38 | 14.6 |

Average increase in flap width (%) = (gain in width (cm))/(flap width intraoperatively (cm)).

still occur despite daily rehabilitation programs and other precautions such as sleeping without a pillow. It is often a major cause of distress and anxiety for the patients, especially when they had already invested so much time and effort into preventing such a complication from occurring.

Expanded full thickness skin grafts from the abdomen to cover the whole anterior neck can provide good results in burn contracture. However, there is evidence in literature, which has shown that free flaps give superior functional results in the reconstruction of scar contractures, especially thin cutaneous perforator flaps [8,10,11]. The ideal microsurgical burn reconstruction is one that replaces the damaged scarred tissue with tissue of the same quality and quantity from donor sites, which have minimal visibility, in a one-staged procedure, without sacrificing other types of tissues unnecessarily. However, surgeons are often faced with many problems when reconstructing burn contractures: first, soft, pliable and healthy tissues, which are ideal for reconstruction are often not preserved during the initial burn injury; second, donor sites for free flaps are often deformed due to previous skin graft harvests; third, the patients suffering from multiple scarred and deformed areas seek with great efforts to minimize scarring in other regions; fourth, microsurgeons limit their practice to select flaps that have proven reliability, despite the fact that in burn patients more flexibility is the selection of free-flap donor sites is necessary; fifth, microsurgery has specific technical hurdles that surgeons must surmount to be able to provide their patients with the best possible treatment. Microsurgical reconstruction may be time-consuming and exhausting if a well coordinated team approach is not put into effect. Apart from the initial exhausting effort, the surgeon must be willing to deal with emergent explorations and salvage procedures whenever necessary. The benefits of free tissue transfer in select patients without significant coexistent medical histories outweigh the risks of the longer surgery and anesthesia time and the added costs of a longer hospital stay. Free tissue transfer, in the patients with indications for its use, provides a good cosmetic outcome and a definitive solution for the problem with a significantly less requirement for postoperative physical rehabilitation than skin grafts and some local flaps; sixth, the flaps may be thinned if the aesthetic requirement is of concern; finally, free-flap surgery adds the risk of complete failure (although the skin flap can be used as a skin graft if free-flap salvage efforts fail). At this institution, great efforts are taken to improve, simplify and expedite free-flap surgery. In our department, the lateral thigh region is rarely used as a skin graft donor site during the acute burn treatment in case free-flap surgery is later required. In patients where these regions were used, the surgeon must be flexible in finding other areas for use if available. Currently, we have restructured our principles for acute burn care to exclude the use of the thighs, back and upper arms as donor sites for skin grafts. These regions are preserved for reconstruction of areas following contracture release. Although retrieving a skin graft from this region does not affect later flap survivability, it will not allow for an optimal aesthetic outcome. Avoiding the use of the thigh skin as a donor site for skin grafts is only practical in small to medium sized burns, as the need for initial wound coverage will outweigh the benefit of preserving these sites, and in some cases, these will be the only or best donor sites a burn patient will have. In that situation the thigh skin may be used and one has to accept the potential for a disadvantaged cosmetic outcome if a free flap is performed from that region.

Classifying the region of the neck into zones that have clinical significance and surgical implications is necessary in order to properly prioritize the areas undergoing contracture release and reconstruction. Donor sites for free tissue transfer are often limited in burn patients and the size that can be harvested without causing significant morbidity at the donor site is limited. The anterior cervical region is divided into zones with the thyroid cartilage as the intersection point of both vertical and horizontal line, thus, dividing the neck into four zones. It has been shown that the main component of neck extension occurs in the upper neck [16–18]. Thus, based on our classification system, zones I and II of the anterior cervical skin are required to undergo the greatest amount of stretch. Teleologically, the extensibility of the soft tissue in these zones is most essential to maintaining neck extension. Zone III and IV allow for further extension of the neck and take a secondary role in neck movements. Therefore, when a limited size of free flap can be harvested, priority is given to zone I and II as more gain can be obtained from reconstructing this region. For surgical purposes, we have found a benefit in classifying territories in the neck based on the anatomic classification of zones in order to assist in planning flap design. The flap can be inset to reconstruct the neck in several possible combinations. Reconstruction of all territories results in the most dramatic improvement in the flexion contracture. However, this has the highest chance of resulting in significant donor site morbidity. If donor site morbidity is a significant concern for the patient, then reconstructing the CA territory (zone I and II) results in the most gain while donor site closure can be performed primarily without the need for skin grafts.

It was also noted in this series that postoperative stretching of the flap used for reconstruction occurs, especially in patients whose flap did not have adequate dimensions for a full resurfacing of the area of contracture, where an inadequate resection of scar was performed. The limitation of reconstructive territories often caused inadequate release of contracture. More residual scars result in more stretching of the flap along the direction of cervical extension because only soft, pliable tissues (e.g. flaps) can divert larger forces. Therefore, lesser increase in the flap width was seen in CAB and CB flap reconstructions where the scars were almost completely replaced without tethering of residual scars. We found that there was an impressive

increase in the width of flaps placed in the CA territory when compared with free flaps placed in the CB territory during neck extension, especially if only one small flap is used. Free flaps for CA territory are also aesthetically more important due to their proximity to the face. In addition, distortions in the reconstruction can have aesthetic and functional implications on facial tissue in proximity (i.e. lip ectropion). Thus, in select patients, free flaps for CA territory is indicated for the correction of distortions in lower facial soft tissue.

This classification system has been developed and adopted at this institution and has proven to be beneficial when deciding which areas should be reconstructed. The exact location of the scar in the neck creates specific and predictable limitations in the range of motion. For example, zone I scars characteristically limits lateral flexion and rotation of the neck. Nevertheless, this prioritization system can be applied to reconstructions involving skin grafts, as the key feature of identifying these zones and territories is which ones yield the most gain in neck extension with the least amount of donor tissue.

The Neck Extension Deficit Grading System serves as a practical functional assessment, because the severity reflects the patients' physical difficulties with neck extension and associated daily tasks [8]. Patients with grade E1 deficits are unable to see objects placed above the level of their head. Limitation in neck extension prohibits these patients from extending the range of visualization field in upward gaze. Patients with grade E2 (or greater) deficits often characteristically tilt their whole body backwards to make eye contact with another person, as their upward gaze cannot reach the normal "eye-level" visual range. As for those with severe mentosternal synechia (grade E3), they make minimal eye contact, adapt a characteristic stooped posture and have a persistent upward gaze that is severely limiting during daily activities and daily interactions. In this series of patients reconstructed with free flaps were able to achieve normal neck extension and maintain this gain for the duration of the follow-up period. Interestingly, patients followed for up to 3 years did not have any regression in neck extension even though minimal exercises were performed.

The principles behind the algorithm used for planning these reconstructions where a release is performed followed by free tissue transfer are outlined herein:

(1) Total scar release and replacement is the main goal and priority of reconstruction.
(2) A one-staged reconstruction with primary closure of one donor site was preferred over other alternatives as these patients suffer enough from multiple scars.
(3) Reconstruction of the CAB territory is preferred when all four zones are involved. However, if donor sites are limited or in order to limit donor site morbidity, priority is given to the CA region. This type of reconstruction is a compromise between restoring function in the neck without causing significant harm at the donor sites. In this study, flaps placed into the CA territory were the most common type of reconstruction.
(4) Flaps placed into the CB territory are used only in cases with scars limited to zones III and IV and should not be the first option if the scar advances superiorly into zones I and II.
(5) Flaps inset into L territories are only suitable for scars involving the lateral neck (zone I and IV or zone II and III). In these patients, we have found an added benefit in performing z-plasties around the flap margin. By performing these z-plasties, the junction between healthy flap tissue and scared tissue is less dramatic and less post operative contracture occurs as a result.
(6) In patients with the most severe types of limitation in neck extension, donor site morbidity becomes less of a priority. Severe scars with grade E3 extension deficit require extensive resurfacing with larger flaps. We have tended to allow the patient's desires to guide the choice of reconstruction.

Choice of free flaps and flap design is critical in order to optimize the results of reconstruction. In our practice, a variety of flaps are considered including free split perforator flaps, double free flaps and preexpanded free flaps [19–23]. The thigh is an ideal donor site for the provision of free flaps in our burn center because of the availability of multiple flaps in one region, the lack of significant anatomic variation, the ability to thin perforator flaps from this region, the ability to use a two team approach in most cases, the benefit of avoiding sacrifice of a major vessel in the limb, and the ability to harvest a flap of significant size while being able to close the donor site primarily [24–28]. The drawback of thigh skin is that it is quite different in color from that of the neck. Flaps of the thigh can also be harvested in the true freestyle method, where an anterior midline incision is made without preoperative Doppler assessment. Intraoperative judgment on the number of perforators should be based on two rules: to achieve primary closure of the donor site and to provide the largest resurfacing flap possible. If two optimal sizable perforators exist over the lateral thigh, free split ALT perforator flaps can be used. The definition of free split flaps was described for pure separate cutaneous paddles supplied by different perforators with a common pedicle [29]. If only one suitable perforator is seen over the lateral thigh, further planning and designing will be required with options such as double free flaps [30] (two independent free flaps with two sets of microanastomoses, e.g. one ALT perforator flap and one tensor fascia lata perforator flap) or preexpanded free ALT flaps (mean a free flap with prefabrication by tissue expansion) [31]. This usually depends on discussions between the surgeon and patient in regard to planning staged procedures with a long-term goal. If a staged procedure can be accepted, a preexpanded free flap is preferred. Otherwise, a one-staged double free flaps procedure can be performed; the two flaps, harvested at the same time, can be from one thigh (e.g. ALT and tensor

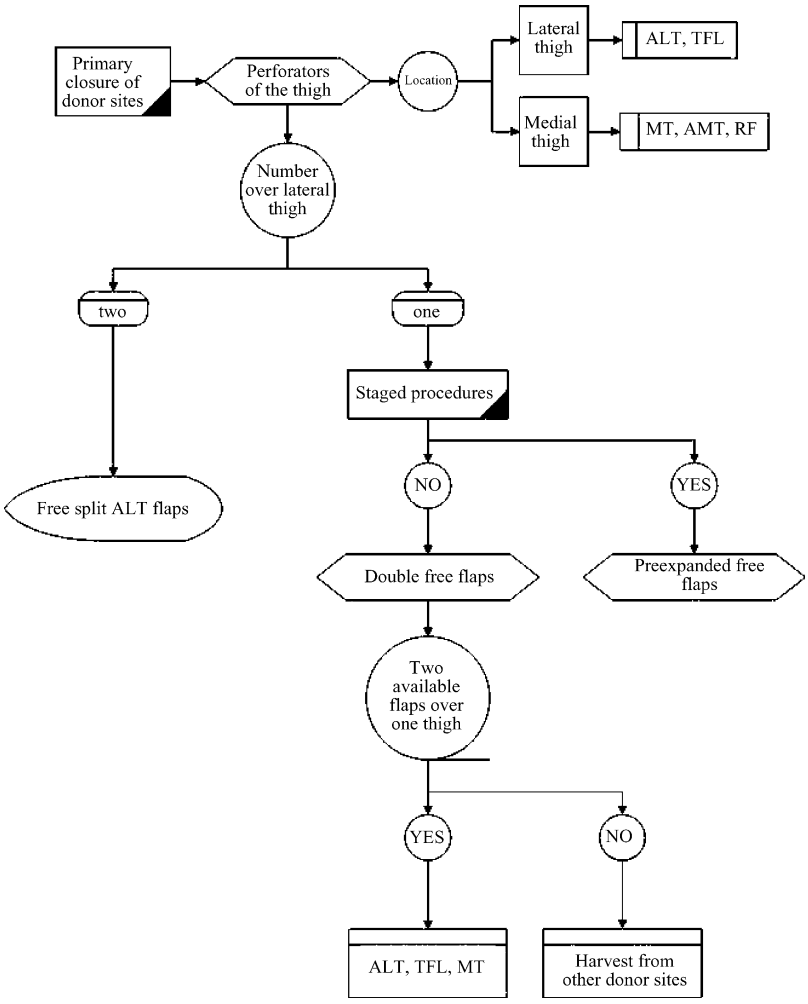


Fig. 3. An algorithm summarizing the planning process of reconstructing anterior cervical contractures.

fascia lata flaps) or one thigh plus another donor sites (e.g. ALT and latissimus dorsi flaps). An algorithm for reconstructing anterior cervical contractures is summarized in Fig. 3.

The contouring and shaping of free flaps in the cervicofacial region is the key to a successful reconstruction. Intraoperative thinning of free cutaneous flaps plays a major role in creating the eventual neck contour. The flap should simulate the thin skin of a normal neck. Other alternative techniques to improve the aesthetic aspects of cervicoplasty include, platysma muscle plication, de-fatting of all cervical planes, anchoring or tenting suture of the flap to the periosteum of the mandible and the strategic placement of suction drains [32–37]. The thin flap will spontaneously fit the revised cervical wound bed by the aforementioned techniques.

In our study, the permanent, improved range of neck motion was achieved within a fairly short period (4 weeks postoperatively), coinciding with the time at which the permanent flap width is reached (Fig. 2). The use of free flaps prevents long painful rehabilitation programs and eliminates the necessity for uncomfortable pressure garments. Postoperative rehabilitation is still essential to prevent fibrosis in the interface between the flap and the healthy wound bed beneath [38]. However, a home rehabilitation program is often adequate. For those with CB reconstructions and those with scar involvement of the whole neck, aggressive rehabilitation is often necessary due to the effects of residual scars. Thus, in principle, the more the residual scars, the more vigorous the rehabilitation will be needed.

Finally, both the burn etiology and the time after initial injury showed no statistical significance to functional outcome, whilst free flap territory was statistically significant. This implies that many post-burn contracture patients may be candidates for free-flap reconstruction. However, the types of free-flap reconstruction need to be carefully considered to achieve better results. Appropriate planning and placement of free flaps in anterior cervical contracture reconstructions is essential to achieve a good surgical outcome.

Skin grafts and local flaps yield good results when performed for the reconstruction of post-burn contracture defects by experienced surgeons. Free tissue transfer can find its indications in patients with minimal medical

co-morbidities who are willing to undergo a longer surgical procedure and a longer hospital stay with the benefit of potentially improved aesthetic outcomes at both the site of reconstruction and the flap donor site, and long term maintenance of the results with minimal requirement for postoperative physical rehabilitation.

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