Thoracodorsal Artery Scapular Tip Autogenous Transplant

Vascularized Bone With a Long Pedicle and Flexible Soft Tissue

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Objective: To demonstrate that the 3 reconstructive advantages of the thoracodorsal artery scapular tip transplant (Tdast), a long pedicle, independently mobile tissue components, and the 3-dimensional nature of the scapular tip, will improve the quality and success of complex reconstructions by avoiding vein grafting, preventing the need for 2 separate transplants, and facilitating bony inset.

Design: Prospective case series.

Setting: Tertiary care academic medical center.

Patients: Twenty-one patients (male to female ratio, 16:5; mean age, 52 years) underwent reconstruction of the upper, middle, and lower face from 2001 through 2006. Indications for reconstruction were tumor ablation in 11 patients, secondary reconstruction in 4 patients, osteoradionecrosis in 4, and posttraumatic reconstruction in 2. Seventeen patients underwent radiation.

Interventions: All patients underwent harvest of an autogenous transplant of scapular tip bone and latissimus dorsi soft tissue based on the thoracodorsal artery. The mean bone length was 5.2 cm (range, 2.5-9.0 cm), and the mean cutaneous surface area was 68 cm² (range, 20-250 cm²).

Main Outcome Measures: Reduction of vein grafting, avoidance of 2 transplants, use of the triangular shape of the scapular tip in reconstruction, complications, and shoulder function.

Results: The success rate of transplantation was 100%. The use of this transplant avoided vein grafting in 16 patients and the need for 2 separate transplants in 11 patients, and the 3-dimensional nature of the scapular tip facilitated inset in 13 patients. In 14 patients, more than 1 of these reconstructive advantages was achieved. In 6 patients, all 3 were accomplished. Eleven patients experienced a complication. The major complication rate was 33%, and the minor complication rate was 33%. The mean Constant-Murley test of shoulder function score was 87 of 100 (range, 74-100).

Conclusions: The Tdast is an excellent choice for reconstruction in the head and neck as an alternative to procedures requiring vein grafting and multiple free tissue transplants, or in which the 3-dimensional contour of the scapular tip aids in reconstruction. The complication rate should be assessed in the context of the risk factors of the patient population and the outcome with respect to stable employment, increasing body mass index, and maintenance of shoulder function.


There are 4 donor sites commonly used for autogenous transplantation to reconstruct head and neck defects that require bone: the fibula, iliac crest, scapula, and forearm. Several other donor sites, such as the tibia and metatarsal, have been described but have not had widespread use. The ideal osseous transplant would be accompanied by ample soft tissue that would have the flexibility to reconstruct a wide variety of defects, would have a long vascular pedicle and would be easily shaped into a variety of 3-dimensional defects. None of the 4 osseous donor sites can satisfy all these needs; an innovation to develop and describe a new osseous donor site would benefit patients, particularly those patients with vessel-depleted necks, with the most complex, multisurfaced defects, and with defects in the mid or upper face.

The scapular tip donor site was described by Uglesić et al.1 The scapular tip is supplied by the thoracodorsal dorsal artery vascular system. The pedicle length is longer than any other osseous donor site, and the scapular tip is triangular and can be harvested in a variety of 3-dimensional shapes. The triangular tip is useful for palatal maxillary and orbital reconstruction. The lateral border with the tip can also be harvested and is useful in mandibular reconstruction. In addition, the thoracodorsal vascular system also supplies the latissimus muscle with its over-
lying skin, the serratus muscle, and is closely associated with the circumflex scapular vascular pedicle. The availability of a variety of soft-tissue options on the thoracodorsal pedicle prevents the need for 2 free tissue transfers in situations in which there are bone and higher volume soft-tissue requirements to reconstruct a defect.

We evaluate the use of the thoracodorsal artery scapular tip autogenous transplant (Tdast) in patients with complex, multisurface defects and previously treated, vessel-depleted necks. We hypothesize that the 3 reconstructive advantages of the Tdast—a long pedicle, independently mobile tissue components, and the 3-dimensional nature of the scapular tip—will improve the quality and success of complex reconstructions by avoiding vein grafting, preventing the need for 2 separate transplants, and facilitating bony inset.

STUDY DESIGN

This prospective case series included 21 patients with major defects of the head and neck reconstructed by surgeons in the microvascular program of the Department of Otolaryngology—Head and Neck Surgery at the University of Michigan Health System, Ann Arbor, from May 2001 to December 2006.

PATIENT POPULATION

The inclusion criteria were designed to include patients who had extensive defects and intense concomitant treatment. Patients were eligible if they had a defect of the head and neck reconstructed with a thoracodorsal artery scapular tip osseous transplant. Indications for reconstruction were tumor ablation in 11 of the 21 patients (52%), secondary reconstruction in 4 (19%), osteoradionecrosis in 4 (19%), and posttraumatic reconstruction in 2 (10%).

Seventeen males and 5 females met the inclusion criteria. One patient declined to participate, leaving 16 males and 5 females with a mean age of 52 years (range, 3-74 years). It should be noted that the scapula is incompletely ossified until 20 years of age.2 The overall mean follow-up duration was 31.6 months (range, 5-81 months). All patients had a bony defect: 9 of the 21 patients (43%) had defects of the midface, 9 (42%) had a combined mucosal-cutaneous oral cavity defect, 2 (9%) had an upper face defect, and 1 (5%) had a defect of the oropharynx.

The mean cutaneous portion of the transplant was 68 cm² (range, 95-250 cm²). The treatment regimen was intense in this cohort: 17 of 21 patients (80%) received radiation. Of these 17 patients, 5 (29%) failed radiation and underwent salvage surgery, 5 (29%) received postoperative radiation, 2 (12%) failed treatment with chemoradiation and underwent salvage surgery, and 5 (29%) received postoperative chemoradiation. Of the 5 of 17 patients who failed radiation (29%), 2 underwent postoperative chemoradiation. Of the 21 patients, recipient vascular access was attained with a neck dissection for 8 (38%), a neck exploration for 11 (52%), and a temporal artery exploration for the remaining 2 (10%).

SURGICAL APPROACH

Patient positioning was one of the important components of surgical planning that reduced operative time and facilitated a partial 2-team approach. Rather than performing the extirpa-

OUTCOME MEASURES

Outcome measures included were major and minor complications, shoulder function assessment, reduction in vein grafting, prevention of the use of multiple free tissue transfers, and use of the 3-dimensional shape of the bone of the scapular tip.
Shoulder function was assessed using the Constant-Murley test of shoulder function (hereinafter, Constant test), a validated, cross-disease, administered, objective evaluation of shoulder impairment. In addition, there is a subjective portion of the test that includes having the patient quantify their degree of shoulder impairment related to pain during daily activity, recreation, work, sleep, and movement. Objective measures include formal evaluation of range of motion as well as static weight testing. The test is scaled to a 100-point cumulative score, where higher scores denote better shoulder function. The Constant test was performed during a clinic visit at least 12 months following completion of treatment (mean, 30 months [range, 12-68 months]). At the time of the cross-sectional assessment there were 9 surviving patients who underwent Constant shoulder testing.

STATISTICAL ANALYSIS

Univariate data were tabulated on radiation, defect, body mass index, complications, Constant test score, neck dissection, and Tdast characteristics.

The Tdast was used in defects where 1 or more of 3 reconstructive challenges were present. First, vein grafting would be required because the vascular access was limited adjacent to the defect; second, 2 separate transplants would be required to optimize the soft-tissue reconstruction because the defect included 2 epithelial surfaces, such as the skin and the oral cavity mucosa; third, the triangular shape, or curve, of the scapular tip assisted in the reconstruction of the bony defect. The long pedicle of the Tdast donor site avoided vein grafting in 16 of the 21 patients (76%). Had we chosen an alternative donor site, such as the lateral border of the scapula or the fibula or the iliac crest, then vein grafting would have been required to reach the recipient vessels in these 16 patients. Of the remaining 5 patients, 2 underwent a vein graft despite the length of the Tdast vascular pedicle; the other 3 patients did not have vascular access issues, and a primary vascular anastomosis would have been possible even if an alternative donor site had been chosen. The mean length of the bone and pedicle measured together was 27 cm (range, 23-32 cm). The mean bone length was 5.2 cm (range, 2.5-9.0 cm). If the mean bone length is subtracted from the total distance from the scapular tip to the axillary artery, this length corresponds well with the 20 cm of pedicle length from the proximal end of the bone reported by Uglesˇic´ et al.1

With respect to the second reconstructive advantage of the Tdast, the availability of 2 independent cutaneous paddles avoided the harvest from 2 separate donor sites in 11 of the 21 patients (52%). Had we chosen an alternative osseous donor site, such as the fibula or the iliac crest, then 11 patients would have required a reconstruction that would have required 2 separate donor sites; 1 of the donor sites would have been harvested as an osteocutaneous transplant, and the second would have been soft tissue. The use of the Tdast avoided the need for a second donor site in these 11 patients. None of the remaining 10 patients would have required 2 donor sites.

With respect to the third reconstructive advantage, the shape of the scapular tip replaced the need for osteotomy in 13 of the 21 patients (62%) (Figure 2). If these 3 reconstructive advantages are taken together, 8 patients (38%) derived benefit from at least 2 of these advantages and 6 (29%) derived benefit from all 3 reconstructive advantages (Figure 3). The 2-paddle advantage associated with an independent bone component was most useful in the patients with an oral cavity defect. Nine of the 11 patients with an oral cavity defect (82%) avoided

**RESULTS**

The length of the pedicle was estimated by measuring the distance from the axillary artery to the scapular tip on a preoperative chest computed tomographic (CT) scan. If a preoperative CT scan was not available, then a postoperative CT scan was used, and the contralateral donor site was measured. This is a composite measure that includes the length of the pedicle and bone together. The preoperative CT scan was available from 9 patients, and the postoperative scan was available from 5 patients. Patients younger than 18 years were excluded from this outcome measure.

Major complications were those that included death, loss of the transplant, and return to the operating room for secondary reconstruction. Minor complications were those requiring medical treatment, hematoma, and local wound care that did not require an operative procedure.

Shoulder function was assessed using the Constant-Murley test of shoulder function (hereinafter, Constant test), a validated, cross-disease, administered, objective evaluation of shoulder impairment. In addition, there is a subjective portion of the test that includes having the patient quantify their degree of shoulder impairment related to pain during daily activity, recreation, work, sleep, and movement. Objective measures include formal evaluation of range of motion as well as static weight testing. The test is scaled to a 100-point cumulative score, where higher scores denote better shoulder function.
harvest in 2 different donor sites, and 7 (64%) avoided a vein graft. Avoidance of vein grafting was the most valuable advantage for the orbital defect patients. Six of the 7 patients with an orbital defect (86%) avoided vein grafting, and 6 of the 7 (86%) derived benefit from the shape of the scapula (Figures 4, 5, 6, 7, and 8).

The success rate of transplantation was 100% (21 of 21 patients), but 3 patients underwent reexploration, 2 for venous congestion and 1 for pedicle avulsion. Both patients with venous congestion experienced this within 5 hours after surgery and had a simultaneous hematoma. The avulsion was a result of patient agitation during rapid emergence from general anesthetic. This episode occurred in the operating room, was identified because of an expanding neck hematoma associated with sudden change in the appearance of the transplant, and was immediately repaired. The overall complication rate was 32% (11 of 21 patients). Of the 11 patients who experienced a complication, 5 had 1 complication, 4 had 2 complications, and 2 had 3 complications. If divided by major and minor complications, 7 of the 21 patients (33%) experienced at least 1 major complication, and 7 (33%) experienced at least 1 minor complication. Of the 7 patients who developed a major complication, 3 of the 7 developed pedicle compromise as detailed at the begin-

ning of this paragraph, and the remaining 4 patients developed partial necrosis of the transplant. Of the 4 patients who developed partial necrosis of the transplant, 3 of the occurrences were in the latissimus component, and 1 occurrence was in the parascapular component. All 4 patients were taken to the operating room promptly for debridement, and 2 of the 4 patients with partial transplant necrosis also developed a fistula, which healed without further operative intervention. None of the patients who developed partial necrosis required further tissue transfer or tissue transplantation.

There was a relationship among radiation, prior reconstructive procedures, and partial transplant necrosis. As mentioned in the “Methods” section, 17 of the 21 patients (81%) underwent radiation treatment; of these 17 patients, 9 (53%) underwent radiation prior to sal-
vage surgery with the Tdast for reconstruction. All of the patients who developed partial necrosis of the transplant had undergone prior radiation treatment. Of the 9 patients who had undergone prior radiation treatment, 4 (44%) developed partial necrosis of the cutaneous transplant. There was also a relationship between prior reconstructive procedures and partial necrosis of the transplant. Seven of the 21 patients (33%) had undergone reconstruction with a tissue transplant or a regional flap prior to the Tdast. Of these 7 patients, 4 (57%) developed partial necrosis of the transplant, whereas 1 of 14 (7%) who did not undergo prior reconstruction developed necrosis of the transplant. Stated another way, of the 4 patients who developed partial necrosis of the transplant, 3 had undergone prior reconstructive procedures. These data suggest that partial necrosis of the transplant is related to prior radiation treatment and prior reconstructive procedures. Interestingly, the 3 patients who experienced pedicle compromise and the 4 patients who experienced partial transplant necrosis were mutually exclusive. Pedicle compromise did not seem to be related to a history of radiation or reconstructive procedures. Of the 7 patients who experienced a minor complication, the most common minor complication was a hematoma.

The donor site complication rate was 10% (2 of 21 patients). The complications were 1 each of hematoma and wound dehiscence. Both of these patients also experienced complications in the transplant inset site. Factors such as size of the transplant and low body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared) were considered as possible predisposing factors, but neither of these patients underwent harvest of a combined Tdast and parascapular transplant, nor were their transplants above the median surface area for the cohort, nor were their BMIs below the median value. They were healthy-appearing males whose BMI values were 31.3 and 26.7, respectively, and whose surface area of the transplant was 60 cm².

The late complication rate was 24% (5 of 21 patients). Of these 5 patients, 4 had 1 late complication, and 1 had 2 late complications. Plate exposure was considered a late complication, and all 5 patients experienced a plate exposure. The patient who experienced 2 complications had a plate exposure and nonunion of the mandible that required a fibula transplant. This is the only patient in the cohort who required a second transplant. Late complications were associated with early complications; all of the patients who developed a late complication also had an early complication. Of these 5 patients who developed a late complication, the associated early complications were as follows: 3 patients had partial necrosis, 1 patient had pedicle compromise, and 1 patient had a hematoma.

Shoulder function was tested in 9 patients. The mean Constant shoulder function value (of a possible 100) was 87, and the median value was 85 with a range of 74 to 100. All 9 patients could raise their heads above their heads with the elbow in the plane of the back. Of the 17 patients for whom we could evaluate work status, 2 had a negative change in work status. In addition, BMI remained stable; the mean scores were 23.8 preoperatively and 25.3 postoperatively.

The combined myocutaneous latissimus dorsi/osteocutaneous scapular-parascapular free flap was initially described in 1984 by Batchelor and Sully for a massive scalp defect reconstruction. Since that time, published reports have described further use of the Batchelor technique and a variation of this procedure by use of the angular vessels that supply the scapular tip.4,7

Based on the results of this study, the thoracodorsal artery scapular tip transplant is thought to be a valuable option for patients requiring complex reconstructions. The series of patients described herein benefited from the 3 important reconstructive advantages of this transplant. The first advantage demonstrated in this study is the multiple tissue types available with the thoracodorsal artery vascular system. This is an important feature of this donor site because it allows for bony and soft-tissue components that are freely mobile from one another without the need to use 2 separate transplants. Wei et al9 described indications for the use of 2 simultaneous transplants to include extensive composite defects that cannot be adequately addressed with 1 transplant, large intraoral defects, and large defects requiring 3-dimensional reconstruction. In head and neck reconstruction of large defects, the Tdast allows the reconstructive surgeon to separately address 2 distinct anatomical subunits. Examples of this include reconstruction of the palate and orbit in maxillary carcinoma or reconstruction of the mandible and complete tongue in oral cavity carcinoma. Futran et al9 described the successful use of fibula transplant for midface reconstruction. Their series demonstrated excellent results using the fibula transplant for maxillary reconstructions. They noted, however, that the fibula transplant has limitations when used for reconstruction of the maxillary superstructure, which includes the orbital floor and zygomatic complex.9 These limitations are due to difficulty with multiple osteotomies and limited rotation of the skin paddle. Clark et al10 described the use of the scapular angle, supplied by the angular branch of the thoracodorsal artery, for bony re-
construction of the maxilla. They also include a portion of the teres major in their transplants for soft-tissue augmentation or palatal lining with superb results. In our series, many patients were included who had substantial volume loss or skin loss in the mid or upper face, and the use of latissimus dorsi myocutaneous component offers even greater flexibility for reconstruction for these more extensive defects. By using the latissimus dorsi as part of this reconstruction, the soft-tissue and bony components of the reconstruction may be oriented entirely independently.

The second important advantage demonstrated in this study is a long vascular pedicle. Just over 75% of the patients in this study (9 of the 21) avoided the need for vein grafting due to the pedicle length of this transplant. That is, had another donor site been chosen for reconstruction, vein grafting would have been necessary to reach recipient vessels in the neck. This is particularly true in cases of midface and upper-face reconstruction or in patients who have a vessel-depleted neck. While vein grafting in autogenous tissue transplantation is well described, most agree that the use of vein grafts is associated with an increased complication rate. This rate has been reported to be as high as 30% in head and neck reconstruction.\(^\text{11-13}\) The study by Futran et al\(^\text{9}\) required the use of vein grafts in 9 of 27 patients, whereas in the study by Clark et al\(^\text{10}\) using the subscapular system required vein grafting in only 1 case. This finding is consistent in our study: the use of the thoracodorsal system helps reduce the frequency of vein grafting owing to the length of the pedicle.

The third notable feature of this flap is the advantage for recreating 3-dimensional, native contours in the head and neck. The tip of the scapula demonstrates excellent versatility in rebuilding the 3-dimensional bone structures of the craniofacial skeleton. This use of this transplant reproduces the hard palate with minimal contouring. This is in contrast to the fibula transplant, which requires multiple osteotomies and has relatively fewer options for soft-tissue reconstruction. The iliac crest donor site is also valuable for the 3-dimensional shape and the ability to mimic the shape of the hemimaxilla.\(^\text{14}\) With the iliac crest donor site there can be donor site morbidity, and its 3-dimensional shape is not as well suited to total or near-total infrastructure maxillary defects. An advantage of the iliac crest is the quality and quantity of the bone stock available for osseointegrated implants. In this study, no patients underwent osseointegrated implantation of the scapular tip. In addition, it should be noted that the scapula is not completely ossified until a person is 20 years of age.\(^\text{2}\) As a result, if the reconstruction requires the structural characteristics of bone and the patient is younger than 20 years, further imaging should be performed to confirm the degree of ossification of the donor site.

There is reasonable concern over the use of the Tdast with regard to shoulder morbidity. We sought to address this issue by use of the Constant test to determine the effects of transplant harvest. Our limited sample supports the use of this donor site because the morbidity seems to be minimal. This correlates well with the data from Clark et al\(^\text{10}\) which, although using a different scoring index, also showed limited morbidity with harvesting the scapular tip. Presumably, an important step in the prevention of shoulder dysfunction is suturing of the serratus anterior muscle back to the remaining scapula (Figure 6). We also reapproximate the remaining muscles of the rotator cuff with the arm in abduction and the hand superior to the level of the head. After reduced mobilization for 2 weeks, physiotherapy resulted in minimal disability in this small sample. This functional data from the donor site should also be viewed in the context of data regarding morbidity associated with the iliac crest.
osseocutaneous free flap, which is an alternative for mid-face reconstruction. Harvest of the iliac crest has been shown to be associated with a gait disturbance 6 weeks postoperatively in nearly 11% of patients. Furthermore, nearly all patients have some antalgic gait following surgery. This is thought to be due to the loss of the normal muscle attachments of hip flexor and hip stabilizer attachments to the iliac crest. It is possible that much of the disability from the elevation of the iliac crest could be minimized if the anterior iliac spine is preserved and the mid crest is harvested. To our knowledge, there are no published data that have evaluated this outcome.

All cases of partial flap necrosis were associated with previous treatment. Presumably, poor tissue quality of the recipient tissue impaired enosculation. The most common late complication was plate exposure, and this was strongly associated with early complications.

In conclusion, the thoracodorsal artery scapular tip autogenous transplant confers 3 reconstructive advantages that are unique to this donor site, making it ideal for complex head and neck defects. This series demonstrated the advantage of the Tdast as a single transplant in defects in which 2 transplants would be used. It also reduced the need for vein grafting, which is of increased value in vessel-depleted necks. In addition, the native bone contour adds a unique, beneficial aspect because it matches the bone contour in the inset site, and osteotomies are less frequently required. The Tdast is also a durable transplant; there were no transplant losses despite the poor quality of the local tissues and the extent of the defects. The complication rate reflects the condition of the local tissue as it was associated with previous treatment. The effectiveness of this approach is corroborated by the posttreatment employment status and stable, upward-trending BMI.

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REFERENCES