Vascularized Rib for Facial Reconstruction

Steven P. Davison, M.D., D.D.S., James H. Boehmler, M.D., Jason C. Ganz, M.D., and Bruce Davidson, M.D.

Washington, D.C.

The reconstruction of maxillectomy defects is a complex problem encountered in plastic surgery. Defects can range in size and complexity from small defects requiring only soft tissue to complete maxillectomies requiring large tissue bulk, bone, and one or more skin paddles. The most difficult defects involve the skull base and orbit. The reconstructive surgeon is faced with the challenge of isolating the nasopharynx from the dura and globe while simultaneously restoring the bony framework of the maxilla and orbit to support the soft tissue of the cheek. The authors present a series of six reconstructions using a rectus abdominis muscle flap with associated vascularized rib for reconstruction of complex maxillectomy defects. This flap provides large soft-tissue bulk as well as bony support and a long vascular pedicle. A skin island can be taken with the flap, and the donor-site morbidity is comparable to that seen with a vertical rectus abdominis myocutaneous flap. Six flaps were used in five patients over a 20-month period. All patients had stable support of the orbit at follow-up with adequate soft-tissue coverage, and there were no incidences of visual changes. (*Plast. Reconstr. Surg.* 114: 15, 2004.)

The maxilla is a complex three-dimensional structure that creates the inferior orbital rim, lateral nasal walls, hard palate, and projection of the midface. Reconstruction of the bony and soft-tissue defects after skull base and maxilla resection is a difficult task. In addition to providing structural support, the maxilla assists in speech, mastication, and swallowing and provides a barrier between the nasopharynx, the globe, and the brain. Cordiero and Santamaria[1] have previously classified maxillectomy defects based on the extent of soft tissue, palate, and bone resection.

The majority of maxilla reconstructions require soft tissue to obliterate dead space and isolate the nasopharynx. Davison et al.,[2] Cordiero and Santamaria,[1] and Cordiero and Disa[3] have provided algorithms to facilitate reconstruction decision-making. Small defects (Cordiero type I) frequently can be reconstructed using fasciocutaneous flaps. As the defects become larger (Cordiero types II, III, and IV), the reconstructive needs become more complex. Large amounts of soft tissue may be needed to obliterate dead space and prevent communication between the nasopharynx and central nervous system. Bone may be needed to reconstruct the orbit or hard palate. Cordiero defect types IIIa, IIIb, and IV all require reconstruction of the orbital rim. Without a proper bony framework, the soft tissue is prone to sagging with time. This leads to eventual disturbance of facial contour and globe support with significant diplopia and dystopia.

A common solution is to harvest free, nonvascularized bone graft combined with a free flap.[4–7] If the bone graft is not sufficiently isolated from the nasopharynx, infection can quickly lead to graft failure.[6] Vascularized bone grafts, including rib,[8] scapula,[9,10] calvaria,[11] fibula,[12,13] and radial forearm,[1,12,14] can provide vascularized bone that is better able to resist infection. Frequently these flaps do not provide adequate bulk or correct contour to fill large soft-tissue defects. An ideal flap for these complex reconstructions would have sufficient soft-tissue bulk, vascularized bone for support, a long pedicle with adequately sized vessels, and have minimal donor-site morbidity.

We suggest that the rectus abdominis flap with vascularized seventh, eighth, or ninth ribs represents a potentially valuable method to provide both support and soft-tissue bulk for complex maxillectomy reconstructions. This

From the Division of Plastic Surgery and Department of Otolaryngology, Georgetown University Hospital. Received for publication March 25, 2003; revised July 22, 2003.

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article presents five patients with six reconstructions where rectus abdominis with rib free flaps were used for reconstruction of defects after ablative surgery.

Patients and Methods

Patients

Five patients have been reconstructed with a total of six osteo-integrated rectus abdominis flaps. Of these, there were three men and two women ranging in age from 40 to 71 years. All defects were secondary to tumor resection. Four patients had Cordiero type IIIa defects (entire maxilla with inferior orbital rim and floor removal without exenteration of the globe), and one patient had a type IV defect (complete removal of orbit and globe and maxilla with sparing of the hard palate). Three defects involved the skull base. Three flaps utilized the complete width of the rectus abdominis muscle, while three had the muscle split longitudinally to decrease flap bulk. One patient had a skin paddle for coverage of orbital exenteration, whereas four patients did not require skin coverage. Average follow-up was 9 months, with up to 20 months follow-up. Rib graft viability was confirmed by bone scan in three patients and clinically during secondary surgery at 1 year postoperatively in two patients.

Surgical Anatomy

The anatomy of the vertical rectus abdominis myocutaneous flap is well understood.[15] The blood supply (Mathes and Nahai type III circulation) is composed of two major pedicles from the deep inferior and superior epigastric vessels. The rib receives its blood supply from the anterior intercostal vessels. Miller et al.[16] described the connections between the intercostal vessels and the superior epigastric system. The seventh, eighth, and ninth intercostals join the costomarginal artery along the inferior border of the costal margin. The largest of these connections is between the costomarginal artery and the 8th intercostal artery. The costomarginal artery then forms an anastomosis to the superficial epigastric artery along the deep medial surface of the rectus abdominis muscle (Fig. 1). These anastomoses provide the retrograde blood supply to the rib and cartilage when the flap is elevated on the deep inferior epigastric pedicle. When care is taken to dissect the flap without disrupting the costomarginal, superficial epigastric, or intercostal arteries or the periosteal blood supply, retrograde flow can provide adequate blood flow to costocartilage, which has low metabolic demands.

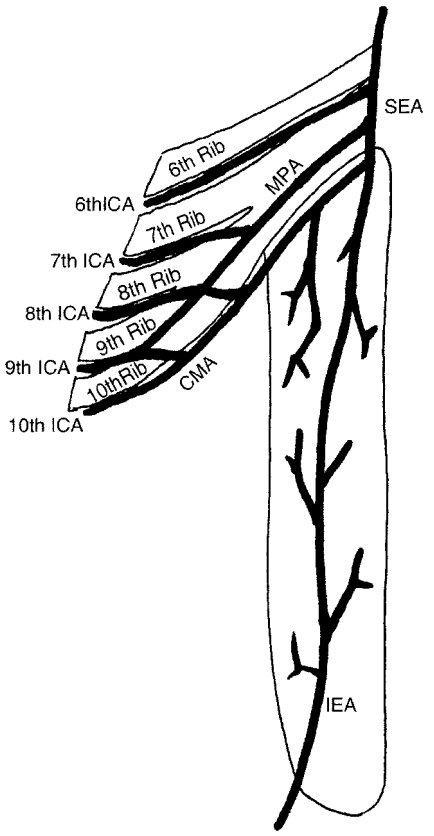

FIG. 1. Schematic of blood flow for the rectus abdominis flap with vascularized bone. Blood flow from the inferior epigastric artery (*IEA*) communicates with the superior epigastric artery (*SEA*), which gives retrograde flow to the costomarginal artery (*CMA*), the musculophrenic artery (*MPA*), and the seventh through tenth intercostal arteries (*ICA*).

Operative Technique

A paramedian incision is marked from the costal margin to the suprapubic region, lying over the belly of the rectus muscle. If skin coverage is needed, a vertical skin paddle as used in a traditional vertical rectus abdominis myocutaneous flap may be designed. A lateral "hockey stick" extension is marked over the confluence of the seventh, eighth, and ninth ribs and used if additional exposure is required (Fig. 2). A standard approach to raising the rectus muscle is used.[15] The skin and subcutaneous tissue are raised down to the anterior rectus abdominis fascia. This, in turn, is reflected, preserving the insertions. An area of rib resection is marked in accordance with the bony requirements of the recipient defect (Fig. 3). When raising the rectus muscle, care is taken

FIG. 2. A lateral "hockey stick" incision can be performed for additional exposure over the seventh, eighth, and ninth ribs.

FIG. 3. The confluence of the seventh, eighth, and ninth ribs are marked. This may be used as a template for rib resection. Care is taken to not disturb the periosteum or perichondrium to ensure adequate blood supply to the rib segment.

to preserve the anterior rectus sheath over these ribs. The margins of the rectus sheath surrounding the ribs are incised down to periosteum and perichondrium. The ribs are cut using either a sagittal saw or knife. Care is taken to avoid pleural injury and periosteal or perichondral stripping during this maneuver. Once all appropriate rib cuts are made, the ribs are elevated from their posterior attachments and raised up in continuity with the flap. The fascia is tacked down to the rib to avoid avulsion. The fascial donor defect can often be closed primarily. When the fascial defect is larger, or if a large segment of rib is taken, a nonabsorbable mesh is used for additional fascial support.

The flap is transferred to the maxillectomy defect (Fig. 4). A transbuccinator, subcutaneous tunnel is dissected to the submandibular region. End-to-end microsurgical anastomoses are completed with the facial vessels. The rib is overrotated to reconstruct the infraorbital rim or as a strut to support the soft tissue above the palate.

If the bulk of the flap is excessive for the deficit, a medial strip of muscle opposite the vascular pedicle is sacrificed. Unless a facial skin soft-tissue deficit exists, the skin paddle is excessive in bulk. Exposed rectus muscle in the oral cavity is allowed to mucosalize.

RESULTS

Six flaps were used in five patients (Figs. 5 and 6). One patient with a large fungating sarcoma experienced flap necrosis at postoperative day 7 secondary to fulminant infection, but underwent a second successful repeat rectus abdominis with vascularized rib free flap. One patient had an anterior skull base recurrence at 1 year. A portion of the vascularized rib was resectioned and the rest was readvanced to reconstruct the new defect. The rib

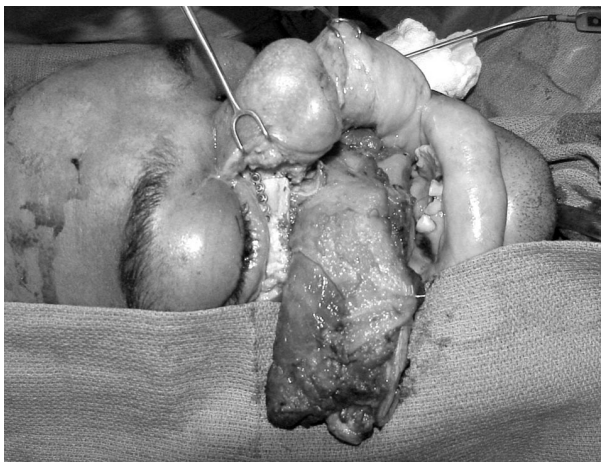

FIG. 4. The rectus with rib flap is inset and affixed with miniplates to provide the appropriate contour of the orbital rim. The rectus muscle is inserted to fill the maxillectomy defect and is allowed to mucosalize.

FIG. 5. A 54-year-old woman with invasive squamous cell carcinoma of the nasopharynx underwent left orbital exenteration with anterior skull base resection (Cordiero type IV defect). (*Left*) The surgical defect had exposed dura and nasopharynx. A 7 × 8-cm skin paddle was used to cover the orbit, and the rib was used to reconstruct the superior orbital rim and lateral nasal wall. (*Right*) The same patient at 1-year follow-up.

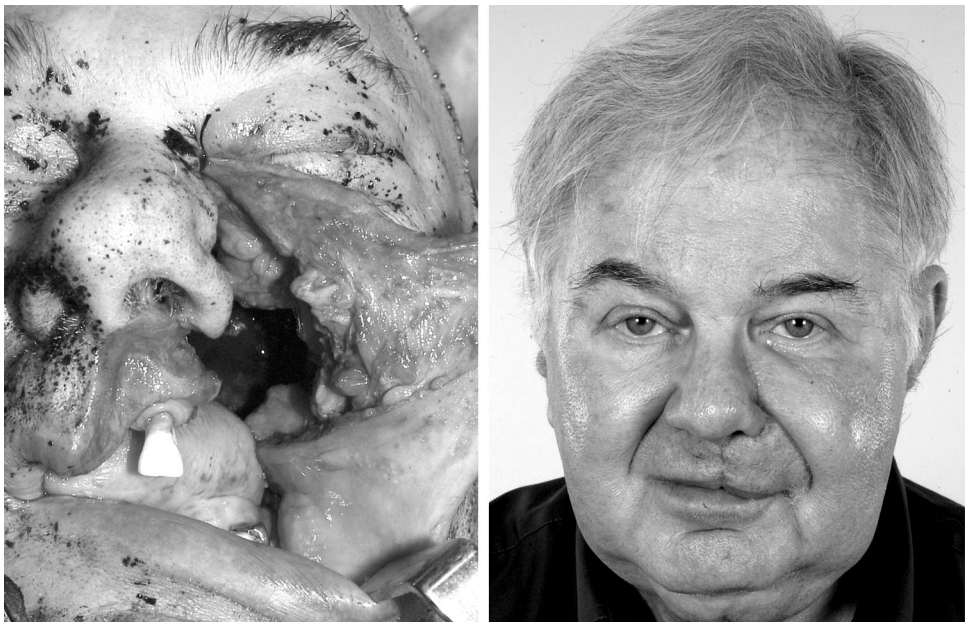

FIG. 6. A 71-year-old man with ameloblastoma underwent resection of the left anterior skull base and complete maxillectomy (Cordiero type IIIa). (*Left*) The ribs were contoured to reconstruct the orbital floor, lateral orbital rim, and the superior aspect of the skull base. (*Right*) The same patient at 5-month follow-up.

showed normal cartilage morphology and bleeding intraoperatively. No patient has had diplopia or visual changes following orbital rim and floor reconstruction. There were no incidences of hernia, pneumothorax, or other donor-site morbidities. Three of the five flaps were further evaluated with bone scan nuclear medicine scans (Fig. 7). Therefore, of five surviving flaps, four flaps were proven to have well-vascularized rib.

FIG. 7. Postoperative bone scan for a patient displaying radioisotope uptake in the vascularized rib graft.

DISCUSSION

Advances in resection of skull base cancers have simultaneously improved the clinical outcome of cancer patients while making their reconstructions more complex. Goals of reconstruction include separating the central nervous system from the nasopharynx, supporting the globe, and obliterating dead space while allowing deglutition and speech. Bone or cartilage grafting, vascularized or nonvascularized, can provide support. With exposure to the nasopharyngeal cavity and its contaminants, resorption is likely without adequate blood supply.[6] Free-tissue transfer can provide necessary blood flow and bulk to the defect but are subject to the deforming forces of gravity. The ideal flap for complex maxillectomy reconstruction would combine vascularized bony support with sufficient soft-tissue bulk to obliterate dead space and separate the nasopharynx from the surrounding structures.

Several osteocutaneous flaps are used in maxillectomy reconstruction, including the scapula, radial forearm, and iliac crest osteocutaneous flaps. The scapula flap[10,17,18] is useful for resections involving the anterior maxilla and inferior orbital rim with skin loss. The separation of the skin pedicle from the bone pedicle allows several degrees of freedom when setting the flap. This flap is helpful for small defects (Cordiero types I or II) and is a good source of skin. The radial forearm flap[19,20] is a workhorse in head and neck reconstruction, especially in relining the oral cavity. When taken with bone, it can be used as a "sandwich flap" to reconstruct the hard palate and lateral nasal wall surfaces.[14] It has the benefit of a long vascular pedicle and is relatively simple to harvest. This flap is ideal for defects of the hard palate,[14,21] where it can create a new lining for the nasal and oral cavities. Iliac crest had been used extensively for mandibular reconstruction,[22] and iliac crest bone grafts have been used for maxilla and orbital rim reconstructions.[4,6] The ilium provides a large amount of dense bone ideal for dental rehabilitation, and can be split as a graft for orbital rim repair.

There are several downsides for each of these free flap options.[6] All three have limited soft-tissue bulk when needed to fill the large maxillectomy defect. The radial forearm flap leaves an obvious donor site that can be of concern to patients. The iliac crest, although a good option for orbital rim reconstruction as a source of bone, is limited by its bulk and by a short vascular pedicle. The scapula, though an abundant source of soft tissue, can have a more significant donor defect, especially if it is combined with a latissimus dorsi flap for bulk. The fibula, though an excellent choice for mandibular reconstruction, is a poor choice for palatal reconstruction unless harvested with significant ptotic soft tissue.

The rectus abdominis muscle is used frequently in reconstructive surgery. It is a Mathes and Nahai type III muscle with a reliable and predictable pedicle. It provides large muscle bulk and can be used with a transverse or vertical skin paddle if needed. Its familiarity to most surgeons makes it easy to elevate. By combining this muscle with the confluence of the seventh, eighth, and ninth ribs while preserving the communications between the superior epigastric and intercostal vessel systems, it is possible to take a vascularized rib graft with the muscle flap for reconstruction of complex maxillectomy defects. The bulk of the muscle provides separation of the nasopharynx from its adjacent structures while the vascularized rib provides resistance to infection and radiation. The vascularized rib is a more reliable and stable support for the soft tissues.

In this clinical series, we used six flaps in five patients, with a flap survival rate of 83 percent and an overall successful reconstruction rate of 100 percent. One patient experienced flap loss

and was successfully reconstructed using the same flap from the contralateral side.

The reliability of this flap as a support for soft tissue is contingent on the vascularity and therefore the longevity of the bone graft. We sought to demonstrate the reliability, and therefore stability, of the vascularized rib with various modalities. Nuclear medicine scans were used in three instances (positron emission tomography and radionucleotide bone scanning) to determine bone viability. Both studies showed positive uptake in the region of the vascularized bone graft. This is highly suggestive of maintenance of its periosteal blood supply. In the one patient who required readvancement of the graft, it was found to bleed during her reoperation at 1 year after her original reconstruction. This graft, though mostly cartilaginous in nature, maintained its original shape, strength, and orientation throughout the year.

Conclusions

The rectus abdominis muscle flap with associated vascularized rib is a new reconstructive option for large postsurgical maxillectomy defects that has not yet been described in the English plastic surgery literature. Our experience with this flap has shown that it provides all of the necessary elements for reconstructing complex maxillectomy defects and maintains its stability as much as 20 months postoperatively. Our initial success with the flap should provide the impetus for further investigation of its use in complex maxillofacial reconstruction.

Steven Paul Davison, M.D., D.D.S.
Division of Plastic Surgery
Georgetown University Hospital
1st floor PHC Building
3800 Reservoir Road NW
Washington, D.C. 20007
davisons@georgetown.edu

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