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Experience with 24 Cases of Reconstructive Anterior Skull Base Surgery: Classification and Evaluation of Postoperative Facial Appearance

ABSTRACT—This article details our experience with 24 cases of anterior skull base reconstruction after tumor resection. They were classified into four types according to the resected region. In 11 cases of type I resection, the orbital part of frontal bone and/or cribriform plate of ethmoid bone were resected. In two cases of type II resection, the orbital contents and partial orbital bone were resected with the addition of type I. In five cases of type III resection, the maxillary bone was resected with the addition of type II. In six cases of type IV resection, the zygomatic bone and/or facial skin were resected with the addition of type III. The tumor originating from intracranial region was 25% of this series and all of them belonged to type I. The tumor originating from extracranial region tumor was 75% and its resected region was more extensive. In type I and II resections, the cranial flap, radial forearm free flap, or a combination of the two was used for reconstruction. The rectus abdominis myocutaneous/muscle free flap was used for reconstruction of massive defects in type III and IV defects. Total incidence of postoperative complications was 16.7%. Donor site deformity of the cranial flap at the frontal and temporal region in types I and II resections and facial contour deformity in zygomatic region and defect of upper and/or lower palpebra in type IV resection were major problems with postoperative facial appearance. Although use of the rectus abdominis myocutaneous free flap combined with costal cartilages improved the midfacial contour, palpebral reconstruction remained an unsolved problem in reconstructive skull base surgery. The reconstructive goals in skull base surgery are not only to obtain safe and reliable skull base reconstruction but also to restore the facial appearance postoperatively.

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During the last two decades, with the advance of cranial flap surgery and free flap transfer, reconstructive skull base surgery after tumor resection has made tremendous progress.[1–10] The obliteration of dead space at the skull base using well-vascularized tissue with an adequate dural closure has provided successful skull base reconstruction with low incidence of postoperative complications, such as cerebrospinal fluid leakage, meningitis, and brain herniation.

In this article, 24 cases of anterior skull base reconstruction after intracranial or extracranial tumor resection were classified into four types according to the resected region and reviewed on diseases, surgical procedures of reconstruction, complications, and problems with postoperative facial appearance.

MATERIALS AND METHODS

From August 1989 until April 1997, 24 skull base reconstructions were carried out at the Hokkaido University Hospital and affiliated hospitals. The ages of these patients (16 men and 8 women) ranged from 36 to 74 years. All patients underwent immediate reconstruction of skull base defects after extracranial and intracranial tumor resection. The follow-up period ranged from 4 months to 3 years.

These cases in our series were classified into four types according to the resected region. Resected regions classified as type I included the orbital part of frontal bone and/or cribriform plate of ethmoid bone. Type II resections included a type I base with the addition of orbital contents and partial resection of the orbital bones. Type III resections included a type II base with the addition of the maxillary bone. Type IV resections included a type III base with the addition of the zygomatic bone and/or facial skin. Orbital invasion of the tumor was noted in types II, III, and IV (Table 1). The diseases, surgical procedures of reconstruction, complications, and problems with postoperative facial appearance were assessed according to the four types.

Table 1. Types of Resection

Type	*Orbital Invasion of Tumor*	*Excisional Region*
I	No	Orbital part of frontal bone and/or cribriform plate of ethmoid bone
II	Yes	Orbital contents and partial orbital bone with the addition of type I
III	Yes	Maxillary bone with the addition of type II
IV	Yes	Zygomatic bone and/or facial skin with the addition of type III

RESULTS

Diseases

In type I, 11 cases presented with four olfactory neuroblastomas, four ethmoid sinus carcinomas, one frontal sinus carcinoma, one meningioma, and one craniopharyngioma. In type II, two cases presented with one ethmoid sinus carcinoma and one maxillary sinus carcinoma. In type III, five cases presented with five ethmoid sinus carcinomas. In type IV, six cases presented with six maxillary sinus carcinomas (Table 2).

Reconstructive Procedures

Autologous fascia such as the deep temporalis fascia, fascia lata, anterior rectus sheath, or lyophilized dura matter graft was used for repair of large dural defects. In the earliest three cases, split-thickness calvarial (outer-table) bone graft was placed at the skull defect; however, bone grafting was not carried out in most cases. In type I, the defect resulting from the resection of the tumor was reconstructed with the frontal and/or temporal myofascial-galeopericranial (MG) flap[11] in eight cases, combination of radial forearm free flap and MG flap in two cases, and radial forearm free flap in one case. In type II, the defect was reconstructed with the temporal muscle flap in one case and combination of radial forearm free flap, temporal muscle flap, and MG flap in one case. In type III, the defect was reconstructed with the rectus abdominis myocutaneous free flap in five cases. In type IV, the defect was reconstructed with the rectus abdominis myocutaneous and/or muscle free flap in four cases and rectus abdominis myocutaneous free flap with vascularized eighth and ninth costal cartilages in two cases. The costal cartilages were supplied by the perichondrial vascular network through the anterior intercostal vessels connecting with the deep inferior epigastric vascular system (Table 3).[12]

Table 2. Diseases

Type	*Disease*	*No. of Cases*
I (n = 11)	Olfactory neuroblastoma	4
	Ethmoid sinus carcinoma	4
	Frontal sinus carcinoma	1
	Meningioma	1
	Craniopharyngioma	1
II (n = 2)	Ethmoid sinus carcinoma	1
	Maxillary sinus carcinoma	1
III	Ethmoid sinus carcinoma	5
IV	Maxillary sinus carcinoma	6

Table 3. Reconstructive Procedures

Type	*Transferred Flap*	*No. of Cases*
I (n = 11)	MG flap	8
	Radial forearm free flap and MG flap	2
	Radial forearm free flap	1
II (n = 2)	Temporalis muscle flap	1
	Radial forearm free flap, temporalis muscle flap and MG flap	1
III	Rectus abdominis myocutaneous free flap	5
IV (n = 6)	Rectus abdominis myocutaneous/muscle free flap	4
	Rectus abdominis myocutaneous free flap with costal cartilages	2

Complications

Extradural abscess was recognized in 2 of 11 cases of type I and 1 of 6 cases of type IV. Partial necrosis of the MG flap was recognized 1 of 11 cases in type I. Postoperative complications were not recognized in types II and III. Total incidence of postoperative complications was 16.7%. In type I, extradural abscess occurred in two cases in which bone graft was used. After removal of the grafted bones, complete healing followed. Partial necrosis of the temporal MG flap was noted in one case. It occurred at the distal area of the flap, which was designed on the contralateral side to the vascular pedicle. In type IV, extradural abscess occurred in one case in which volume of the rectus abdominis myocutaneous free flap was insufficient to obliterate the large dead space at the skull base because the patient was extremely thin (Table 4).

Problems with Postoperative Facial Appearance

Deformity of the donor site of the cranial flap was recognized in three cases of type I and two cases of type II. Slight indentation was seen at the frontal region of the MG flap donor site. These cases required harvest of most of the frontalis muscle to cover the frontal skull base defect. In type II, indentation at the temporal region was obviously noted when the anterior part of the temporal muscle was used for skull base reconstruction (Fig. 1). No specified problems occurred with postoperative facial appearance in type III resections. Good bulk for the reconstruction of facial contour was obtained by the rectus abdominis myocutaneous free flap. The eye socket was newly reconstructed using the cutaneous portion of the rectus abdominis myocutaneous free flap (Fig. 2). In type IV, facial contour deformity in zygomatic region and defect of upper and/or lower palpebra were major problems with postoperative facial appearance. Facial contour deformity in the zygomatic region was recognized in four cases due to resection of the zygomatic process of the maxillary bone and zygomatic bone. In these cases, the rectus abdominis myocutaneous free flap was used to reconstruct the resulting defect without skeletal support. To solve this problem, vascularized eighth and ninth costal cartilages were combined with the rectus abdominis myocutaneous free flap in two cases. The costal cartilages were fixed on the remaining zygomatic process of temporal bone laterally and anterior lacrimal crest of maxillary bone medially to restore the zygomatic arch. The midfacial contour was significantly improved with this technique (Fig. 3). Defect of upper and/or lower palpebra were recognized in 2 cases. Resection of the palpebral tissue due to tu-

Table 4. Complications

Type	*Complication*	*No. of Cases*
I	Extradural abscess	2
	Partial necrosis of MG flap	1
II	None	
III	None	
IV	Extradural abscess	1

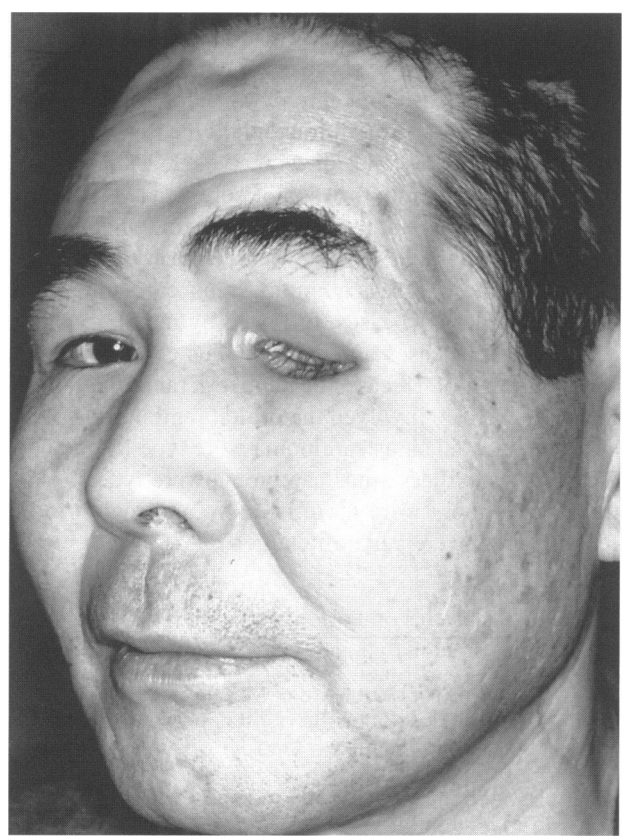

Figure 1. Donor site deformities of of the frontal MG flap and the left temporalis muscle flap were noted.

Figure 2. **(A)** The skin paddle of the transferred rectus abdominis myocutaneous free flap was used for eye socket reconstruction. **(B)** Excellent appearance of the new eye socket.

mor invasion led to unfavorable result in postoperative facial appearance (Fig. 4, Table 5).

DISCUSSION

There are two basic patterns of invasion from tumors involving the skull base: tumors originating from the intracranial region that invade the skull base and extradural compartment from above and extracranial tumors originating from the extracranial region that invade the skull base and intradural compartment from below. In our series, the intracranial type was seen in 6 of 24 cases (25%), and all were type I. Extension of such intracranial tumors was not so extensive, and orbital invasion was not recognized in them. On the other hand, the extracranial pattern was seen in 18 of 24 cases (75%). In these cases, ethmoid sinus carcinoma was most frequent in 10 cases, followed by maxillary sinus carcinoma in 7 cases and frontal sinus carcinoma in 1 case. Thirteen of 18 cases of the extracranial pattern of invasion (72.2%) involved the orbital region. Five of 10 cases of ethmoid sinus carcinoma were type III and 6 of 7 cases of maxillary sinus carcinoma were type IV. Extracranial tumors were more invasive and region to be reconstructed were generally larger.

Table 5. Problems on Postoperative Facial Appearance

Type	*Problem*	*No. of Cases*
I	Deformity of donor site of MG flap	3
II	Deformity of donor site of MG and/or temporalis muscle flap	2
III	Not specified	
IV	Facial contour deformity in zygomatic region	4
	Defect of upper and/or lower palpebra	2

The reconstructive options in this series included cranial flaps such as the frontal MG flap, temporal MG flap, and temporalis muscle flap and free tissue transfers such as the radial forearm free flap and rectus abdominis myocutaneous/muscle free flap. In type I and II resections in which the resected region was not large, cranial flaps, radial forearm free flaps, or a combination of the two was selected. Frontal and temporal MG flaps were indicated to provide sealing the site of dural closure and separation of the cranial cavity from the nasopharynx, paranasal sinuses, and orbit.[1–4,7,8] The temporalis muscle flap was effectively used for obliteration of the dead space located at the lateral skull base and orbit.[6] In particular, orbital dead space in type II resections was well suited to obliteration with the temporalis. The radial forearm free flap was well used for the obliteration of dead space located at the central skull base. The long vascular pedicle of the flap was typically anastomosed to the superficial temporal artery and vein without difficulty. In type III and IV resections in which the resected region was extensive, the rectus abdominis myocutaneous/muscle free flap was preferably used. The flap provided sufficient volume to obliterate the resultant large dead space.[5,7,9,10] The vascular pedicle of the flap was anastomosed to the facial artery and vein in the most cases.

The incidence of postoperative complications in this series was 16.7%. This is acceptable when compared with previous reports.[7,8,10] Two of three cases in which nonvascularized bone grafts were inset at the skull base developed extradural abscess postoperatively and required removal of the grafted bone. The use of nonvascularized bone grafts in the reconstruction of skull base defects without associated well-vascularized soft tissue may lead to dead space surrounding the graft itself and an increased chance for infectious complications. Eventually, the skull base defects were recon-

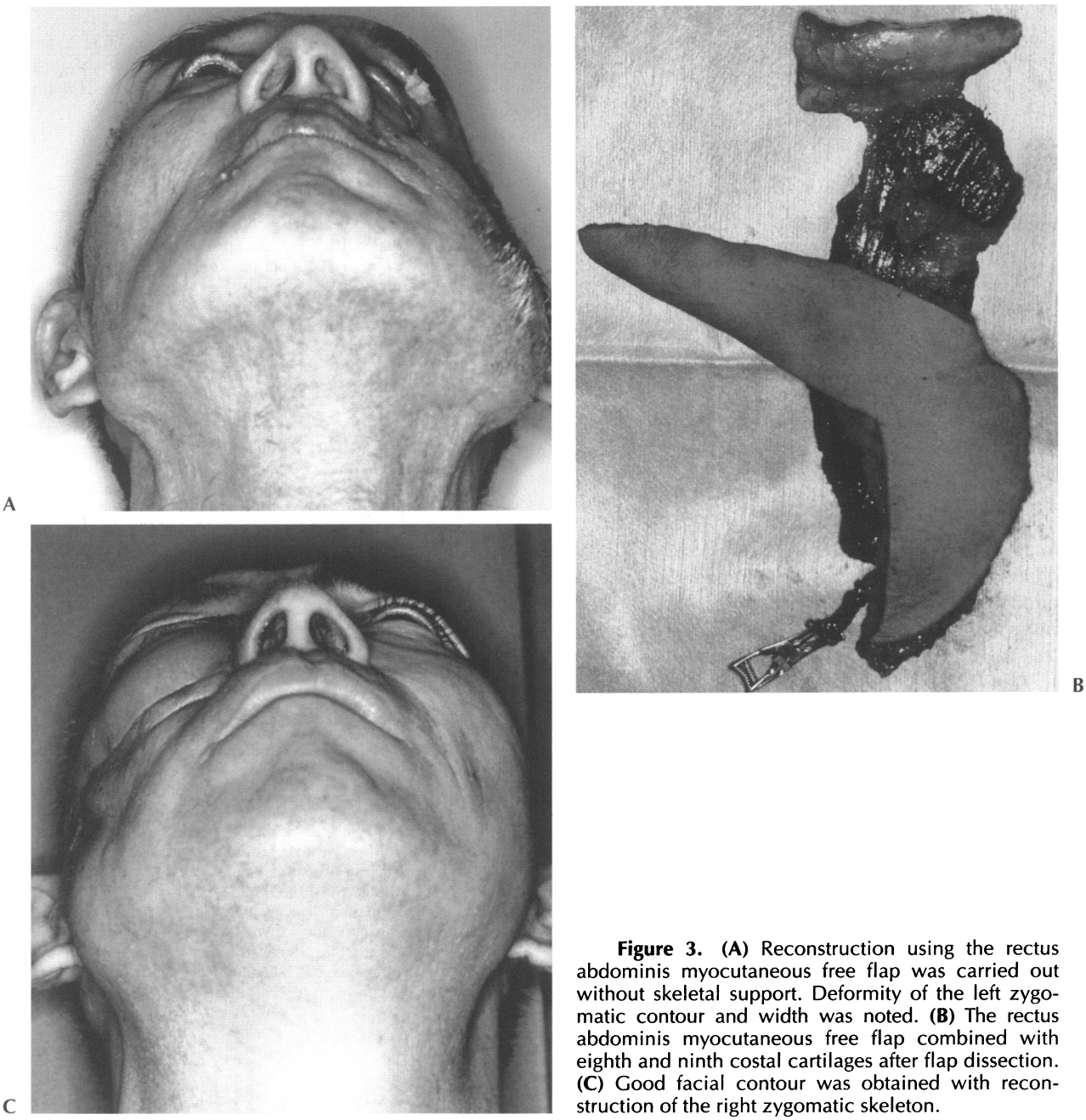

Figure 3. **(A)** Reconstruction using the rectus abdominis myocutaneous free flap was carried out without skeletal support. Deformity of the left zygomatic contour and width was noted. **(B)** The rectus abdominis myocutaneous free flap combined with eighth and ninth costal cartilages after flap dissection. **(C)** Good facial contour was obtained with reconstruction of the right zygomatic skeleton.

structed with soft tissue alone in 23 of 24 cases, and none of them showed any signs of brain herniation. We believe that a well-vascularized flap with sufficient volume may provide adequate support of the brain tissue without the need for bony reconstruction.[11] An extremely thin patient with type IV resection presented with extradural abscess due to insufficient volume of the transferred rectus abdominis myocutaneous flap. In such cases, combination of the cranial flap and rectus abdominis myocutaneous free flap might be necessary to obliterate the dead space at the skull base.

Major problems with postoperative facial appearance in type I and II resections included deformity of donor site of the cranial flap. This was not obvious when the muscular portion of the frontal MG flap was left in place. However, cases in which the frontalis muscle was raised with the MG flap to obtain more secure vascularity showed slight indentation at the forehead. The donor site of the temporal MG flap was not indented even if the temporoparietal muscle was raised with the MG flap. However, deformity at the temporal region was recognized when the anterior part of the temporalis muscle was used for reconstruction. A secondary fat or fascia graft was required to improve the frontal and temporal contour in such cases.

Eye socket reconstruction was required in resection types II, III, and IV. To reconstruct the eye socket, it was important that upper and lower palpebral conjunc-

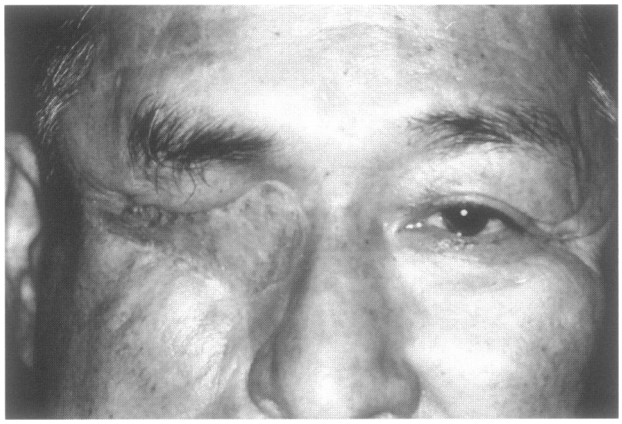

Figure 4. The right upper and lower palpebras were resected due to tumor invasion. The defect was reconstructed with the rectus abdominis muscle free flap and skin graft; however, postoperative facial appearance was unsatisfactory.

tiva portion was left as much as possible and tucking the medial canthal ligament to the remaining bony tissue around the nasal root. The cutaneous portion of the transferred flap was effectively used for reconstruction of the floor of eye socket.

Restoration of zygomatic contour is important on postoperative facial appearance in the reconstruction of type IV defects. The rectus abdominis myocutaneous free flap combined with the eighth and ninth costal cartilages provided good reconstruction of midfacial appearance and the skull base defect. The technique solved the problem of facial contour in the zygomatic region of type IV defects. However, defects of the upper and/or lower palpebra remained an unsolved problem with facial appearance in type IV resections. The conventional flap techniques in reconstructive skull base surgery did not achieve satisfactory palpebral reconstruction. Prosthetic rehabilitation using osseointegrated implant system[13] should be considered as an adjunctive reconstruction of the palpebra and orbit.

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