Review of Skull Base Reconstruction Using Locoregional Flaps and Free Flaps in Children and Adolescents

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ABSTRACT

Tumors of the skull base are rare in children, and reconstruction in such patients has rarely been reported. We reviewed 16 cases of skull base reconstruction in patients under 18 years. The study group consisted of 10 boys and 6 girls, whose ages ranged from 2 to 17 years. Of the 16 cases, eight tumors were benign and eight were malignant. Defects were anterior in six cases, lateral in eight cases, and anterolateral in two cases. Reconstruction was performed with locoregional flaps in 11 cases and with free flaps in 5 cases. No significant difference was found between locoregional flaps and free flaps in total operative time, intraoperative blood loss, or postoperative hospital stay. However, in some cases, total operative time, reconstruction time, and blood loss increased to a degree unacceptable for pediatrics. Minor complications occurred in three patients and a major complication occurred in one case. Of four patients, three patients with postoperative complications had undergone chemoradiotherapy. Because of the physical weakness of pediatric patients, complicated reconstructive procedure should be avoided. We believe locoregional flaps will become the first choice for reconstruction. However, if patients have large, complex defects and have received radiotherapy, appropriate free flaps should be used to avoid postoperative complications.

KEYWORDS: Skull base, skull base reconstruction, pediatrics, child

Tumors of the skull base are more common in children and adolescents than are tumors of the head and neck. In fact, at our institution, patients of this age group account for 14% of patients undergoing skull base reconstruction. However, tumors of the skull base are still rare in children and adolescents, skull base reconstruction in these patients has rarely been described,^{1–3} and the duration of surgery-related procedures and events have never been reported in detail. Even in these

patients, skull base tumors cause large defects of the anterior and middle skull base which can result in functional, aesthetic, and psychological problems as the patients grow.

It would be informative to describe supplemental data from our institution and to assess the current situation of skull base reconstruction in children and adolescents. In addition, locoregional flaps, such as pericranial flaps, are usually employed by neurosurgeons

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or head and neck surgeons, not by plastic surgeons, but at our institution plastic surgeons consistently employ both locoregional flaps and free flaps as options for skull base reconstruction. Accordingly, we have included data for both locoregional flaps and free flaps in the present study. And also we have included comparable data of skull base reconstruction in adult patients in the same period. Therefore, this report reviews our cases of reconstruction using locoregional flaps or free flaps for children and adolescents with skull base tumors, with an emphasis on surgery-related outcomes and complications.

PATIENTS AND METHODS

After obtaining approval from the institutional review board, we reviewed all patients under 18 years who had undergone comprehensive reconstruction of skull base defects after tumor extirpation at the Department of Plastic and Reconstructive Surgery, Tokyo Medical and Dental University Hospital, from July 2000 through July 2009. All patients underwent reconstruction by plastic surgeons using locoregional flaps or free flaps. Patient characteristics, tumor pathology, details of reconstructive methods, surgery-related outcomes, follow-up, and complications were recorded. Additionally surgery-related outcomes and complications in adult population were also recorded.

The defect location was categorized according to the classification previously described by Irish.⁴ In detail, region I indicates tumor that arise anteriorly, involving either cribriform plate or frontal sinuses, and region II indicates defects that occur laterally, involving the infratemporal and pterygopalatine fossae.

Statistical analyses were performed with the unpaired Student's *t*-tests and Fisher exact tests. Differences with *p* value of 0.05 or less were considered significant.

Reconstructive Procedure

For small and localized defects, for example, localized region I and region II defects, of either the anterior or middle skull base, locoregional flaps, such as pericranial flaps and temporalis muscle flaps, are the flaps of first choice, even for pediatric patients (Figs. 1 and 2). Locoregional flaps are usually raised by plastic surgeons before tumor ablation, at the same time as the craniotomy procedure.

To reconstruct larger defects, for example, those beyond the cribriform plate and temporal fossa or those involving extensive surrounding soft tissue, skin, orbital contents, and bone, free flaps are used. These defects are various types of extended or combined region I and region II defects. To avoid postoperative complications, we prefer to use free flaps for patients who have received

Figure 1 Our usual trapezoidal design of anteriorly based pericranial flap in pediatrics.

Figure 2 Even in pediatrics, a pericranial flap with enough size and thickness was able to harvest.

preoperative radiotherapy. Anterolateral thigh free flaps and rectus abdominis myocutaneous free flaps are used depending on the defect's size (Fig. 3). These are the minimum requirements for primary reconstructive surgery of the skull base.

RESULTS

The patients were 10 boys and 6 girls ranging in age from 2 to 17 years (mean age, 12 years). No patient had comorbid conditions or a history of smoking. Tumors were benign in eight patients and malignant in eight patients. The most common tumor was rhabdomyosarcoma ($n=4$). The other tumors were angiofibroma ($n=3$), ossifying fibroma ($n=3$), osteosarcoma ($n=2$), olfactory neuroblastoma ($n=1$), small cell carcinoma ($n=1$), chondromesenchymal hamartoma ($n=1$), and meningioma ($n=1$). The tumors were primary in 15 patients and recurrent in 1 patient. There were two patients who had previously received radiotherapy, one

Figure 3 Complicated skull base defect reconstructed with anterolateral thigh (ALT) free flap in pediatrics. Vastus lateralis muscle was employed to make a blockage between intracranial space and sinonasal cavity and ALT adiposal flap was employed to fill the dead space in the temporal region to prevent depression deformity.

had received chemotherapy, and three had undergone chemoradiotherapy.

Locoregional flaps (seven pericranial flaps and three temporalis muscle flaps) were used to reconstruct region I defects in four patients and region II defects in six patients. Free flaps (one rectus abdominis myocutaneous free flap and five anterolateral thigh free flaps) were used to reconstruct region I defects in two patients, region II defects in two patients, and combined region I and II defects in two patients. All patients had dural defects, which were repaired primarily with free temporal fascia or free thigh fascia grafts. Anastomoses were performed to the superficial temporal artery and vein in two patients, the superficial temporal artery and deep temporal vein in one patient, the facial artery and vein in two patients, and the superior thyroid artery and facial vein in one patient. Total operative time, total reconstruction time, flap ischemic time, intraoperative blood loss, postoperative hospital stay, and the duration of postoperative follow-up in pediatric population are shown in Table 1 and that of adult population in the same period are shown in Table 2. We defined reconstructive time as the duration after tumor extirpation until the end of the whole surgical procedure. Whether using a locoregional flap or free flap, a flap harvest was already performed before the onset of reconstructive time period, because usually a locoregional flap was prepared before the tumor extirpation and a free flap was harvested at the same time of the tumor extirpation.

Table 1 Total Operative Time, Reconstruction Time, Ischemic Time, Intraoperative Blood Loss, Postoperative Hospital Stay, and Follow-Up Period in the Pediatric Population Undergoing Skull Base Reconstruction

	Local & Regional Flaps			Free Flaps		
	Median	Mean	Range	Median	Mean	Range
Total operative time (hours)	12:30	12:08	6:17–16:22	13:39	14:12	11:25–19:09
Total reconstruction time (hours)	3:27	3:28	2:35–4:37	5:14	6:25	4:28–9:11
Flap Ischemic time (hours)	—	—	—	1:10	1:21	0:49–2:17
Intraoperative blood loss (mL)	1300	2083	300–8547	1065	1799	850–5351
Postoperative hospital stay (days)	16	18	10–33	16	22	12–44
Follow-up period (months)	16	25	3–75	14	22	3–67

Table 2 Total Operative Time, Reconstruction Time, Ischemic Time, Intraoperative Blood Loss, Postoperative Hospital Stay, and Follow-Up Period in Adult Population Undergoing Skull Base Reconstruction in the Same Period

	Local & Regional Flaps			Free Flaps		
	Median	Mean	Range	Median	Mean	Range
Total operative time (hours)	11:37	11:44	7:08–17:10	15:32	15:53	9:50–23:16
Total reconstruction time (hours)	2:54	2:52	1:42–4:03	5:54	6:38	3:07–10:40
Flap ischemic time (hours)	—	—	—	1:45	1:47	0:49–3:10
Intraoperative blood loss (mL)	1542	1755	173–3580	1200	1642	104–7434
Postoperative hospital stay (days)	23	30	8–136	21	30	10–117
Follow-up period (months)	17	23	1–80	26	29	3–86

n = 72 patients.

Table 3 Postoperative Complications in the Pediatric Population Undergoing Skull Base Reconstruction

Complication	No. (%)	Type of Flaps	Risk Factors for Complications
Minor complications	3 (18.8%)		
Partial flap necrosis	1	Locoregional flap	Preoperative chemotherapy Placement of postoperative RALS tube
Local abscess	1	Locoregional flap	Preoperative chemoradiotherapy
Postoperative ulcer	1	Free flap	None
Major complications	1 (6.3%)		
Total flap necrosis	1	Free flap	Preoperative chemoradiotherapy (total 58 Gy)

n = 16 patients.

RALS, remote after loading system.

In addition, postoperative complications are shown in Table 3. The frequency and the detail of postoperative complication in pediatrics in comparison with adult patients using locoregional flaps and free flaps are shown in Tables 4 and 5.

Between locoregional flaps and free flaps, total operative time, intraoperative blood loss, and postoperative hospital stay did not differ significantly. However, mean reconstruction time with free flaps was significantly longer ($p = 0.014$), nearly two times longer, than that with locoregional flaps. And also total operative time, reconstruction time, ischemic time, and intraoperative blood loss did not differ significantly in comparison with that of adult. But mean postoperative hospital stay with locoregional flap in pediatrics was significantly shorter ($p = 0.018$) than that of adult.

As for postoperative complication, overall postoperative complication rate did not significantly differ between locoregional flaps and free flaps in pediatrics. And also whether using locoregional flaps or free flaps,

postoperative complication rate did not significantly differ in comparison with that of adults. Although the complication rate did not reach the level of significant difference, usage of free flaps in pediatrics resulted in a higher rate of postoperative complications than usage of locoregional flaps. Meanwhile adult patients had nearly same complication rate whether using locoregional flaps or free flaps.

In addition, minor complication were defined as those that could be treated with only conservative treatment, such as localized debridement, irrigation, antibiotics, and ointments, and major complication were defined as those requiring additional surgical treatment. There were three patients (18.8%) with minor complications (partial flap necrosis, local abscess, and postoperative ulcer) and one patient (6.3%) with a major complication (total flap necrosis). Postoperative complications tended to be minor in the pediatric population, meanwhile adult population tended to develop major complications such as partial or total flap necrosis and

Table 4 Comparison Between Using Locoregional Flaps and Free Flaps Concerning About Postoperative Complications in Pediatric and Adult Population

	Complications (+)			Complications (–)
	Minor	Major	Total	
Pediatrics (<i>n</i> = 16)				
Locoregional flaps (<i>n</i> = 10)	2	0	2 (20%)	8
Free flaps (<i>n</i> = 6)	1	1	2 (33.3%)	4
Adults (<i>n</i> = 72)				
Locoregional flaps (<i>n</i> = 34)	2	4	6 (17.6%)	28
Free flaps (<i>n</i> = 38)	2	5	7 (18.4%)	31

Table 5 Frequency of Major and Minor Complication Observed in Pediatric and Adult Population

	Complication (+)		Complication (–)
	Minor Complication	Major Complication	
Pediatric patients	4 (25%)		12 (75%)
(<i>n</i> = 16)	3 (18.8%)	1 (6.2%)	
Adult patients	13 (18.0%)		59 (82.0%)
(<i>n</i> = 72)	4 (5.6%)	9 (12.5%)	

epidural abscess. But no significant difference was observed in the frequency and the numbers of major and minor complications. Of four patients, three who had postoperative complications had received preoperative or postoperative chemoradiotherapy.

DISCUSSION

Our review of patients undergoing reconstruction after extirpation of skull base tumors shows that these tumors seem to have arisen irrespective of sex, were benign in half of cases, and were of various histological types. Similar characteristics of pediatric skull base tumors have been previously reported.^{1-3,5} The regional distribution of tumors showed no specific tendency.

When the reconstruction time, ischemic time, postoperative hospital stay, and postoperative complication rate associated with skull base reconstruction in adult patients are considered, skull base reconstruction with locoregional flaps or free flaps in children and adolescents should be seen as an equally acceptable surgical procedure. In some cases, however, total operative time, reconstruction time, and intraoperative blood loss increased to an unacceptable degree, considering the physical weakness of the pediatric patients. To preserve important nearby tissues, including the orbital contents, optic nerves, and the internal carotid artery, extirpation of skull base tumors is often a lengthy procedure. Some skull base tumors bleed easily during surgery due to their histological nature and abundance of feeding vessels. Under these circumstances, decreasing the duration of surgery is important for reducing the physical burden on the patient. Additionally, anesthesia exceeding 10 hours is reported to significantly increase the rate of complications after head and neck surgery.⁶ Consequently, we believe locoregional flaps will become the flaps of first choice for skull base reconstruction if they are large enough to cover the defect. These flaps also significantly reduce reconstructive time and postoperative hospital stay. Even in children and adolescents, locoregional flaps, such as pericranial flaps and temporalis muscle flaps, have sufficient vascularity, area, and thickness to cover skull base defects. Such flaps are also favorable from the standpoint of donor-site morbidity. Decreasing donor-site morbidity is especially important in growing patients, but the extent to which sacrifice of the pericranium affects cranial growth is unclear. However, several previous reports^{3,7-9} have suggested that osteotomy and sacrifice of the pericranium have limited effects on postoperative craniofacial development. Therefore, further investigation and the accumulation of additional cases are needed to address this issue. Gil et al¹⁰ have reported that wide resection of skull base tumors decreases postoperative quality of life. Although their study did not directly address graft donor-site morbidity, we speculate that decreasing donor-site morbidity in pa-

tients undergoing skull base reconstruction favorably affects postoperative quality of life, especially in growing children.

For patients who have received preoperative radiotherapy, which can produce complicated defects involving large surrounding soft tissue and bone structure of face and cranium, or who require reconstruction of the orbit, facial skin, or scalp, free flaps, such as anterolateral thigh free flaps and rectus abdominis myocutaneous flaps, can be used to avoid postoperative retraction deformity and to ensure that the area and volume of the graft is sufficient to repair the defect. The adequacy of free flaps has been thoroughly addressed in previous studies.^{1-3,11,12} However, to reduce the duration of the primary surgery, complicated reconstructive procedures should be avoided. Because the pathological types of skull base tumors in children and adolescents vary, it can be difficult to predict the extent of a defect after extirpation and to plan a complicated reconstructive procedure, while considering the potential for subsequent growth. Accordingly, structural bone reconstruction using free calvarial bone, free costal cartilage, or vascularized bone flaps is performed at the secondary revision surgery rather than at the primary surgery.

In postoperative complications, characteristic tendency was observed in children and adolescents that most postoperative complications in our series were minor compared with adult population. We speculate that a reason for this is that pediatric patients rarely have severe comorbid conditions, such as diabetes, hypertension, and peripheral artery disease, which are thought to interfere with wound healing and microvascular anastomosis. Furthermore, children and adolescents are thought to have a greater capacity for spontaneous recovery. Gil et al¹³ have found in their multicenter survey that the most common complications after skull base surgery in children and adolescents are local wound-related complications. These characteristics help limit the severity of postoperative complications.

In addition, there is no significant difference in postoperative complication rate whether using locoregional flaps or free flaps in pediatrics, even compared with the adults. Therefore flap selection should be decided with the defect size, surgical stress, and donor-site morbidity, not with the age of the patient. Meanwhile, although it did not reach to the statistical difference, using free flaps in pediatrics tended to have higher postoperative complication rate than using locoregional flaps compared with that of adult. We speculate that free flaps in pediatrics are possibly affected by preoperative chemoradiotherapy or negligible injury to the elevated flaps due to technical error during surgical procedure because a vascular pedicle and perforator of free flaps in pediatrics is rather small and narrow compared with the adult. In fact, one case of total flap necrosis in our case had a history of

multiple systemic chemotherapy and irradiation to the skull base and neck region. Therefore particular care should be taken not to damage vascular pedicle and perforator of free flaps, if free flaps were employed to the pediatrics. However, our series was small and our notion remains speculation.

CONCLUSION

Comprehensive skull base reconstruction using locoregional flaps or free flaps is practical and appropriate. To reduce total operative time, postoperative hospital stay, and donor-site morbidity, locoregional flaps are better be considered the flap of first choice for skull base reconstruction, even in children and adolescents, as long as the flap is large enough to cover the defect. Long, complicated reconstructive procedures should be avoided to reduce total operative time, intraoperative blood loss, and postoperative hospital stay. In addition, further study involving a large number of cases is needed to clarify the characteristics of skull base reconstruction in children and adolescents which help limit the severity postoperative complications.

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