The Laryngoscope

Free Flap Transfer for Pediatric Head and Neck Reconstruction: What Factors Influence Flap Survival?

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Objectives: The objective of this study was to identify the factors that influence free flap survival after head and neck reconstructive surgery in pediatric patients.

Methods: One hundred thirty consecutive cases of head and neck reconstruction with free flaps in pediatric patients at the Department of Oral and Maxillofacial Surgery at Peking University School and Hospital of Stomatology, Beijing, People's Republic of China, between 1999 and 2017 were reviewed. A single head and neck surgical team performed all the included surgeries. Demographic and surgical patient data with possible associations with free flap survival were recorded. Relevant influencing factors were determined using the χ^2 test and logistic regression analysis.

Results: There were 135 free flap transfers performed in the patients, with an overall success rate of 95.6%. Free flap failure occurred in six flaps (4.4%). Arterial crisis was the main cause of flap failure. The overall complication rate was 7.0%. Patient age (5–9 years old; odds ratio, 13.397; 95% confidence interval, 1.167–153.838; $P = 0.037$) was a statistically significant risk factor influencing free flap survival. Donor site, defect region, recipient vessel, and surgery time were not associated with free flap outcome.

Conclusion: Free flap transfer for head and neck reconstruction in pediatric patients is safe and reliable. However, special attention should be paid to pediatric patients under 9 years of age when performing head and neck reconstruction.

Key Words: Pediatric, influencing factors, free flap survival, head and neck reconstruction.

Level of Evidence: 4

***Laryngoscope*, 129:1915–1921, 2019**

INTRODUCTION

Head and neck defects can cause severe functional and cosmetic deformities in pediatric patients. Recently, the use of microsurgery for free flap transfer is commonly used in head and neck reconstructions at many centers.[1–3] Although free flap transfer in pediatric patients presents many challenges, there have been many series published in the past 20 years demonstrating the safety and reliability of free flap transfer in such patients[4–17] and its increasing use in head and neck reconstruction.[4,5,8,9,17–25]

Although high success rates (range 90%–99%)[4,5,8,9,17–25] have been reported for free flap transfers in pediatric head and neck reconstruction, few studies have investigated factors affecting free flap survival. So what factors influence pediatric free flap survival? According to our experience and literature,[17,26] we suspect it might be related to patient age, flap type, defect region, recipient vessel, or surgery time. This study specifically assessed patient characteristics and surgical data for 130 patients who received 135 free flap transfers performed by a single surgical team in the Department of Oral and Maxillofacial Surgery at Peking University School and Hospital of Stomatology Beijing, People's Republic of China, with the goal of identifying factors that influence free flap survival in pediatric head and neck reconstruction.

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Editor's Note: This Manuscript was accepted for publication on June 22, 2018.

This study was supported by the National Supporting Program for Science and Technology of China (No. 2014BAI04B06). The authors have no other funding, financial relationships, or conflicts of interest to disclose.

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DOI: 10.1002/lary.27442

MATERIALS AND METHODS

Pediatric cases of head and neck reconstruction using microvascular free flaps performed by a single surgical team at the Department of Oral and Maxillofacial Surgery at Peking University School and Hospital of Stomatology between May 1999 and March 2017 were reviewed. Demographic and surgical patient data with possible associations with free flap survival were recorded.

Each possible influencing factor was examined by univariate analysis using the χ^2 test. Factors with P values < 0.10 were included in logistic regression models to identify significant risk factors associated with free flap failure. All measured data were analyzed using IBM SPSS Statistics, version 21.0 (IBM, Armonk Corp., NY). $P < 0.05$ was considered statistically significant.

RESULTS

Patient Demographics

This study consisted of 130 pediatric patients (76 males and 54 females; mean age, 14.55 ± 2.99 years;

median age, 15 years; age range, 5–18 years). The follow-up time varied from 2 months to 18 years. The most common etiology was tumor, followed by trauma, congenital deformity, and inflammation conditions (Table I).

Regions of the Defects and Selection of Free Flaps

The regions of the patients' defects included the mandible, maxilla, cheek, palate, tongue, and mouth floor. The mandible (94 of 130, 72.3%) was the most common.

A multidisciplinary team conducted a comprehensive evaluation on each patient, noting the position and size of the defect, as well as the patient's age and general medical condition, to select the type and size of free flap needed. There were 135 free flap transfers performed in the 130 children: one child had three flaps transferred simultaneously, and three children had a second flap transferred when the primary flap failed. We used six kinds of free flaps: two kinds of osseous flaps and four kinds of soft tissue flaps. The reconstruction methods used for different defects are shown in Table II.

There were 3,340 patients who underwent 3,447 free flap transfers for head and neck reconstructions during the study period. Pediatric patients accounted for 3.9% of 3,340 patients, with pediatric flaps accounting for 3.9% of 3,447 flaps.

Surgical Technique and Recipient Vessels

All operations were performed simultaneously by two teams: one team resected the tumor, and the other was responsible for flap harvesting, vascular anastomosis, and defect reconstruction. Flap harvesting and the vascular anastomoses were performed by a single team (X.P., C. M., and Y.W.).

Every set of recipient vessels included one artery and one or two veins (Table III). The arteries that we chose were branches of the external carotid artery. Sometimes we cut off the external carotid artery before it emitted the maxillary artery to get a large diameter blood vessel. We used end-to-end anastomosis for most vessels, except for five internal jugular veins that were performed using end-to-side anastomoses. All microsurgical anastomoses were performed under 4 × magnification with a head-mounted loupe. The mean operating time was 6.1 hours.

TABLE I.
Etiological Characteristics of 130 Pediatric Patients Who Underwent Reconstructive Surgery.

Characteristic	*n* (%)
Tumor	111 (85.4)
Benign	73 (56.2)
Malignant	38 (29.2)
Trauma	10 (7.7)
Inflammation conditions	4 (3.1)
Congenital deformity	5 (3.8)

TABLE II.
The Reconstruction Methods Used for Different Defects

Region of Defect (*n*)	Fibula	Iliac Crest	ALTF	Forearm	Scapular	Rectus Abdominis
Mandible (94)	88	4	1	1	0	2
Maxilla (23)	9	0	13	0	0	4
Cheek (8)	0	0	0	2	5	1
Palate (3)	0	0	0	3	0	0
Tongue (1)	0	0	0	1	0	0
Mouth floor (1)	0	0	1	0	0	0
Total (130)	97	4	15	7	5	7

ALTF = anterolateral thigh flap.

Postoperative Monitoring and Care

Flaps were monitored by direct observation every half hour on the day of surgery, then every hour for 3 days, and then every 2 hours for 2 days. We observed the color, texture, skin texture, pinprick test results, and swelling degree of the flap. Once a vascular crisis was identified in a patient, immediate re-exploration was performed, and the vessels were anastomosed again when necessary.

Survival Status

Of the 135 flaps, 129 were successful (success rate, 95.6%). Vascular crises occurred in seven flaps, including four cases of arterial crisis and three cases of venous crisis. One flap was successfully salvaged, whereas six flaps failed. The vascular crisis rate was 5.2%, and the successful salvage rate was 14.3%. Vascular crises developed in three flaps postoperatively in the first 24 hours, three within 48 to 72 hours, and one within 10 days (Table IV).

Univariate analysis in the six cases of unsuccessful free flap transfer indicated that patient age ($P = 0.011$) and flap type ($P = 0.056$) were two potential influencing factors for free flap survival. Defect region ($P = 0.219$),

TABLE III.
Recipient Vessels of the 135 Free Flaps

Recipient Vessel	*n*
Artery	135
Facial A	101
Lingual A	13
External carotid A	11
Superior thyroid A	9
Superficial temporal A	1
Vein	158
External jugular V	80
Facial V	50
Common facial V	10
Retromandibular V	10
Internal jugular V	5
Internal jugular V branches	3

A = artery; V = vein.

TABLE IV.
Impact of Timing of Re-exploration Surgery on Flap Failure

Time (h)	Number of Flaps	Flap Survival	Flap Loss
Arterial vasospasm	3	0	3
0–24	2	0	2
24–72	0	0	0
> 72	1	0	1
Arterial thrombosis	1	0	1
0–24	0	0	0
24–72	1	0	1
> 72	0	0	0
Venous thrombosis	3	1	2
0–24	1	1	0
24–72	2	0	2
> 72	0	0	0

recipient artery choice ($P = 0.292$), and surgery time ($P = 0.533$) were not associated with free flap outcomes (Table V). Logistic regression analysis identified only patient age (5–9 years, $P = 0.037$) as a statistically significant risk factor for free flap survival (Table VI).

Complications

The postoperative complication rate was 7.0%. Early complications, those occurring within 30 days of surgery, occurred in six patients (4.7%). Late complications occurred in three patients (2.3%) (Table VII). All patients who had complications recovered with treatment. There were no severe complications.

All patients tolerated oral feedings after the gastric and tracheal tubes were discontinued. Postoperative speech functioning was normal, and all patients had normal or near-normal facial appearance and function after surgery.

TABLE V.
Univariate Analysis of Potential Influencing Factors for Free Flap Survival

Characteristic	Flap Success	Flap Failure	*P* Value
Age (years)			
5–9	8	3	
10–14	49	1	0.011‡*
15–18	72	2	
Flap type			
Osseous flap	99	2	0.056†*
Soft tissue flap	30	4	
Defect region			
Midface	25	3	0.219†
Lower face	99	3	
Recipient artery			
Facial A	97	4	
Lingual A	12	1	0.292‡
Superior thyroid A	8	1	
Surgery time			
≤ 6 hours	71	2	0.533‡
> 6 hours	58	4	

*$P < 0.1$.
†Continuity correction χ^2 test.
‡Fisher exact test.
A = artery; lower face = mandible, cheek, tongue, mouth floor; midface = maxilla, palate

TABLE VI.
Logistic Regression Analysis of Influencing Factors for Free Flap Survival

		OR 95% CI		
	OR	Lower	Upper	*P* Value
Age (years)				
5–9	13.397	1.167	153.838	0.037*
10–14 (reference)	1			
15–18	1.527	0.132	17.709	0.735
Donor site				
Osseous flap	0.224	0.035	1.439	0.115
Soft tissue flap (reference)	1			

Hosmer–Lemeshow statistic: 0.682, $P = 0.877$.
*$P < 0.05$.
CI = confidence interval; OR = odds ratio.

DISCUSSION

Pediatric head and neck defects represent surgical challenges for the reconstructive surgeon. This study reviewed our experience with 130 pediatric patients. The 95.6% flap survival rate in this series is similar to what has been reported in the literature.[4,5,18–22]

Vascularized free flap transfer was first attempted in children in 1975, shortly after its application in adults.[7] The earliest vascularized free flap was only used in limb defect repairs.[7,27–29] With the development of microsurgery, however, the scope of reconstruction in children broadened to the restoration of head and neck defects.

Flap failure in head and neck reconstruction is usually caused by vascular crises, including thrombosis and vasospasm.[28,29] Poor recipient vessel condition, small vessel size, endothelial damage, and inappropriate vascular pedicle length or position relative to the anastomosed

TABLE VII.
Complications Seen With the 135 Free Flap Cases

Complication	*n*
Early	6
Wound infection (RS)	2
Hematoma (RS)	2
Wound hydrops (RS)	1
Wound dehiscence in shank (DS)	1
Late	3
Infection of bone graft (RS)	1
Numbness of dorsalis pedis (DS)	1
Difficulty in walking (DS)	1

DS = donor site; RS = recipient site.

vessels all contribute to the occurrence of thrombosis and vasospasm.

However, systemic diseases that affect vessel condition, such as diabetes, hypertension, and arteriosclerosis, are very rare in children, creating a more favorable recipient environment for free flaps.[25] Additionally, benign tumor resection and trauma are dominant causes of head and neck defects in pediatric patients; thus, fewer patients have received radiotherapy preoperatively. This is also a factor that contributes to flap success because a history of irradiation is a potential risk factor for poor free flap survival in adults.[26]

Vessel size is associated with factors such as patient age, donor site, and recipient vessel choice. Endothelial damage to the anastomosed vessels is associated with factors such as the microsurgical technique and surgery time. The defect region determines the vascular pedicle length required. Additionally, the postoperative management and monitoring protocol may influence free flap outcome.

Initially, the technical feasibility of performing microsurgery in pediatric patients was a challenge. Smaller vessel size and vasospasm are two common problems compared with adults, particularly in younger children. Gilbert[16] reported that a 0.7-mm vessel diameter was the lower limit vessel size for safe anastomosis in children, whereas Shapiro et al.[15] considered the minimal feasible vessel diameter for anastomosis to be 0.5 mm. There is controversy about whether children's vessels are prone to vasospasm. Duteille et al.[6] deemed pediatric vessels more prone to vasospasm and thrombosis, which is consistent with findings from certain other studies.[13–15] On the other hand, still other studies have suggested that pediatric vessels are not prone to vasospasm.[5,11,12] Aboelatta and Aly[10] reported that patients 5 to 10 years of age present greater challenges in terms of surgical technique; patients under 5 years have more problems with flap outcomes; and patients over 10 years can undergo microsurgical procedures similar to adults. Serletti et al.[12] reported that vessel characteristics of children between 13 and 17 years of age are closer to those of adults. Margaret et al.[17] reported that patient age is not associated with the free flap outcome. In our study, based on the theory that children enter puberty at about 10 years of age and show a high facial growth rate before 14 years,[30,31] the patients were divided into three age groups: 5 to 9, 10 to 14, and 15 to 18 years. We found that the free flap failure rate was significantly higher ($P < 0.05$) in the 5 to 9 years age group than in the other two groups. Although the small diameter of the vessels did not affect the anastomoses, as suggested in the literature, the thinner walls were vulnerable to injury. In the 5 to 9 years age group, three flaps failed, including two arterial vasospasms (66.7%) and one venous thrombosis (33.3%). Of the six flaps that failed overall in all age groups, arterial vasospasms occurred in three (50%). However, due to the limited number of flap failures, we can only preliminarily speculate that the high free flap failure rate may be associated with small vessel size and a tendency to spasm. Thus, for children under 9 years of age, this should be taken into consideration during preoperative risk assessments. Furthermore, care must be taken to avoid trauma during vascular anastomosis. If vasospasm does occur in surgery, papaverine can be used to treat it.

Several studies have assessed donor flaps for pediatric head and neck reconstructions.[5,17,19,23,24] In our study, the mandible and maxilla were common defect regions: the majority were bone defects (117 of 130, 90%), and most were reconstructed with osseous flaps (101 of 117, 86.3%). Although the scapula, fibula, and iliac crest are all excellent choices for mandibular reconstruction, the fibula was the most common osseous flap (97 of 101, 96.0%) used. The scapula has lower donor site morbidity in a child,[19,32] and the scapular tip apophysis may offer greater remodeling potential.[19,24,32] However, in our study, the length of the mandibular defect was greater than 10 cm in 80% of cases; thus, the bone length of a scapular flap was insufficient. Furthermore, the patient must be in a lateral position when the scapula is harvested, and tumor resection is performed simultaneously by a second surgical team, which undoubtedly increases the difficulty and duration of surgery. The fibula can be molded into various shapes according to the particular bone defects present and provides a double cortex layer for implant stability. In addition, its location is advantageous for a two-team surgery.[33,34] Hence, the fibula was found to be the best choice for bone defect reconstruction in our study.

We know that surgery using osseous flaps for functional reconstruction is complicated, with longer operation times. Therefore, we wondered if the survival rates for osseous and soft tissue flaps would differ in pediatric head and neck reconstructions. However, statistical analysis showed that the success rates for osseous and soft tissue flaps in our series (98.0% and 88.2%, respectively) did not significantly differ ($P = 0.056$).

Traditionally, midfacial defects are obturated with bulky dental prostheses. At present, the free flap has become the preferred method for reconstruction of midfacial defects in adults as well as in children.[24,35] Few studies have compared the rates of flap failure for the midface and lower face. Because the recipient vessels that we selected were all in the neck, our midfacial reconstructions required the preparation of long vascular pedicles. At some point, venous or arterial transplantation was performed in pediatric patients with the use of short vascular pedicles,[36] which may increase the risk of postoperative anastomotic thrombosis. In our pediatric series, no statistically significant difference in flap failure rates was found between midfacial and lower facial reconstructions ($P = 0.219$). The reason might be that none of the patients needed venous or arterial transplantation because we chose free flaps with long vascular pedicles for the midfacial reconstructions.

In our study, postoperative vascular crises occurred in seven flaps, with arterial crises in four cases and venous crises in three cases. Arterial crises accounted for 57.1% of the vascular crises, which differs from findings in adults who have mainly venous crises.[26,37] It is regrettable that the only flap with a venous crisis was salvaged successfully, whereas two cases with venous crises and

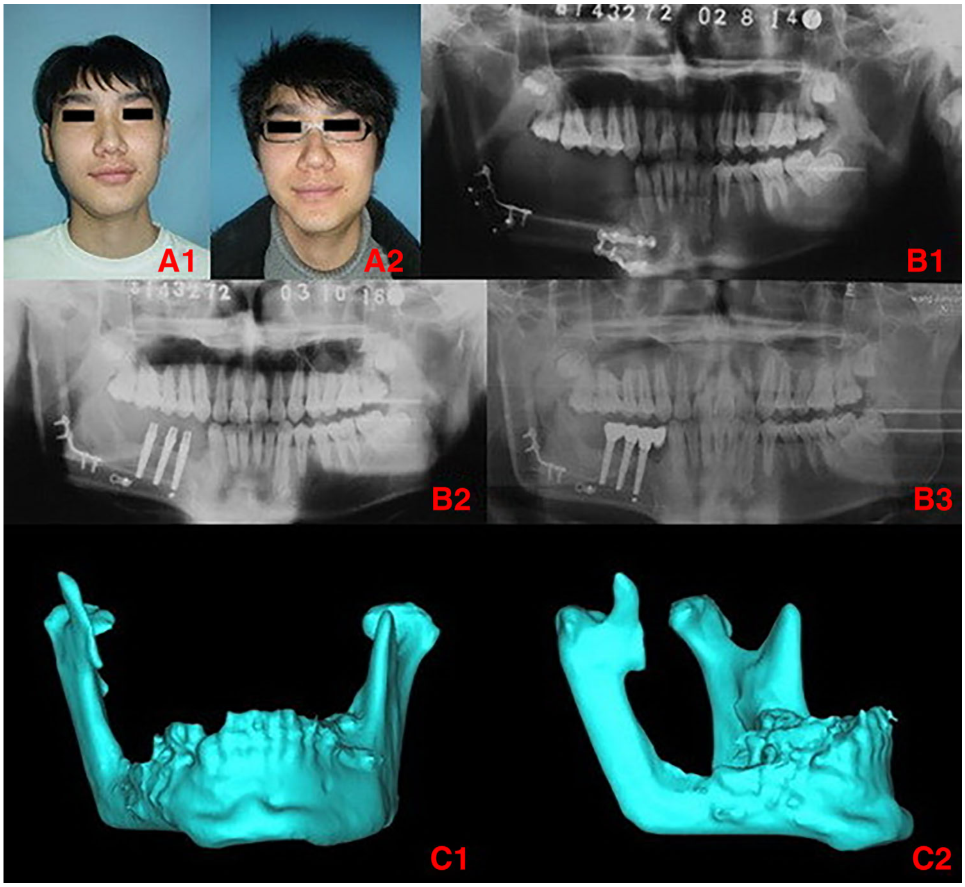

Fig. 1. A 13-year-old patient who underwent mandible reconstruction with a free fibula flap. (A1) Patient's 3-month postoperative photograph. (A2) Patient's photograph at 18 years. (B1–B3) Panoramic radiographs at 14 years, 16 years, and 18 years showed that the fibula grew with the mandible. (C1–C2) A three-dimensional computed tomography showed that the fibula healed well and the condylar process was remodeled. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

all four cases with arterial crises failed. The successful salvage rate of 14.3% was lower than that for adults in our department.[26] This was most likely because the early stages of arterial crises are difficult to detect; therefore, the cases were detected later on, when there was less chance of successful rescue.[26] Considering that arterial crises are more common in children than in adults, monitoring personnel should be aware of the risk of early arterial crisis in pediatric patients. Auxiliary monitoring instruments such as Doppler sonography could be used if equipment conditions are met.[38–40] However, there are many vessels in the region of neck, and the artery we used for anastomosis is very close to the external carotid artery and the branches. This greatly increases the probability of false positive. Thus, Doppler is not routinely used for flap monitoring in our study. We recommend closer flap observation for pediatric patients, and that surgeons not hesitate to explore should any signs of vascular crisis occur.

Venous thromboses occurred in two facial veins and one internal jugular vein. Our research has identified that flap failure is not associated with the recipient vein.[26] However, we questioned whether vascular crisis occurrence was associated with the recipient artery. We found no study to have compared the rates of flap failure for anastomoses to different branches of the external carotid artery in pediatric patients. In general, however, it is believed that the larger the vessel diameter, the lower the rate of flap failure. Yet, in the present study, no statistically significant difference was found between the recipient artery choice and flap failure ($P = 0.292$). Therefore, it is suggested that it is not the choice of the vessel to be anastomosed that matters as much as how well it matches with the donor vessel.

Although some studies have reported that children tolerate longer operative periods better than adults,[5,41] both Haljamae[42] and Singh et al.[43] found that anesthesia duration is associated with the postoperative complication rate. In general, the longer the operation, the longer the vessel is exposed, and the greater the vascular injury. In our study, the mean surgery time was 6.1 hours (median time, 6 hours). Therefore, the subjects were divided into two groups based on their surgery time, ≤ 6 hours and > 6 hours. Subsequent analysis found no statistically significant correlation between surgery time and free flap failure in our pediatric study cohort ($P = 0.533$).

Surgical technique has been reported to be the most important component affecting free flap success.[44] The three surgeons on our surgical team who performed the reconstruction surgeries (X.P., C.M., and Y.W.) all have much experience in microvascular anastomoses such that the quality of the vascular anastomoses was ensured.

Postoperative monitoring and care are also important factors that influence flap survival in pediatric patients. We suggest that direct clinical observation is the most effective method. In our study, all venous crises occurred in the first 72 hours, whereas three arterial crises occurred in the first 72 hours, and one occurred 10 days postoperation. These findings are similar to those seen in adults.[26,45] Therefore, the first 3 days after surgery represent a critical period for free flap survival in pediatric patients. Fortunately, with the development of intensive care, flaps can be better monitored to help prevent flap failure.

Traditionally, postoperative coordination of treatment is a challenge in children. It is difficult for children to maintain their head strictly motionless after surgery. Thus, we employed certain targeted pre- and postoperative measures. Surgeons and parents encouraged the children and repeatedly explained their conditions to them with patience. According to each patient's mental state and tolerance, an analgesic and sedative should be given. In this study, because the appropriate perioperative measures were taken, we had no problems obtaining the cooperation of most of the children postoperatively, and the children seemed to do even better than most adult patients.

Finally, when considering the use of free flaps in pediatric patients, whether the osseous flap will continue to grow with the native tissue and whether the acquisition of the flap from a growing donor site adversely affects future long-term growth are of great importance. Upton and Guo[5] reported on a series of 21 free fibula flap transfers for reconstruction of mandibular defects and found that fibulas transferred to the mandible did not grow. Other studies have found the same phenomenon.[5,46,47] As a result, some patients eventually required orthognathic surgery or the transfer of new flaps for surgical correction as they grew. On the contrary, most series on pediatric head and neck reconstruction have reported that free flaps seem to grow commensurately with surrounding structures.[4,19,22,47,48] We reviewed a series of 51 patients < 18 years of age who underwent mandibular reconstruction with vascularized fibula flaps from 15 articles; we found that the number of patients with preserved growth potential was greater than those with no growth potential and concluded that the growth potential of the fibula was related to age, condylar preservation, tumor pathology, and postoperative radiotherapy. This systematic review showed that whereas reconstruction after benign lesion resection, reconstruction between 8 and 12 years of age (which was termed the rapid growth stage), and condylar preservation facilitate postoperative mandibular growth, postoperative radiotherapy inhibits the same.[49]

In our experience, most free flaps continue to grow with the recipient area, and there is no marked evidence that surgery influences donor site growth. We had some cases with continuous radiographs during follow-up that demonstrate growth of transferred fibula (Fig. 1). However, the question of whether free flaps, especially free fibula flaps used to reconstruct mandibular defects, grow with native tissues still requires long-term follow-up until adulthood and in-depth, accurate research.

CONCLUSION

Free flap transfers for head and neck reconstruction in pediatric patients is safe and reliable. We recommend that more attention be paid to pediatric patients under 9 years of age when performing head and neck reconstructive surgery. Furthermore, free flap outcomes in pediatric head and neck reconstruction may be improved by meticulous surgical technique, adequate postoperative monitoring and care, and the timely recognition and management of complications.

ACKNOWLEDGMENT

We would like to thank the native English-speaking scientists of Elixigen Company (Huntington Beach, CA) for editing our article.

BIBLIOGRAPHY

1. Mao C, Peng X, Zhang L, Wang Y. Simplified head and neck reconstructive microsurgical techniques and their clinical applications. *Chinese Arch Otolaryngol Head Neck Surg* 2016;23:127–130.
2. Weckx A, Loomans N, Lenssen O. Perforator free flaps in head and neck reconstruction: a single-center low-volume experience. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2017;123:429–435.
3. Vamadeva SV, Tadros A. Head and neck reconstruction. *Br J Hosp Med (Lond)* 2016;77:343–348.
4. Jacob LM, Dong W, Chang DW. Outcomes of reconstructive surgery in pediatric oncology patients: review of 10-year experience. *Ann Surg Oncol* 2010;17:2563–2569.
5. Upton J, Guo L. Pediatric free tissue transfer: a 29-year experience with 433 transfers. *Plast Reconstr Surg* 2008;121:1725–1737.
6. Duteille F, Lim A, Dautel G. Free flap coverage of upper and lower limb tissue defects in children: a series of 22 patients. *Ann Plast Surg* 2003;50:344–349.
7. Harii K, Ohmori K. Free groin flaps in children. *Plast Reconstr Surg* 1975;55:588–592.
8. Konttila E, Koljonen V, Kauhanen S, Kallio P, Tukiainen E. Microvascular reconstruction in children: a report of 46 cases. *J Trauma* 2010;68:548–552.
9. Arnold DJ, Wax MK, Microvascular Committee of the American Academy of Otolaryngology–Head and Neck Surgery. Pediatric microvascular reconstruction: a report from the Microvascular Committee. *Otolaryngol Head Neck Surg* 2007;136:848–851.
10. Aboelatta YA, Aly HM. Free tissue transfer and replantation in pediatric patients: technical feasibility and outcome in a series of 28 patients. *J Hand Microsurg* 2013;5:74–80.
11. Akcal A, Karsidag S, Sucu DO, Turgut G, Ugurlu K. Microsurgical reconstruction in pediatric patients: a series of 30 patients. *Ulus Travma Acil Cerrahi Derg* 2013;19:411–416.
12. Serletti JM, Schingo VA Jr, Deuber MA, Carras AJ, Herrera HR, Reale VF. Free tissue transfer in pediatric patients. *Ann Plast Surg* 1996;36:561–568.
13. Devaraj VS, Kay SP, Batchelor AG, Yates A. Microvascular surgery in children. *Br J Plast Surg* 1991;44:276–280.
14. Canales F, Lineaweaver WC, Furnas H, et al. Microvascular tissue transfer in paediatric patients: analysis of 106 cases. *Br J Plast Surg* 1991;44:423–427.
15. Shapiro J, Akbarnia BA, Hanel DP. Free tissue transfer in children. *J Pediatr Orthop* 1989;9:590–595.
16. Gilbert A. Reconstruction of congenital hand defects with microvascular toe transfers. *Hand Clin* 1985;1:351–360.
17. Margaret JS MM, Michael EK, et al. Microsurgical reconstruction following oncologic resection in pediatric patients: a 15-year experience. *Ann Surg Oncol* 2017;24:4009–4016.
18. Bilkay U, Tiftikcioglu YO, Temiz G, Ozek C, Akin Y. Free-tissue transfers for reconstruction of oromandibular area in children. *Microsurgery* 2008;28:91–98.
19. Warren SM, Borud LJ, Brecht LE, Longaker MT, Siebert JW. Microvascular reconstruction of the pediatric mandible. *Plast Reconstr Surg* 2007;119:649–661.

20. Crosby MA, Martin JW, Robb GL, Chang DW. Pediatric mandibular reconstruction using a vascularized fibula flap. *Head Neck J Sci Spec* 2008;30:311–319.
21. Fowler NM, Futran ND. Utilization of free tissue transfer for pediatric oromandibular reconstruction. *Facial Plast Surg Clin North Am* 2014;22:549–557.
22. Mao C, Yu GY, Peng X, Guo CB, Huang MX, Zhang Y. Analysis of 30 consecutive free flap transplantation for head and neck reconstruction in paediatric patients. *Hua Xi Kou Qiang Yi Xue Za Zhi* 2004;22:477–480.
23. Yazar S, Wei FC, Cheng MH, Huang WC, Chuang DC, Lin CH. Safety and reliability of microsurgical free tissue transfers in paediatric head and neck reconstruction—a report of 72 cases. *J Plast Reconstr Aesthet Surg* 2008;61:767–771.
24. Genden EM, Buchbinder D, Chaplin JM, Lueg E, Funk GF, Urken ML. Reconstruction of the pediatric maxilla and mandible. *Arch Otolaryngol Head Neck Surg* 2000;126:293–300.
25. Mustoe TA, Upton J. Head and neck free flaps: are they safe in the irradiated or pediatric-patient. *Head Neck Surg* 1988;10:S3–S11.
26. Zhou W, Zhang WB, Yu Y, et al. Risk factors for free flap failure: a retrospective analysis of 881 free flaps for head and neck defect reconstruction. *Int J Oral Maxillofac Surg* 2017;46:941–945.
27. Mast BA, Newton ED. Aggressive use of free flaps in children for burn scar contractures and other soft-tissue deficits. *Ann Plas Surg* 1996;36:569–575.
28. Ross DA, Chow JY, Shin J, et al. Arterial coupling for microvascular free tissue transfer in head and neck reconstruction. *Arch Otolaryngol Head Neck Surg* 2005;131:891–895.
29. Fukuiwa T, Nishimoto K, Hayashi T, Kurono Y. Venous thrombosis after microvascular free-tissue transfer in head and neck cancer reconstruction. *Auris Nasus Larynx* 2008;35:390–396.
30. Pomerance HH. Nelson textbook of pediatrics. *Arch Pediatr Adolesc Med* 1997;151:324.
31. Ochoa BK, Nanda RS. Comparison of maxillary and mandibular growth. *Am J Orthod Dentofacial Orthop* 2004;125:148–159.
32. Teot L, Souyris F, Bosse JP. Pedicle scapular apophysis transplantation in congenital limb malformations. *Ann Plast Surg* 1992;29:332–340.
33. Hidalgo DA. Fibula free flap: a new method of mandible reconstruction. *Plast Reconstr Surg* 1989;84:71–79.
34. Bahr W, Stoll P, Wachter R. Use of the "double barrel" free vascularized fibula in mandibular reconstruction. *J Oral Maxil Surg* 1998;56:38–44.
35. O'Connell DA, Futran ND. Reconstruction of the midface and maxilla. *Curr Opin Otolaryngol Head Neck Surg* 2010;18:304–310.
36. Garfein E, Doscher M, Tepper O, Gill J, Gorlick R, Smith RV. Reconstruction of the pediatric midface following oncologic resection. *J Reconstr Microsurg* 2015;31:336–342.
37. Nahabedian MY, Singh N, Deune EG, Silverman R, Tufaro AP. Recipient vessel analysis for microvascular reconstruction of the head and neck. *Ann Plast Surg* 2004;52:148–155; discussion 156–147.
38. Chao AH, Meyerson J, Povoski SP, Kocak E. A review of devices used in the monitoring of microvascular free tissue transfers. *Expert Rev Med Devices* 2013;10:649–660.
39. Poder TG, Fortier PH. Implantable Doppler in monitoring free flaps: a cost-effectiveness analysis based on a systematic review of the literature. *Eur Ann Otorhinolaryngol Head Neck Dis* 2013;130:79–85.
40. Wax MK. The role of the implantable Doppler probe in free flap surgery. *Laryngoscope* 2014;124(suppl 1):S1–S12.
41. Yucel A, Aydin Y, Yazar S, Altintas F, Senyuva C. Elective free-tissue transfer in pediatric patients. *J Reconstr Microsurg* 2001;17:27–36.
42. Haljamae H. Anesthetic risk factors. *Acta Chir Scand Suppl* 1989;550:11–19; discussion 19–21.
43. Singh B, Cordeiro PG, Santamaria E, Shaha AR, Pfister DG, Shah JP. Factors associated with complications in microvascular reconstruction of head and neck defects. *Plast Reconstr Surg* 1999;103:403–411.
44. Spiegel JH, Polat JK. Microvascular flap reconstruction by otolaryngologists: prevalence, postoperative care, and monitoring techniques. *Laryngoscope* 2007;117:485–490.
45. Bui DT, Cordeiro PG, Hu QY, Disa JJ, Pusic A, Mehrara BJ. Free flap reexploration: indications, treatment, and outcomes in 1193 free flaps. *Plast Reconstr Surg* 2007;119:2092–2100.
46. Guo L, Ferraro NF, Padwa BL, Kaban LB, Upton J. Vascularized fibular graft for pediatric mandibular reconstruction. *Plast Reconstr Surg* 2008;121:2095–2105.
47. Phillips JH, Rechner B, Tompson BD. Mandibular growth following reconstruction using a free fibula graft in the pediatric facial skeleton. *Plast Reconstr Surg* 2005;116:419–424.
48. Temiz G, Bilkay U, Tiftikcioglu YO, Mezili CT, Songur E. The evaluation of flap growth and long-term results of pediatric mandible reconstructions using free fibular flaps. *Microsurgery* 2015;35:253–261.
49. Zhang WB, Liang T, Peng X. Mandibular growth after paediatric mandibular reconstruction with the vascularized free fibula flap: a systematic review. *Int J Oral Maxillofac Surg* 2016;45:440–447.