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The Great Auricular Nerve as a Nerve Graft Donor: An Anatomical and Clinical Study of the Maximum Harvestable Length and Branches

Mayu Ueno | Kentaro Tanaka | Kyoichi Murakami | Naoya Ishida

Reconstructive Plastic Surgery, Institute of Science Tokyo, Tokyo, Japan

Correspondence: Mayu Ueno (mayu.plas@tmd.ac.jp)

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ABSTRACT

Background: For immediate facial nerve reconstruction during head and neck tumor resection, a great auricular nerve (GAN) graft can be potentially harvested in the same surgical field during tumor resection. However, it is often avoided because a GAN graft is only approximately 5 cm long without any branches, and a sural nerve graft is recommended for larger defects. We investigated the length of the GAN that can be harvested in 18 patients, along with the evaluation of postoperative facial nerve palsy.

Methods: We retrospectively analyzed 18 cases of immediate facial nerve reconstruction using the GAN from 2018 to 2023 at our hospital. In most cases, we traced the GAN to the back surface of the sternocleidomastoid and harvested the nerve graft immediately before the loops of the cervical nerve plexus or bifurcation into the phrenic nerve. This tracing method allowed the collection of a longer nerve graft with more branches.

Results: The mean length of the harvested GAN was 8.16 cm (95% confidence interval 7.42–8.89 cm), with the longest graft being 10.5 cm. The GAN grafts had an average of 1.83 branches and were 1.76–2.23 mm in diameter. Three patients had two peripheral transected edges of the facial nerve, each of which was sutured with a branch of the GAN graft. Three patients had five–six peripheral edges and required additional nerve grafts, such as the sural nerve. Postoperative facial nerve palsy was grade III or IV by House–Brackmann and FNGS 2.0 in all cases.

Conclusions: For immediate facial nerve reconstruction, the GAN can be harvested in a length of at least 8 cm and few branches by sufficient dissection of the back surface of the sternocleidomastoid muscle, including its branches and other sensory nerves, with few complications.

1 | Introduction

During resection of head and neck tumors, such as parotid gland tumors and cancers of the external auditory canal, the facial nerve is often resected simultaneously. For nerve defects with large gaps that cannot be simply sutured, nerve grafts are used for immediate facial nerve reconstruction. These grafts include autografts, allografts, and synthetic nerve conduit grafts (Stocco et al. 2023; Colen et al. 2009). While artificial nerves (nerve conduits) such as PGA-C tubes have the advantage of not requiring the sacrifice of a donor nerve, the ideal gap length for ensuring good reconstruction results is 6 mm to 3 cm according to previous studies (Jiang et al. 2010; Rbia and Shin 2007). Although various nerve conduits are available, they may not be as effective as autografts.

The great auricular nerve (GAN) is useful as an autologous nerve reconstruction material because it can be harvested in the same surgical field during resection of head and neck tumors. However, most studies have reported that a graft of approximately 5 cm length with a few branches can be harvested from the GAN, and that the sural nerve should be used for nerve defects closer to 10 cm.

The sural nerve is an excellent autologous nerve graft because it can be harvested as a long, well-branched nerve graft and the sensory deficit after harvesting is small (Bamba et al. 2021; Ehretsman et al. 1999). However, the graft needs to be harvested from an area completely separate from the head and neck surgical field, which means injury to a healthy area that is not affected by the disease. In rare cases, some patients may experience severe postoperative pain and numbness. At our hospital, we are actively attempting to use the GAN for immediate facial nerve reconstruction. Except for cases in which the GAN needs to be resected along with the tumor, it can be used for nerve defects that require multiple branches and grafts longer than 5 cm. To objectively demonstrate the effectiveness of the GAN as an autograft for facial nerve reconstruction, we investigated the length of the GAN graft that can actually be harvested in 18 patients who underwent immediate facial nerve reconstruction using the GAN, along with evaluating the occurrence of postoperative facial nerve palsy.

2 | Materials and Methods

A total of 18 patients who underwent immediate facial nerve reconstruction using the GAN at our institution from 2018 to 2023 were retrospectively evaluated. This study has been approved by the Medical Research Ethics Committee of the Institute of Science Tokyo (receipt number: M2000-2177). Preoperative consultation with a head and neck surgeon was performed, and this study did not include cases in which the GAN could not be used because adequate tumor resection required concomitant resection of the GAN. The mean age of the patients was 56.2 (17–74) years, and 11 patients were men. The causative diseases were external auditory canal carcinoma (EAC) in 11 patients, parotid carcinoma in three, middle ear carcinoma in two, and facial nerve schwannoma in two patients. We tracked the GAN to the back surface of the sternocleidomastoid (SCM) and collected the nerve graft immediately before the loops of the cervical plexus or bifurcation into the phrenic nerve in most cases (Figure 1). For each patient, we analyzed the length, diameter, and number of branches of the harvested nerve, which were recorded from the surgical records or intraoperative photographs using Image J (NIH, US). We also investigated whether other nerve grafts were used in combination or whether free flaps or free fat transplantation were required for soft tissue filling. Ten patients with video recordings of facial nerve palsy between 1 and 1.5 years postoperatively were also evaluated for the degree of postoperative facial nerve paralysis by a plastic surgeon. We used Yanagihara's method (40-point method), which is the most commonly used scale in Japan, and the Sunnybrook facial grading system. We also graded them using the House–Brackmann grading system, the global standard scale, and FNGS 2.0, which is a 2009 revision of the House–Brackmann facial grading system by the Facial Nerve Disorders Committee (Vrabec et al. 2009).

3 | Results

In all 18 patients, the GAN was present on the anterior surface of the SCM; the distal end of the GAN was captured and marked with a nylon thread by the head and neck surgeon during tumor

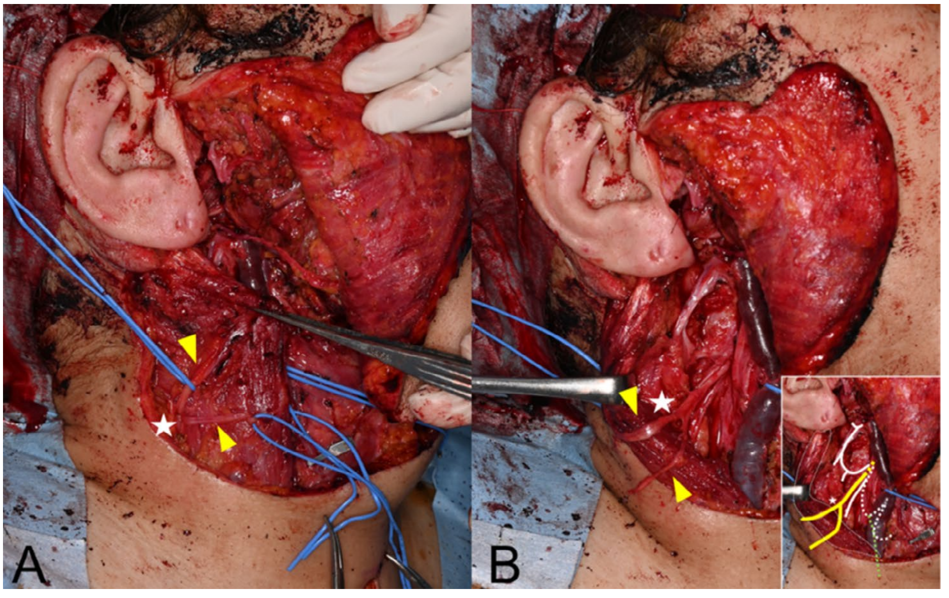

FIGURE 1 | The great auricular nerve (GAN) tracked back to the sternocleidomastoid (SCM). (A) The GAN on the front of the SCM, (B) GAN is pulled out through Erb's point to the back of the SCM. In this case, because the facial nerve had two peripheral ends, we used a GAN graft with only two branches and the remaining cervical plexus branches. Arrowheads: posterior and deep branches of the GAN, star: Erb's point, yellow line: the GAN, white line: visible cervical plexus, white dotted line: the cervical plexus is invisible in this photograph, green dotted line: phrenic nerve is invisible in this image.

TABLE 1 | All date of the patients, reconstruction and harvested GAN graft.

No.	Age/sex	Disease	Soft tissue required	GAN graft Length (cm)	GAN graft Branches	Peripheral FN ends	Other nerve graft	Suture pattern
1	55 M	EAC	Free fat	10	2	2		
2	17 F	Middle ear ca.	Free fat	8	2	1		
3	51 F	Parotid ca.		5.5	2	2		
4	52 M	Parotid ca.	ALT flap	8.5	3	6	Motor nerve of ALT	
5	44 M	EAC	Free fat	6	1	1		
6	67 F	EAC	Free fat	10	3	1		
7	69 M	EAC	Free fat	7	1	1		
8	51 M	EAC		8.5	2	2		
9	72 F	EAC	Free fat	7	1	1		
10	57 M	FN schwannoma		6	3	1		
11	50 M	Parotid ca.		9	3	5	Sural nerve	
12	67 F	FN schwannoma		9.3	2	1		
13	52 F	EAC		9	1	1		
14	40 M	Middle ear ca.	Free fat	7	2	1		
15	62 M	EAC		8	2	5	Sural nerve	
16	69 M	EAC	Free fat	10.5	1	1		
17	62 F	EAC	Free fat	8	1	1		
18	74 M	EAC	Free fat	9.5	1	1		

Abbreviations: ALT, anterolateral thigh; ca., carcinoma; EAC, external auditory canal carcinoma; FN, facial nerve; GAN, greater auricular nerve.

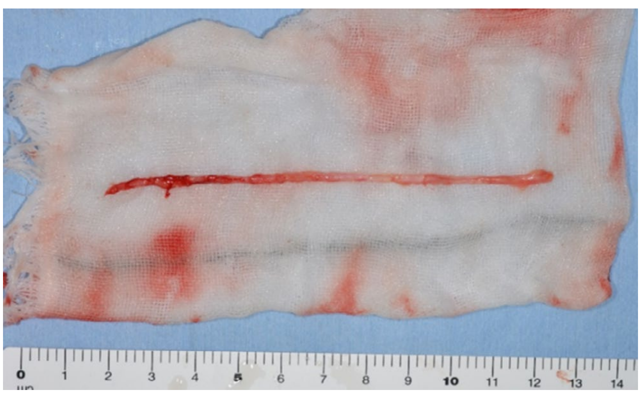

FIGURE 2 | The longest great auricular nerve (GAN) graft collected measured 10.5 cm.

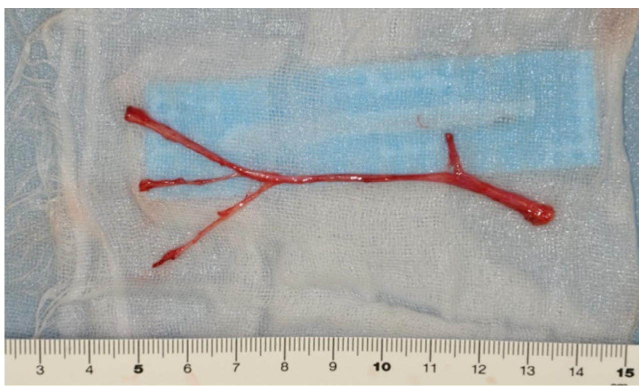

FIGURE 3 | One of the most bifurcated great auricular nerve (GAN) grafts collected (three branches).

resection. In all cases, the GAN ran around to the back of the SCM at the posterior edge of the SCM and continued to the cervical plexus.

The mean length of the GAN graft in the 18 patients was 8.16 cm (95% confidence interval 7.42–8.89 cm) (Table 1), with the longest graft being 10.5 cm (Figure 2). The average diameter of the GAN graft was 2.23 mm at the proximal end and 1.76 mm at the main distal end. Nerve grafts with one to three branches were harvested (Figure 3), with the average number of branches being 1.83. During reconstruction, three patients had two peripheral facial nerve ends, each sutured using only one branch of the GAN graft (Figure 4). In another three patients, there were five to six peripheral ends, requiring not only a GAN graft but also a sural nerve graft or the motor branch of the lateral vastus lateralis, which was harvested at the time of anterolateral thigh (ALT) flap collection. An ALT flap was used in one case of parotid carcinoma for a skin defect, and non-vascularized free fat grafts from the lower abdomen were used in 10 other cases of EAC and middle ear carcinoma to prevent cerebrospinal fluid leakage. In the remaining seven cases, there were no soft tissue defects, and only nerve reconstruction was performed. The degree of postoperative facial paralysis was evaluated using four grading methods in 10 patients, in whom videos of facial paralysis were recorded between 1 and 1.5 years postoperatively. The

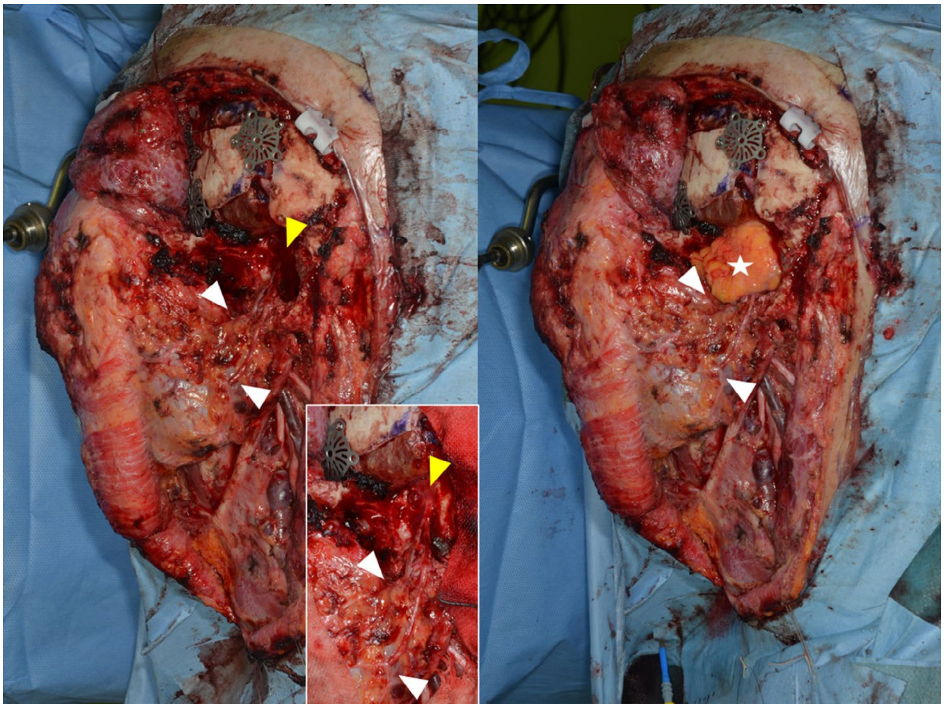

FIGURE 4 | In one case of facial nerve reconstruction, the two ends of the facial nerve were sutured to two ends of the great auricular nerve (GAN) graft. A nonvascularaized fat graft was also used. Yellow arrowhead: the end of the GAN graft connected to the central facial nerve, white arrowhead: two ends of the GAN graft connected to the peripheral facial nerve ends, white star: nonvascularized free fat graft to prevent cerebrospinal fluid leakage.

TABLE 2 | Evaluation of postoperative facial nerve palsy.

No.	POD	Yanagihara's 40-point grading	Sunnybrook	House–Brackmann	FNGS 2.0 score	FNGS 2.0 grade
1	410	12	29	IV	18	IV
2	541	18	38	IV	19	IV
4	494	12	37	V	16	IV
6	529	18	51	IV	14	III
8	527	6	42	IV	14	III
10	445	16	34	III	15	III
11	513	14	48	III	13	III
12	466	16	51	III	12	III
13	445	14	43	III	15	IV
16	436	12	25	V	19	IV
Average		13.8	39.8	III–IV (3.8)	15.5	III–IV (3.6)

Abbreviation: POD, postoperative day.

mean scores were 12.5 in Yanagihara's 40-point method and 39.8 in the Sunnybrook grading system (Table 2). According to House–Brackmann and FNGS 2.0, all cases of postoperative facial paralysis were graded III or IV.

4 | Discussion

This study is the first to identify the length and branches of the GAN that can be harvested in clinical practice for facial nerve reconstruction, in addition to showing its excellent potential as a nerve graft by tracking it to the back surface of the SCM. Most surgeons in Japan dissect the GAN only from the front surface of the SCM and do not track it to the back and deep to the SCM, harvesting only an approximately 5 cm GAN graft with no branches. By dissecting to the posterior aspect of the SCM, the branches to other sensory nerves also derived from the cervical plexus can be identified, thus ensuring a greater number of branches in the graft. The GAN graft is useful for reconstructing the nerve gap not only during facial nerve immediate reconstruction but also secondary facial animation reconstruction, such as masseter nerve or hypoglossal nerve transfer (Biglioli et al. 2012). We hope that this study will help clinicians to utilize GAN grafts more profitably.

The GAN is a sensory nerve that arises from the second and third cervical nerves (Tubbs et al. 2007) and is mainly distributed to the supraparotid gland and the dorsal and caudal third of the auricle and mastoid process (Peuker and Filler 2002; Lefkowitz et al. 2013) (Figure 5). Together with the other cervical nerves, it forms the cervical plexus, which branches into the transverse cervical and supraclavicular nerves, both of which emerge anteriorly from the posterior edge of the SCM and run toward the subcutaneous area of the anterolateral neck (Tubbs et al. 2007). This point is also called Erb's point (Baker et al. 2012). There are various theories regarding the branching of the GAN, with many researchers speculating that it has two branches: an anterior branch and posterior branch (Lefkowitz et al. 2013; Altafulla et al. 2019). However, further anatomical studies have revealed that the GAN divides into three branches: an anterior branch, a posterior superficial branch, and a deep posterior branch, which is a branch from either of the two branches, although the names of these branches may vary (Vieira et al. 2002; Yang et al. 2015). The branching pattern varies (Yang et al. 2015), and resection of the anterior branch is considered inevitable in parotidectomy because it runs deep through the parotid capsule before entering the skin (Vieira et al. 2002; Iwai and Konishi 2015). Even if the anterior branch is resected, at least two branches of the GAN may be secured if the posterior and deep branches are preserved.

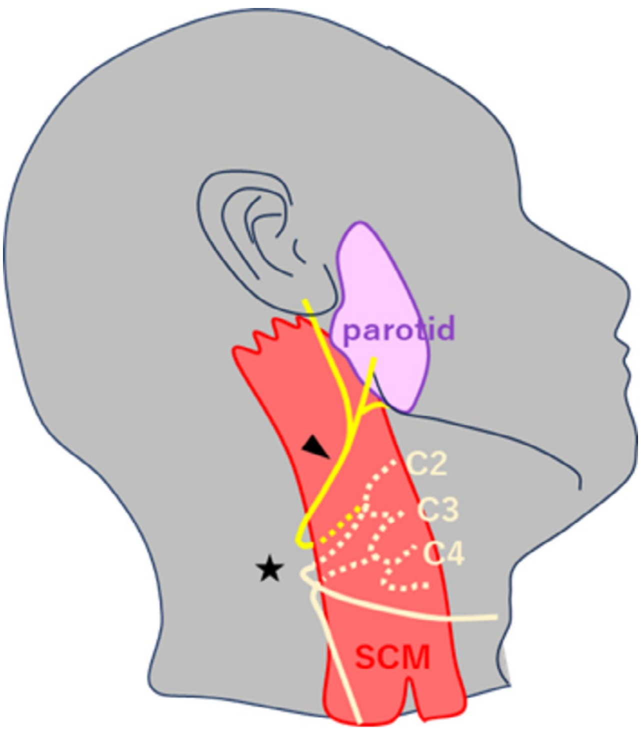

FIGURE 5 | The anatomical schema of the great auricular nerve (GAN). Arrow head: GAN, star: Erb's point. The GAN originates from the cervical plexus and emerges on front surface of sternocleidomastoid muscle (SCM), turning at Erb's point with the transcervical and supraclavicular nerves. The GAN branches into two or three branches, each innervating the supraparotid and postauricular regions and the earlobe.

As described in previous studies, in all cases in this study, the GAN turned to the back surface of the SCM at Erb's point and continued to the cervical plexus. In the majority of these cases, we obtained two or more branches; in seven cases, only one branch was obtained. In all cases, the GAN was harvested after tumor resection and determination of the nerve graft requirement (one peripheral and one central end), which likely influenced the number of branches that were collected.

It is also possible to secure three to five branches by tracing the GAN beyond Erb's point to the back of the SCM and resecting the transverse cervical nerve, which branches from the cervical plexus, and possibly the supraclavicular nerve (Baker et al. 2012), which arises from C3 to C4.

One of the postoperative complications of harvesting the GAN is immediate postoperative sensory insensitivity of the area innervated by this nerve, mainly in the auricular region. Vieira et al. (2002) investigated postoperative perceptual disturbances in 30 cases of parotid tumor resection with posterior branch-sparing surgery and total GAN amputation surgery. They reported that the parotid area and mandibular angle area were nearly completely paralyzed at 1 week postoperatively but gradually recovered to very mild insensitivity within approximately 1 year. There are also reports on harvesting of the transverse cervical and supraclavicular nerves from the same plexus, which show that postoperative paresthesia does not interfere with daily life. Onitsuka et al. (2006) administered a postoperative questionnaire for assessing numbness and pain in the neck and shoulder, along with a shoulder joint range of motion test to five patients with unilateral lymph node metastases requiring bilateral neck dissection, including C2–C4 resection on the metastatic side and C2–C4 preservation on the contralateral side. The results showed that there was only a small difference between the two sides in the satisfaction rates related to neck perception, and most of the patients had "a little" symptoms at 1 year postoperatively. Considering the fact that even with sural nerve harvesting, areas of insensitivity may persist, and although rare, some patients may complain of postoperative numbness (Bamba et al. 2021), there is no need to be overly afraid of cervical insensitivity following GAN harvesting, leading to the harvesting of the sural nerve in a different surgical field.

The average diameter at the most proximal and most distal point of the GAN graft calculated by Image J was 2.23 and 1.76 mm, respectively. Altafulla et al. reported that the diameter of the GAN is 1.58 mm proximally (Altafulla et al. 2019), which is thinner than that measured in our study. Although the level of measurement was not specified, they probably measured the nerve diameter at Erb's point, that is, at the posterior margin of the SCM. We obtained a nerve graft with a larger diameter by following the GAN more proximally, just before the cervical nerve plexus. The diameter of the facial nerve varies greatly from site to site. The diameter of the proximal edge of the facial nerve is 1.16–1.58 mm at the level of the facial canal (Myckatyn and Mackinnon 2004), as measured during the EAC excision operation, or empirically about 2 mm at the time of nerve suturing after releasing it from the narrow bone facial canal. The diameter where it exits the stylomastoid foramen is 2.66 mm (Humphrey and Kriet 2008) as measured during parotid gland tumor excision. The diameter of each of the five branches of the distal facial nerve is 0.8 to 1.2 mm (Pascual et al. 2019). Ortigüela et al. reported that the diameter of a sural nerve graft is 2.0–4.0 mm (Ortigüela et al. 1987). Based on these reports and the diameter of the GAN graft in this study, we can say GAN is a better nerve graft for facial nerve defect reconstruction as it has a more appropriate diameter.

The mean scores for postoperative facial nerve paralysis were 12.5 by Yanagihara's 40-point method and 39.8 by Sunnybrook grading. The average House–Brackmann grade was 3.8 and that of FNGS 2.0 was 3.6, with 15.5 points before grading. Lee et al. reported that the postoperative average FNGS 2.0 score of 12 patients reconstructed by a sural nerve graft was 14.6 (Lee et al. 2015). Recent studies on immediate facial nerve surgery after facial nerve damage have shown an average outcome of Grade III or IV functionality (based on the House–Brackmann scale). Compared to these findings, the paralysis scores after reconstruction of the facial nerve using the GAN in this study were not inferior to those of the peroneal nerve. Recovery from postoperative facial paralysis is dependent on many factors, including postoperative radiation, length of the nerve defect, and environment of the transplant bed, making general comparisons difficult. A randomized controlled trial comparing the GAN and sural nerve or other nerve grafts is warranted.

4.1 | Limitations

This was a retrospective study, and in each case, the GAN graft was not collected as fully as possible. This is because the GAN graft was collected after tumor resection, that is, after the length of the facial nerve defect and number of branches required had been determined. Consequently, it is highly possible that only the required length of the nerve graft was collected and not the maximum length. Therefore, longer GAN grafts with more branches could potentially have been collected than those reported in this study; for example, if the study was conducted on cadavers. Regarding the evaluation of postoperative facial nerve palsy, it was difficult to analyze a comparable population with sural nerve reconstruction due to differences in the underlying disease and soft tissue reconstruction methods. Accordingly, it was not possible to demonstrate the non-inferiority of the GAN graft as a reconstruction material. In the future, randomized allocation studies of nerve graft selection should be conducted. Furthermore, since most of the patients in this study had EAC carcinoma, which is a rare disease with a poor prognosis, several patients came to our hospital for surgery from distant areas of Japan and then returned to their hometowns for postoperative treatment. Therefore, we could not conduct a valid follow-up for postoperative auricular and neck insensitivity. In the future, we plan to conduct a follow-up study on postoperative complications with a larger sample size.

5 | Conclusion

The GAN, as a nerve graft for immediate facial nerve reconstruction, can be harvested and utilized up to a length of at least 8 cm with few branches by performing dissection of the back of the SCN muscle, including the branches of the GAN and other sensory nerves, with few complications.

Acknowledgments

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data supporting the findings of this study are available within the article. Raw photographs and movies were preserved at our hospital and are available from the corresponding author Mayu Ueno on request. All study participants provided comprehensive informed consent for use of clinical data and intraoperative photographs, and the study design was approved by our hospital committee. This manuscript contains no digital images or photographs of participants that can be identified. This is a retrospective study and involved no intervention on the human body.

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