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Outcomes of Facial Nerve Grafting in 155 Cases: Predictive Value of History and Preoperative Function

*Ömer Afşın Özmen, †Maurizio Falcioni, †Lorenzo Lauda, and †Mario Sanna

**Department of Otorhinolaryngology, Uludağ University Faculty of Medicine, Bursa, Turkey; and †Gruppo Otologico, Piacenza, Italy*

Objective: To investigate the factors that were effectual on the recovery of the facial nerve functions after repair with grafting.
Study Design: Retrospective case review.
Setting: Private neuro-otologic and cranial base quaternary referral center.
Patients: One hundred ninety-four patients underwent facial nerve grafting during lateral cranial base surgery between July 1989 and December 2009. The mean age of the patients was 44.1 ± 15.8 years (range, 2–79 yr). There were 94 male and 100 female patients. Facial nerve functions were normal in 89 patients, whereas facial nerve paresis or paralysis was present for a mean duration of 25.4 months (range, 1–600 mo) in the rest of the patients.
Main Outcome Measure: Final facial nerve motor function.
Results: Best outcome, which was Grade III according to House-Brackmann scale, was achieved in 105 of 155 patients with a follow-up of 1 year or longer (67.7%). Final result was grade IV in 23 (14.8%), grade V in 8 (5.2%), and grade VI in 19 patients (12.3%). Preoperative deficit duration was found to be the only significant factor that affected the prognosis (p = 0.027). Receiver operating characteristic curve analysis revealed that the most critical time for recovery to grades III and IV function is 6 months ($p < 0.001$).
Conclusion: A number of factors were implicated to affect the success rate of facial nerve grafting, but only the duration of preoperative facial nerve deficit was found to be significant. Thus, timely management of facial nerve problems is critical for achieving optimal results. **Key Words:** Anastomosis—Cerebellopontine angle tumors—Facial nerve—Facial paralysis—Graft—Cranial base surgery.

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Facial nerve paralysis is the most frustrating complication after lateral cranial base surgery both for the patients and for the surgeons. Although facial paralysis is not a life-threatening condition, it has functional, cosmetic, psychological, and social implications (1).

Fortunately, the incidence of permanent facial paralysis has been diminished by the improvement of the surgical technique and use of intraoperative monitoring; however, in a small proportion of patients, preserving the integrity of the facial nerve may not be possible. Immediate repair of the facial nerve is desirable when such an injury has occurred. An interposition graft should be used whenever proximal and distal stumps are available, but tensionless primary repair is not feasible.

The best possible functional outcome after facial nerve has been cut is House-Brackmann (HB) grade III, whichever method of reconstruction is used. However, HB grade III could not be achieved in all cases. The present study aimed to investigate the factors that were effectual on the recovery of the facial nerve functions after repair with grafting by the experience at Gruppo Otologico that was built up over 20 years.

MATERIALS AND METHODS

A retrospective chart review of cases, which underwent lateral cranial base surgery at the Gruppo Otologico between July 1989 and December 2009, was performed. One hundred ninety-four patients of 2,547 were found to undergo facial nerve grafting. Patients who did not have a follow-up of at least 1 year or complete medical records were excluded from the study, reducing the group to 155 cases. The patients who were operated for temporal bone carcinomas also were excluded from the study because all of them underwent postoperative radiation therapy. Some of the patients were previously reported (2).

The ages of the patients ranged from 2 to 79 years (mean ± standard deviation, 44.1 ± 15.8 yr). Distribution of sex (94 male and 100 female patients) and side involved (99 right and 95 left) were almost equal. The majority of the patients had the diagnosis of facial nerve tumor (FNT; 69 patients) and vestibular schwannomas (VSs; 65 patients). Other causes included petrous

Address correspondence and reprint requests to Ömer Afşın Özmen, M.D., Uludağ Üniversitesi Tıp Fakültesi Kulak BurunBoğaz A.D., 16059 Görükle-Bursa, Turkey; E-mail: oaozmen@yahoo.com

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bone cholesteatomas (PBCs; 24 patients), iatrogenic or traumatic lesions (18 patients), jugular paragangliomas (10 patients), and 8 other miscellaneous diseases.

Preoperative and postoperative facial nerve function was directly evaluated by the physicians of the Gruppo Otologico, according to the HB grading scale (1). Facial nerve functions were normal in 89 patients, whereas facial nerve paresis (grade II, 13; grade III, 14; grade IV, 7; and grade V, 11) or paralysis (grade VI, 60) was present in 105 patients preoperatively. The mean duration of the deficit was 25.4 months (range, 1–600 mo). The majority of the patients with normal preoperative facial functions had VS (60 of 89).

All surgical procedures were performed by the senior author (M. S.). Various surgical procedures were used (76 translabyrinthine approaches, 1 retrosigmoid approach, 38 transcochlear approaches, 18 transotic approaches, 10 middle cranial fossa approaches, 18 transmastoid approaches, 14 combined middle cranial fossa, transmastoid approaches, 9 petrosectomies, and 10 infratemporal fossa approaches; transparotid approach also was used in 6 cases in addition to the above-mentioned procedures). The sural nerve was selected as the donor site in all cases except in four, in which the great auricular nerve was used. The length of nerve grafts was adjusted to eliminate any cause of tension. In cases with cerebellopontine angle (CPA) involvement, a long graft was progressively laid on the surface of the brainstem, the trigeminal nerve, and the anterior wall of the internal auditory canal (IAC) to maximize the surface area of contact and stabilized with biological glue to decrease chances of displacement. A bony support was frequently available when the temporal bone was being worked on. In case the hearing had to be destroyed, the cochlear turns might be opened and used as a new facial canal. In the early cases, fibrin glue was used only in cases where bony support was available. Over time, fibrin glue was used more frequently because this technique seemed to be technically easier and less traumatic for the nerve, leaving the microsutures only for particular situations, for example, in lesions extending into the parotid gland. Stump approximation also was secured with a fascial cuff in some situations, particularly at the level of the CPA (3,4).

Definitive facial function was accepted as the main outcome measure. Seven factors were taken into consideration in the analysis of function: preoperative facial nerve grading, duration of preoperative facial nerve paralysis if present, etiology of the paralysis, location of the anastomosis, the technique used in the proximal and distal anastomosis site, and presence or absence of rerouting.

Statistical analysis of the data was performed using Statistical Package for Social Sciences (SPSS) for windows version 16 (SPSS Inc., Chicago, IL, USA). Quantitative data were analyzed with Student's *t* test. Categorical data were analyzed with χ^2 test. For ordinal or nonparametric data, Kruskall-Wallis test was used if more than 2 groups were present; Mann-Whitney *U* test was used for analysis of 2 samples and for subgroup analysis. Univariate analysis, which was performed by the use of a logistic model, was applied to identify the most significant and independent factors influencing outcome. Statistical significance was accepted as $p < 0.05$. For subgroup analysis, Bonferroni correction was used to adjust the *p* value.

RESULTS

Data analysis was performed on 155 cases, with a follow-up of 1 year or longer. Thirty-nine patients were lost to follow-up; therefore, they were excluded from the study. The mean follow-up was 41.7 ± 34 (range, 12–195 mo).

At the last follow-up, 105 (67.7%) of the 155 patients had recovered to a grade III facial function, 23 (14.8%) to a grade IV function, and 8 (5.2%) to a grade V function, whereas 19 (12.3%) showed no recovery at all. Figure 1 shows the postoperative FN function in all 155 patients.

Patients who recovered to HB grade III were younger than those who did not (42 versus 47.2). This difference was close to significance ($p = 0.053$). Similarly, when the ages of patients that recovered to grades III and IV or not were analyzed, approximate results were encountered (42.7 versus 48.7, $p = 0.062$). Age was not detected as a significant factor in multivariate analysis ($p = 0.891$).

Preoperative facial nerve grade was found to have a significant effect on the outcome ($p = 0.004$; Fig. 2). In the subgroup analysis, the outcome of grade I was significantly better than that of grade II ($p = 0.003$), grade IV ($p = 0.003$), and grade VI ($p = 0.001$). However, preoperative facial function was not found to be a significant factor in the multivariate analysis ($p = 0.161$).

Preoperative deficit duration (onset accepted as the first sign of weakness) was found to be significantly different in patients with grade III compared to grades IV–VI and grades III–IV compared to grades V–VI facial nerve functions ($p < 0.001$). Multivariate analysis also showed that preoperative facial paralysis duration as the only significant factor that affected the prognosis ($p = 0.027$). Receiver operating characteristic curve analysis was used to calculate the cutoff value for the duration of the facial paralysis. According to this, the most critical time for recovery to grade III was found to be 5 months, and that for recovery to grades III and IV function was 6 months ($p < 0.001$) (Fig. 3). In particular, patients without a preoperative deficit or with a deficit lasting less than 6 months showed a much higher percentage of postoperative grades III and IV functions than those with a preoperative deficit lasting more than 6 months (93% versus 61%, $p < 0.001$). We also analyzed the preoperative deficit for 1 year, and there were significantly

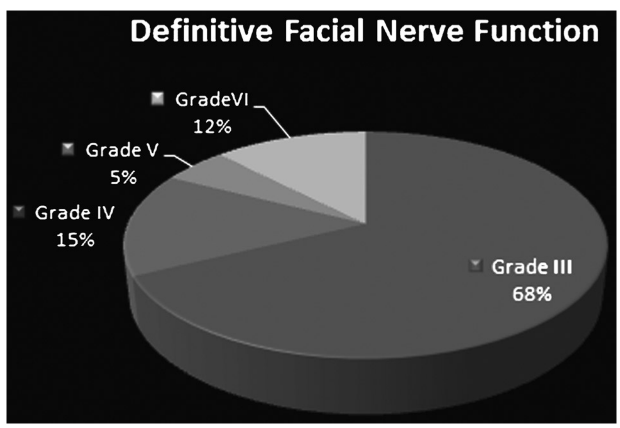

FIG. 1. Postoperative facial nerve functions according to the HB grading system.

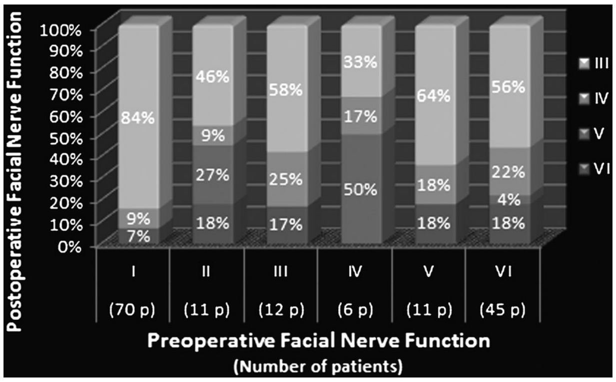

FIG. 2. Postoperative facial nerve recovery rates according to preoperative facial nerve function.

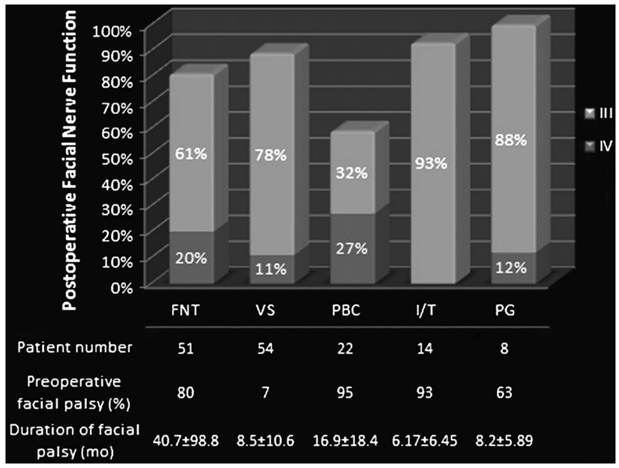

FIG. 4. Postoperative recovery rates to grades III and IV according to major causes in accordance to preoperative facial nerve functions. FNT indicates facial nerve tumor; I/T, iatrogenic/traumatic; PBC, petrous bone cholesteatoma; PG, paraganglioma; VS: vestibular schwannoma.

higher rates of grades III and IV functions if the duration of deficit was less than 1 year (91 versus 52%, $p < 0.001$).

The functional results were analyzed according to the 5 most frequent etiologic groups. The lowest recovery rates were encountered for the PBC cases, whereas the most favorable outcomes were encountered in iatrogenic/traumatic group (Fig. 4). The statistical analysis pointed out significant differences between groups ($p < 0.001$), and the subgroup analysis revealed significant difference between PBC group compared with iatrogenic/traumatic ($p < 0.001$) and VS ($p = 0.003$) groups after Bonferroni correction. However, the preoperative facial paralysis duration was not homogenous between groups, and the etiologic origin was not found to be a significant factor in multivariate analysis ($p = 0.829$).

The site of anastomosis was analyzed by combining the proximal and distal sites of anastomosis. According to this, 3 groups were formed: 1) intradural anastomosis, which includes grafting from CPA to IAC; 2) transdural anastomosis, which has the proximal site at CPA or IAC and distal site from the labyrinthine segment to the extratemporal portion of the facial nerve; and 3) extradural anastomosis, which has both sites of anastomosis between the labyrinthine segment to the extratemporal portion. There was a significant difference between the 3 groups ($p = 0.024$). In the subgroup analysis, transdural anastomosis was found to have worse outcome compared with both intradural ($p < 0.001$) and extradural anastomosis ($p < 0.001$). Outcomes of intradural and extradural anastomosis were similar ($p = 0.568$) (Fig. 5). However, the duration of facial nerve paralysis was not homogenous between groups, which also seemed to be the cause of the difference between the groups, and the anastomosis site was found to be insignificant in the multivariate analysis ($p = 0.886$). The technique used for anastomosis was grouped as glue or suture, and there was no difference between anastomosis technique both in the proximal ($p = 0.529$) and distal sites ($p = 0.906$).

We also performed a subgroup analysis for major causes. In VS group, tumor size and facial functional outcome was analyzed. There was a great variability in tumor size, which was between 0.5 and 4.5 (2.73 ± 0.99); however, there was not any relationship between the size of the

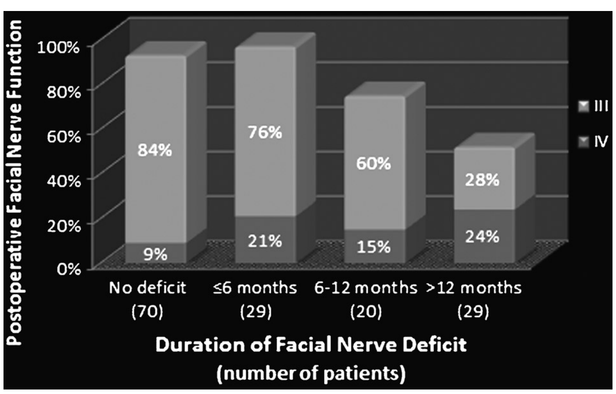

FIG. 3. Facial nerve recovery rates according to the duration of functional deficit. The recovery rates were presented for patients belonging to each time interval separately.

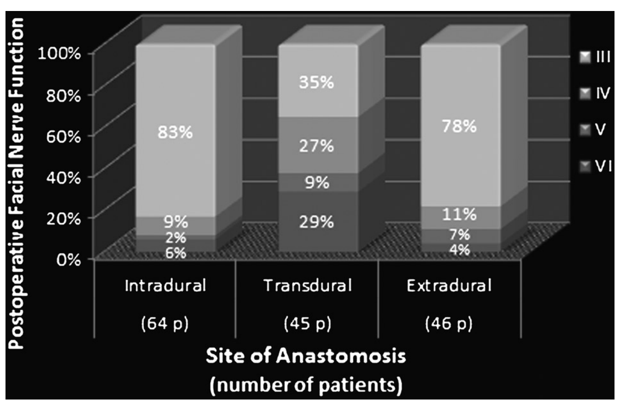

FIG. 5. Postoperative facial nerve recovery rates according to site of anastomosis. p indicates patients.

tumor and cases reaching to grade III or not ($p = 0.388$). In FNTs, we analyzed the total number of invaded segments and the facial nerve functional outcome. As the number of invaded segments increased, the rate of recovery to HB grade III was found to decrease significantly ($p = 0.045$).

DISCUSSION

Ideal outcome for a facial nerve recovery includes complete synchronous restoration of muscle tone and symmetry at rest as well as voluntary facial movement without synkinesis. Once the facial nerve is interrupted, the best possible outcome of facial nerve function is HB grade III regardless of the method used. Thus, the rate of patients recovered to HB grade III, which includes restoration of the symmetric muscle tone, strong eye closure, and oral sphincter competence, remains as the indicator of success. HB grade IV also may signify an acceptable outcome, as the patient achieves at least normal muscle tone at rest, and facial functions may be maintained with minor corrections (e.g., eyelid implant). The reports on the outcome of interposition grafting of the facial nerve are limited in the literature. The rate of HB grade III function changes from 13% to 86%, whereas HB grades III and IV was achieved in 50% to 95% of the patients (Table 1) (2,5–12). The results of the present study were consistent with the literature, with 68% HB grade III and 83% HB grades III and IV.

The best repair option for a transected facial nerve is end-to-end reapproximation. However, if the gap between the 2 stumps precludes a tensionless anastomosis, interposition grafting is indicated, provided that proximal and distal stumps are available. Although a few centimeters can be gained to establish a primary anastomosis by rerouting, this also would deteriorate the blood supply of the nerve, and there is the risk of further injury to the nerve. Thus, interposition graft may be used to reconstruct any defect longer than 1 cm, as shorter grafts were reported to be associated with poor results (13). Interposition graft capacitates the surgeon to connect all the way from the CPA to the distal branches in the parotid gland.

Although the number of patients reaching to HB grade III usually favors primary anastomosis compared with interposition grafts, the difference was not found to be significant in most of the studies (8,10,14). Two important factors may be responsible for a worse result associated with interposition grafting compared to primary repair. It is suggested that fibrosis increases, and lesser axons pass thorough each anastomotic line (15). Thus, primary coaptation requiring only one anastomosis is more advantageous than a graft repair, which is associated with 2 anastomoses. Another factor that should be considered is the peculiarities of the sensory nerves that are almost exclusively used as the donor. Although nerves that are similar to facial nerve in diameter are selected, there are certain inevitable differences between sensory and motor nerves. Sensory nerves contain greater number of fibers than motor nerves; on the other hand, these fibers are lesser in diameter (16). Regeneration through such a graft was shown to create a different neural architecture than the original nerve: many of the regenerated fibers became unmyelinated, and small amount of myelinated fibers were found to be smaller in size than the original (17).

Pathophysiology of the facial nerve lesion is complex in case of tumor compression, and pathologic changes appear to start long before being clinically evident. Two important factors are responsible for maintaining normal facial function. The first one is the motor neuron reserve. Facial functions were reported to be preserved until more than 50% of motor neurons had been degenerated (18). Further neural degeneration and axonal demyelination is counterbalanced with the collateral sprouting and hypertrophy of the innervated muscle fibers. By this way, if the patient is affected by a very slowly growing disease, facial paralysis can be avoided until less than 10% of the motor neurons are functional (19). Thus, patients with preoperative facial paralysis should have more severe damage, which would leave the nerve incapable of regenerating through the anastomosis. Proximal injury to the

TABLE 1. *Outcomes of facial nerve reconstruction by interposition grafting*

	No. of cases	Cause	Preoperative facial palsy (%)	Duration of facial palsy (mean)	Postoperative facial function (%)			
					HB III	HB IV	HB V	HB VI
Gunther et al. (5)	21	Facial neuroma	71	0.5–29 (5.4) mo	86	9	5	—
Samii and Matthies (12)	42	VS	21	1–95 (18.3) mo	73	21	6	—
Magliulo et al. (6)	6	PBC	100	<2 yr	67		33	
Stephanian et al. (7)	24	Multiple	63	<1 yr 1–2 yr >2 yr 9 4 2	45	36	18	
Malik et al. (8)	25	Multiple	100	NS	56	54		
King et al. (9)	12	Multiple	NS	NS	41	17	25	17
Arriaga and Brackmann (10)	8	Multiple	75	3–13 (7.4) mo	13	37	25	25
Bascom et al. (11)[a]	61/72	Multiple	NS	1–189 (13) mo	61	21	10	8
Falcioni et al. (2)	56	Multiple	68	1–120 (20.2) mo	46	25	13	16
Present study	155	Multiple	54	1–600 (25.4) mo	68	15	5	12

NS indicates not specified; PBC, petrous bone cholesteatoma; VS, vestibular schwannoma.

[a]Although most of the patients (61 of 72) were treated with interposition grafting, the results of interposition grafting were not reported separately, and the results of primary repair was better than that of grafting. May's facial nerve grading system (FNGS) was used in this study, which was adapted to House-Brackmann (HB) classification (FNGS I–II as HB III, FNGS III as HB IV, FNGS IV as HB V, and FNGS V as HB VI).

nerve also was reported to be associated with slower rate of recovery, which also would be related to lesser regenerative capacity (20). Involvement of the proximal segments of the nerve was not found to be associated with poor prognosis in the present study; however, VS was the main cause in this site, which was associated with a better outcome. On the other hand, transdural anastomosis inferred a poor prognosis, but this also would be related to the underlying pathology, namely, FNT and PBC, which constituted the cause in most of these cases. Experimentally, age was reported to be associated with less efficient neural regeneration (21); the subject is controversial in clinical studies (8,20).

Irrespective of the grade, duration of the preoperative facial dysfunction, which also was noticed in a number of previous studies, was found as the single most important prognostic factor in the present study (2,14). In a previous study, we calculated the critical time for surgery as 1 year after diagnosis of facial paralysis to obtain optimal facial recovery (2). In the present study, cutoff point was found as 6 months, which at least strengthen our previous report. This matters most in patients with FNTs having HB grades I and II function because these patients will most probably end up with HB grade III. On the other hand, when the facial paralysis eventually progress, the patient may have to face an unfavorable result.

We had the clinical impression that the bigger the tumor, the worse the facial grafting outcome. However, this is not supported by the results of the present study. The size of the tumor is important, but neural injury might be affected by other factors. For instance, the compression force exerted on the nerve might be greater by a smaller tumor located in IAC or fallopian canal. The tumor-nerve interaction also may be different in different tumors. In some of the VSs, the tumor was found to be densely bound to facial nerve obscuring the cleavage plane (18). Even invasion to the facial nerve has been reported (22). Cystic nature of the tumor seems to be an important factor as they reduce the anatomic preservation rate of the facial nerve (12).

Although, it was not found to be a significant factor in the multivariate analysis, PBC was associated with the most unfavorable outcome. This might indicate more severe damage to the nerve. Cholesteatoma is known to cause facial paralysis by compression and invasion of the nerve. Several enzymes are formed in the cholesteatoma, which were associated with bone resorption; however, they have never been reported to have an additional role in facial paralysis (23).

There is a high interrater variability in the evaluation of HB grading system (9). Moreover, there may be a large variability between the patients in the same grade. Namely, some patients in the grade III had facial nerve functions close to grade II; however, the forehead branches of the facial nerve never reported to function after interposition grafting. Nevertheless, it is a practical system and also the most common grading system that permits comparison between different studies. In some reports, HB grade II function was reported after end-to-end anastomosis, but this is an unusual finding (8). In Gruppo Otologico, it is tended to report the functions in the lower grade when hesitated.

Facial nerve reconstruction is more challenging in the CPA and IAC. Almost all of our patients were operated on with transmastoid and translabyrinthine procedures, which provide an excellent approach for the reconstruction of the facial nerve with interposition grafting (3,4,24,25). Another factor that eases the technical difficulty in proximal anastomosis is the fibrin glue. Use of glue elicits an easier and less traumatic way of anastomosis without diminishing the stability of the anastomosis (10,14).

Duration of follow-up was accepted as 12 months in majority of the studies. One year is appropriate to confirm failure of anastomosis, if no sign of recovery is present by this time. However, better function may be anticipated in case of ongoing recovery. Although first signs of return of facial functions are usually encountered around 6 months, recovery continues up to 2 years (20,26). Better performance was encountered in the subsequent follow-up of some patients from our previous study, which would probably be valid for patients with minimum follow-up in the present study.

An important problem of the previous studies on facial nerve grafting is the small sample size. The present study provides the largest series from a single institution, which may elicit adequate data for multivariate analysis.

CONCLUSION

Interposition grafting stands out as an indispensable technique in the facial nerve reconstruction, allowing the surgeon to repair implausible defects. There are a number of factors associated with the success rate of facial nerve grafting, but only duration of preoperative facial nerve deficit was found to be significant. Thus, timely management of the facial nerve problems is critical for achieving optimal results.

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