Otology & Neurotology
26:284–291

A Comparison of Surgical Techniques Used in Dynamic Reanimation of the Paralyzed Face

Tass H. Malik, Gerard Kelly, Aftab Ahmed, Shakeel R. Saeed, and Richard T. Ramsden

University Department of Otorhinolaryngology—Head and Neck Surgery, Manchester Royal Infirmary, Oxford Road, Manchester, England, U.K.

Objectives: To compare the outcomes of three surgical techniques used in the rehabilitation of the paralyzed face.
Study Design: Retrospective study.
Setting: University-based tertiary referral center.
Patients: Between 1976 and 2000, rehabilitative facial nerve surgery was performed on 70 adult patients with varying underlying diseases.
Intervention: Three methods of facial nerve rehabilitative surgery were performed: end-to-end anastomosis, cable nerve graft interposition, and classic faciohypoglossal transposition.
Main Outcome Measures: The House-Brackmann grade was scored at 6, 12, 24, and 36 months by the two senior authors. A favorable outcome was defined as House-Brackmann Grade ≤ III. Other parameters recorded were repair technique, age, nerve rerouting, whether the repair was immediate or delayed, and the anatomic position of the nerve defect in relation to the geniculate ganglion.
Results: Data were available on 66 patients (94%), of whom 13 had an end-to-end anastomosis, 25 a cable nerve graft interposition, and 28 a classic faciohypoglossal transposition. At 24 months, a House-Brackmann Grade ≤ III was achieved in 84.6% of those who underwent end-to-end anastomosis, 56.0% of those who underwent cable nerve graft interposition, and 25.0% of those who underwent classical faciohypoglossal transposition. End-to-end anastomosis and cable nerve graft interposition were superior to classic faciohypoglossal transposition (log-rank test, $p = 0.0013$). Twenty-five percent of all cases demonstrated improvement in House-Brackmann grade after 24 months. Increasing age at the time of repair was associated with a poorer outcome ($p = 0.03$ on logistic regression).
Conclusion: End-to-end anastomosis confers the best facial function, followed by cable nerve graft interposition and then classic faciohypoglossal transposition. Contrary to some previous opinions, improvement in facial function can still occur 2 years after surgical repair, particularly with classic faciohypoglossal transposition. **Key Words:** Cable nerve graft interposition—Classic faciohypoglossal transposition—End-to-end anastomosis—Paralyzed face—Rehabilitative surgery—Facial nerve—Reanimation—Repair.
Otol Neurotol **26:**284–291, 2005.

Facial nerve paralysis is one of the most devastating peripheral nerve injuries. The effects are further exaggerated by the relative hyperactivity of the contralateral side. The patient suffers serious functional, cosmetic, and psychological problems, with impaired ability to communicate both verbally and nonverbally. In particular, the loss of oral competence may lead to drooling and difficulty with articulation; loss of the eye sphincter function, especially in the absence of tearing, can lead to blurred vision, exposure keratopathy, and corneal ulceration. Perhaps the most dramatic impact of facial paralysis, however, is the psychological effect on the patient. Sufferers are self-conscious, and this can result in cases of isolation and fear of interaction with others. The cosmetic deformity of a complete facial paralysis is evident to everyone, even on cursory inspection.

There is a broad spectrum of dynamic and static reconstructive techniques available to reanimate the paralyzed face, none of which fully restore facial function. These methods rarely reestablish independent movement of the eyelids and midface (1). Although voluntary movement may be improved, no method restores the lost spontaneous involuntary movement associated with emotion. The suitability of each restorative technique is related to the location, cause, and duration of the facial nerve injury and the general health and prognosis of the patient. Synkinesis (mass movement) remains a problem, resulting in a loss of regional independent muscle movement.

In our institution, three methods of dynamic repair of a disrupted facial nerve have been used in the past 23 years: direct end-to-end coaptation, cable nerve graft

Address correspondence and reprint requests to Shakeel R. Saeed, M.D., University Department of Otolaryngology—Head and Neck Surgery, Manchester Royal Infirmary, Oxford Road, Manchester M13 9WL, England, U.K.; Email s.r.saeed@btopenworld.com

interposition (both of which use the same facial nucleus to reinnervate the muscles it previously innervated), and the ipsilateral classic faciohypoglossal transposition (where another motor nucleus provides cortical input to the facial musculature).

PATIENTS AND METHODS

The case notes of all patients who had undergone a facial nerve repair between 1976 and 2000 were examined retrospectively. Our institution is a tertiary referral center for neurotology and skull base surgery. All patients had a complete facial paralysis (House-Brackmann [HB] Grade VI) caused by the pathologic process and/or surgery to eradicate the disease. After a variable time interval (ranging from none to several years), the facial nerve was repaired using one of three techniques: end-to-end coaptation, cable nerve graft interposition, or classic faciohypoglossal transposition.

The HB grade of each patient was recorded at the outpatient review at or nearest to 6, 12, 24, and 36 months after repair of the facial nerve. The two senior authors graded the patient's facial function. For those patients in whom the facial nerve was repaired before 1986 (the time at which we routinely used the HB grading system), the HB grade was derived from photographs or videos depicting the face at rest and on movement. To assess the outcome of the repair statistically, HB grades were divided into two groups: Group 1, HB Grade III or better; and Group 2, HB Grade IV or worse. The division into these groups is an important one because HB Grade III or better implies the ability to close the eye completely and reduce morbidity to the eye. A successful outcome was defined as HB Grade III or better at 24 months after surgery.

Data recorded from the case notes included the following: type of repair (end-to-end coaptation, cable nerve graft interposition, or classic faciohypoglossal transposition), age at the time of nerve repair, sex, cause (disease or surgery) of facial nerve defect, interval between nerve deficit and nerve repair, position of nerve defect (proximal or distal to the geniculate ganglion), whether the facial nerve was rerouted or not, and HB grade before the original operation. Patients were excluded from the study if no data were available on the HB grade at or after 24 months after nerve repair.

Statistical analysis was by the Fisher's two-tailed exact test with a level of $p < 0.05$ indicating a significant result. The results for the three different methods of nerve repair were also plotted as Kaplan-Meier survival curves, and statistical significance between the three methods was calculated using the log-rank test. The effect of the age of the patient and outcome of each method of nerve repair was assessed by logistic regression.

RESULTS

Seventy patients had facial reanimation procedures. Results were available in 66 patients (94%). Data were unavailable in the remainder because three patients had been lost to follow-up and one patient had died.

All patients had a HB Grade VI paralysis before reanimation. In most cases, this was caused by a transection of the facial nerve, which was identified and repaired at the original operation by either end-to-end coaptation or cable nerve graft interposition, when technically feasible. Less often, usually after surgery for vestibular schwannoma, the nerve was thought to be anatomically intact but the face remained paralyzed despite a period of observation, necessitating a second (delayed) reanimation procedure.

A standard method of nerve repair was carried out in most cases. The nerve ends were trimmed, and the coaptation was performed with a 9-0 nylon (Prolene, Ethicon, Inc., Somerville, NJ, U.S.A.) suture (usually three sutures in the perineurium) and the anastomosis wrapped in a vein or temporalis fascia graft. Fibrin glue was used if sutures were difficult to place at the facial nerve stump if the site of repair was in the posterior fossa.

General demographics

Thirty-one patients were male and 35 were female. The mean age was 43 years (range, 17–67 yr).

Cause of facial nerve paralysis

The pathologic processes resulting in facial paralysis areshown in Figure 1. The cause of the paralysis was the pathologic process itself in 17 of 66 (25.7%) cases, but in most cases (49 of 66 [74.3%]) the facial paralysis was caused by surgical intervention to eradicate the disease process. Because vestibular schwannoma constitutes the largest group (30 patients), a subanalysis was conducted (Table 1).

Outcome of facial nerve reanimation methods

The distribution of repair methods is shown in Table 2. Of the 25 patients that had a cable nerve graft repair, the greater auricular nerve was used in 24 cases; in the

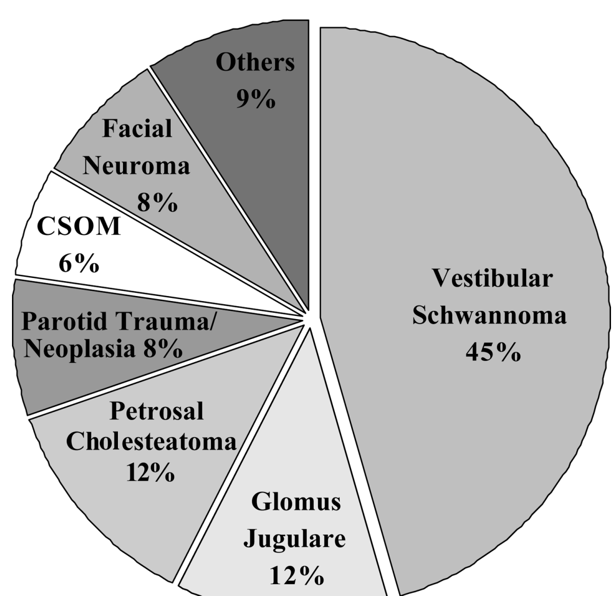

FIG. 1. Causes of facial paralysis. CSOM, chronic suppurative otitis media. Others: meningioma (3%), cholesterol granuloma (1.5%), synovial sarcoma (1.5%), hypoglossal schwannoma (1.5%), skull base fracture (1.5%).

TABLE 1. *Subanalysis of vestibular schwannoma excision*

	No.
Approach	
Translabyrinthine	21
Suboccipital or retrosigmoid	9
Repair method	
End-to-end anastomosis	6
Cable nerve graft interposition	4
Faciohypoglossal transposition	20

remaining case, the donor nerve was the sural nerve. The HB grades after each method of repair are listed in Table 3. Using our definition of a favorable outcome as HB Grade ≤ III by 24-month follow-up, the results of each method of repair were compared with each other, as shown in Table 4.

Figure 2 shows the results of the three methods of nerve repair another way as a Kaplan-Meier survival curve. The data were right-censored. The "survival" probability of an individual changes when the endpoint is reached, resulting in an upward step. Because most of our patients were seen at 6, 12, 24, and 36 months, most of the steps are seen at these intervals. The Kaplan-Meier method is usually performed with more continuous data. When the three methods of facial nerve reanimation are compared using the log-rank test, the results are highly significant ($p = 0.0013$). The survival curve shows that by 24 months, the fastest rate of improvement had occurred with end-to-end coaptation, followed by cable nerve graft interposition and then faciohypoglossal transposition.

Interestingly, according to the data available, by 36 months, the faciohypoglossal transposition estimate reaches the same endpoint as cable nerve graft interposition, but end-to-end coaptation is still the best method of repair, with 85% of patients reaching HB Grade III or better. For all three methods, continuing improvement after 24 months was seen in 8 of 32 (25%) cases, particularly in the faciohypoglossal transposition group (5 of 13 patients where data were available). Continued improvement after 24 months was seen in 1 of the 5 cases in the end-to-end group and in 2 of 14 cases in the cable nerve graft interposition group where data were available.

Failure rate of the three methods

Table 5 shows the failure rate (HB grade not improving from VI after repair) of the three methods of nerve repair.

Achievement of HB Grade II

Only two patients achieved a HB grade of II. These patients were in the group repaired by end-to-end coaptation.

TABLE 2. *Method of facial nerve repair*

Repair method	No.	%
End-to-end coaptation	13	19.7
Cable nerve graft	25	37.9
Classic faciohypoglossal transposition	28	42.4

TABLE 3. *Overall analysis of success of repair by method used*

	End-to-end coaptation (%)	Cable nerve graft (%)	Faciohypoglossal transposition (%)	Fisher's exact test
HB Grade ≤ III at 24 mo	11/13 (84.6)	14/25 (56.0)	7/28 (25.0)	$p = 0.001$

Effect of time interval between initial and reparative surgery

The only method of repair with a time interval between initial and reparative surgery was classic faciohypoglossal transposition (median, 9 mo; range, 0–5 yr). This delay was to allow for possible spontaneous improvement in the facial function when there was uncertainty as to the nerve's integrity. In this group, a repair interval of 12 months or less was compared with that of more than 12 months (Table 6). Interestingly, one of the faciohypoglossal transposition repairs performed 5 years after the initial paralysis showed improvement to Grade IV at 24 months after the repair.

Effect of rerouting the facial nerve

Table 7 shows the outcome of 37 cases of end-to-end coaptation and cable graft grafts analyzed together for the effect of rerouting of the nerve at the tympanic and mastoid portions. None of the faciohypoglossal transposition cases were rerouted. Even when analyzed individually for each method, the effect of rerouting on a favorable outcome for end-to-end coaptation and cable nerve graft interposition was not statistically significant.

Effect of age

Overall, when all three methods of repair were analyzed together, increasing age was associated with a poorer outcome ($p = 0.03$ on logistic regression). However, the faciohypoglossal transposition group appeared to be confounded with age (Table 8): this group had the oldest patients and the worst outcome at 24 months, raising the possibility of a selection bias for older patients undergoing this procedure. Once this was adjusted for age, there was a significant difference in the three treatment groups ($p = 0.05$).

Effect of pre- or postgeniculate nerve defect

Table 9 shows the results (where data were available in 64 cases) of all the methods of nerve repair when the

TABLE 4. *Comparison of success of methods of repair*

Repair method	Fisher's exact test
End-to-end coaptation versus cable nerve graft	$p = 0.15$
Cable nerve graft versus faciohypoglossal transposition	$p = 0.03$
End-to-end coaptation versus faciohypoglossal transposition	$p = 0.005$

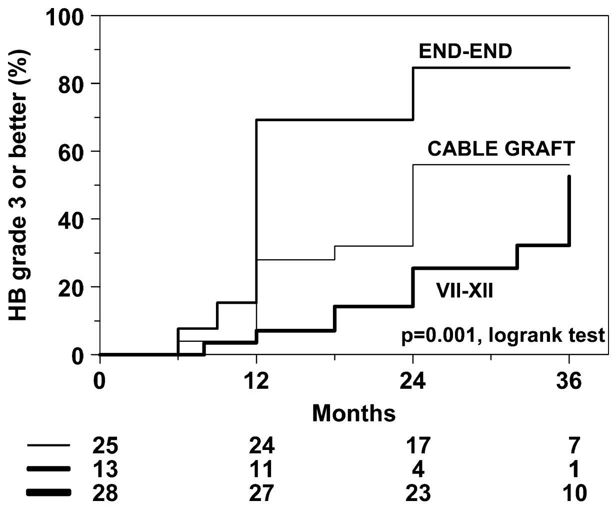

FIG. 2. Kaplan-Meier analysis of HB Grade ≤ III with the three methods of nerve repair.

position of the nerve defect relative to the geniculate ganglion (proximal or distal) was analyzed for a favorable outcome. When analyzed individually for each of the three methods, the effect of a pre- or postganglionic defect on a favorable outcome for each of the three methods was also not statistically significant.

Effect of preoperative HB grade

This is defined as the HB grade just before the original excisional surgery, before the facial function deteriorated to HB Grade VI. When analyzed in 65 patients, a preoperative HB Grade I to III did not improve successful outcome when compared with HB Grade IV to VI (Table 10). The effect of a preoperative HB Grade I also did not confer any advantage when compared with Grade II to VI.

Effect of malignant disease

There were four cases of malignancy, the outcomes of which are shown in Table 11.

DISCUSSION

Since 1821, when Sir Charles Bell (2) established that the facial nerve was responsible for the motor control of the 17 pairs of facial muscles, the ideal reanimatory procedure for the paralyzed face has remained elusive. The ideal outcome includes the complete synchronous restoration of muscle tone and symmetry at rest as well as voluntary facial movement without synkinesis. Reestablishing eye sphincter function for corneal protection and oral sphincter competence is the most important functional aim. The symmetric restoration of involuntary control that occurs with emotional responses is important for nonverbal communication, but no method of facial reanimation can achieve this. Synkinesis also remains a major problem because it is very difficult to dissociate the movements of muscles, even by fascicular alignment and perineural coaptation (3). Dynamic reanimation requires a functioning nerve distal to the anastomosis, intact motor end plates, and viable muscles.

Various scoring systems have been devised for grading the severity of the facial nerve impairment, but the most universally accepted and used is the HB six-point grade (4) because of its simplicity, reproducibility, and low interobserver variability (5). However, it relies on the subjective judgment of *trained* observers: having the two most senior authors grade the recovery reduced this bias. This grading system has been criticized because it does not take into account regional differences and may not be sensitive enough to discriminate small variations.

In our study, the largest group of patients requiring facial nerve repair were patients with a vestibular schwannoma (45%). Although the overall rate of facial nerve paralysis in our institution is low (3% for all tumor sizes), in the past 25 years over 1,000 vestibular schwannoma operations have been performed. The most frequent method of reanimation for vestibular schwannoma patients was the faciohypoglossal transposition, because of failure of any recovery even after apparent anatomic preservation of the facial nerve.

End-to-end coaptation is performed when the ends of a transected facial nerve can be joined without tension. It is universally accepted that end-to-end neurorrhaphy generally yields the best results (6). This was shown in

TABLE 5. *Failure rates of repair methods*

Method of repair	No. of failures	%
End-to-end coaptation	0/13	0
Cable interpositional nerve graft	2/25	8
Faciohypoglossal transposition	2/28	7

TABLE 6. *Effect of delayed repair on successful outcome*

	No. of patients with repair interval <12 mo (%)	No. of patients with repair interval >12 mo (%)	Fisher's exact test
HB Grade ≤ III at 24 mo	4/15 (27)	3/13 (23)	p = 1.0 (NS)

NS, not significant.

TABLE 7. *The effect of rerouting the nerve on successful outcome*

	No. of patients where nerve was rerouted (%)	No. of patients where nerve was not rerouted (%)	Fisher's exact test
HB Grade ≤ III at 24 mo	10/14 (71)	15/23 (65)	p = 1.0 (NS)

NS, not significant.

TABLE 8. *Age of repair each method of repair*

	Median age (yr)	Range (yr)
End-to-End coaptation	36	18–63
Cable nerve graft	42.5	17–63
Faciohypoglossal transposition	51.5	20–67

TABLE 10. *Effect of preoperative HB grade on successful outcome*

	Preoperative HB Grade I–III (%)	Preoperative HB GradeIV–VI (%)	Fisher's exact test
HB Grade ≤ III at 24 mo	23/43 (53)	9/22 (41)	$p = 0.4$

our study, with 84.6% cases attaining HB Grade ≤ III at 24 months. In fact, most cases (69.2%) attained HB Grade ≤ III by 12 months, with 53.4% showing evidence of some improvement from HB Grade VI by 6 months. Luetje and Whittaker (7) demonstrated a similar magnitude of improvement to HB Grade ≤ IV in 16 of 19 patients with at least 18-month follow-up.

An interpositional nerve graft is used if there is a significant gap between the proximal and distal ends or a tensionless repair is not possible despite rerouting the facial nerve within the temporal bone. The nerve graft donor is usually taken from the cervical plexus (in particular, the greater auricular nerve); if a segment longer than 6 cm is required, the sural nerve is used. In our series, most cases (56%) of cable nerve graft interposition have reached HB Grade ≤ III by 24 months. Magliulo et al. (8) demonstrated that two of six cable nerve graft interpositions continued to improve at 2-year follow-up. We demonstrated that only 2 of 14 patients in whom data were available continued to improve in their HB grade after 24 months. Gidley et al. (1) did not find any correlation between an alternative non-HB recovery score and the length of graft used. This has been confirmed by May (9), who also reported that the number of grafts and the site of injury did not adversely affect the outcome.

The classic faciohypoglossal transposition is an end-to-end neurorrhaphy performed between the proximal hypoglossal nerve whose donor axons reinnervate the facial muscles via the existing distal facial nerve trunk. This cranial nerve substitution is thought to be the most successful nerve transfer procedure because of the close connections of facial and hypoglossal nerves at the motor cortex and brainstem and thus the already established close association of facial and tongue movements. The indications for its use in our series were mainly related to cerebellopontine angle surgery where, despite anatomic preservation of the facial nerve and a time period of at least 12 months, there was no evidence of spontaneous functional or electromyographic recovery of the facial muscles. Faciohypoglossal transposition was also performed earlier when the proximal facial nerve stump at the brainstem was not available for coaptation. The resulting ipsilateral tongue paralysis is not as disabling as initially thought unless other lower cranial nerves are also impaired (8,10,11).

To prevent ipsilateral tongue paralysis, variations of the classic faciohypoglossal transposition have evolved (e.g., jump interpositional graft hypoglossal facial anastomosis, atlas repair, descendens hypoglossi anastomosis, XII longitudinal split). However, the classic faciohypoglossal transposition remains the most robust and reliable method because it incorporates the maximum number of axons. In their series of 137 cases of faciohypoglossal transposition, Conley and Baker (12) noted severe tongue atrophy was present in only 25% of cases. Gavron and Clemis (13) also confirmed this, with 95% patients attaining satisfactory tone and voluntary response. In our series, most cases (85.7%) showed evidence of improvement (HB Grade ≤ V) by 12 months. The results of other studies are shown in Table 12 (14–17).

Synkinesis remains a significant problem with faciohypoglossal transposition. It occurs in up to 67% of patients (14). The hypoglossal is not a fascicular nerve, and so it is difficult to attempt to overcome this problem. In an attempt to reduce mass movement, we have recently used a modified faciohypoglossal transposition, whereby a cable is interposed between the distal facial nerve (end-to-end) and the hypoglossal nerve (end-to-side). This preserves tongue movement; however, the facial function outcomes are awaited.

From our study, the three methods of reanimation result in different rates of improvement. There is a hierarchy, with end-to-end coaptation giving the best results at 24 months, followed by cable nerve graft interposition and then classic faciohypoglossal transposition. End-to-end coaptation tended to achieve a faster rate of recovery compared with cable nerve graft interposition (although the difference was not statistically significant). This tendency may be because there are two sites of coaptation

TABLE 9. *Effect of pre- and postganglionic facial nerve defect on successful repair*

	Preganglionic deficit (%)	Postganglionic deficit (%)	Fisher's exact test
HB Grade ≤ III at 24 mo	19/43 (44)	11/21 (52)	$p = 0.6$

TABLE 11. *Analysis of malignant disease*

Disease	Repair method	HB Grade at 24 mo
Synovial sarcoma	Cable nerve graft	3
Parotid adenoidcystic carcinoma	Cable nerve graft	4
Parotid low-grade carcinoma	Cable nerve graft	4
Malignant glomus	End-to-End	3

TABLE 12. *Results of previous faciohypoglossal transposition studies*

Study	Outcome	Follow-up period	Notes
Samii and Matthies[15]	74% HB Grade III	Not stated	
Luxford and Brackmann[16]	8.3% of 48 patients "poor" response	Not stated	
Brundy et al.[17]	30 total 33% Grade II		Also had EMG
Pensak et al.[14]	61 total 10% "poor"		Post vestibular schwannoma surgery repair, at 5–7 d

EMG, electromyography.

in cable nerve graft interposition compared with one in end-to-end coaptation and therefore increased fibrosis and axonal loss at the coaptation sites (18). Arriaga and Brackmann (19) compared the results of end-to-end coaptation and cable nerve graft interposition performed at the same time as the cerebellopontine angle procedure. They found that HB Grade ≤ IV was achieved in 7 of 13 cases for end-to-end coaptation and 4 of 8 cases of cable nerve graft: this was not statistically significant.

Magliulo et al. (8), in their comparative article, demonstrated HB Grade ≤ III in 8 of 17 (47%) patients who had undergone faciohypoglossal and 4 of 6 (67%) who had undergone cable nerve graft interposition. However, they did not mention the time of the grading.

Our study shows that faciohypoglossal transposition, when compared with the other two methods, is associated with a poorer outcome at 24 months. However, by 36 months, according to the data available, faciohypoglossal transposition achieved the same success (66%) as cable nerve graft interposition, an observation not noted in previous studies. This slower rate of improvement can be explained by the concept of neural plasticity. After faciohypoglossal transposition, the patient slowly learns to associate tongue movements (e.g., against the incisor teeth) with activation of facial muscles. Initially, the patient has to do this very consciously, but gradually, with practice, concentration, and motivation, this becomes a less actively conscious process.

In faciohypoglossal transposition, the distance of nerve regeneration is less than that of end-to-end coaptation or cable nerve graft interposition. Considering, as a general rule, that regenerating motor axons grow at an average of 1 mm/d (20), one would expect the facial muscles reanimated by faciohypoglossal transposition to show the first signs of recovery, provided that the motor end plates and muscle have not atrophied. Clearly, this does not happen, which lends support to the importance of neural plasticity, implying that central relearning occurs between the facial and hypoglossal nuclei and cortex.

May (9), using his own facial grading score, reported a "superb or excellent" outcome in 7 of 8 end-to-end coaptations, 9 of 27 cable nerve graft interpositions, and 10 of 11 faciohypoglossal transpositions. Samii and Matthies (21) followed 38 patients who had undergone surgery for vestibular schwannoma. When the facial nerve was repaired at the cerebellopontine angle, 61 to 70% reached HB Grade III, but a higher proportion (79%) reached HB Grade III when faciohypoglossal transposition was performed.

In patients who underwent end-to-end coaptation, there were no cases of complete failure and most cases (53.4%) showed evidence of some improvement (HB Grade ≤ V) by 6 months. We believe that if there is no improvement from HB Grade VI noted at 12 months, there is unlikely to be subsequent improvement. In the cable nerve graft interposition cohort, the failure rate was 8%; in one case, failure was thought to be attributable to either tension on the coaptation despite rerouting, or ischemic necrosis of the graft. Those patients who have undergone cable nerve graft interposition and are still HB Grade VI at 24 months are unlikely to improve subsequently (i.e., a total failure can only be ascribed at 24 mo).

Complete failure to improve from HB Grade VI in 7% of the faciohypoglossal transposition group was thought to be because of a poorly anatomically defined hypoglossal nerve at the time of surgery. In this cohort, most cases (85.7%) showed evidence of improvement (HB Grade ≤ V) by 12 months, and if no improvement occurred by 24 months, the procedure was realistically regarded as a complete failure, although there was a 3.6% chance that it could subsequently improve marginally.

May (9) reported complete failure (poor outcome) in 1 of 8 end-to-end coaptation cases and 9 of 27 cable nerve graft interposition cases, with no failures in 11 of the faciohypoglossal group. Samii and Matthies (21) ascribed failure to the following factors: late surgery, experience of the surgeon, surgical problems (e.g., tension), degeneration of distal neuromuscular unit, the effects of the disease process in neurofibromatosis Type 2, and the presence of residual disease.

Our study showed that impairment of facial function (HB Grade ≥ II) before the complete paralysis was not associated with a worse outcome after reparative surgery, suggesting this factor does not appear to affect the regenerative potential of the facial nerve. This finding is in agreement with Gidley et al. (1), who found no effect with cable nerve graft interposition, but at odds with Bascom et al. (6), whose study found this factor to be important for end-to-end coaptation and cable nerve graft interposition. Arriaga and Brackmann (19), when evaluating prognostic factors relating to end-to-end coaptation and cable nerve graft interposition facial nerve repairs at the cerebellopontine angle, found that a preoperative HB Grade I was associated with a better recovery.

For end-to-end coaptation, a successful outcome is related to the interval of repair (22): an earlier repair prevents scar and neuroma formation and makes identification of the transected ends easier. May (23) recommends that the nerve be repaired no less than 30 days after injury. Bascom et al. (6) found that a delay of more than 3 months was associated with a poorer outcome. Conley (3) recommended a repair before 30 days when the axoplasmic flow is maximal. May (9) suggested one of the reasons for poorer results after 3 months was that the axon diameter decreases by a factor of eight.

In our series, 11 of 13 cases were treated immediately after recognition that the nerve had been transected, and the remaining 2 cases were treated within 5 weeks. For cable nerve graft interposition, Conley (3) and May (9) stated that the best results were obtained when the repair interval was less than 1 year after injury; preferably, 30 days.

May (22) stated that "faciohypoglossal transposition was found to be ideal for reanimating the paralyzed face more than 2 years after injury." Nevertheless, it is generally accepted that for faciohypoglossal transposition, a short time interval is related to a better outcome, before complete nerve fiber or facial muscle atrophy or nerve fibrosis occurs (10,12). In their study of 137 faciohypoglossal transpositions, Conley (24) found that a repair interval of less than 2 years was associated with better movement and a 2% complete failure rate, whereas surgery after 2 years resulted in a 10% failure rate and worse movement. Conley and Baker (12) reported a case of a "good outcome" 10 years after the onset of facial paralysis. In our series, the longest time interval of 5 years resulted in HB Grade IV at 24 months, and there was no statistically significant trend of worse outcome with increased delay.

Rerouting can provide up to 17 mm of extra length to the facial nerve for a tensionless coaptation (25). This can be performed both in the temporal bone and in the parotid gland. However, rerouting risks traumatizing and devascularizing the facial nerve and consequently preventing its improvement. This was not borne out by our findings.

Our study showed that there was a tendency for a worse outcome (HB Grade ≥ IV at 24 mo) with increasing age when all three methods of reanimation were analyzed together. This factor was supported by Gavron and Clemis (13) and Clemis and Gavron (26), but not by Conley (27).

May (9) stated that younger patients have an increased potential for nerve regeneration because they have more nerve fibers. The blood supply of the facial nerve runs under the epineurium and there appears to be a watershed zone in the labyrinthine portion (28). The blood supply at and distal to the geniculate ganglion is the superficial petrosal branch of the middle meningeal artery. The labyrinthine artery supplies the nerve in the internal auditory meatus. Where possible, our cases were classified into either pre- or postgeniculate nerve injury to reflect the change in blood supply to see whether this affected the way the nerve regenerated or distally degenerated. This is the first study that has analyzed this factor and found it to be of no prognostic value.

In our study, there were only four patients with malignant disease; in two of them, the preoperative HB grade was I, and in two the HB grade was II. The three parotid malignancies were completely excised, but the malignant glomus tumor had distant recurrence. Malignancy did not appear to impair nerve reanimation in our very limited cases.

We concede that because the study was not randomized and is retrospective, a large selection bias exists as to the method of repair. HB grade is subjective, and there is observer bias (the two persons performing the operation were those performing the grading). There may also be some observer variation. Although this is probably one of the largest comparative studies on this subject, the numbers are still too small for multivariate analysis.

CONCLUSION

1. This is the only comparative study that highlights the *rate* of improvement with the three methods of dynamic reanimation of the paralyzed face. End-to-end coaptation achieves the fastest rate of improvement of HB grade, followed by interpositional nerve grafting and then faciohypoglossal transposition.
2. The most reliable method of reanimation of the paralyzed face is end-to-end anastomosis. The other two methods (cable nerve graft interposition and faciohypoglossal transposition) have a less than 10% total failure rate at 24 months.
3. Patients should not expect an improvement more than HB Grade III for any of the reanimatory procedures discussed.
4. For patients who have undergone end-to-end coaptation and in whom there is no improvement from HB Grade VI at 12 months, subsequent improvement is unlikely, and one should consider faciohypoglossal transposition.
5. For those who have had cable nerve graft interposition and are still HB Grade VI at 24 months, subsequent improvement is unlikely (i.e., a total failure can only be ascribed at 24 mo), and one should consider faciohypoglossal transposition.
6. For faciohypoglossal transposition, improvement can still occur 2 years after nerve repair, and surgery should not necessarily be regarded as a failure if at 2 years the result is not optimal. Most cases (85.7%) show evidence of improvement (HB Grade ≤ V) by 12 months, and if no improvement occurs by 24 months, the procedure should be regarded as a complete failure.
7. In our study, the factor that adversely affects the successful outcome (HB Grade III or better at 24 mo) is increasing age. The following factors did not appear to affect this outcome: malignant disease, preoperative facial nerve weakness (HB Grade ≥ II), time interval of greater than 12 months between onset of paralysis and repair by faciohypoglossal transposition, rerouting the facial nerve in the temporal bone, and location of the injury relative to the geniculate ganglion.

8. It is preferable, where feasible, to reroute the facial nerve and perform an end-to-end coaptation than to perform a cable nerve graft interposition.

Acknowledgments: We are grateful to Mr. David Ryder, Senior Statistician, Christie Hospital, Manchester, for his analysis.

REFERENCES

1. Gidley PW, Gantz BJ, Rubinstein JT. Facial nerve grafts: from cerebellopontine angle and beyond. *Am J Otol* 1999;20:781–8.
2. Bell C. On the nerves: giving an account of some experiments on their structure and function which leads to a new arrangement of the systems. *Phil Trans R Soc (Biol)* 1821;3:398, 424.
3. Conley J. Perspectives in facial reanimation. In May M, ed. *The Facial Nerve*. New York: Thieme, 1986.
4. House JW, Brackmann DE. Facial nerve grading system. *Otolaryngol Head Neck Surg* 1985 93:146–7.
5. Evans RA, Harries M, Baguley DM, Moffat DA. Reliability of the House Brackmann grading system for facial palsy. *J Laryngol Otol* 1989;103:1045–6.
6. Bascom DA, Schaitkin BM, May M, Klein S. Facial nerve repair: a retrospective review. *Facial Plast Surg* 2000;16:309–13.
7. Luetje CM, Whittaker CK. The benefits of VII-VII neuroanastomosis in acoustic tumor surgery. *Laryngoscope* 1991;101:1273–5.
8. Magliulo G, D'Amico R, Forino M. Results and complications of facial reanimation following cerebellopontine angle surgery. *Eur Arch Otorhinolaryngol* 2001;258:45–8.
9. May M. Surgical rehabilitation of facial palsy: total approach. In May M, ed. *The Facial Nerve*. New York: Thieme, 1986.
10. Hammerdschlag PE. Facial reanimation with jump interpositional graft hypoglossal facial anastomosis and the hypoglossal facial anastomosis: evolution in the management of facial paralysis. *Laryngoscope* 1999;109(Suppl):1–23.
11. Cusimano MD, Sekhar L. Partial hypoglossal to facial nerve anastomosis for reinnervation of the paralysed face in patients with lower cranial nerve palsies: technical note. *Neurosurgery* 1994;35:532–4.
12. Conley J, Baker DC. Hypoglossal-facial nerve anastomosis for reinnervation of the paralyzed face. *Plast Reconstr Surg* 1979;63:63–72.
13. Gavron JP, Clemis JD. Hypoglossal facial nerve anastomosis: a review of the forty cases caused by facial nerve injuries in the posterior fossa. *Laryngoscope* 1984;94:1447–50.
14. Pensak ML, Jackson GC, Glasscock ME, Gulya AJ. Facial reanimation with the VII-XII anastomosis: analysis of the functional and psychological results. *Otolaryngol Head Neck Surg* 1985;94:305–8.
15. Samii M, Matthies C. Indication, technique and results of facial nerve reconstruction. *Acta Neurchir (Wien)* 1994;130:125–39.
16. Luxford WM, Brackmann DE. Facial nerve substitution: a review of 66 cases. *Am J Otol* 1985:Nov(Suppl):55–7.
17. Brundy J, Hammerschlag PE, Cohen NL, Ranshoff J. Electromyographic rehabilitation of the facial function and introduction of a facial paralysis grading scale for hypoglossal facial nerve anastomosis. *Laryngoscope* 1988;98:405–10.
18. Atlas M, Lowinger DSG. A new technique for hypoglossal facial nerve repair. *Laryngoscope* 1997;107:984–91.
19. Arriaga MA, Brackmann DE. Facial nerve repair techniques in cerebellopontine angle tumor surgery. *Am J Otol* 1992;13;356–9.
20. Davis R, Telischi F. Traumatic facial nerve injuries: review of diagnosis and treatment. *J Craniomaxillofac Trauma* 1995;1:30–41.
21. Samii M, Matthies C. Management of 1000 vestibular schwannomas (acoustic neuromas): the facial nerve—preservation and restitution of function clinical study. *Neurosurgery* 1997;40:684–95.
22. May M. Management of cranial nerves I through VII after skull base surgery. *Otolaryngol Head Neck Surg* 1980;88:560–75.
23. May M. Facial reanimation after skull base trauma. *Am J Otol* 1985;Nov(Suppl):62–7.
24. Conley J. Hypoglossal facial anastomosis. In Brackmann DE, ed. *Neurological Surgery of the Ear and Skull Base*. New York: Raven, 1982:93–8.
25. Yarbrough WG, Brownlee RE, Pillsbury HC. Primary anastomosis of extensive facial nerve defects: an anatomic study. *Am J Otol* 1993;14:238–46.
26. Clemis JD, Gavron JP. Hypoglossal facial anastomosis: report on 36 cases with posterior fossa facial paralysis. In Graham MD, House WF, eds. *Disorders of the Facial Nerve*. New York: Raven, 1982:499–505.
27. Conley J. The treatment of longstanding facial paralysis: a new concept. *Trans Am Acad Ophthalmol Otol* 1974;78:386–92.
28. Jackson CG, von Doersten PG. The facial nerve: current trends in diagnosis, treatment and rehabilitation. *Med Clin North Am* 1999;83:179–95.