Experience with 60 Adult Patients with Facial Paralysis Secondary to Tumor Extirpation

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Background: The aim of this study was to present the authors' experience with facial reanimation in adult patients following tumor extirpation and to analyze the functional outcomes.

Methods: From 1978 to 2006, 60 adult patients underwent facial reanimation for facial paralysis following tumor extirpation. There was one patient with bilateral facial paralysis. Thus, evaluation was carried out in 61 hemifaces. Three independent assessors evaluated the preoperative and postoperative videos using the Terzis grading scale for eye closure, smile, depressor, and overall aesthetic and functional outcomes. Preoperative and postoperative electromyographic interpretations and the effect of demographic variables were also evaluated.

Results: There was significant improvement regarding preoperative versus postoperative outcomes for overall aesthesis and function. Good and excellent results were observed in 72.14 percent of the hemifaces ($n = 44$). The difference between preoperative and postoperative electromyographic results was of statistical significance ($p < 0.0001$) for each target reinnervated. Better results were observed in younger patients (≤35 years) ($p = 0.023$) and in early cases ($p = 0.019$).

Conclusions: The results of this present series illustrate that age and denervation time correlate with the final functional outcome. Cross-facial nerve grafts should ideally be used in patients with denervation time less than 6 months or more than 2 years combined with muscle transfers. In patients with a denervation time between 6 months and 2 years, the use of the babysitter procedure can yield a superior outcome. (*Plast. Reconstr. Surg.* 130: 51e, 2012.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, IV.

Facial palsy is caused in 5 percent of patients by a tumor invading the facial nerve during its course from the brainstem to the mimic musculature.[1] In such cases, treatment consists of complete tumor resection with either facial nerve preservation or subsequent facial nerve reconstruction.[2] Preservation of the facial nerve following tumor extirpation is possible but is not always feasible. Preservation rates vary for given tumor sizes and types, surgical approaches, and previous treatments.[3–6]

Facial reanimation is reserved for cases with poor facial nerve function or complete paralysis following tumor extirpation. The goal of facial reanimation is to provide a symmetrical, coordinated, voluntary, and involuntary motion and competent eye and oral sphincters.

The aim of this study was to present our center's experience with facial paralysis in adults following tumor extirpation. Most of the cases were complex and required multistage facial reanimation procedures. A detailed documentation of all of the surgical procedures cited in this series can be found in previous publications.[7–13] The Institutional Review Board Committee of the Eastern Virginia Medical School approved the protocol of this retrospective review.

PATIENTS AND METHODS

From 1978 to 2006, 166 patients with facial paralysis following tumor extirpation were referred to

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Table 1. Demographic Characteristics

Variable	Hemifaces (%)	Mean	Range
Age			
Male	14 (22.95)	39.3 yr	20–48 yr
Female	47 (77.05)	40.9 yr	21–63 yr
Tumor location			
Intracranial	37 (60.65)		
Intratemporal	11 (18.04)		
Extratemporal	13 (21.31)		
Denervation time		8.9 yr	2 mo–38.8 yr
Side			
Right	39 (63.94)		
Left	22 (36.06)		

Table 2. Tumor Types and Anatomical Locations

Tumor Type	Hemifaces	Benign	Malignant
Intracranial (n = 37)			
Acoustic neuroma	28	36	1
Other	9		
Intratemporal (n = 11)			
Cholesteatoma	5	10	1
Facial nerve neuroma	3		
Other	3		
Extratemporal (n = 13)			
Mixed tumor	4	10	3
Hemangioma	3		
Other	6		
Total	61	56	5

our center for surgical treatment. Seventy-eight patients did not undergo surgical treatment. Twenty-eight patients underwent only primary repair of the facial nerve. Sixty patients underwent facial reanimation with the classic three-stage reanimation and are included in the current study. Inclusion criteria consisted of the following: (1) age 18 years old or older; (2) facial paralysis following tumor extirpation; (3) having undergone reanimation with the classic three-stage approach; (4) follow-up greater than or equal to 2 years. Demographic characteristics of the patients are summarized in Table 1. The distribution of tumor types (benign/malignant) according to the anatomical location is summarized in Table 2. The mean age of the patients was 40.7 years. The mean follow-up was 4.3 years. The mean denervation time was 8.8 months.

Preoperative Evaluation

Evaluation included thorough history, detailed clinical examination, and electrophysiologic testing that included needle electromyography and nerve conduction studies and documentation of facial movements using standardized videos and photographs according to a time-tested protocol. Similar testing took place during postoperative office visits

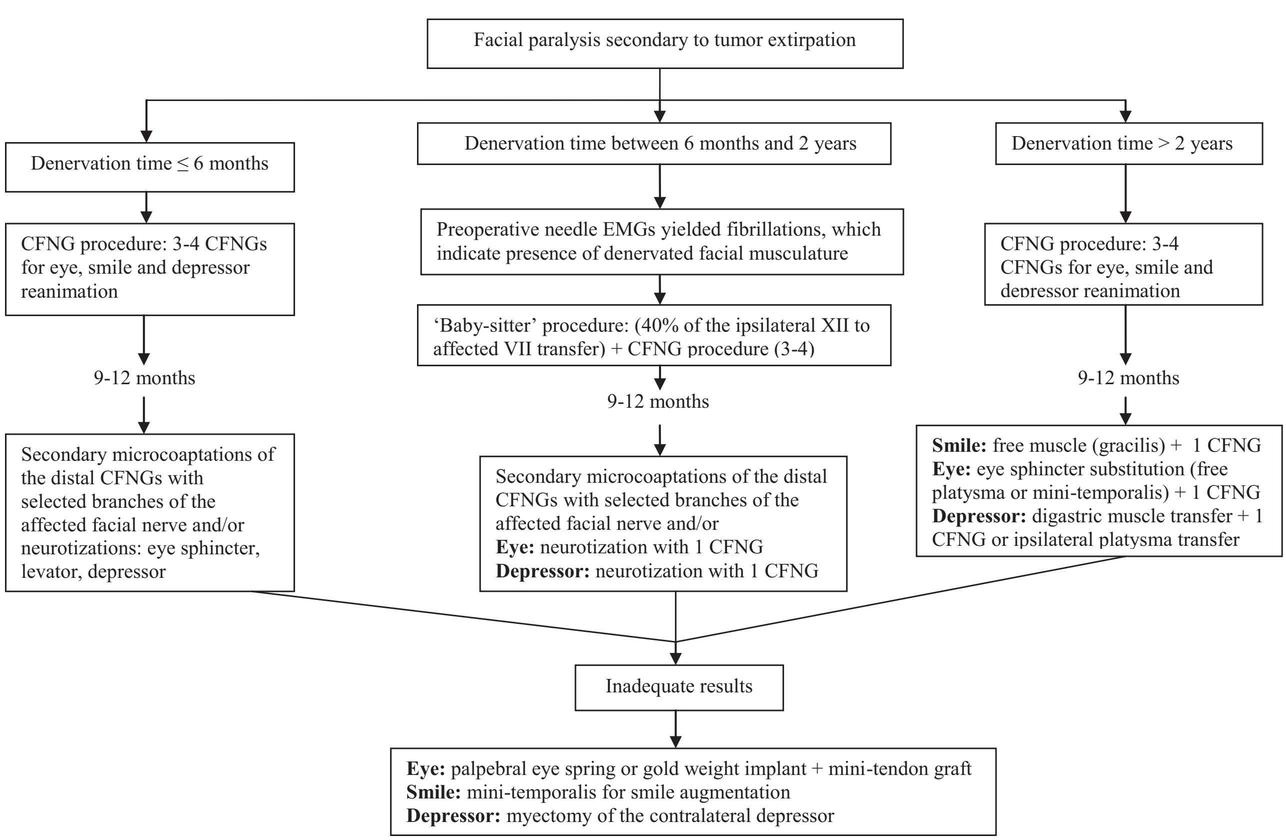

Fig. 1. Algorithm for dynamic reanimation in facial nerve paralysis. *CFNG*, cross-facial nerve graft; *EMG*, electromyography.

for comparative purposes. Bilateral high-resolution computed tomography scans of the facial nerve canal or magnetic resonance imaging was performed as needed.

Microsurgical Reconstruction

First Stage

In patients with denervation time less than or equal to 6 months or greater than 2 years, two to four cross-facial nerve grafts are coapted in end-to-end fashion to selected distal branches of the unaffected facial nerve.[7] The number of cross-facial nerve grafts depends on the degree of facial paralysis (partial or complete) and the individual patient's needs. In late cases (≥2 years), when the facial musculature has atrophied, cross-facial nerve grafts are used in combination with free muscle transfers. In patients with denervation time between 6 months and 2 years, the babysitter procedure is used, in which 40 percent of the ipsilateral hypoglossal nerve is coapted to the affected facial nerve and is supplemented with three to four cross-facial nerve grafts.[7,8] In patients with either incomplete recovery of the depressor muscle function after cross-facial nerve graft neurotization, or in patients with evidence of remaining depressor muscle after needle electromyography, a mini-hypoglossal transfer to either the cervicofacial branch of the affected facial nerve, or by means of direct neurotization to the depressor muscle, is performed.[14]

Second Stage

During this stage, free or regional muscle transfers take place in combination with secondary microcoaptations or direct neurotizations of dysfunctional targets. The term "secondary microcoaptations" pertains to the coaptations between selected branches of the affected facial nerve with the cross-facial nerve grafts, which usually take place 9 to 12 months after the first stage. The aim of muscle transfer is to substitute or augment a specific target.

Third Stage (Revisions)

At this stage, ancillary procedures are used, as needed, for enhancement of the dynamic procedures that took place in the previous stages of reanimation. Our center has developed detailed algorithms of the ancillary and revision procedures for compensation of common infirmities of dynamic reanimation.[15] An algorithm for facial reanimation and ancillary procedures is provided in Figure 1.

Special Techniques

In patients with bilateral facial paralysis following tumor extirpation with involvement of other cranial nerves, the senior author uses either the C7 root[16] or the accessory nerve as the motor donor.[7] In cases of facial paralysis with an anesthetic cornea, a clinical condition known as neurotrophic keratopathy, the senior author (J.K.T.) has developed a technique of direct neurotization of the anesthetic cornea using the contralateral supraorbital and supratrochlear nerves as sensory

Table 3. Nerve Transfers for Facial Reanimation

Nerve Transfer	Hemifaces	Mean CFNGs	Mean INGs
CFNGs	30	3.5	—
Babysitter procedure	28	3.5	1.2
CN XI transfer	1	—	1
CN XI transfer plus mini-hypoglossal transfer	2	—	1.5

INGs, ipsilateral nerve grafts; CFNGs, cross-facial nerve grafts; CN XI, accessory nerve.

Table 5. Mean Reviewers' Scores for Overall Functional and Aesthetic Results

Grade	No. of Hemifaces (%)
Poor	—
Fair	9 (14.75)
Moderate	8 (13.11)
Good	30 (49.18)
Excellent	14 (22.96)
Total	61 (100)

Table 4. Mean Reviewers' Scores for Overall Functional and Aesthetic Results According to the Type of Nerve Transfer

	Mean Reviewers' Scores					
Nerve Transfer	Poor	Fair (%)	Moderate (%)	Good (%)	Excellent (%)	Hemifaces
CFNGs	—	5 (8.19)	3 (4.90)	13 (21.31)	9 (14.75)	30
Baby-sitter procedure	—	2 (3.28)	5 (8.21)	16 (26.23)	5 (8.21)	28
CN XI transfer	—	1 (1.64)	—	—	—	1
CN XI transfer plus mini-hypoglossal transfer	—	1 (1.64)	—	1 (1.64)	—	2
Hemifaces	—	9 (14.75)	8 (13.11)	30 (49.18)	14 (22.96)	61 (100%)

CFNGs, cross-facial nerve grafts; CN XI, accessory nerve.

donors, which seems to be a permanent solution to this serious condition, as it effectively restores some corneal sensation.[17] In patients with involvement of the ipsilateral or bilateral hypoglossal nerves, which results in tongue asymmetry, restoration of tongue movement, bulk, and shape has been achieved with the use of a direct tongue neurotization procedure using as motor donors the ipsilateral accessory or the cervical plexus motor donors or the ipsilateral C7 root.[7,18]

Postoperative Management

At the sixth postoperative week, ultrasound therapy and massage are used to prevent adhesions between either the nerve grafts or the transferred muscle and the overlying skin envelope. Moreover, each patient follows an exercise regimen in front of a mirror. A slow pulse stimulator (The Liberson slow pulse stimulator; J. D. Medical, Fountain Valley, Calif.) is used in cases where the babysitter procedure takes place to maintain the bulk of the facial musculature and halt the denervation process. When a free muscle has been used to restore smile, no slow pulse stimulation is indicated; otherwise, there can be sequelae of contraction that is too powerful.

Data Analysis

Three independent assessors evaluated separately the preoperative and postoperative videos using the Terzis grading scales for eye closure, smile, depressor, and overall aesthetic and functional outcome.[8,11,12,19] There was one patient with bilateral facial paralysis. Thus, evaluation was carried out in 61 hemifaces.

Preoperative and postoperative electromyographic interpretations were evaluated by using a four-point scale (from 0 to 3) developed in our center.[20] The effect of demographic variables was investigated by comparison of the measured parameters.

Fig. 2. Example of late left facial paralysis secondary to extratemporal tumor (mixed tumor of the parotid gland) extirpation in a 63-year-old female patient. Preoperatively, there was asymmetry in her smile that was graded fair (*left*). The denervation time was 37.5 years at the time of her first operation in our center. She had her first stage of reconstruction with two cross-facial nerve grafts. Eleven months later, the patient underwent the second stage of reconstruction with mini-temporalis muscle transfer for smile augmentation, which was neurotized by the previously placed cross-facial nerve graft. Note improvement in smile 2 years later (*right*). The lower cross-facial nerve graft was placed to neurotize the transferred pedicle digastric for left depressor complex substitution. In this case, the patient declined to have further surgery, so the second cross-facial nerve graft was not used. Her smile was graded as good.

Statistical Analysis

Comparisons between preoperative and postoperative mean reviewers' scores were performed using the Wilcoxon signed rank test. Data from three or more postoperative groups were compared using the Kruskal-Wallis test (denervation time, tumor location). The Mann-Whitney *U* test was used to investigate the effect of sex and age on the clinical outcome and to compare preoperative and postoperative electromyographic interpretations. Statistical analysis was performed using SAS 9.1.3 (SAS Institute, Inc., Cary, N.C.). The significance level was set at 0.05.

RESULTS

Nerve Transfers

In the majority of hemifaces, the cross-facial nerve graft procedure ($n = 30$) and the babysitter procedure ($n = 28$) were used. In three hemifaces, the accessory nerve was used as the motor donor. The nerve transfers used are summarized in Table 3. The mean reviewers' scores for overall functional and aesthetic results according to the type of nerve transfer are summarized in Table 4.

Overall Outcome

There was significant improvement regarding preoperative versus postoperative overall aesthesis and function ($p < 0.0001$). Good and excellent results were observed in 72.14 percent of the hemifaces ($n = 44$) (Table 5; Figs. 2 through 11).

Eye Closure

Direct neurotization was performed in 41 hemifaces, of which secondary intervention with static procedures (mini-tendon, eye spring, gold weight) was needed in 15 hemifaces. A static procedure was used as the main procedure in seven cases. Eye sphincter substitution was performed in 11 hemifaces, with frontalis ($n = 5$) and platysma ($n = 2$) being the most commonly used muscles (Table 6). Eye closure was graded as good and

Fig. 3. Example of late right facial paralysis secondary to extratemporal tumor (adenocarcinoma of the parotid gland) extirpation in a 54-year-old female patient who also had a history of left Bell palsy during her pregnancy 30 years previously. Preoperatively, there was asymmetry in her smile that was graded as fair (*left*). The denervation time was 24 years at the time of her first operation in our center. She had her first-stage reconstruction with three sural nerve grafts from the ipsilateral right facial nerve. Ten months later, the patient underwent the second stage of reconstruction, which involved a double free muscle transfer with a free gracilis muscle transfer for smile augmentation and a small segment of free adductor longus muscle for eye sphincter substitution. Both muscles were neurotized by the previously placed nerve grafts. Ten months later, she had a left platysma transfer for depressor substitution (*right*). Her smile was graded as good.

Fig. 4. Example of late left facial paralysis secondary to intratemporal tumor (cholesteatoma) extirpation in a 44-year-old male patient. Preoperatively, there was asymmetry in his smile that was graded poor (*left*). The denervation time was 19 years at the time of his first operation in our center. He had his first-stage reconstruction with four cross-facial nerve grafts and, 11 months later, a free gracilis muscle transfer for smile augmentation that was neurotized by two cross-facial nerve grafts. Ten months later, he had a third stage of reconstruction that involved a free segmental occipitalis muscle transfer for eye sphincter substitution that was neurotized by the upper cross-facial nerve graft, carrying "eye" fibers from the contralateral facial nerve. Note the improvement in smile 2 years later (*right*). The fourth cross-facial nerve graft was placed to neurotize directly the left depressor complex but was not used. His smile was graded as good and he was able to close his eye.

excellent in 62.59 percent of the hemifaces (n = 38) ($p < 0.0001$) (Table 7).

Smile

Levator neurotization was performed in 17 hemifaces. Muscle transfers for levator substitution was performed in 38 hemifaces with free gracilis ($n = 26$), mini-temporalis ($n = 17$), or other muscle ($n = 1$). In six hemifaces with previously placed free gracilis muscle, the mini-temporalis was used for levator augmentation (Table 8). The mini-temporalis was neurotized by the trigeminal nerve alone in six hemifaces and by both the trigeminal nerve and a cross-facial nerve graft in 11 cases. Good and excellent results were observed in 57.37 percent ($n = 35$) of the hemifaces ($p < 0.0001$) (Table 7).

Depressor

Direct neurotization was performed in 39 hemifaces. The muscle transfers included digastric ($n = 7$) and platysma ($n = 5$) muscles. In six cases, myectomy of the contralateral depressor was performed (Table 9). Good and excellent results were observed in 54.09 percent ($n = 33$) of the hemifaces ($p < 0.0001$) (Table 7).

Electromyography Results

Mean preoperative and postoperative results of the electromyography study for eye sphincter, levator, and depressor are summarized in Table 10. The difference between preoperative and postoperative electromyography results was statistically significant ($p < 0.0001$ for each target).

Special Procedures

Corneal neurotization was performed in five hemifaces. The facial paralysis was caused by extirpation of intracranial tumors ($n = 4$) and an extratemporal tumor ($n = 1$). After surgery, all hemifaces showed improvement of corneal health and remained ulcer free. Numbness of the contralateral forehead was resolved over an

Fig. 5. Example of late right facial paralysis secondary to intratemporal tumor (schwannoma) in a 40-year-old male patient. The denervation time was 17 years at the time of his first operation in our center. He had first-stage reconstruction with four cross-facial nerve grafts. Ten months later, he had free gracilis transfer for smile restoration that was neurotized with two of the previously placed cross-facial nerve grafts. Fifteen months later, the patient had his third stage of reconstruction with contralateral frontalis transfer for right eye sphincter substitution that was neurotized by the upper cross-facial nerve graft carrying eye fibers from the contralateral intact facial nerve. Preoperative smile and overall appearance are shown on the *left*. The fourth cross-facial nerve graft was placed for depressor augmentation but was not used. His smile was graded as poor. The final postoperative result is shown on the *right*. His smile was graded as good.

average of 3 months. In four hemifaces, both the contralateral supratrochlear and supraorbital nerves were used as donors, and in one hemiface only the contralateral supraorbital nerve was used as a donor (Table 11).

Tongue neurotization was performed in one hemiface. The ipsilateral accessory nerve was used as the motor donor. Postoperatively, speech intelligibility was improved.

The accessory nerve was used as the motor donor for tongue neurotization ($n = 1$) and for facial reanimation ($n = 3$). In two hemifaces, the accessory nerve transfer was combined with mini-hypoglossal transfer. Outcomes were validated as poor in two hemifaces and as good in one.

Prognostic Factors

The effect of demographic variables on facial reanimation outcome is summarized in Table 12. According to this, sex ($p = 0.80$) and tumor location ($p = 0.92$) were not correlated with the functional outcome. Our population was divided into two age groups (≤ 35 years, $n = 27$; and >35 years, $n = 34$). The results were significantly better for the younger group ($p = 0.023$). As far as denervation time is concerned, patients who underwent facial reanimation within 12 months ($n = 13$) had superior results, and there was a statistically significant difference ($p = 0.019$).

DISCUSSION

There is common agreement that the earliest possible repair (at best, at the time of the tumor extirpation surgery) will result in the best functional outcome of all surgical rehabilitation techniques.[21] However, some surgeons are reluctant to consider facial nerve repair, especially when postoperative radiotherapy is planned. Gidley et al.[22] studied the effect of radiotherapy on facial nerve recovery and concluded that facial nerve grafting or repair is successful in patients who receive postoperative radiotherapy.

Fig. 6. Example of late incomplete right facial paralysis secondary to intracranial tumor (cerebellar astrocytoma) extirpation in a 27-year-old female patient. The denervation time was 16.5 years at the time of her first operation in our center. She had first-stage reconstruction with three cross-facial nerve grafts and tongue neurotization from the ipsilateral eleventh cranial nerve. One year later, the patient had second-stage reconstruction with secondary microcoaptations between selected branches of the affected facial nerve and the previously placed cross-facial nerve grafts (because of residual function in the paretic facial musculature). Preoperative smile and overall appearance are shown on the *left*. Her smile was graded as poor. The final postoperative result is shown on the *right*. Her smile was graded as good.

The group of patients requiring facial nerve reconstruction following head and neck tumor extirpation are least likely to have a nerve graft because of their perceived poor prognosis.[23] In contrast, dynamic reconstruction is the standard of care, as patients are unlikely to die because of their underlying disease.[24] Moreover, dynamic reanimation can promise both aesthetic and functional improvement.

Nerve Transfers

The cross-facial nerve graft procedure yields favorable results up to 6 months after the facial nerve injury. In cases of denervation time more than 2 years, the classic cross-facial nerve graft procedure should be accompanied by free muscle transfer 9 to 12 months later. The senior author (J.K.T.) introduced the use of extensive intraoperative microstimulation and mapping of motor territories of the branches of the contralateral facial nerve, and then the selected branches are coapted to the cross-facial nerve grafts.

By this means, the function of the contralateral facial nerve is preserved and better results on facial reanimation are achieved. In the current series, the cross-facial nerve graft procedure was used in 30 hemifaces, with good and excellent results in 22 hemifaces (73.34 percent). In general, the number of cross-facial nerve grafts is assessed by the degree of facial nerve paralysis and the individual patient's needs, but usually two to four nerve grafts are used. However, it is still impossible to predict the outcomes following facial reanimation. Thus, it is preferable to have available motor donors for improving moderate results after dynamic facial reanimation.

In cases with denervation time between 6 months and 2 years, the babysitter procedure is the treatment of choice. It was introduced in 1984 by the senior author (J.K.T.)[25–27] and combines the benefits of the cross-facial nerve graft procedure and of the classic hypoglossal-to–facial nerve transfer without the risk of downgrading tongue function. In this procedure, the mini-hypoglossal transfer is used only to rapidly salvage the paretic facial

Fig. 7. Example of late incomplete right facial paralysis secondary to intracranial tumor (acoustic neuroma) extirpation in a 41-year-old female patient. The denervation time was 21 years at the time of her first operation in our center. She had first-stage reconstruction with four cross-facial nerve grafts. Fourteen months later, the patient had second-stage reconstruction with secondary microcoaptations between selected branches of the affected facial nerve with the previously placed cross-facial nerve grafts (because of residual function in the paretic facial musculature). Three years later, she had a third stage of secondary surgery with eye spring insertion to the right upper eyelid, mini-temporalis transfer for smile augmentation, and ipsilateral digastric transfer for depressor substitution. Preoperative smile and overall appearance are shown on the *left*. Her smile was graded as fair. The final postoperative result is shown on the *right*. Her smile was graded as good.

musculature, whereas the cross-facial nerve grafts provide the "pacemaker" for coordinated animation. The use of 40 percent of the hypoglossal nerve does not cause tongue atrophy, as in the classic hypoglossal-to–facial nerve transfer, and can provide powerful motor innervation to the paralyzed facial musculature.[26]

Although the best timing for using the mini-hypoglossal transfer is within 2 years after the onset of the facial paralysis, satisfactory results have been produced even in cases with longer denervation time, if the facial nerve is in-continuity.[8] In the current series, use of the babysitter procedure yielded good and excellent results in 21 of 27 hemifaces (77.78 percent).

There was no synkineses or mass action noted following partial hypoglossal nerve transfer to the main facial nerve trunk in any of the patients in the current series. The absence of synkineses in the current series could be attributed to the following factors: (1) most of the patients in this series were complex cases with complete absence of ipsilateral facial nerve function and long denervation time; (2) the use of muscle transfers (either pedicled or free), of either ipsilateral musculature or free transferred musculature, decrease the possibility of synkinesis development; and (3) in earlier cases where the babysitter procedure was used (presentation of the patient over 6 months and before 2 years), the use of the partial hypoglossal nerve to the main facial nerve trunk could have resulted in mass action, but because of the concomitant placement of the cross-facial nerve grafts, the face is animated only through the cross-facial nerve grafts and not by means of the partial hypoglossal nerve. Thus, none of these patients exhibit synkinesis.

Muscle Transfers

Free muscle transfer and regional muscle transposition are the two options available for substitution of the paretic facial musculature in late cases of facial paralysis (denervation time >2 years).[28] Terzis and

Fig. 8. Example of incomplete right facial paralysis secondary to intracranial tumor (arteriovenous malformation of the pons) extirpation in a 21-year-old female patient. The denervation time was 2.5 years at the time of her first operation in our center. Her first-stage reconstruction involved the babysitter procedure: right mini-hypoglossal transfer to the ipsilateral mandibular branch and three cross-facial nerve grafts. One year later, the patient had mini-temporalis transfer for smile augmentation, mini-tendon graft to the right lower eyelid, and secondary microcoaptations of the previously placed cross-facial nerve grafts with the ipsilateral upper zygomatic and main zygomatic branches of the right facial nerve. Twenty months later, she had a third stage of reconstruction that involved a free gracilis muscle transfer for smile augmentation. Preoperative smile and overall appearance are shown on the *left*. Her smile was graded as poor. The final postoperative result is shown on the *right*. Her smile was graded as good.

Bruno[19] and Terzis and Lee[29] introduced two homologous muscles for dynamic restoration of eye closure and blink: the contralateral pedicled frontalis and the contralateral free platysma. In the current series, eye sphincter substitution was performed in 11 hemifaces, with frontalis ($n = 5$) and platysma ($n = 2$) being the most commonly used muscles. In four hemifaces, secondary intervention with static procedures was performed. Good and excellent results were obtained in eight hemifaces (72.72 percent).

The free muscle transfer remains the cornerstone in the reconstruction of the paralyzed face, with the gracilis being the most commonly used free muscle transfer in adults.[11,30–32] However, it is still impossible to predict the outcomes following free muscle transfer to the face. The senior author (J.K.T.) advocates the use of mini-temporalis transfer to augment moderate results after free muscle transfer for smile.[13] The mini-temporalis is neurotized by the trigeminal nerve. When the mini-temporalis is used as a sole procedure for smile reanimation, a cross-facial nerve graft is also used for direct neurotization of the mini-temporalis to coordinate smile on both sides. In the current series, levator substitution was performed in 38 hemifaces with free muscle transfer ($n = 27$) and pedicled muscle transfer ($n = 17$). In free muscle transfer, secondary intervention with pedicled muscle transfer was performed in six cases. Results were graded as good and excellent in 28 hemifaces (73.68 percent).

In our center, depressor reanimation has always been addressed aggressively[12] either with mini-hypoglossal transfer to the cervicofacial branch of the affected facial nerve or pedicle muscle transfer. The anterior belly of the digastric muscle and the platysma muscle are considered the workhorses of depressor substitution.[12,14] In the current series, depressor substitution was performed in 12 hemifaces with platysma ($n = 5$) and digastric

Fig. 9. Example of complete left facial paralysis secondary to intracranial tumor (acoustic neuroma) extirpation in a 33-year-old male patient. The denervation time was 14 months at the time of his first operation in our center. He had first-stage reconstruction with the baby-sitter procedure: mini-hypoglossal to the ipsilateral left facial nerve transfer and three cross-facial nerve grafts. Ten months later, the patient had secondary microcoaptations of the previously placed cross-facial nerve grafts and corresponding branches of the left facial nerve. Preoperative smile and overall appearance are shown on the *left*. His smile was graded as poor. The final postoperative result is shown on the *right*. His smile was graded as good.

($n = 7$) muscle. Results were graded as good in 10 hemifaces (83.34 percent).

Special Procedures

An understanding of corneal reinnervation in eyes with normal sensibility has been achieved by observing the healing process in healthy patients following procedures such as penetrating keratoplasty.[33] Although reinnervation in this setting follows a predictable timeline, in facial paralysis patients, reinnervation time was lengthened. This procedure can prevent many common complications of neurotrophic keratopathy.[17] In our series, cornea neurotization was performed in five hemifaces, which showed improvement of corneal health and remained ulcer free without adjunctive therapy for 16 years of follow-up.

Tongue neurotization is another innovative technique introduced by the senior author.[7,18] Restoring verbal capability is equally as important as facial reanimation. Speech development depends on both the stimuli that the patient receives and learning potential. The cognitive process of learning requires normal mental abilities. In addition, cortical learning takes place if there is a muscle target with which the brain can work. Tongue neurotization was performed in one hemiface, with improvement in speech intelligibility.

Our center has used a modified approach for accessory nerve transfer by using an end-to-side neurorrhaphy to the attached nerve graft. Using this modification, the two motor branches of the accessory nerve are preserved and the affected facial musculature is supplied with adequate motor axons. The senior author (J.K.T.) has mainly used this technique in bilateral developmental facial paralysis cases (Möbius syndrome) and not as a routine procedure because of less dynamic and natural results.[34,35] The accessory nerve transfer was used in one hemiface for tongue neurotization and in another three hemifaces for facial reanimation with poor results ($n = 2$) and in one hemiface with good results.

Demographic Variables

Age is the most important factor influencing the functional outcome in facial reanimation procedures.[36] In our study, the younger the pa-

Fig. 10. Example of complete left facial paralysis secondary to intracranial tumor (acoustic neuroma) extirpation in a 24-year-old female patient. The denervation time was 3 years at the time of her first operation in our center. She had first-stage reconstruction with three cross-facial nerve grafts. Ten months later, the patient had secondary microcoaptations of the previously placed cross-facial nerve grafts with corresponding branches of the left facial nerve. Five months later, she had a third operation that involved contralateral pedicle frontalis muscle transfer for left eye sphincter substitution. Preoperative smile and overall appearance are shown on the *left*. Her smile was graded as poor. The final postoperative result is shown on the *right*. Her smile was graded as excellent.

tient was at the time of the surgical intervention, the better the postoperative result ($p = 0.023$). However, the senior author does not consider the age of 35 years as a "cutoff" for cross-facial nerve graft and free muscle transfer, as there are older patients who, despite their chronologic age, are in great condition and who demand "physiologic reanimation" when the various options are presented to them, even if such surgical management will involve three stages of reconstruction and longer operations. Thus, if such patients are "cleared" medically, the three-stage reanimation strategy can be implemented.

Although female patients may feel more affected by facial paralysis, sex does not influence the functional outcome.[37] In our series, patient sex did not adversely affect the outcome ($p = 0.80$). The denervation time is particularly important because the motor end plates must be reinnervated within 1 year if motor function is to be restored.[38,39] In our series, better outcomes were achieved in early cases ($\leq$12 months) ($p = 0.019$).

No significant correlation was found between tumor location and clinical outcome ($p = 0.92$). This is most likely related to the fact that the majority of the hemifaces were late cases (denervation time >2 years) and thus multistage surgical approaches were equally used for overcoming the facial asymmetry. In the current series, only five of 60 patients (with malignant tumors) had chemotherapy and thus it was impossible to identify the impact of the chemotherapy on facial reanimation.

Other Series

To the best of our knowledge, there is a paucity in the literature of reports of dynamic facial reanimation following tumor extirpation. This is, until now, the largest series of patients with facial paralysis following tumor extirpation operated on by a single surgeon (J.K.T.). The existing sporadic reports are focused mainly on either smile restoration[40] or the hypoglossal-to–facial nerve transfer.[40–42]

Takushima et al.[40] reported a series of 45 patients with facial paralysis following parotid tumor ablation who underwent a two-stage reconstruction for smile reanimation with good and excellent re-

Fig. 11. Example of complete left facial paralysis secondary to intracranial tumor (acoustic neuroma) extirpation in a 46-year-old female patient. The denervation time was 2 years at the time of her first operation in our center. She had first-stage reconstruction with the babysitter procedure: left mini-hypoglossal to the left facial nerve trunk and concomitant placement of four cross-facial nerve grafts. Fourteen months later, the patient had secondary microcoaptations of selected branches of the left facial nerve with the previously placed cross-facial nerve grafts along with a mini-temporalis transfer for smile augmentation and left cornea neurotization. Preoperative smile and overall appearance are shown on the *left*. Her smile was graded as poor. The final postoperative result is shown on the *right*. Her smile was graded as good.

Table 6. Procedures Performed for Eye Closure Reanimation

Procedures for Eye Closure	No. of Hemifaces
Mini-tendon graft	2
Mini-tendon graft plus gold weight	1
Mini-tendon graft plus eye spring	1
Eye spring	3
Neurotizations	26
Neurotizations plus static procedures (mini-tendon, eye spring, gold weight)	15
Eye sphincter substitution plus static procedures	4
Eye sphincter substitution	7

sults in 84 percent of cases. Arai et al.[41] reported a series of eight patients who underwent hemi-hypoglossal–to–facial nerve transfer for treatment of unilateral facial paralysis following acoustic neurinoma resection with good results in all cases and a mild or moderate degree of hypoglossal nerve atrophy on the operated side.

Kukwa et al.[42] reported a series of 23 patients with facial paralysis following surgery for a cerebellopontine angle tumor that had a hypoglossal-to–facial nerve transfer and simultaneous coaptation of the cervical ansa with the distal stump of the hypoglossal nerve. In 18 patients, simultaneous with the neural repairs, additional transpositions of the temporalis and masseter muscles were performed. Using the House-Brackmann classification, eight patients had grade II, 10 patients had grade III, and five patients had grade IV outcome.

CONCLUSIONS

The results of this present series illustrate that age and denervation time correlate with the final functional outcome in patients who undergo facial reanimation following tumor extirpation. When the contralateral facial nerve is selected as the donor nerve, cross-facial nerve grafts should ideally be used in patients with denervation time less than 6 months or greater than 2 years combined with muscle transfers. In patients with a denervation time longer than 6 months and less

Table 7. Preoperative and Postoperative Functional Grading for Eye Sphincter, Levator, and Lower Lip Depressor

	Functional Grading Scores				
Target	Preoperative	Postoperative	G & E Results (%)	Hemifaces	p
Eye sphincter	1.70 (range, 1–3)	3.77 (range, 2–5)	38 (62.59)	61	<0.0001*
Levator	1.72 (range, 1–3)	3.69 (range, 2–5)	35 (57.37)	61	<0.0001*
Depressor	1.93 (range, 1–3)	3.59 (range, 2–5)	33 (54.09)	61	<0.0001*

G & E, good and excellent.
*Statistically significant.

Table 8. Procedures Performed for Smile Reanimation

Procedures for Smile	No. of Hemifaces
Levator substitution with free gracilis	20
Levator augmentation with mini-temporalis	11
Levator substitution with free gracilis plus mini-temporalis	6
Levator substitution with free pectoralis minor transfer	1
Levator neurotization	17

Table 9. Procedures Performed for Lower Lip Depressor

Procedures for Depressor	No. of Hemifaces
Depressor substitution with platysma	5
Depressor substitution with digastric	7
Depressor neurotization	39
Myectomy of the unaffected depressor	5

Table 11. Procedures Used in Severe Cases of Posttumor Facial Paralysis

Procedure	No. of Hemifaces
Cornea neurotization	5
Tongue neurotization	1
CN XI transfer	3

CN XI, accessory nerve.

Table 12. Effect of Demographic Variables on the Facial Reanimation Outcome

Variable	No. of Hemifaces (%)	p
Age		0.023*
18–35 years	27 (44.26)	
>35 years	34 (55.74)	
Sex		0.80
Male	14 (22.95)	
Female	47 (77.05)	
Denervation time		0.019*
0–12 months	13 (21.31)	
13–36 months	18 (29.51)	
≥37 months	30 (49.18)	
Tumor location		0.92
Intracranial	37 (60.65)	
Intratemporal	11 (18.04)	
Extratemporal	13 (21.31)	

*Statistically significant.

Table 10. Mean Preoperative and Postoperative Electromyography Results for Eye Sphincter, Levator, and Lower Lip Depressor

	EMG Mean Scores			
Target	Preoperative	Postoperative	Hemifaces	p
Eye sphincter	0.61 (range, 0–2)	1.98 (range, 1–3)	61	<0.0001*
Levator	0.63 (range, 0–2)	2.03 (range, 1–3)	61	<0.0001*
Depressor	0.65 (range, 0–2)	1.86 (range, 1–3)	61	<0.0001*

EMG, electromyography.
*Statistically significant.

than 2 years, the use of the babysitter procedure can result in superior outcomes.

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PATIENT CONSENT

Patients provided written consent for the use of their images.

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