Comprehensive Surgical Treatment of Migraine Headaches

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The purpose of this study was to investigate the efficacy of surgical deactivation of migraine headache trigger sites. Of 125 patients diagnosed with migraine headaches, 100 were randomly assigned to the treatment group and 25 served as controls, with 4:1 allocation. Patients in the treatment group were injected with botulinum toxin A for identification of trigger sites. Eighty-nine patients who noted improvement in their migraine headaches for 4 weeks underwent surgery. Eighty-two of the 89 patients (92 percent) in the treatment group who completed the study demonstrated at least 50 percent reduction in migraine headache frequency, duration, or intensity compared with the baseline data; 31 (35 percent) reported elimination and 51 (57 percent) experienced improvement over a mean follow-up period of 396 days. In comparison, three of 19 control patients (15.8 percent) recorded reduction in migraine headaches during the 1-year follow-up ($p < 0.001$), and no patients observed elimination. All variables for the treatment group improved significantly when compared with the baseline data and the control group, including the Migraine-Specific Questionnaire, the Migraine Disability Assessment score, and the Short Form-36 Health Survey. The mean annualized cost of migraine care for the treatment group ($925) was reduced significantly compared with the baseline expense ($7612) and the control group ($5530) ($p < 0.001$). The mean monthly number of days lost from work for the treatment group (1.2) was reduced significantly compared with the baseline data (4.41) and the control group (4.4) ($p = 0.003$). The common adverse effects related to injection of botulinum toxin A included discomfort at the injection site in 27 patients after 227 injections (12 percent), temple hollowing in 19 of 82 patients (23 percent), neck weakness in 15 of 55 patients (27 percent), and eyelid ptosis in nine patients (10 percent). The common complications of surgical treatment were temporary dryness of the nose in 12 of 62 patients who underwent septum and turbinate surgery (19.4 percent), rhinorrhea in 11 (17.7 percent), intense scalp itching in seven of 80 patients who underwent forehead surgery (8.8 percent), and minor hair loss in five (6.3 percent). Surgical deactivation of migraine trigger sites can eliminate or significantly reduce migraine symptoms. Additional studies are necessary to clarify the mechanism of action and to determine the long-term results. (*Plast. Reconstr. Surg.* 115: 1, 2005.)

Migraine headache affects an estimated 12 percent of the American population.[1] Every year, 28 million patients suffer from migraine

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headache[2] and lose a collective 112 million workdays and $14 billion in productivity. Introduction of the triptans[3] was a major advance in the treatment of migraine headache, but patients still must endure migraine headache symptoms until the medications take effect. Also, triptans can cause drowsiness, weight gain, and hair loss and are contraindicated in patients with coronary artery disease or a history of stroke, or in those who are pregnant.

On the basis of reports by patients whose migraine headaches disappeared after forehead rejuvenation, which included removal of the corrugator supercilii muscle, a retrospective study was conducted by the authors. Of 314 patients who had undergone this procedure, 39 had migraine headache before surgery; 31 experienced either complete elimination of or significant improvement in their migraine headache over an average follow-up period of 47 months ($p < 0.001$).[4]

Encouraged by these findings, we initiated a prospective pilot study,[5] which confirmed the findings of the retrospective study. These results, further anatomical investigations leading to identification of additional trigger sites, and review of the pertinent literature addressing the role of the septum and turbinates in treatment of migraine headache[6–9] prompted us to design two additional surgical techniques and conduct a more in-depth study of the four most common trigger sites, which is the subject of this report.

Patients and Methods

Patient Selection

After approval by the institutional review boards from two organizations, the recruited volunteers completed a preliminary migraine headache questionnaire. The diagnosis of migraine headache was confirmed by the neurologist of the research team in accordance with the guidelines established by the International Headache Society. The presence of enlarged turbinates and the type of nasal septal deviation were documented.[10] All participants completed relevant questionnaires, including general health, migraine headache, the Migraine Disability Assessment score,[11] the Short Form-36 Health Survey,[12] and the Migraine Specific Questionnaire,[13] before any treatment and again at the 1-year follow-up.

Study Design and Randomization

Of 125 volunteers diagnosed with migraine headache, 100 were randomly assigned to the treatment and 25 to the control group (4:1 allocation). The patients in the treatment group underwent injection of 25 units of botulinum toxin A in each trigger site following the algorithm outlined in Figure 1. A maximum of three injections of botulinum toxin A were given to each patient approximately 1 month apart. If the injection of botulinum toxin A resulted in complete elimination or significant improvement (at least 50 percent reduction from the baseline) in intensity and/or frequency of migraine headache lasting at least 4 consecutive weeks, the patient was considered a candidate for surgery. The 25 patients in the control group received injection of 0.5 ml of saline as placebo. Of this group of patients, 19 patients completed the 1-year follow-up and 17 patients underwent detection and surgical deactivation of the trigger sites.

Demographic variables and comorbid conditions were documented. All patients maintained a diary describing the frequency, intensity (on a visual analogue scale ranging from 0 to 10, with 10 being the most severe), duration (in hours) of migraine headache, associated symptoms, possible triggers, and any functional disability caused by the headaches. Both groups recorded time lost from work and all direct and indirect expenses related to their migraine headaches.

Surgical Procedures

For patients with a frontal trigger migraine headache, the glabellar muscle group—including the corrugator supercilii, depressor supercilii, and procerus muscles—was removed through a palpebral incision to relieve compression of the supraorbital and supratrochlear nerves, which traverse these muscles. The patients with temporal migraine headache underwent endoscopic removal of 3 cm of the zygomaticotemporal branch of the trigeminal nerve to prevent its compression by the temporalis muscle. The nerve travels between this muscle and the lateral orbital wall and is commonly transected during craniofacial or aesthetic forehead surgery, with no reported consequence. Patients who experienced both temporal and frontal migraine headache underwent removal of the zygomaticotemporal branch of the trigeminal

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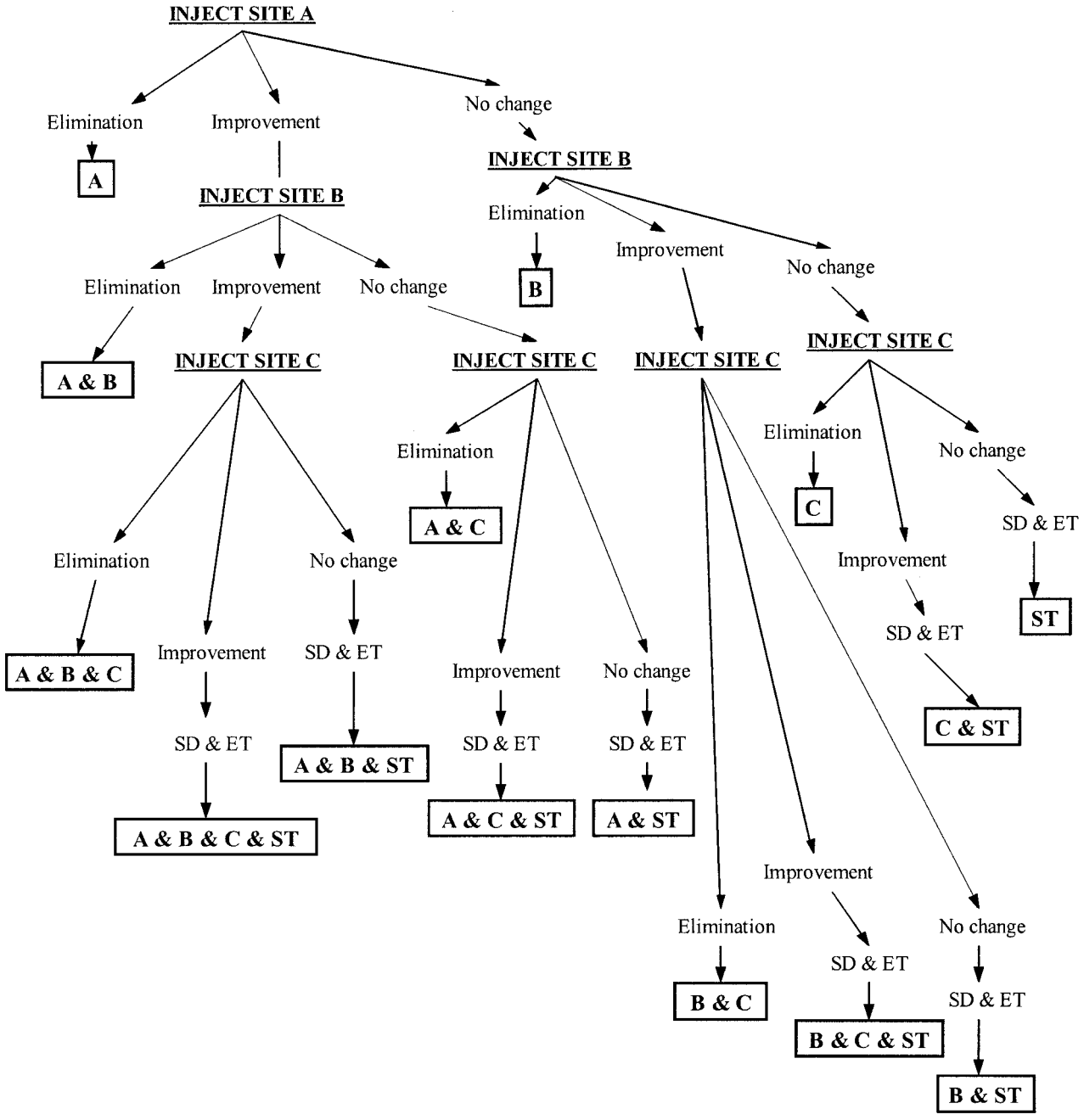

FIG. 1. Algorithm for identification of the trigger sites based on response to injection of botulinum toxin A. *A*, most common trigger site; *B*, next most common trigger site; *C*, third most common trigger site; *SD*, septal deviation; *ET*, enlarged turbinates; *ST*, septum and turbinates; *rectangles*, identified trigger sites.

nerve and glabellar muscle group through an endoscopic approach.

A small portion of the semispinalis capitis muscle surrounding the greater occipital nerve was removed and the nerve was shielded from the muscle with a subcutaneous flap to avert occipital migraine headache. Patients with migraine headache triggered from the septum and turbinates underwent septoplasty and inferior and/or middle turbinectomies based on intranasal abnormality.[6–9] Patients and the research team completed comprehensive questionnaires to document the complications at 1 and 12 months postoperatively.

Statistical Analysis

Dependent variables consisted of "total composite scores" calculated from the instruments

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and/or the change in final scores relative to the baseline. Other variables, such as expenses and measures of morbidity, were analyzed and compared between the two groups using standard and migraine headache–specific instruments. A Migraine Headache Index was calculated by multiplying together the frequency, intensity, and duration of migraine headache, and this was compared with the baseline Migraine Headache Index.

Statistix Version 8 (Analytical Software, Inc., Tallahassee, Fla.) and StatView Version 5 (SAS Institute, Inc., Cary, N.C.) were used for statistical analysis. Descriptive statistics and frequency distributions were computed for all variables. Means and standard error were compiled for all interval variables. Proportion and percentage were evaluated for the nominal and categorical variables. To test the equality of means of two continuous variables (such as composite intensity score, change in intensity score, and expenses between the groups), two-tailed, two-sample *t* tests and nonparametric tests of Wilcoxon rank sum were used. To compare the mean intensity of migraine headache scores measured at the baseline and last visit and over time (3, 6, 9, and 12 months), two-tailed paired *t* tests, Wilcoxon signed rank tests, and repeated measures analysis of variance (or covariance) with and without rank, respectively, were used. Chi-square analyses were performed to test for a relationship between categorical variables such as surgical sites and patients' improvement status.

Various other statistical techniques, such as multiple regressions and multiple logistic analysis, were used to model composite scores and to identify significant factors associated with the patients' migraine headache condition and improvement. An alpha of 0.05 was used to assess significance. If necessary, adjustments for multiple comparisons were made through Bonferroni correction.

RESULTS

Study Population

Of the 100 patients in the treatment group, 98 received injection of botulinum toxin A. The remaining two patients declined the study after assignment. Trigger sites were detected on 91 patients, and they underwent surgery. Of the remaining seven patients, one did not respond to botulinum toxin A injections and six either declined surgery or were excluded for noncompliance with study protocol.

Of the 91 patients who underwent surgery, 89 completed follow-up requirements and constituted the final "treatment group." The mean follow-up period for these 89 patients was 396 days, ranging from 233 to 629 days. Of the 25 patients in the control group, 19 completed the required 1-year follow-up and requisite questionnaires.

Baseline Characteristics

The mean age for the treatment group was 43.4 ± 1.1 years, and the mean age for the control group was 42.9 ± 1.7 years ($p = 0.8$). The two groups were comparable in all respects except for the emotional component of the Migraine Specific Questionnaire (Table I).

Comparison of the Two Groups at 1-Year Follow-Up

There were statistically significant improvements in all the measured variables in the treatment group when compared with the control group. The mean monthly frequency of migraine headache in the treatment group was 3.8 ± 0.4, compared with 10.2 ± 1.7 ($p < 0.001$) for the control group. The Migraine Headache Index was 12.6 ± 3.1 in the treatment group, compared with 90.6 ± 33.6 in the control group ($p = 0.03$) (Table II).

TABLE I
Baseline Data

Variable	Treatment	Control	*p**
No.	89	19	—
Age (yr)	43.4 ± 1.0†	42.9 ± 1.7	0.83
Frequency (MH/mo)	10.9 ± 0.8	9.9 ± 1.7	0.57
Intensity (analogue scale, 0–10)	8.6 ± 0.13	8.8 ± .24	0.56
Duration (hr)	1.40 ± 0.14	1.30 ± 0.25	0.71
MHI	102.6 ± 10.8	107.6 ± 31.1	0.88
MIDAS	3.5 ± 0.11	3.6 ± 0.16	0.58
MSQEM (Mental Migraine Score)	51.9 ± 3.4	32.2 ± 4.9	0.002
MSQPRE	67.0 ± 30.1	63.1 ± 2.9	0.35
MSQRES	47.5 ± 2.3	44.4 ± 3.8	0.48
SFMEN	45.4 ± 1.27	44.2 ± 2.71	0.69
SFPH	43.8 ± 1.61	44.1 ± 1.42	0.89
Average annual cost of care for MH (per patient)	$ 7612 ± 1680	$ 4962 ± 2588	0.74
Workdays lost (days/mo)	4.41 ± 0.89	6.23 ± 1.49	0.28

* The *p* value was obtained from the two-sample *t* test and confirmed by Wilcoxon's signed rank test.

† Mean ± standard error.

MHI, Migraine Headache Index; MIDAS, Migraine Disability Assessment Score; MSQEM, Migraine-Specific Questionnaire, emotional; MSQPRE, Migraine-Specific Questionnaire, preventive; MSQRES, Migraine-Specific Questionnaire, restrictive; SFMEN, SF-36 Health Survey, mental; SFPH, SF-36 Health Survey, physical; MH, migraine headache.

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TABLE II
Follow-Up at 1 Year

Variable	Treatment	Control	*p**
No.	89	19	—
Frequency (MH/mo)	3.8 ± 0.4†	10.2 ± 1.7	<0.001
Intensity (analogue scale, 0–10)	4.0 ± 0.3	7.0 ± 0.3	<0.001
Duration (hr)	0.35 ± 0.05	0.99 ± 0.2	0.007
MHI	12.6 ± 3.1	90.6 ± 33.6	0.03
MIDAS	1.84 ± 0.18	3.67 ± 0.59	<0.001
MSQEM	88.1 ± 2.6	34.0 ± 5.7	<0.001
MSQPRE	89.7 ± 2.2	57.2 ± 4.7	<0.001
MSQRES	83.1 ± 2.9	38.2 ± 3.5	<0.001
SFMEN	48.1 ± 1.3	40.2 ± 2.7	0.014
SFPH	51.6 ± 1.3	46.6 ± 1.6	0.033
Average annual cost of care for MH (per patient)	$ 925 ± 121	$5530 ± 873	<0.001
Workdays lost (days/mo)	1.2 ± 0.34	4.4 ± 0.92	0.003

* The *p* value was obtained from the two-sample *t* test and confirmed by Wilcoxon's signed rank test.

† Mean ± standard error.

MHI, Migraine Headache Index; MIDAS, Migraine Disability Assessment Score; MSQEM, Migraine-Specific Questionnaire, emotional; MSQPRE, Migraine-Specific Questionnaire, preventive; MSQRES, Migraine-Specific Questionnaire, restrictive; SFMEN, SF-36 Health Survey, mental; SFPH, SF-36 Health Survey, physical; MH, migraine headache.

Outcome at 1 Year Compared with the Baseline

All measured variables improved significantly for the treatment group (Table III). Only migraine headache intensity and duration improved significantly for the control group; however, improvement in these variables was at least three-fold better for the treatment group than for the control group.

Overall Surgical Outcome

When at least 50 percent reduction in baseline migraine frequency, intensity, or duration was used to assess the results, 82 of the 89 patients in the treatment group (92 percent) benefited from surgery; 31 (35 percent) reported elimination of migraine headache and 51 (57 percent) experienced improvement. In comparison, only three of the 19 patients (15.8 percent) in the control group noted such improvement after 1-year follow-up ($p < 0.001$), and no patients reported elimination of migraine headache. Eighty-three of the 89 patients (93.3 percent) in the treatment group experienced greater than 50 percent reduction in Migraine Headache Index, whereas only eight of the 19 control group patients (42.1 percent) experienced such a change ($p < 0.001$).

Analysis by Trigger Site in Treatment Group

When the data were analyzed in relation to the specific trigger sites, the forehead was one of the trigger sites for 80 of the 89 patients (90 percent) in the treatment group (Table IV), of which 79 (99 percent) had a positive change in frontal migraine headache after surgery; 51 (64 percent) reported elimination and 28 (35 percent) noted a significant decrease. Seventy-one of the 89 patients (80 percent) reported having temporal migraine headache. Of these, 70 (99 percent) experienced a positive change following surgery; 45 (63 percent) noted elimination and 25 (35 percent) observed a significant decrease. Those who had occipital migraine headache encompassed 34 (38 percent) of the treatment patients. Of this group, 34 (100 percent) reported a positive change from the surgery on this site; 21 (62 percent) observed elimination of their migraine headache and 13 (38 percent) reported improvement. A total of 62 of the 89 (70 percent) patients were identified as having an intranasal trigger site. Of these, 55 (89 percent) recorded a positive change on this site; 21 (34 percent) reported elimination and 34 (55 percent) experienced improvement.

Changes Over Time

Average frequency, intensity, duration, and Migraine Headache Index were measured at the baseline and at 3, 6, 9, and 12 months after surgery. The data are summarized and *p* values reported in Figure 2. There was significant improvement in all measurements for the treatment group compared with the control group and over time.

Outcomes in Patients with Aura

Twenty-three (25.8 percent) of the 89 patients in the treatment group and five (26.3 percent) of 19 patients in the control group experienced aura ($p = 0.96$). When all of the variables were compared between these two groups, only the Migraine Disability Assessment score at baseline was different for patients with aura (3.82 ± 0.12 versus 3.4 ± 1.4; $p = 0.04$). In addition, patients with aura had higher migraine headache intensity at 12-month follow-up (4.30 ± 0.9 versus 2.3 ± 0.5; $p = 0.04$). There was no significant difference between the groups on any of the other variables.

Time Lost from Work

The mean number of days lost from work for the treatment group was 4.41 ± 0.89 per month at baseline and declined to 1.2 ± 0.34 ($p < 0.001$) after surgery, which was fewer

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TABLE III
One-Year Change from the Baseline by Group (Mean Difference)

Variable	Treatment	*p**	Control	*p**
No.	89	—	19	—
Frequency (MH/mo)	–7.14‡ ± 0.71†	<0.001	0.37 ± 1.04	0.73
Intensity (analogue scale, 0–10)	–4.57 ± 0.33	<0.001	–1.81 ± 2.8	<0.001
Duration (hr)	–1.05 ± 0.14	<0.001	–0.29 ± 0.11	0.018
MHI	90.0 ± 9.6	<0.001	–17.0 ± 12.1	0.18
MIDAS	–1.70‡ ± 0.18	<0.001	0.06 ± 0.13	0.67
MSQEM	36.18 ± 3.95	<0.001	1.78 ± 5.1	0.73
MSQPRE	22.61 ± 3.3	<0.001	–5.83 ± 4.1	0.17
MSQRES	35.57 ± 3.43	<0.001	–6.22 ± 3.82	0.12
SFMEN	2.93 ± 1.69	0.091	–4.0 ± 2.78	0.17
SFPH	8.0 ± 1.39	<0.001	2.5 ± 1.6	0.14
Average annual cost of care for MH (per patient)	–$ 6390 ± 1658	<0.001	—	—
Workdays lost (days/mo)	–3.24 ± 0.94	0.001	–1.75 ± 1.78	0.34

* The *p* value was obtained from the two-sample *t* test and confirmed by Wilcoxon's signed rank test.
† Mean ± standard error.
‡ Negative value for frequency, intensity, duration, Migraine Disability Score, migraine care cost, and workdays lost implies improvement.
MHI, Migraine Headache Index; MIDAS, Migraine Disability Assessment Score; MSQEM, Migraine-Specific Questionnaire, emotional; MSQPRE, Migraine-Specific Questionnaire, preventive; MSQRES, Migraine-Specific Questionnaire, restrictive; SFMEN, SF-36 Health Survey, mental; SFPH, SF-36 Health Survey, physical; MH, migraine headache.

compared the control group (4.4 ± 0.92) ($p = 0.003$).

Cost of Migraine Care

The average baseline annual cost of care for migraine headache for patients in the treatment group was $7612 ± $1680. This decreased to a mean of $925 ± $121 during the first postoperative year ($p < 0.001$), which was significantly less than the average annual cost of care for the control group ($5530 ± $873) ($p < 0.001$). The estimated mean cost of total surgical care was $6956 for each patient in the treatment group.

Adverse Effects

Complications related to injection of botulinum toxin A. These included complications commonly associated with injection of botulinum toxin A (Table V), except for a newly discovered complication. Nineteen patients (23.2 percent) who underwent injection of botulinum toxin A in the temporal area exhibited hollowing of the temples as a consequence of temporalis muscle atrophy. This gave the patient's face an hourglass appearance.[14]

Surgical complications. Minor and transient complications are listed in Table V. Excessive intraoperative bleeding in four (4.5 percent) and postoperative epistaxis in three (4.8 percent) patients required infusion of desmopressin.[15]

Of the 62 patients who underwent septum and turbinate surgery, three (4.8 percent) developed sinusitis early in the recovery period in the beginning of the study. This complication was stopped by prolonging the postoperative antibiotic course from 1 to 3 weeks.

Eight patients (12.9 percent) were noted to have slight recurrence of septal deviation, but only one patient (1.6 percent) was symptomatic. Four patients (6.6 percent) with a history of chronic sinusitis underwent sinus surgery for deterioration of the symptoms an average of 9.25 months after their migraine headache sur-

TABLE IV
Results Based on Specific Migraine Headache Trigger Sites (Surgical Treatment Group, $n = 89$)

Trigger Sites	No. of Patients	Overall Improvement, *n* *p**	Elimination of MH N (%)	Improvement of MH N (%)
Frontal	80 (90%)	79 (99%) <0.001 (79/80 vs 1/80)	51 (64%)	28 (35%)
Temporal	71 (80%)	70 (99%) <0.001(70/71 vs1/71)	45 (63%)	25 (35%)
Occipital	34 (38%)	34 (100%) 0.003 (34/34 vs 0/34)	21 (62%)	13 (38%)
Septoplasty	62 (70%)	55 (89%) <0.001 (55/62 vs 7/62)	21 (34%)	34 (55%)

* The *p* value was calculated from comparing patients who noted overall improvement to patients who did not.
MH, migraine headache; vs, versus.

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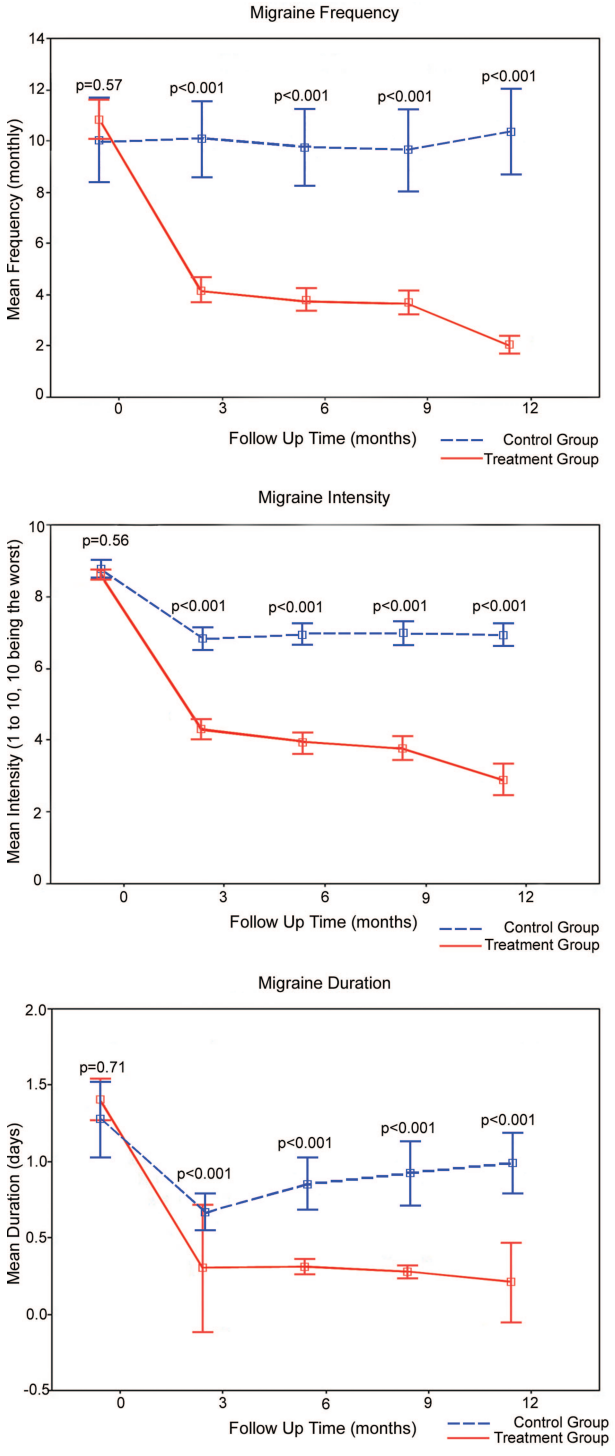

FIG. 2. Change in mean frequency, intensity, and duration of the headaches for the treatment and control groups over the first year of follow-up.

gery, presumably because of the scarring around the meatus. Data were no longer collected for these patients.

Seven of 80 patients (8.8 percent) who underwent forehead surgery experienced intense scalp itching that lasted an average of 6 months. One patient (1.3 percent) observed significant temporary alopecia. One patient developed a small hematoma of the upper eyelid that resolved spontaneously.

DISCUSSION

The contemporary understanding of migraine headache pathogenesis includes four basic concepts: (1) neuronal hyperexcitability during the interictal phase; (2) cortical spreading depression as the basis of aura; (3) trigeminal nerve activation at a peripheral and central origin that accounts for the headache; and (4) the provocative concept that progressive central sensitization is possibly related to periaqueductal gray matter damage.[16] Of these four concepts, that which may have relevance to our findings is peripheral activation of the trigeminal nerve. Migraine headache is postulated to be caused by dilatation of large vessels innervated by the trigeminal nerve.[8,17–24] Vasodilatation is the consequence of release of calcitonin gene–related peptide, substance P, and neurokinin A, found in the cell bodies of trigeminal neurons.[25–27] What prompts the release of these peptides remains unclear. We propose that it may be the mechanical stimulation of the potentially hyperexcited, peripheral sensory nerves that instigates this process. In three of four trigger sites studied here, the sensory nerves traverse the muscles. As to the fourth site, contact between the turbinates and the deviated septum may cause migraine headache in some patients.[6–9]

Burstein et al.[28] demonstrated that sensitization of nociceptors results in increased spontaneous neuronal discharges. There is an increase in receptiveness to both painful and nonpainful stimuli. Often, the receptor fields are expanded and patients feel pain over a greater portion of the dermatome. Clinically, this phenomenon is recognized as hyperalgesia and cutaneous allodynia.

In a chronic constrictive injury model in rodents, Bennett and Zie[29] placed a temporary ligature around the sciatic nerve, which resulted in local and remote allodynia. A lowered pain threshold occurred, similar to what was noted in the study by Burstein et al.[28] Burstein et al. concluded that the physiologic and anatomical changes that occur in the animal model represent activation of the central nervous system from a primary peripheral insult, a likely mechanism for triggering migraine head-

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TABLE V
Adverse Events

Activity	Nature of Adverse Event	No.	Site(s)
BT-A Injection*	Discomfort at injection site	20 (36.4%)	O
		6 (7.3%)	T
		1 (1.1%)	F
	Temple hollowing	19 (23.2%)	T
	Neck weakness/stiffness	15 (27.3%)	O
	Eyelid ptosis	9 (10%)	F
	Flu-like symptoms	5 (5.5%)	F, T, O
	Bruising/swelling	4 (4.9%)	T
		2 (2.2%)	F
Surgery†	Temporary nasal dryness	12 (19.4%)	S
	Rhinorrhea	11 (17.7%)	S
	Slight recurrence of septal deviation	8 (12.9%)	S
	Intense itching	7 (8.8%)	F
	Minor hair loss	5 (6.3%)	F
	Abnormal intraoperative bleeding	4 (4.5%)	F, T, O, S
	Short-term neck stiffness	3 (8.8%)	O
	Epistaxis requiring desmopressin	3 (4.8%)	S
	Sinus infection	3 (4.8%)	S
	Long-term neck stiffness	1 (2.9%)	O
	Hematoma	1 (1.3%)	F
	Unilateral airway reduction	1 (1.6%)	S
	Significantly major hair loss	1 (1.3%)	F

* F, frontal ($n = 90$); O, occipital ($n = 55$); T, temporal ($n = 82$).
† F, frontal ($n = 80$); O, occipital ($n = 34$); S, septum/turbinates ($n = 62$); T, temporal ($n = 71$).

ache and an explanation for the effectiveness of surgery described in our study.

Several studies have indicated that pericranial injection of botulinum toxin A reduces migraine headache, this efficacy being attributed to botulinum toxin A's antiinflammatory and central effects.[30–34] Had the central or antiinflammatory effects of botulinum toxin A played a prominent role in treating migraine headache, the authors[31–33] would not have suggested injection in multiple sites, and patients who underwent injection in one trigger site would have noted a positive change in other trigger sites as well. Improvement of migraine headache outside of the injected site was not observed following the 227 single-site injections given in our study.

We surmise that reducing or eliminating the mechanical stimulation of a possibly sensitized nerve, through either injection of botulinum toxin A or surgery, prevents the onset of pain. Elimination of friction between a deviated septum and an enlarged turbinate provides a similar outcome.[6–9] Although vascular dilatation occurs in advanced stages of migraine headache, we suggest that it is the consequence of the cascade of events triggered in the periphery, rather than it being the prompter of the events.

When the data were analyzed on the basis of surgery of a specific trigger site, the results were substantially superior compared with the overall results because of proper identification of the trigger sites. Eleven of the 91 (12.1 percent) patients who underwent surgery had only one trigger site, 21 (23.1 percent) had two trigger sites, 39 (42.9 percent) had three trigger sites, and 20 (22.0 percent) had four trigger sites identified. Those who did not observe elimination of migraine headache could have had more trigger sites than were detected. We will continue to improve methods of identifying trigger sites and uncovering other, less common sites.

Conclusions

We conclude that surgical deactivation of migraine headache trigger sites is efficacious. However, a sufficient number of patients should be followed for a meaningful period of time before the term "cure" can be used for those who become symptom-free. Additional studies are necessary to further clarify the pathophysiology of migraine headache and the mechanism of the surgical benefits in treating this condition.

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