Comparing Migraine Headache Index versus Monthly Migraine Days after Headache Surgery: A Systematic Review and Meta-Analysis

Benjamin H. Ormseth, BS[1]
Hassan ElHawary, MD, MSc[2]
Maria T. Huayllani, MD[1]
Kevin D. Weber, MD[3]
Pamela Blake, MD[4]
Jeffrey E. Janis, MD[1]

Columbus, OH; Montreal, Quebec, Canada; and Houston, TX

Prevention

Background: Nerve deactivation surgery for the treatment of migraine has evolved rapidly over the past 2 decades. Studies typically report changes in migraine frequency (attacks/month), attack duration, attack intensity, and their composite score—the Migraine Headache Index—as primary outcomes. However, the neurology literature predominantly reports migraine prophylaxis outcomes as change in monthly migraine days (MMD). The goal of this study was to foster common communication between plastic surgeons and neurologists by assessing the effect of nerve deactivation surgery on MMD and motivating future studies to include MMD in their reported outcomes.

Methods: An updated literature search was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The National Library of Medicine (PubMed), Scopus, and Embase were systematically searched for relevant articles. Data were extracted and analyzed from studies that met the inclusion criteria.

Results: A total of 19 studies were included. There was a significant overall reduction in MMDs [mean difference (MD), 14.11; 95% CI, 10.95 to 17.27; $I^2 = 92\%$], total migraine attacks per month (MD, 8.65; 95% CI, 7.84 to 9.46; $I^2 = 90\%$), Migraine Headache Index (MD, 76.59; 95% CI, 60.85 to 92.32; $I^2 = 98\%$), migraine attack intensity (MD, 3.84; 95% CI, 3.35 to 4.33; $I^2 = 98\%$), and migraine attack duration (MD, 11.80; 95% CI, 6.44 to 17.16; $I^2 = 99\%$) at follow-up (range, 6 to 38 months).

Conclusion: This study demonstrates the efficacy of nerve deactivation surgery on the outcomes used in both the plastic and reconstructive surgery and neurology literature. *(Plast. Reconstr. Surg.* 153: 1201e, 2024.)

The World Health Organization has ranked migraine as the nineteenth most common disease worldwide causing disability, and among neurologic conditions, it ranks second in terms of years lost to disability.[1,2] Despite this considerable burden, pharmacologic intervention remains insufficient for a large proportion of patients with migraine, with 5.1% of patients in a headache clinic population experiencing refractory migraine attacks.[3,4] As such, the current landscape necessitates novel methods for combating migraine morbidity.

In 2000, Guyuron et al.[5] published a study challenging the traditional understanding of migraine as an exclusively centrally mediated condition. After corrugator supercilii muscle resection for forehead rejuvenation surgery, patients experienced improvement, or elimination, of their chronic migraine. The resulting hypothesis that compression of peripheral nerves can trigger migraine attacks led to the development of surgical techniques to deactivate these compression sites.[6] Despite the mounting evidence demonstrating its efficacy, the novelty of the procedure and

From the Departments of [1]Plastic and Reconstructive Surgery and [3]Neurology, Ohio State University Wexner Medical Center; [2]Division of Plastic and Reconstructive Surgery, McGill University Health Center; and [4]Headache Center of River Oaks.
Received for publication January 10, 2023; accepted May 30, 2023.

DOI: 10.1097/PRS.0000000000010800

Disclosure statements are at the end of this article, following the correspondence information.

Related digital media are available in the full-text version of the article on www.PRSJournal.com.

the complexity of the pathophysiology have led to hesitation from established headache medicine specialists.[7–9]

Two authors describing concerns about the migraine surgery literature have directly commented on the use of the Migraine Headache Index (MHI) as a primary outcome measure.[7,8] MHI is defined as the multiplication of migraine frequency (attacks/month), intensity (on a scale of 1 to 10), and duration (number of hours per 24-hour period), and was first used by Guyuron and Amini in 2005.[10] Since then, the plastic and reconstructive surgery (PRS) community has used it as a primary outcome metric to assess headache surgery effect sizes and response rates. However, the International Headache Society (IHS) has advised against the use of migraine attack intensity, duration, or MHI as primary outcomes.[11,12] Instead, for investigations on preventive treatment of chronic migraine, the IHS endorses change in the number of days per month patients experience migraine [ie, monthly migraine days (MMD)]. An alternative is the change in headache days of moderate to severe intensity per month (including headaches of all classifications).

This discordance in outcomes is in part responsible for apprehension in recognizing or adopting headache surgery literature by the nonsurgical medical community.[7–9] Therefore, to help bridge the gap between surgeons and neurologists who provide care for these patients, we aimed to identify headache surgery investigations reporting on change in MMD and determine the effect of surgery using an official outcome endorsed by the IHS. Moreover, we hope this study serves as an impetus for future PRS publications to include MMD as a primary outcome.

MATERIALS AND METHODS

Search Method

The systematic literature review performed in the current study is an update from a previous systematic review published by the senior author (J.E.J.).[13] The most recent article included from this original search was published in 2020. As such, an updated literature review was conducted to identify relevant articles published since then.

This systematic review was conducted according to the guidelines from the *Cochrane Handbook for Systematic Reviews of Intervention*[14] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[15] An electronic search of the National Library of Medicine (PubMed), Scopus, and Embase was performed for articles published between January of 2020 and September of 2022. The search strategy was generated using the following terms: ("migraine surgery" OR "headache surgery" OR "peripheral nerve decompression surgery" OR "migraine surgery anatomy" OR "extracranial nerve anatomy" OR "migraine AND trigger point" OR "migraine disorders/surgery"[MeSH] OR "headache disorders/surgery"[MeSH] OR "microvascular decompression surgery/therapeutic use" [Mesh]). All study designs were included in the search.

Two authors (B.O. and H.E.) independently reviewed the search entries using strict inclusion and exclusion criteria (defined below). After removing duplicates, articles were first screened by title and abstract, followed by full-text review. Discrepancies between reviewers were resolved by consensus.

Study Criteria

The inclusion criterion was any clinical study investigating the effect of nerve deactivation surgery on migraine frequency, reported as either MMD or total migraine attacks per month. In most studies included, International Classification of Headache Disorders guidelines were used to diagnose migraine, and the official diagnosis was made by a board-certified neurologist. In each study, patients were asked to report their migraine attack frequency either as the number of days per month they experienced a migraine attack (MMD) or the total number of migraine attacks experienced per month. The IHS classification of a migraine day is the presence of a headache lasting at least 4 hours that meets International Classification of Headache Disorders criteria for migraine or a headache successfully treated with migraine-specific acute medications. Studies that only reported on percentage reduction in frequency without reporting on preoperative and postoperative values were excluded, as these data could not be converted into a mean difference (MD) for meta-analysis. Studies conducted with identical patient samples to other included studies were excluded. Biomechanical studies were excluded. Studies published in languages other than English were excluded.

Data Extraction and Synthesis

Two authors (B.O. and H.E.) extracted relevant study variables, including study title, authors, year of publication, study design, country of publication, nerve compression site addressed through surgery, sample size, percentage of female participants, mean age, and average follow-up.

The primary outcomes extracted were the mean number of MMDs experienced in the months leading to surgery and those at follow-up. If available, secondary outcomes extracted were mean number of overall migraine attacks per month, migraine attack intensity (on a scale from 1 to 10), migraine attack duration (in hours), and MHI. Means, standard deviations, changes in means, rates, and *P* values from each study were extracted. All data were recorded in Microsoft Excel.

Data synthesis was conducted according to recommendations provided by the *Cochrane Handbook for Systematic Reviews of Intervention*.[14] For studies reporting duration as days, values were converted to hours. For studies with multiple subgroups undergoing headache surgery, preoperative means and corresponding standard deviations (SDs) for respective outcome variables were combined among subgroups using the formula provided within the Cochrane handbook.[16–22] Postoperative means and SDs were similarly combined. For studies missing SDs but reporting MDs with exact *P* values,[16,17] SDs were calculated as described in the Cochrane handbook.

Data Analysis

We performed our meta-analysis using Review Manager version 5.3 (The Cochrane Collaboration). For effect measurements, MD was used because all five outcomes were measured similarly using patient-reported symptom data. In addition, all five outcomes can be expressed in standardized units. A 95% confidence interval was used. The individual effect sizes were weighted according to the reciprocal of their variance (calculated as the square of the standard error).[23] The overall effects of all studies were computed with a DerSimonian and Laird random-effects model. Forest plots were generated for each outcome.

Heterogeneity was reported as τ^2, χ^2, or I^2 values. A sensitivity analysis was performed for each outcome to detect the influence of a single study on the overall effect. This was done by sequentially recalculating the MD and confidence interval after omitting one study at a time. Funnel plots were generated for each outcome to assess the risk of publication bias.

Any complications reported by the included studies were extracted, and a pooled analysis of complications was performed.

RESULTS

Search Outcomes and Characteristics

The studies selected from the original systematic review[13] were re-evaluated with the current inclusion and exclusion criteria. After reassessing for eligibility, 16 studies were excluded because they did not report data on migraine frequency,[5,24–38] five were excluded because they reported percentage reduction in frequency but no values on preoperative or postoperative frequency,[39–43] and one was excluded because it was conducted on a duplicate patient sample from a separate study.[44] The remaining 16 studies were included in the current meta-analysis.[10,16–20,22,45–53]

In the updated search, we identified 305 unique records from PubMed, Scopus, and Embase after removal of duplicates. A total of 32 full-text articles were then reviewed for inclusion. Three satisfied all inclusion and exclusion criteria.[21,54,55] The results of the updated and previous literature searches are summarized in Figure 1.

Of the 19 studies included, five were randomized controlled trials, four were prospective case series, and 10 were retrospective studies. A total of 1603 patients were included in the meta-analysis. The sample sizes varied from 13 to 335 patients. The follow-up ranged from 6 to 38 months. Age ranged from 9 to 72 years, and the percentage of female participants ranged from 60% to 100%. Six different sites were addressed during surgery, including the frontal, temporal, greater occipital, nasal, lesser occipital, and auriculotemporal nerves. The general characteristics of the included studies are summarized in Table 1.

Monthly Migraine Days

Eight studies reported on mean MMD both preoperatively and postoperatively. The MD ranged from 5.31 to 22. The reduction ranged from 36.2% to 91.7%. The weighted MD across studies was 14.11 days/month (95% CI, 10.95 to 17.27). Heterogeneity was measured as $\tau^2 = 17.27$; $\chi^2 = 82.65$, $df = 7$ ($P < 0.00001$); $I^2 = 92\%$. The results are summarized in Figure 2. A sensitivity analysis was conducted, and no individual study significantly affected the pooled results. Publication bias was evaluated using a funnel plot (**see Figure, Supplemental Digital Content 1**, which shows a funnel plot for studies reporting MMD, ***http://links.lww.com/PRS/G736***), and no overt signs of asymmetry were observed. The original extracted MMD data are summarized in the Supplemental Digital Content. (**See Table, Supplemental Digital Content 2**, which shows extracted MMD data by

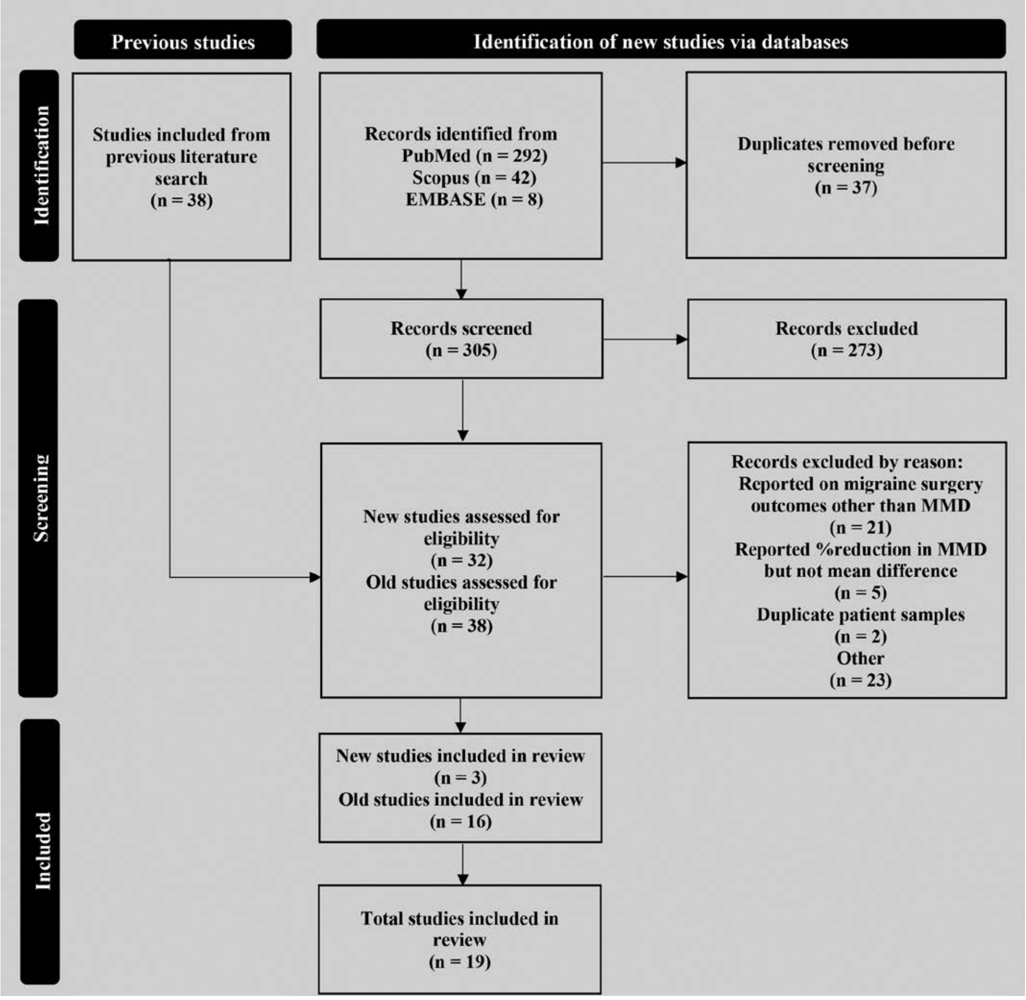

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram of study selection for the meta-analysis.

individual study. A, arterectomy performed; AT, atraumatic; NA, no arterectomy performed; NP, no precipitating event; PE, precipitating event; T, traumatic, ***http://links.lww.com/PRS/G737***.)

Total Migraine Attacks per Month

A total of 12 studies reported on mean total migraine attacks per month both preoperatively and postoperatively. The MD ranged from 2.5 to 20. The reduction ranged from 25.3% to 87.5%. The weighted MD across studies was 8.65 migraine attacks/month (95% CI, 7.84 to 9.46). Heterogeneity was measured as $\tau^2 = 1.13$; $\chi^2 = 113.96$, $df = 11$ ($P < 0.00001$); $I^2 = 90\%$. The results are summarized in Figure 3. A sensitivity analysis was conducted, and no individual study significantly affected the pooled results. Publication bias was evaluated using a funnel plot (**see Figure, Supplemental Digital Content 3**, which shows a funnel plot for studies reporting total migraine attacks per month, ***http://links.lww.com/PRS/G738***), and no overt signs of asymmetry were observed. The original extracted data on total migraine attacks per month are summarized in the Supplemental Digital Content. (**See Table, Supplemental Digital Content 4**, which shows extracted migraine attack frequency per month data by individual study. *BTA*, botulinum toxin A; *N*, narcotic user; *NN*, nonnarcotic user; *NR*, not reported; *OAR*, occipital artery resection; *TON-NR*, third occipital nerve not removed; *TON-R*, third occipital nerve removed, ***http://links.lww.com/PRS/G739***.)

Migraine Headache Index

A total of 15 studies reported on mean MHI both preoperatively and postoperatively. The MD ranged from 7.7 to 135.68. The reduction ranged from 26.3% to 93.1%. The weighted MD across studies was 76.59 (95% CI, 60.85 to 92.32).

Table 1. Characteristics of Included Studies

Study	Study Design	Country	Compression Sites Addressed (Single Site, Multiple Sites, or Both)	No.	No. Female (%)	Mean Age, yrs (SD)	Mean Follow-Up, mo, (SD)
Adenuga et al.[20] (2014)	Retrospective comparative	USA	F, T, GON, N	202	177 (87.6)	45.1 (12.3)	32.4 (22.2)
Chepla et al.[45] (2012)	Retrospective comparative	USA	Both: F, T, GON, N	86	42 (97.67)	44.5 (2.6)	12[a]
Chmielewski et al.[19] (2013)	Retrospective comparative	USA	Single: GON	170	149 (87.6)	45.0[b]	20.7[b]
Gatherwright et al.[17] (2018)	RCT	USA	Both: F, T, N, AT, GON	13	13 (100)	41.8[b]	21.6[b]
Gfrerer et al.[46] (2014)	Retrospective case series	USA	Both: F, T, GON, AT, LON	35	30 (85.7)	46.1 (12.7)	17.5 (4.7)
Gfrerer et al.[22] (2019)	Prospective case series	USA	Both: F, T, GON, N, LON, AT, nummular	83	71 (86)	45 (13)	12[a]
Gualdi et al.[54] (2021)	Retrospective case series	Italy	Single: F	15	9 (60)	41 (10)	12[a]
Guyuron and Amini[10] (2005)	RCT	USA	Single: T	89	NR	43.3 (1.2)	12[a]
Guyuron et al.[49] (2009)	RCT	USA	Both: F, T, GON, N	49	NR	44.9 (9.0)	12[a]
Guyuron et al.[47] (2015)	RCT	USA	Single: T	19	18 (94.7)	38.2[b]	12[a]
Guyuron et al.[48] (2015)	Retrospective case series	USA	Both: F, T, GON, N, AT	14	11 (78.6)	16.0 (2.3)	38.7 (28.4)
Janis et al.[50] (2011)	Retrospective case series	USA	Both: F, T, GON, N	24	23 (95.8)	44.4[b]	21.7[b]
Jose et al.[51] (2018)	Prospective case series	India	Multiple: F, T	30	13 (76.7)	36.4 (9.2)	11.1 (2)
Lee et al.[16] (2013)	Retrospective comparative	USA	Single: GON	229	87 (30)	45.0	NR
Liu et al.[18] (2012)	Retrospective comparative	USA	Both: F, T, GON, N	335	NR	NR	12[a]
Omranifard et al.[52] (2016)	RCT	Iran	Both: F, T, GON, N	25	22 (88)	42	12[b]
Ortiz et al.[21] (2020)	Prospective case series	USA	Both: F, T, GON, AT, LON	142	116 (82)	44 (14)	12.9 (11.8–15.2)[c]
Poggi et al.[53] (2008)	Retrospective case series	USA	Both: F, T, GON	18	16 (89%)	41 (8.6)	16[b]
Torabi et al.[55] (2020)	Prospective case series	USA	Both: F, T, GON	25	22 (88)	45.9 (15.7)	13.1[b]

AT, auriculotemporal; F, frontal; GON, greater occipital nerve; LON, lesser occipital nerve; N, nasal; NR, not reported; RCT, randomized controlled trial; T, temporal.
[a]Follow-up was 12 months for all patients.
[b]SD not reported.
[c]Median and interquartile range.

Heterogeneity was measured as $\tau^2 = 848.05$; $\chi^2 = 643.87$, $df = 14$ ($P < 0.00001$); $I^2 = 98\%$. The results are summarized in Figure 4. A sensitivity analysis was conducted, and no individual study significantly affected the pooled results. Publication bias was evaluated using a funnel plot (**see Figure, Supplemental Digital Content 5**, which shows funnel plot for studies reporting MHI, ***http://links.lww.com/PRS/G740***), and no overt signs of asymmetry were observed. The original extracted MHI data are summarized in the Supplemental Digital Content. (**See Table, Supplemental Digital Content 6**, which shows extracted MHI data by individual study. *AT*, atraumatic; *BTA*, botulinum toxin A; *N*, narcotic user; *NN*, nonnarcotic user; *NP*, no precipitating event; *NR*, not reported; *PE*, precipitating event; *T*, traumatic; *TON-NR*, third occipital nerve not removed; *TON-R*, third occipital nerve removed, ***http://links.lww.com/PRS/G741***.)

Migraine Attack Intensity

A total of 16 studies reported on mean migraine attack intensity both preoperatively and postoperatively. All studies evaluated migraine attack intensity on a 10-point scale. The MD ranged from 2.1 to 6.0. The reduction ranged from 28.0% to 82.2%. The weighted MD across studies was 3.84 (95% CI, 3.35 to 4.33). Heterogeneity

Study or Subgroup	Pre-operative Mean	SD	Total	Post-operative Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Gatherwright 2018	14.69	6.26	13	9.38	6.9	13	10.8%	5.31 [0.25, 10.37]
Gfrerer 2014	18.5	10.4	35	3.7	6	35	12.1%	14.80 [10.82, 18.78]
Gfrerer 2019	19.5	8.87	83	6.35	8.57	83	13.6%	13.15 [10.50, 15.80]
Gualdi 2021	24	4	15	2	2	15	14.0%	22.00 [19.74, 24.26]
Guyuron 2015	14.1	1.8	19	2.3	0.8	19	14.9%	11.80 [10.91, 12.69]
Guyuron 2015a	25	8.37	14	5	7.84	14	9.7%	20.00 [13.99, 26.01]
Janis 2011	16.52	11.11	24	3.78	6.45	24	10.8%	12.74 [7.60, 17.88]
Ortiz 2020	19.44	9.38	142	6.65	8.6	142	14.1%	12.79 [10.70, 14.88]
Total (95% CI)			**345**			**345**	**100.0%**	**14.11 [10.95, 17.27]**

Heterogeneity: $Tau^2 = 17.27$; $Chi^2 = 82.65$, df = 7 ($P < 0.00001$); $I^2 = 92\%$
Test for overall effect: Z = 8.75 ($P < 0.00001$)

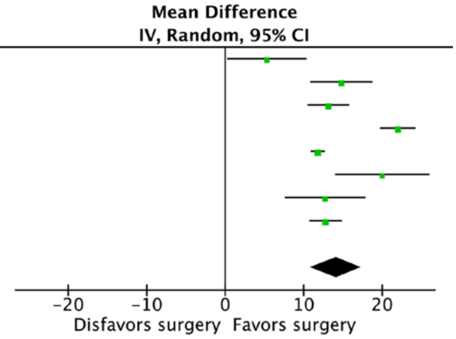

Fig. 2. Forest plot for the number of monthly migraine days before versus after surgery using the DerSimonian and Laird random-effects model of mean differences.

Study or Subgroup	Pre-operative Mean	SD	Total	Post-operative Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Adenuga 2014	14.57	9.43	202	6.46	8.21	202	9.0%	8.11 [6.39, 9.83]
Chepla 2012	13.89	0.93	86	5.97	0.81	86	15.0%	7.92 [7.66, 8.18]
Chmielewski 2013	16.12	9.33	170	6.65	8.64	170	8.3%	9.47 [7.56, 11.38]
Guyuron 2005	10.9	0.8	89	3.8	0.4	89	15.1%	7.10 [6.91, 7.29]
Guyuron 2009	9.9	6	49	7.4	5.8	49	6.7%	2.50 [0.16, 4.84]
Guyuron 2015a	25	8.37	14	5	7.84	14	1.6%	20.00 [13.99, 26.01]
Jose 2018	15.2	6.3	30	1.9	2.4	30	6.5%	13.30 [10.89, 15.71]
Lee 2013	17.07	8.92	229	7.15	3.51	229	11.2%	9.92 [8.68, 11.16]
Liu 2012	13.2	8.91	335	4.74	6.77	335	11.4%	8.46 [7.26, 9.66]
Omranifard 2016	15.91	3.31	25	6.41	2.33	25	9.6%	9.50 [7.91, 11.09]
Poggi 2008	11.9	9.3	18	3.7	4.4	18	2.4%	8.20 [3.45, 12.95]
Torabi 2020	16.3	9.7	25	5.8	4.1	25	3.1%	10.50 [6.37, 14.63]
Total (95% CI)			**1272**			**1272**	**100.0%**	**8.65 [7.84, 9.46]**

Heterogeneity: $Tau^2 = 1.13$; $Chi^2 = 113.96$, df = 11 ($P < 0.00001$); $I^2 = 90\%$
Test for overall effect: Z = 20.89 ($P < 0.00001$)

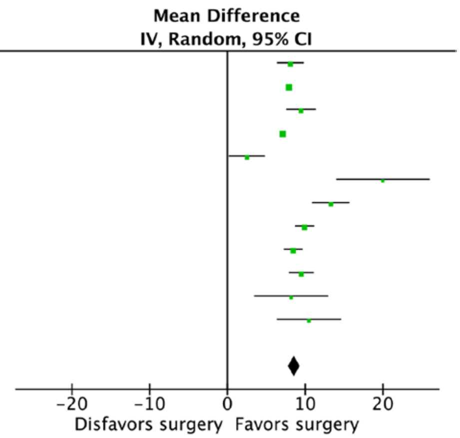

Fig. 3. Forest plot for the mean total migraine attacks per month before versus after surgery using the DerSimonian and Laird random-effects model of mean differences.

Study or Subgroup	Pre-operative Mean	SD	Total	Post-operative Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Adenuga 2014	99.95	90.31	202	29.55	53.81	202	7.1%	70.40 [55.90, 84.90]
Chepla 2012	120.3	21.84	86	26.45	6.51	86	7.5%	93.85 [89.03, 98.67]
Gatherwright 2018	52.6	26.24	13	4.7	26.24	13	6.8%	47.90 [27.73, 68.07]
Gfrerer 2014	99.4	95.7	35	10.1	18	35	5.8%	89.30 [57.04, 121.56]
Gfrerer 2019	125.24	99.82	83	29.94	56.36	83	6.4%	95.30 [70.64, 119.96]
Guyuron 2005	102.6	10.8	89	12.6	3.1	89	7.6%	90.00 [87.67, 92.33]
Guyuron 2009	29.3	30.8	49	21.6	29.6	49	7.3%	7.70 [−4.26, 19.66]
Guyuron 2015	148.1	84.78	14	12.42	20.51	14	4.6%	135.68 [89.99, 181.37]
Guyuron 2015a	42	9.5	19	2.9	0.9	19	7.6%	39.10 [34.81, 43.39]
Janis 2011	106.59	89.72	24	10.27	28.17	24	5.3%	96.32 [58.70, 133.94]
Lee 2013	118.95	124.44	229	26.53	51	229	7.0%	92.42 [75.00, 109.84]
Liu 2012	94.86	123.25	335	19.24	40.49	335	7.2%	75.62 [61.73, 89.51]
Omranifard 2016	134	41.7	25	11.81	9.03	25	7.0%	122.19 [105.47, 138.91]
Ortiz 2020	105.07	86.49	142	27.39	51.85	142	7.0%	77.68 [61.09, 94.27]
Torabi 2020	48.4	72.1	25	7.3	27.4	25	5.9%	41.10 [10.87, 71.33]
Total (95% CI)			**1370**			**1370**	**100.0%**	**76.59 [60.85, 92.32]**

Heterogeneity: $Tau^2 = 848.05$; $Chi^2 = 643.87$, df = 14 ($P < 0.00001$); $I^2 = 98\%$
Test for overall effect: Z = 9.54 ($P < 0.00001$)

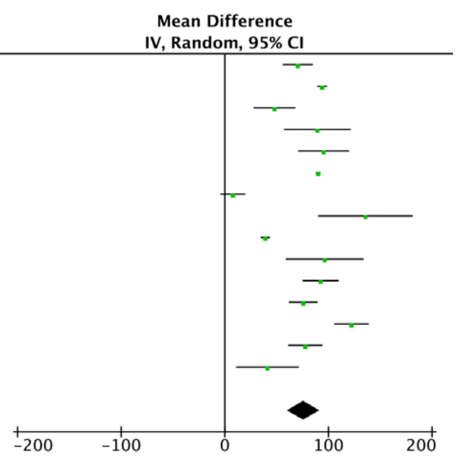

Fig. 4. Forest plot for the migraine headache index before versus after surgery using the DerSimonian and Laird random-effects model of mean differences.

was measured as $\tau^2 = 0.83$; $\chi^2 = 830.24$, $df = 15$ ($P < 0.00001$); $I^2 = 98\%$. The results are summarized in Figure 5. A sensitivity analysis was conducted, and no individual study significantly affected the pooled results. Publication bias was evaluated using a funnel plot (**see Figure, Supplemental Digital Content 7**, which shows a funnel plot for studies reporting migraine attack intensity, ***http://links.lww.com/PRS/G742***), and no overt signs of asymmetry were observed. The original extracted

Study or Subgroup	Pre-operative Mean	Pre-operative SD	Pre-operative Total	Post-operative Mean	Post-operative SD	Post-operative Total	Weight	Mean Difference IV, Random, 95% CI
Adenuga 2014	8.42	1.51	202	4.76	3.51	202	7.0%	3.66 [3.13, 4.19]
Chepla 2012	8.43	0.2	86	5.56	0.44	86	7.6%	2.87 [2.77, 2.97]
Chmielewski 2013	8.14	2.27	170	4.29	3.52	170	6.8%	3.85 [3.22, 4.48]
Gfrerer 2014	9.2	1	35	3.3	3.3	35	5.4%	5.90 [4.76, 7.04]
Gfrerer 2019	7.83	1.44	83	4.62	3.17	83	6.5%	3.21 [2.46, 3.96]
Guyuron 2005	8.6	0.13	89	4	0.3	89	7.6%	4.60 [4.53, 4.67]
Guyuron 2009	6.2	1.7	49	3	3.5	49	5.5%	3.20 [2.11, 4.29]
Guyuron 2015	7	0.3	19	2.9	0.8	19	7.3%	4.10 [3.72, 4.48]
Guyuron 2015a	8.2	1.52	14	4.3	3.25	14	3.6%	3.90 [2.02, 5.78]
Janis 2011	7.25	2.08	24	3.31	2.5	24	5.0%	3.94 [2.64, 5.24]
Jose 2018	7.3	3.5	30	1.3	1.4	30	4.8%	6.00 [4.65, 7.35]
Lee 2013	8.15	2.4	229	4.55	2.5	229	7.1%	3.60 [3.15, 4.05]
Liu 2012	7.91	2.04	335	4.19	3.54	335	7.2%	3.72 [3.28, 4.16]
Omranifard 2016	8.31	0.28	25	4.06	0.18	25	7.5%	4.25 [4.12, 4.38]
Ortiz 2020	7.65	1.4	142	4.8	3.14	142	6.9%	2.85 [2.28, 3.42]
Torabi 2020	7.5	1.6	25	5.4	3.6	25	4.3%	2.10 [0.56, 3.64]
Total (95% CI)			**1557**			**1557**	**100.0%**	**3.84 [3.35, 4.33]**

Heterogeneity: $Tau^2 = 0.83$; $Chi^2 = 830.24$, df = 15 ($P < 0.00001$); $I^2 = 98\%$
Test for overall effect: Z = 15.26 ($P < 0.00001$)

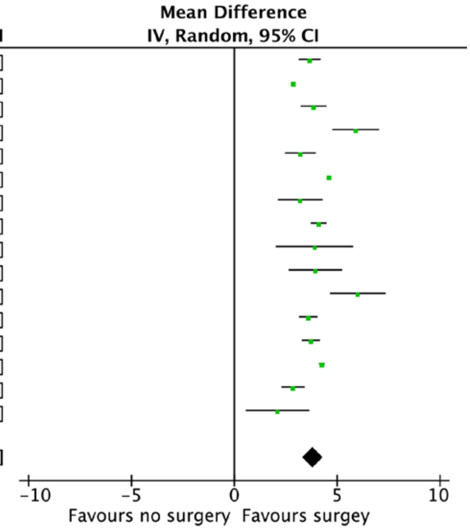

Fig. 5. Forest plot for the average migraine attack intensity before versus after surgery using the DerSimonian and Laird random-effects model of mean differences.

migraine attack intensity data are summarized in the Supplemental Digital Content. (**See Table, Supplemental Digital Content 8**, which shows extracted migraine attack intensity data by individual study. *A*, arterectomy performed; *AT*, atraumatic; *BTA*, botulinum toxin A; *N*, narcotic user; *NA*, no arterectomy performed; *NN*, nonnarcotic user; *NP*, no precipitating event, *NR*, not reported; *OAR*, occipital artery resection; *PE*, precipitating event; *T*, traumatic; *TON-NR*, third occipital nerve not removed; *TON-R*, third occipital nerve removed, ***http://links.lww.com/PRS/G743***.)

Migraine Attack Duration

A total of 15 studies reported on mean migraine attack duration both preoperatively and postoperatively. Durations were reported in total hours or days. For studies reporting duration as days, values were converted to total hours to standardize units for meta-analysis. The MD ranged from 3.9 to 25.2 hours. The reduction ranged from 41.1% to 75.0%. The weighted MD across studies was 11.80 (95% CI, 6.44 to 17.16). Heterogeneity was measured as $\tau^2 = 105.56$; $\chi^2 = 1051.98$, $df = 14$ ($P < 0.00001$); $I^2 = 99\%$. The results are summarized in Figure 6. A sensitivity analysis was conducted, and no individual study significantly affected the pooled results. Publication bias was evaluated using a funnel plot (**See Figure, Supplemental Digital Content 9**, which shows a funnel plot for studies reporting migraine attack duration, ***http://links.lww.com/PRS/G744***), and no overt signs of asymmetry were observed. The original extracted migraine attack duration data are summarized in the Supplemental Digital Content. (**See Table, Supplemental Digital Content 10**, which shows extracted migraine attack duration data by individual study. *A*, arterectomy performed; *AT*, atraumatic; *BTA*, botulinum toxin A; *N*, narcotic user; *NA*, no arterectomy performed; *NN*, nonnarcotic user; *NP*, no precipitating event; *NR*, not reported; *OAR*, occipital artery resection; *PE*, precipitating event; *T*, traumatic; *TON-NR*, third occipital nerve not removed; *TON-R*, third occipital nerve removed, ***http://links.lww.com/PRS/G745***.)

Complications

Of the included studies, eight reported complications after migraine surgery, three reported no postoperative complications, and eight did not discuss complications. Among the 11 studies discussing complications (including those reporting their absence), there were a total of 401 participants. The most commonly recorded complication was ecchymosis [n = 35 (8.83%)]. Other important complications included hair loss or thinning [n = 20 (4.99%)], itching [n = 13 (3.24%)], dryness [n = 12 (2.99%)], rhinorrhea [n = 11 (2.74%)], temporal hollowing [n = 10 (2.49%)], numbness or paresthesia persisting for 1 year [n = 8 (2%)], septal deviation recurrence [n = 8 (2%)], and neck stiffness [n = 5 (1.25%)]. The corresponding site of deactivation for each complication was not reported in four of the eight studies reporting complications, and thus, these data could not be pooled appropriately. A summary of complications and the studies they were reported in can be seen in Table 2.

Study or Subgroup	Pre-operative Mean	SD	Total	Post-operative Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Adenuga 2014	24	25.3	202	12.81	23.19	202	6.7%	11.19 [6.46, 15.92]
Chepla 2012	29.04	5.52	86	13.44	3.6	86	7.0%	15.60 [14.21, 16.99]
Chmielewski 2013	25.64	30.24	170	10.24	20.49	170	6.6%	15.40 [9.91, 20.89]
Gfrerer 2014	16.8	12	35	4.8	9.6	35	6.7%	12.00 [6.91, 17.09]
Gfrerer 2019	20.43	17.36	83	10.38	14.5	83	6.7%	10.05 [5.18, 14.92]
Guyuron 2005	33.6	3.36	89	8.4	1.2	89	7.1%	25.20 [24.46, 25.94]
Guyuron 2009	12.96	13.2	49	7.2	11.04	49	6.7%	5.76 [0.94, 10.58]
Guyuron 2015	9.6	1.4	19	4.8	2.2	19	7.1%	4.80 [3.63, 5.97]
Guyuron 2015a	17.04	9.84	14	6	6.96	14	6.4%	11.04 [4.73, 17.35]
Janis 2011	24.96	21.36	24	11.28	11.52	24	5.7%	13.68 [3.97, 23.39]
Lee 2013	23.58	37.47	229	11.51	47.9	229	6.1%	12.07 [4.19, 19.95]
Liu 2012	25.76	39.37	335	10.89	23.8	335	6.7%	14.87 [9.94, 19.80]
Omranifard 2016	25.2	11.04	25	11.28	6	25	6.7%	13.92 [8.99, 18.85]
Ortiz 2020	16.01	8.23	142	8.45	9.17	142	7.0%	7.56 [5.53, 9.59]
Torabi 2020	9.5	9.3	25	5.6	6.6	25	6.8%	3.90 [−0.57, 8.37]
Total (95% CI)			**1527**			**1527**	**100.0%**	**11.80 [6.44, 17.16]**

Heterogeneity: Tau^2 = 105.56; Chi^2 = 1051.98, df = 14 (P < 0.00001); I^2 = 99%
Test for overall effect: Z = 4.32 (P < 0.0001)

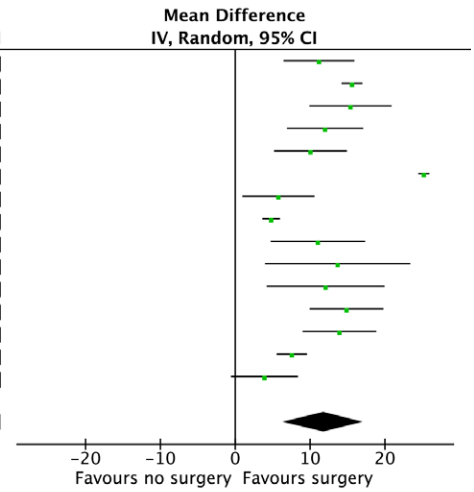

Fig. 6. Forest plot for the average migraine attack duration before versus after surgery using the DerSimonian and Laird random-effects model of mean differences.

Table 2. Complication Rate Listed by Category[a]

Complication	No. of Studies	No. of Participants with Complication	Complication Rate (%)
Ecchymosis[49,50,53]	3	35	8.73
Hair loss or thinning[10,48,49,52]	4	20	4.99
Itching[10,45,48,52]	4	13	3.24
Temporary nasal dryness[10]	1	12	2.99
Rhinorrhea[10]	1	11	2.74
Temporal hollowing[48]	1	10	2.49
Numbness or paresthesia persisting for 1 year[22,45,48,49]	4	19	2.00
Septal deviation recurrence[10]	1	8	2.00
Neck stiffness[10,48]	2	5	1.25
Bleeding[10]	1	4	1.00
Infection[10]	1	3	0.75
Epistaxis[10]	1	3	0.75
Hematoma[10]	1	2	0.50
Seroma[22]	1	2	0.50
Hyposensitivity[50]	1	1	0.25
Hypertrophic scarring[45]	1	1	0.25
Wound dehiscence[22]	1	1	0.25
Unilateral airway reduction[10]	1	1	0.25
Residual corrugator supercilia function[48]	1	1	0.25
Uneven brow movement[48]	1	1	0.25
Peri-incisional burn[53]	1	1	0.25

[a]Only studies reporting complications were included in the analysis. A total of 401 patients were included among the studies.

DISCUSSION

The results of this systematic review and meta-analysis corroborate previous reviews demonstrating the efficacy and safety of headache surgery using nerve deactivation procedures.[13,56,57] The key finding is the significant postoperative reduction in MMD pooled across studies. Secondary outcomes similarly demonstrated significant reductions. The three most common complications across studies were ecchymosis, operative-site incisional alopecia, and itching. Major complications such as intraoperative bleeding and wound dehiscence were very rare (≤1%).

The focus of this review is to demonstrate the effect of nerve deactivation surgery on MMD, the outcome commonly used in the neurology literature. PRS studies on headache surgery traditionally have emphasized MHI as the primary outcome, which is problematic considering the guidelines established for evaluating migraine treatment. In the first edition of its guidelines for controlled trials of drugs in migraine from

1991, the IHS provided a formal recommendation against the use of headache indices.[58] They stated that intensity is difficult to standardize and subject to changes by relief medication, and duration is subject to medication used along with difficulty defining onset to termination. Because both of these attack characteristics are included in the calculation of the MHI, the IHS ultimately stated that the collective headache index cannot be meaningfully compared among different trial participants. Moreover, the IHS cited a study that demonstrated that in most cases where a decrease in the headache index was found, this was attributable to a decrease in frequency rather than intensity or duration.[59]

Further guidelines published in 2000, 2008, and 2018 have echoed similar recommendations.[11,12,60] Across all four publications spanning 27 years, they have consistently endorsed change in MMDs as one of three standard primary efficacy outcomes. The other outcomes are response rate measured as the proportion of patients with a 50% or greater decrease in MMD and the change in headache days of moderate to severe intensity per month (including headaches of all classifications). The change in MMD has been used by neurologists in randomized controlled trials on migraine prophylaxis drugs, including recent studies investigating antibodies that target the calcitonin gene-related peptide pathway.[61–65]

Because of this discrepancy in outcome reporting and the consideration that neurologists are the traditional experts on nonsurgical migraine treatment, the primary purpose of the current study is to demonstrate the efficacy of headache surgery through the same lens utilized by neurologists investigating novel therapies for migraine prophylaxis. The significant decrease and narrow confidence interval demonstrated in the current meta-analysis provide strong evidence in support of headache surgery efficacy.

As a secondary purpose, the current study is also meant to motivate future PRS publications to report directly on preoperative and postoperative MMD data. We identified 31 studies reporting on outcomes of headache surgery without any mention of MMD.[5,10,16,18–20,24–38,45,49,51–53,55,66–69] This is a significant body of evidence that could exist in the databases already constructed by the study authors. If so, we suspect this omission might be attributable to a lack of awareness about the preferred outcome metrics used in the neurology literature, and we hope our work will provide evidence to standardize migraine treatment metrics across both disciplines.

A salient weakness of the current study is the high degree of heterogeneity of the procedures performed, as we included data on surgical procedures involving a variety of trigger sites. It is possible that some procedures are more effective than others depending on the surgical technique applied and the number of trigger sites approached in each patient. The range of sites deactivated per patient ranged from one to six among the studies included. The field of headache surgery is in its youth, and methods of deactivation have evolved over the past 2 decades. We recommend that future studies report migraine metrics by site of deactivation to determine outcomes more objectively.[70]

Another weakness of the current study is the inclusion of varying levels of evidence (1 through 4) in our analysis. However, including all outcome studies and maximizing available data outweighs the negatives of pooling multiple study designs together. In addition, although duplicate patient samples were removed, several studies were conducted by similar author groups, and therefore, patients might have been counted more than once. This could potentially bias the findings of the study, and interpretation of the results should be done with caution. Nevertheless, the current meta-analysis provides a higher level of evidence than individual investigations, and the findings support ongoing efforts to make migraine surgery more accessible in the right setting.

CONCLUSIONS

Previous meta-analyses have reported on headache surgery outcomes, but the current meta-analysis incorporates new publications with a particular emphasis on change in MMD. This is the outcome endorsed by the IHS and used in neurology investigations on novel medical migraine therapeutics. The pooled results in our study provide data to better compare outcomes after headache surgery with those of medical migraine treatments. We hope future studies on headache surgery will report outcomes as change in MMD to facilitate communication between the PRS and neurology communities.

Jeffrey E. Janis, MD
915 Olentangy River Road
Columbus, OH 43212
jeffrey.janis@osumc.edu
X (formerly Twitter): jjanismd
Instagram: JeffreyJanisMD

DISCLOSURE

Dr. Janis receives royalties from Thieme and Springer Publishing. The other authors have no financial disclosures to report.

REFERENCES

1. Headache Classification Subcommittee of the International Headache Society. The International Classification of Headache Disorders 2nd Edition. *Cephalalgia.* 2004;24(suppl 1):8–160.
2. Feigin VL, Abajobir AA, Abate KH, et al. Global, regional, and national burden of neurological disorders during 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet Neurol.* 2017;16:877–897.
3. Kung TA, Guyuron B, Cederna PS. Migraine surgery: a plastic surgery solution for refractory migraine headache. *Plast Reconstr Surg.* 2011;127:181–189.
4. Irimia P, Palma JA, Fernandez-Torron R, Martinez-Vila E. Refractory migraine in a headache clinic population. *BMC Neurol.* 2011;11:94.
5. Guyuron B, Varghai A, Michelow BJ, Thomas T, Davis J. Corrugator supercilii muscle resection and migraine headaches. *Plast Reconstr Surg.* 2000;106:429–434; discussion 435.
6. Afifi AM, Peled ZM, Janis JE. Headache and migraine surgery: a look back and into the future. In: *Surgical Treatment of Chronic Headaches and Migraines.* Springer Publishing; 2020:203–206.
7. Mathew PG. A critical evaluation of migraine trigger site deactivation surgery. *Headache* 2014;54:142–152.
8. Diener H, Bingel U. Surgical treatment for migraine: time to fight against the knife. *Cephalalgia* 2015;35:465–468.
9. McGeeney BE. Migraine trigger site surgery is all placebo. *Headache* 2015;55:1461–1463.
10. Guyuron B, Kriegler JS, Davis J, Amini SB. Comprehensive surgical treatment of migraine headaches. *Plast Reconstr Surg.* 2005;115:1–9.
11. Silberstein S, Tfelt-Hansen P, Dodick D, et al. Guidelines for controlled trials of prophylactic treatment of chronic migraine in adults. *Cephalalgia* 2008;28:484–495.
12. Tassorelli C, Diener HC, Dodick DW, et al.; International Headache Society Clinical Trials Standing Committee. Guidelines of the International Headache Society for controlled trials of preventive treatment of chronic migraine in adults. *Cephalalgia* 2018;38:815–832.
13. ElHawary H, Barone N, Baradaran A, Janis JE. Efficacy and safety of migraine surgery: a systematic review and meta-analysis of outcomes and complication rates. *Ann Surg.* 2022;275:e315–e323.
14. Higgins J, Thomas J, Chandler J, et al. *Cochrane Handbook for Systematic Reviews of Interventions, Version 6.3.* Cochrane; 2022.
15. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *J Clin Epidemiol.* 2009;62:e1–e34.
16. Lee M, Lineberry K, Reed D, Guyuron B. The role of the third occipital nerve in surgical treatment of occipital migraine headaches. *J Plast Reconstr Aesthet Surg.* 2013;66:1335–1339.
17. Gatherwright JR, Wu-Fienberg Y, Guyuron B. The importance of surgical maneuvers during treatment of frontal migraines (site I): a prospective, randomized cohort study evaluating foraminotomy/fasciotomy, myectomy, and arterectomy. *J Plast Reconstr Aesthet Surg.* 2018;71:478–483.
18. Liu MT, Armijo BS, Guyuron B. A comparison of outcome of surgical treatment of migraine headaches using a constellation of symptoms versus botulinum toxin type A to identify the trigger sites. *Plast Reconstr Surg.* 2012;129:413–419.
19. Chmielewski L, Liu MT, Guyuron B. The role of occipital artery resection in the surgical treatment of occipital migraine headaches. *Plast Reconstr Surg.* 2013;131:351e–356e.
20. Adenuga P, Brown M, Reed D, Guyuron B. Impact of preoperative narcotic use on outcomes in migraine surgery. *Plast Reconstr Surg.* 2014;134:113–119.
21. Ortiz R, Gfrerer L, Hansdorfer MA, Tsui JM, Nealon KP, Austen WG. The efficacy of surgical treatment for headaches in patients with prior head or neck trauma. *Plast Reconstr Surg.* 2020;146:381–388.
22. Gfrerer L, Hulsen JH, McLeod MD, Wright EJ, Austen WG. Migraine surgery: an all or nothing phenomenon? Prospective evaluation of surgical outcomes. *Ann Surg.* 2019;269:994–999.
23. Deeks JJ, Higgins J. Statistical algorithms in Review Manager. Published May 2022. Available at: https://documentation.cochrane.org/revman-kb/files/210600101/210600103/1/1654774257333/Statistical_methods_in_revman.pdf.
24. Bearden WH, Anderson RL. Corrugator superciliaris muscle excision for tension and migraine headaches. *Ophthalmic Plast Reconstr Surg.* 2005;21:418–422.
25. Caruana G, Bertozzi N, Elena B, Grieco MP, Grignaffini E, Raposio E. Endoscopic forehead surgery for migraine therapy: personal technique. *Ann Ital Chir.* 2014;85:583–586.
26. de Ru JA, Schellekens PPA, Lohuis PJFM. Corrugator supercilii transection for headache emanating from the frontal region: a clinical evaluation of ten patients. *J Neural Transm.* 2011;118:1571–1574.
27. Dirnberger F, Becker K. Surgical treatment of migraine headaches by corrugator muscle resection. *Plast Reconstr Surg.* 2004;114:652–657; discussion 658.
28. Ducic I, Hartmann EC, Larson EE. Indications and outcomes for surgical treatment of patients with chronic migraine headaches caused by occipital neuralgia. *Plast Reconstr Surg.* 2009;123:1453–1461.
29. Guyuron B, Tucker T, Davis J. Surgical treatment of migraine headache. *Plast Reconstr Surg.* 2002;109:2183–2189.
30. Kurlander DE, Punjabi A, Liu MT, Sattar A, Guyuron B. In-depth review of symptoms, triggers, and treatment of temporal migraine headaches (site II). *Plast Reconstr Surg.* 2014;133:897–903.
31. Lee M, Erickson C, Guyuron B. Intranasal pathology in the migraine surgery population: incidence, patterns, and predictors of surgical success. *Plast Reconstr Surg.* 2017;139:184–189.
32. Lee M, Monson MA, Liu MT, Reed D, Guyuron B. Positive botulinum toxin type A response is a prognosticator for migraine surgery success. *Plast Reconstr Surg.* 2013;131:751–757.
33. Lin SH, Lin HC, Jeng CH, Hsieh CH, Lin YH, Chen CC. Experience of surgical treatment for occipital migraine in Taiwan. *Ann Plast Surg.* 2016;76(Suppl 1):S80–S84.
34. Park DY, Choo OS, Hong SY, Kim HJ. Infratemporal fossa cellulitis caused by a remnant iatrogenic foreign body after a bimaxillary operation. *J Craniofac Surg.* 2015;26:e196–e197.
35. Peled ZM. A novel surgical approach to chronic temporal headaches. *Plast Reconstr Surg.* 2016;137:1597–1600.
36. Raposio E, Bertozzi N. Trigger site inactivation for the surgical therapy of occipital migraine and tension-type headache: our experience and review of the literature. *Plast Reconstr Surg Glob Open* 2019;7:e2507.
37. Raposio E, Caruana G. Tips for the surgical treatment of occipital nerve-triggered headaches. *Eur J Plast Surg.* 2017;40:177–182.

38. Raposio E, Simonacci F. Frontal trigger site deactivation for migraine surgical therapy. *Plast Reconstr Surg Glob Open* 2020;8:e2813.
39. Afifi AM, Carbullido MK, Israel JS, Sanchez RJ, Albano NJ. Alternative approach for occipital headache surgery: the use of a transverse incision and "W" flaps. *Plast Reconstr Surg Glob Open* 2019;7:e2176.
40. Ascha M, Kurlander DE, Sattar A, Gatherwright J, Guyuron B. In-depth review of symptoms, triggers, and treatment of occipital migraine headaches (site IV). *Plast Reconstr Surg.* 2017;139:1333e–1342e.
41. Kurlander DE, Ascha M, Sattar A, Guyuron B. In-depth review of symptoms, triggers, and surgical deactivation of frontal migraine headaches (site I). *Plast Reconstr Surg.* 2016;138:681–688.
42. Larson K, Lee M, Davis J, Guyuron B. Factors contributing to migraine headache surgery failure and success. *Plast Reconstr Surg.* 2011;128:1069–1075.
43. Liu MT, Chim H, Guyuron B. Outcome comparison of endoscopic and transpalpebral decompression for treatment of frontal migraine headaches. *Plast Reconstr Surg.* 2012;129:1113–1119.
44. Guyuron B, Kriegler JS, Davis J, Amini SB. Five-year outcome of surgical treatment of migraine headaches. *Plast Reconstr Surg.* 2011;127:603–608.
45. Chepla KJ, Oh E, Guyuron B. Clinical outcomes following supraorbital foraminotomy for treatment of frontal migraine headache. *Plast Reconstr Surg.* 2012;129:656e–662e.
46. Gfrerer L, Maman DY, Tessler O, Austen WG. Nonendoscopic deactivation of nerve triggers in migraine headache patients: surgical technique and outcomes. *Plast Reconstr Surg.* 2014;134:771–778.
47. Guyuron B, Harvey D, Reed D. A prospective randomized outcomes comparison of two temple migraine trigger site deactivation techniques. *Plast Reconstr Surg.* 2015;136:159–165.
48. Guyuron B, Lineberry K, Nahabet EH. A retrospective review of the outcomes of migraine surgery in the adolescent population. *Plast Reconstr Surg.* 2015;135:1700–1705.
49. Guyuron B, Reed D, Kriegler JS, Davis J, Pashmini N, Amini S. A placebo-controlled surgical trial of the treatment of migraine headaches. *Plast Reconstr Surg.* 2009;124:461–468.
50. Janis JE, Dhanik A, Howard JH. Validation of the peripheral trigger point theory of migraine headaches: single-surgeon experience using botulinum toxin and surgical decompression. *Plast Reconstr Surg.* 2011;128:123–131.
51. Jose A, Nagori SA, Roychoudhury A. Surgical management of migraine headache. *J Craniofac Surg.* 2018;29:e106–e108.
52. Omranifard M, Abdali H, Ardakani M, Talebianfar M. A comparison of outcome of medical and surgical treatment of migraine headache: in 1 year follow-up. *Adv Biomed Res.* 2016;5:121.
53. Poggi JT, Grizzell BE, Helmer SD. Confirmation of surgical decompression to relieve migraine headaches. *Plast Reconstr Surg.* 2008;122:115–122.
54. Gualdi A, Cambiaso-Daniel J, Gatti J, et al. Selective denervation of the corrugator supercilii muscle for the treatment of idiopathic trigeminal neuralgia purely paroxysmal distributed in the supraorbital and supratrochlear dermatomes. *J Headache Pain* 2021;22:9.
55. Torabi R, Bourn L, Veith J, et al. Population-based health utility assessment of migraine headache symptoms before and after surgical intervention. *Plast Reconstr Surg.* 2020;145:210–217.
56. Nagori SA, Jose A, Roychoudhury A. Surgical management of migraine headaches: a systematic review and meta-analysis. *Ann Plast Surg.* 2019;83:232–240.
57. Vincent AJPE, van Hoogstraten WS, Maassen Van Den Brink A, van Rosmalen J, Bouwen BLJ. Extracranial trigger site surgery for migraine: a systematic review with meta-analysis on elimination of headache symptoms. *Front Neurol.* 2019;10:89.
58. International Headache Society Committee on Clinical Trials in Migraine. Guidelines for controlled trials of drugs in migraine, first edition. *Cephalalgia* 1991;11:1–12.
59. Tfelt-Hansen P, Standnes B, Kangasneimi P, Hakkarainen H, Olesen J. Timolol vs propranolol vs placebo in common migraine prophylaxis: a double-blind multicenter trial. *Acta Neurol Scand.* 1984;69:1–8.
60. Tfelt-Hansen P, Block G, Dahlöf C, et al.; International Headache Society Clinical Trials Subcommittee. Guidelines for controlled trials of drugs in migraine: second edition. *Cephalalgia* 2000;20:765–786.
61. Goadsby PJ, Reuter U, Hallström Y, et al. A controlled trial of erenumab for episodic migraine. *N Engl J Med.* 2017;377:2123–2132.
62. Dodick DW, Ashina M, Brandes JL, et al. ARISE: a phase 3 randomized trial of erenumab for episodic migraine. *Cephalalgia* 2018;38:1026–1037.
63. Skljarevski V, Oakes TM, Zhang Q, et al. Effect of different doses of galcanezumab vs placebo for episodic migraine prevention: a randomized clinical trial. *JAMA Neurol.* 2018;75:187–193.
64. Wells RE, O'Connell N, Pierce CR, et al. Effectiveness of mindfulness meditation vs headache education for adults with migraine: a randomized clinical trial. *JAMA Intern Med.* 2021;181:317–328.
65. Lipton RB, Goadsby PJ, Smith J, et al. Efficacy and safety of eptinezumab in patients with chronic migraine: PROMISE-2. *Neurology* 2020;94:e1365–e1377.
66. Chen G, You H, Juha H, et al. Trigger areas nerve decompression for refractory chronic migraine. *Clin Neurol Neurosurg.* 2021;206:106699.
67. Eskilsson A, Ageberg E, Ericson H, Marklund N, Anderberg L. Decompression of the greater occipital nerve improves outcome in patients with chronic headache and neck pain: a retrospective cohort study. *Acta Neurochir.* 2021;163:2425–2433.
68. Gfrerer L, Hansdorfer MA, Ortiz R, et al. Patient pain sketches can predict surgical outcomes in trigger-site deactivation surgery for headaches. *Plast Reconstr Surg.* 2020;146:863–871.
69. Raposio G, Raposio E. Temporal surgery for chronic migraine treatment: a minimally-invasive perspective. *Ann Med Surg (Lond).* 2022;76:103578.
70. Huayllani MT, Janis JE. Migraine surgery and determination of success over time by trigger site: a systematic review of the literature. *Plast Reconstr Surg.* 2023;151:120e–135e.