Surgical Treatment of Migraine Headache: Back to the Future

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Summary: Understanding the history and evolution of ideas is key to developing an understanding of complex phenomena and is the foundation for surgical innovation. This historical review on migraine surgery takes us back to the beginnings of interventional management for migraine centuries ago, and reflects on present practices to highlight how far we have come. From Al-Zahrawi and Ambroise Paré to Bahman Guyuron, two common themes of the past and present have emerged in the treatment of migraine headache. Extracranial treatment of both nerves and vessels is being performed and analyzed, with no consensus among current practitioners as to which structure is involved. Knowledge of past theories and new insights will help guide our efforts in the future. One thing is clear: Where we are going, there are no roads. At least not yet. (*Plast. Reconstr. Surg.* 142: 1036, 2018.)

Understanding the history and evolution of ideas is critical in surgery and surgical research. Knowledge of past theories and new insights is key to developing an understanding of complex phenomena and is the foundation for surgical innovation. Migraine headache is an example of a complicated disease that has been studied for centuries without consensus as to its pathophysiology or treatment. Historically, surgeons have not been appreciably involved in the treatment of patients suffering from migraine. Only in the past two decades has extracranial trigger deactivation for migraine headache been introduced and used more routinely in surgical practice. However, the concept of interventional therapy for migraine headache is fascinating and dates back hundreds of years.

This article is focused on the surgical treatment of migraine headache in the more recent past for which well-preserved evidence exists. There are scarce reports of earlier surgical treatments of the head and neck that go back to ancient Egypt.[1]

HISTORY OF SURGICAL TREATMENT OF MIGRAINE

Theories on the extracranial origin and corresponding treatment of migraine headache have existed for centuries. Early surgical interventions for migraine focused mainly on the treatment of blood vessels to alleviate migraine pain.

Remarkably, the first preserved description of the operative treatment of migraine headache can be traced back approximately 1000 years. Al-Zahrawi, an Andalusian physician widely regarded as the greatest Muslim surgeon of his time (936 to 1013 AD[2]), was well known for treating the disease by cauterization. His most important contribution to the medical literature was *Kitab al-Tasrif* (Figs. 1 through 3), an encyclopedia of medicine and surgery, which was translated to Latin and other European languages and was considered a standard reference for medical students long after his death. In this body of work, he extensively described his technique for cauterization of areas of the skull to alleviate migraine pain (Fig. 1).[3]

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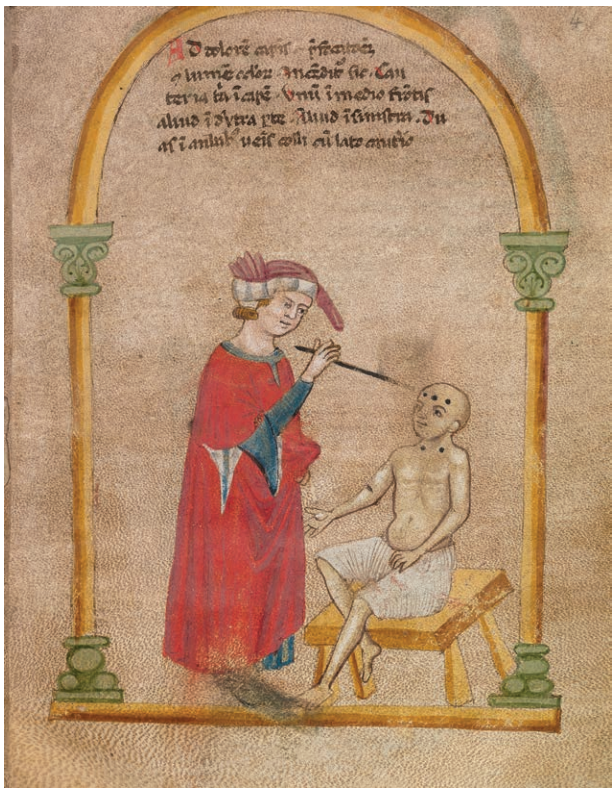

Fig. 1. Depiction of cauterization procedure described by Al-Zahrawi. (From Abū al-Qāsim Khalaf ibn ʼAbbās al-Zahrāwī. *Octauii Horatiani rerum medicarum lib. quatuor: Albucasis chirurgicorum omnium primarij*, lib. tres; 1532. Image MS. Laud. Misc. 724m fol. 94r. Copy of original image and copyright obtained by Bodleian Libraries, University of Oxford on November 29, 2017.)

His cauterization therapy for migraine followed the principle of starting with simple, less morbid interventions before escalating treatment (Fig. 2).[3] As an initial intervention, he described the use of caustic cauterization (Fig. 3)[3,4]:

> […] take one clove of garlic […] then cut open the site of pain in the temple […] until there is room to contain the clove under the skin; […] then bind up the wound tightly […] and leave for fifteen hours.[4]

An alternative to caustic cautery was actual cautery:

> […] heat a cautery […] apply it then to the site of pain, hold your hand steady and revolve it little by little. Let the thickness of the skin burnt be about half; […].[4]

In chronic cases, Al-Zahrawi suggested the following:

> […] cauterize him over again a little above the first cautery; then cauterize him on each frontal prominence with one cautery so as to remove the thickness of the skin and expose […] bone […] and burn him with one stroke on the hinder part of the head known as the occiput; […] .[4]

Fig. 2. Preparation of surgical instruments and various operations on the head including trepanning and cauterization by Al-Zahrawi. (From Abū al-Qāsim Khalaf ibn ʼAbbās al-Zahrāwī. *Octauii Horatiani rerum medicarum lib. quatuor: Albucasis chirurgicorum omnium primarij*, lib. tres; 1532. Image MS. Rawl. C. 328, fol. 4r Copy of original image and copyright obtained by Bodleian Libraries, University of Oxford on November 29, 2017.)

To see the full English translation of migraine therapies by Al-Zahrawi, see Appendix 1. (**See Appendix, Supplemental Digital Content 1**, which shows text excerpts on the surgical treatment of migraine by Al-Zahrawi borrowed from the 1973 English translation of Al-Zahrawi's medical treatise from the 1400s, ***http://links.lww.com/PRS/C997***.[4]) Approximately 600 years later, the famous French barber-surgeon Ambroise Paré (1510 to 1590) rejected the notion of cauterization. Paré served as a military surgeon under several French kings, and at the time the standard of care for battlefield injuries was cauterization. However, keenly aware of the morbidity and mortality associated

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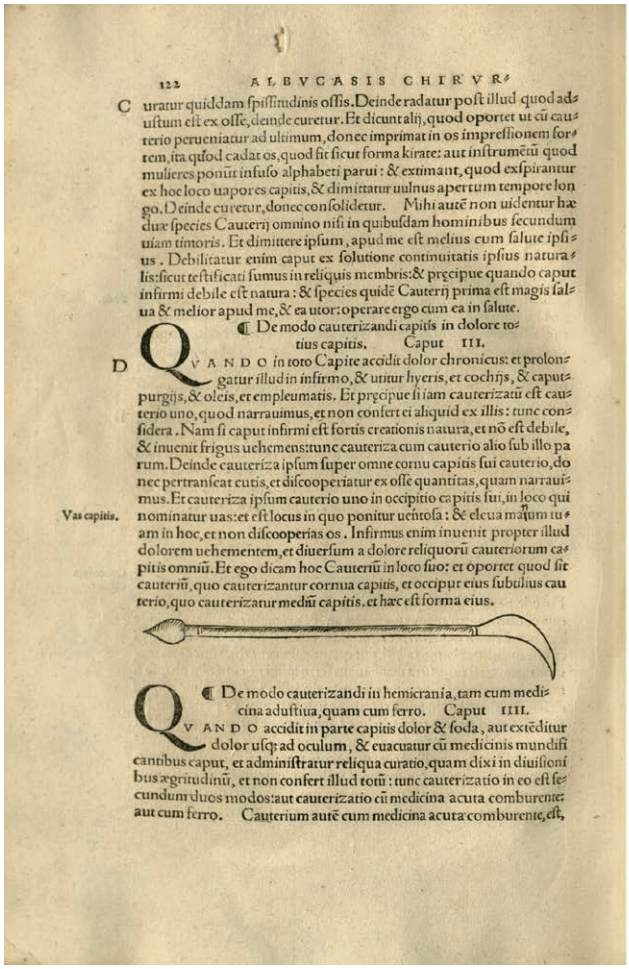


122 ALBVCASIS CHIRVR.

C uratur quiddam ſpiſſitudinis oſſis. Deinde radatur poſt illud quod adu-
ſtum eſt ex oſſe, deinde curetur. Et dicunt alij, quod oportet ut cū cau-
terio perueniatur ad ultimum, donec imprimat in os impreſſionem for-
tem, ita quōd cadat os, quod fit ſicut forma kirate: aut inſtrumētū quod
mulieres ponūt infuſo alphabeti parui: & extimant, quod exſpirantur
ex hoc loco uapores capitis, & dimittatur uulnus apertum tempore lon
go. Deinde curetur, donec conſolidetur. Mihi autē non uidentur hæ
duæ ſpecies Cauterij omnino niſi in quibuſdam hominibus ſecundum
uiam timoris. Et dimittere ipſum, apud me eſt melius cum ſalute ipſi-
us. Debilitatur enim caput ex ſolutione continuitatis ipſius natura-
lis: ſicut teſtificati ſumus in reliquis membris: & precipue quando caput
infirmi debile eſt natura: & ſpecies quidē Cauterij prima eſt magis ſalu-
ua & melior apud me, & ea utor: operare ergo cum ea in ſalute.

¶ De modo cauterizandi capitis in dolore to-
tius capitis. Caput III.

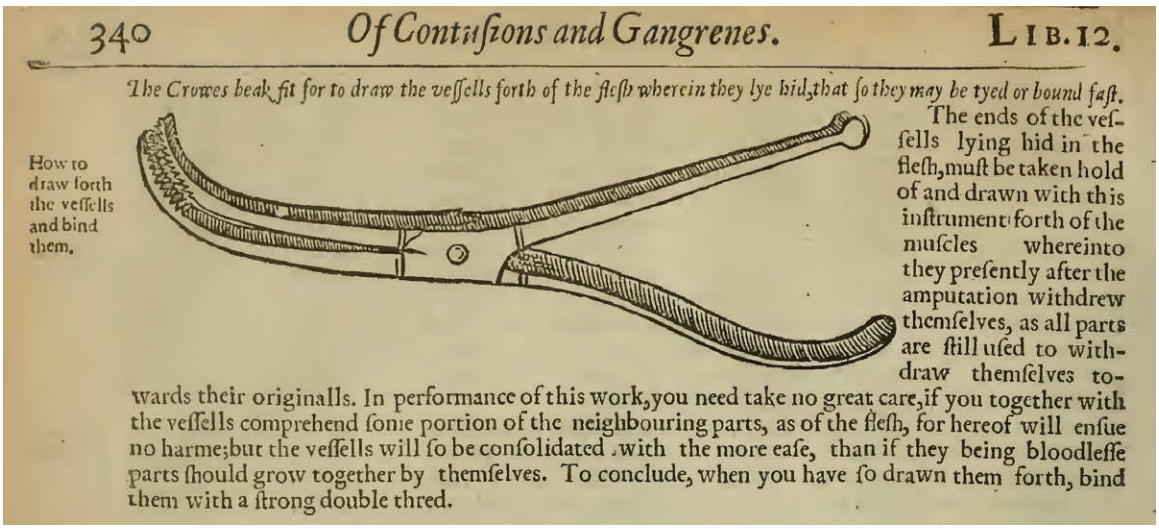
D QVANDO in toto Capite accidit dolor chronicus: et prolon-
gatur illud in infirmo, & utitur hyeris, et cochijs, & caput-
purgijs, & oleis, et empleumatis. Et precipue ſi iam cauterizatū eſt cau-
terio uno, quod narrauimus, et non confert ei aliquid ex illis: tunc con-
ſidera. Nam ſi caput infirmi eſt fortis creationis natura, et nō eſt debile,
& inuenit frigus uehemens: tunc cauteriza cum cauterio alio ſub illo pa
rum. Deinde cauteriza ipſum ſuper omne cornu capitis ſui cauterio, do
nec pertranſeat cutis, et diſcooperiatur ex oſſe quantitas, quam narrauiſ-
mus. Et cauteriza ipſum cauterio uno in occipitio capitis ſui, in loco qui
Vas capitis. nominatur uas: et eſt locus in quo ponitur uēntoſa: & elcua manum tu-
am in hoc, et non diſcooperias os. Infirmus enim inuenit propter illud
dolorem uehementem, et diuerſum a dolore reliquorū cauteriorum ca-
pitis omniū. Et ego dicam hoc Cauterīū in loco ſuo: et oportet quod ſit
cauteriū, quo cauterizantur cornua capitis, et occiput eius ſubtilius cau
terio, quo cauterizatur medīū capitis. et hæc eſt forma eius.

¶ De modo cauterizandi in hemicrania, tam cum medi-
cina aduſtiua, quam cum ferro. Caput IIII.

Q VANDO accidit in parte capitis dolor & ſoda, aut extēditur
dolor uſq; ad oculum, & euacuatur cū medicinis mundifi
cantibus caput, et adminiſtratur reliqua curatio, quam dixi in diuiſioni
bus ægritudinū, et non confert illud toti: tunc cauterizatio in eo eſt ſe-
cundum duos modos: aut cauterizatio cū medicina acuta comburente:
aut cum ferro. Cauterium autē cum medicina acuta comburente, eſt,

" When [...] the patient has cleared his head with purging drugs and there has been applied the other treatment that I have mentioned in the sections on diseases, but to no avail; in this disorder cauterization is of two sorts, either with caustic or with the actual cautery. This is the manner of cauterization with caustic: take one clove of garlic [...] then cut open the site of pain in the temple [...] until there is room to contain the clove under the skin; [...] then bind up the wound tightly [...] and leave for fifteen hours; then unbind it, remove the garlic, and leave the wound open for two or three days; then apply cotton wool soaked in butter until it suppurates "

Fig. 3. Latin translation of Al- Zahrawi's *Kitab al-Tasrif* (Abū al-Qāsim Khalaf ibn ´Abbās al-Zahrāwī. *Octauii Horatiani rerum medicarum lib. quatuor: Albucasis chirurgicorum omnium primarij*, lib. tres; 1532), with excerpts from an English translation (Abū al-Qāsim Khalaf ibn ´Abbās al-Zahrāwī. *Albucasis on Surgery and Instruments: A Definitive Edition of the Arabic Text with English Translation and Commentary*. Berkeley: University of California Press; 1973). (Image and copyright obtained from the Center for the History of Medicine, Countway Library of Medicine, Harvard University.)



340 *Of Contuſions and Gangrenes.* LIB. 12.

The Crowes beak fit for to draw the veſſells forth of the fleſh wherein they lye hid, that ſo they may be tyed or bound faſt.

How to draw forth the veſſells and bind them.

The ends of the veſſells lying hid in the fleſh, muſt be taken hold of and drawn with this inſtrument forth of the muſcles whereinto they preſently after the amputation withdrew themſelves, as all parts are ſtill uſed to withdraw themſelves towards their originalls. In performance of this work, you need take no great care, if you together with the veſſells comprehend ſome portion of the neighbouring parts, as of the fleſh, for hereof will enſue no harme; but the veſſells will ſo be conſolidated with the more eaſe, than if they being bloodleſſe parts ſhould grow together by themſelves. To conclude, when you have ſo drawn them forth, bind them with a ſtrong double thred.

Fig. 4. Illustration depicting the bec de corbin from an English translation of Paré's *Treatise on Surgery* (Ambroise Paré. *The Works of Ambrose Parey, Chyrurgeon to Henry II, Francis II, Charles IX, and Henry III, Kings of France*. London: J. Hindmarsh; 1691). (Permission for use granted from the Center for the History of Medicine, Countway Library of Medicine, Harvard University.)

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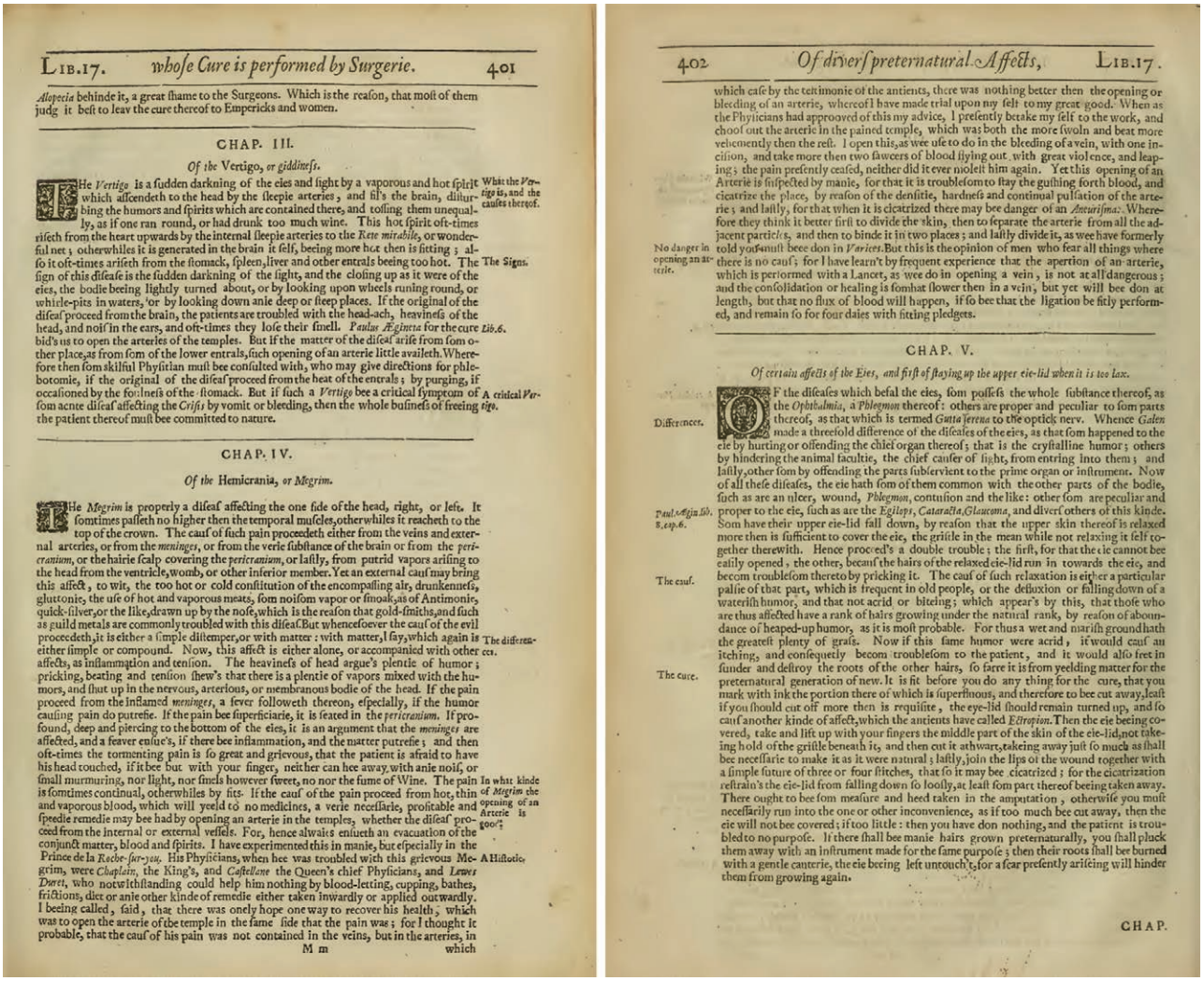

Lib.17. *whose Cure is performed by Surgerie.* 401

Alopecia behinde it, a great shame to the Surgeons. Which is the reason, that most of them judg it best to leav the cure thereof to Empericks and women.

CHAP. III.

Of the Vertigo, *or giddiness.*

The *Vertigo* is a sudden darkning of the eies and sight by a vaporous and hot spirit which assendeth to the head by the sleepie arteries, and fil's the brain, disturbing the humors and spirits which are contained there, and tolling them unequally, as if one ran round, or had drunk too much wine. This hot spirit oft-times riseth from the heart upwards by the internal sleepie arteries to the *Rete mirabile*, or wonderful net; otherwhiles it is generated in the brain it self, beeing more hot then is fitting; also oft-times ariseth from the stomack, spleen, liver and other entrals beeing too hot. The sign of this disease is the sudden darkning of the sight, and the closing up as it were of the eies, the bodie beeing lightly turned about, or by looking upon wheels runing round, or whirle-pits in waters, or by looking down anie deep or steep places. If the original of the disease proceed from the brain, the patients are troubled with the head-ach, heavinesse of the head, and noise in the ears, and oft-times they lose their smell. *Paulus Ægineta* for the cure bid's us to open the arteries of the temples. But if the matter of the disease arise from som other place, as from som of the lower entrals, such opening of an arterie little availeth. Wherefore then som skilful Physitian must bee consulted with, who may give directions for phlebotomie, if the original of the disease proceed from the heat of the entrals; by purging, if occasioned by the foulnesse of the stomack. But if such a *Vertigo* bee a critical symptom of som acute disease affecting the *Crisis* by vomit or bleeding, then the whole businesse of freeing the patient thereof must bee committed to nature.

What the *Vertigo* is, and the causes thereof.

The Signs.

Lib.6.

A critical *Person.*

CHAP. IV.

Of the Hemicrania, *or Megrim.*

The *Megrim* is properly a disease affecting the one side of the head, right, or left. It somtimes passeth no higher then the temporal muscles, otherwhiles it reacheth to the top of the crown. The cause of such pain proceedeth either from the veins and external arteries, or from the *meninges*, or from the verie substance of the brain or from the *pericranium*, or the hairie scalp covering the *pericranium*, or lastly, from putrid vapors arising to the head from the ventricle, womb, or other inferior member. Yet an external cause may bring this affect, to wit, the too hot or cold constitution of the encompassing air, drunkennesse, gluttonie, the use of hot and vaporous meats, som noisom vapor or smoak, as of Antimonie, quick-silver, or the like, drawn up by the nose, which is the reason that gold-smiths, and such as guild metals are commonly troubled with this disease. But whencesoever the cause of the evil proceedeth, it is either a simple distemper, or with matter; with matter, I say, which again is either simple or compound. Now, this affect is either alone, or accompanied with other affects, as inflammation and tension. The heavinesse of head argue's plentie of humor; pricking, beating and tension shew's that there is a plentie of vapors mixed with the humors, and shut up in the nervous, arterious, or membranous bodie of the head. If the pain proceed from the inflamed *meninges*, a fever followeth thereon, especially, if the humor causing pain do putresie. If the pain bee superficiarie, it is seated in the *pericranium*. If profound, deep and piercing to the bottom of the eies, it is an argument that the *meninges* are affected, and a feaver ensue's, if there bee inflammation, and the matter putresie; and then oft-times the tormenting pain is so great and grievous, that the patient is afraid to have his head touched, if it bee but with your finger, neither can hee away with anie noise, or small murmuring, nor light, nor smels however sweet, no nor the fume of Wine. The pain is somtimes continual, otherwhiles by fits. If the cause of the pain proceed from hot, thin and vaporous blood, which will yeeld to no medicines, a verie necessarie, profitable and speedie remedie may bee had by opening an arterie in the temples, whether the disease proceed from the internal or external vessels. For, hence alwaies ensueth an evacuation of the conjunct matter, blood and spirits. I have experimented this in manie, but especially in the Prince de la *Roche-sur-yon*. His Physitians, when hee was troubled with this grievous Megrim, were *Chaplain*, the King's, and *Castellane* the Queen's chief Physicians, and *Lewes Duret*, who notwithstanding could help him nothing by blood-letting, cupping, bathes, frictions, diet or anie other kinde of remedie either taken inwardly or applied outwardly. I beeing called, said, that there was onely hope one way to recover his health, which was to open the arterie of the temple in the same side that the pain was; for I thought it probable, that the cause of his pain was not contained in the veins, but in the arteries, in

The differences.

In what kinde of *Megrim* the opening of an Arterie is good.

A Historie.

M m which

402 *Of divers preternatural Affects,* Lib.17.

which case by the testimonie of the antients, there was nothing better then the opening or bleeding of an arterie, whereof I have made trial upon my self to my great good. When as the Physicians had approoved of this my advice, I presently betake my self to the work, and choos out the arterie in the pained temple, which was both the more swoln and beat more vehemently then the rest. I open this, as wee use to do in the bleeding of a vein, with one incision, and take more then two sawcers of blood flying out with great violence, and leaping; the pain presently ceased, neither did it ever molest him again. Yet this opening of an Arterie is suspected by manie, for that it is troublesom to stay the gushing forth blood, and cicatrize the place, by reason of the densitie, hardnesse and continual pulsation of the arterie; and lastly, for that when it is cicatrized there may bee danger of an *Aneurisma*. Wherefore they think it better first to divide the skin, then to separate the arterie from all the adjacent particles, and then to binde it in two places; and lastly divide it, as wee have formerly told you must bee don in *Varices*. But this is the opinion of men who fear all things where there is no cause; for I have learn't by frequent experience that the apertion of an arterie, which is performed with a Lancet, as wee do in opening a vein, is not at all dangerous; and the consolidation or healing is somhat slower then in a vein, but yet will bee don at length, but that no flux of blood will happen, if so bee that the ligation be fitly performed, and remain so for four daies with fitting pledgets.

No danger in opening an arterie.

CHAP. V.

Of certain affects of the Eies, and first of staying up the upper eie-lid when it is too lax.

Of the diseases which befal the eies, som possess the whole substance thereof, as the *Ophthalmia*, a *Phlegmon* thereof: others are proper and peculiar to som parts thereof, as that which is termed *Gutta serena* to the optick nerv. Whence *Galen* made a threefold difference of the diseases of the eies, as that som happened to the eie by hurting or offending the chief organ thereof; that is the crystalline humor; others by hindering the animal facultie, the chief causer of sight, from entring into them; and lastly, other som by offending the parts subservient to the prime organ or instrument. Now of all these diseases, the eie hath som of them common with the other parts of the bodie, such as are an ulcer, wound, *Phlegmon*, contusion and the like: other som are peculiar and proper to the eie, such as are the *Egilops*, *Cataracta*, *Glaucoma*, and divers others of this kinde. Som have their upper eie-lid fall down, by reason that the upper skin thereof is relaxed more then is sufficient to cover the eie, the gristle in the mean while not relaxing it self together therewith. Hence proceed's a double trouble; the first, for that the eie cannot bee easily opened; the other, because the hairs of the relaxed eie-lid run in towards the eie, and becom troublesom thereto by pricking it. The cause of such relaxation is either a particular palsie of that part, which is frequent in old people, or the defluxion or falling down of a waterish humor, and that not acrid or biteing; which appear's by this, that those who are thus affected have a rank of hairs growing under the natural rank, by reason of aboundance of heaped-up humor, as it is most probable. For thus a wet and marish ground hath the greatest plenty of grass. Now if this same humor were acrid, it would cause an itching, and consequetly becom troublesom to the patient, and it would also fret in sunder and destroy the roots of the other hairs, so farre it is from yeelding matter for the preternatural generation of new. It is fit before you do any thing for the cure, that you mark with ink the portion there of which is superfluous, and therefore to bee cut away, least if you should cut off more then is requisite, the eye-lid should remain turned up, and so cause another kinde of affect, which the antients have called *Ectropion*. Then the eie being covered, take and lift up with your fingers the middle part of the skin of the eie-lid, not taking hold of the gristle beneath it, and then cut it athwart, takeing away just so much as shall bee necessarie to make it as it were natural; lastly, join the lips of the wound together with a simple future of three or four stitches, that so it may bee cicatrized; for the cicatrization restrain's the eie-lid from falling down so loosly, at least som part thereof being taken away. There ought to bee som measure and heed taken in the amputation, otherwise you must necessarily run into the one or other inconvenience, as if too much bee cut away, then the eie will not bee covered; if too little: then you have don nothing, and the patient is troubled to no purpose. If there shall bee manie hairs grown preternaturally, you shall pluck them away with an instrument made for the same purpose; then their roots shall be burned with a gentle canterie, the eie being left untouch't, for a fear presently arising will hinder them from growing again.

Difference.

Paul. Ægin. lib. 6. cap. 6.

The cause.

The cure.

CHAP.

Fig. 5. Paré's description of ligation of his own and his patients' superficial temporal artery as published in his *Treatise on Surgery* (*below*, *left* and *above*, *right*) (Ambroise Paré. *The Works of Ambrose Parey, Chyrurgeon to Henry II, Francis II, Charles IX, and Henry III, Kings of France*. London: J. Hindmarsh; 1691). On a side note, Paré describes blepharoplasty (*below*, *right*). (Permission for use granted from the Center for the History of Medicine, Countway Library of Medicine, Harvard University.)

with cauterization on the battleground, Paré instead promoted the notion of vessel ligature, and invented a surgical instrument known as the bec du corbin, which resembles the modern hemostat (Fig. 4).[5] He went on to apply his concept of vessel ligature to the treatment of migraine headache, and described ligation of the superficial temporal artery for headache pain in his textbook *Treatise on Surgery* (Fig. 5).[5]

> I open this (artery), as wee use to do in the bleeding of a vein, with one incision, and take more then two sawcers of blood flying out with great violence, and leaping; […] Yet this opening of an arterie is […] troublesome stay the gushing forth blood, and […] when it is cicatrizes there may bee danger of an Aneuisma. Wherefore they think it better […] to divide the skin, then to separate the arterie from all the adjacent particles, and then to binde in to places; and lastly divide it, as wee have formerly told you must bee don in Varices [sic].[5]

Of historical note, most portraits of Paré emphasize his superficial temporal artery, which he eventually ligated to treat his own migraine pain (Fig. 6).[6] See the full text of Paré's approach to migraine surgery in Appendix 2. (**See Appendix, Supplemental Digital Content 2**, which shows text excerpts on the surgical treatment of migraine by Ambroise Paré borrowed from his *Treatise on Surgery*, ***http://links.lww.com/PRS/C998***.[5])

An extended approach to treating vessels was used by Aretaeus of Cappadocia (Turkey) (Fig. 7). His work did not become known until long after his death, when copies were printed in Latin in

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Fig. 6. Portrait of Ambroise Paré depicting a prominent left superficial temporal artery. (Permission for use granted from the Center for the History of Medicine, Countway Library of Medicine, Harvard University.)

Fig. 7. Portrait of Aretaeus. (From Janos Z. *Icones veterum aliquot ac recentium medicorum philosophorumque, elogiolis suis editae*. Antverpiae: Ex officina Christophori Plantini; 1574. Open source, available at: https://collections.nlm.nih.gov/catalog/nlm:nlmuid-101434447-img. Accessed October 30, 2017.)

1552. Few bibliographic details are known about him, but he is thought to have practiced between 100 and 200 AD.[7] Considered one of the greatest medical scholars after Hippocrates, Aretaeus is known for his detailed classification of headache, which is referenced in the literature to this day.[7] Unfortunately, only two books of Aretaeus have survived, a pathology textbook (*De causis et signis acutorum et chronicorum morborum*) and a clinical textbook (*De causis et signis acutorum*).[8] In his approach to treating headache, he advised surgeons to…

> Incise the vein that runs upward in the middle of the forehead, as bleeding here is very important [. . .] then carry out a good-sized incision at the crown in order to draw a large quantity of blood and to incise the deep layer. Incisions that get to the bone are beneficial to headache. If the wounds have become scars, then cut out the arteries. There are two on either side. One is situated behind the ear […]. The other lies before the ear, close by. It runs along the tragus. […] Cut out the bigger arteries where they lie on the bone, because it is very good if one removes these arteries.[9]

Many physicians who treated migraine pain subsequently chose blood-letting as their treatment of choice. Famous examples include Thomas Willis (1621 to 1675), considered by many to be the father of modern neuroscience, and Robert Whytt (1714 to 1766), one of the most accomplished Scottish neurophysiologists of his time, who promoted arteriotomies at the headache site. Whytt also applied leeches to the temples.[10] Another concept, described by W. Möllendorff in 1867, was compression of arteries for treatment of headache pain.[11]

> During a hemicranial attack the common carotid artery on the painful side is compressed […] so much that the pulse of the temporal artery starts to disappear, the head pain wears off as if by magic […] the other way round, the pain, if not yet reached its full climax, increases by compression of the carotid artery on the other side.[11]

This same concept was used in Europe in the Middle Ages to treat migraine pain by using an "imposition crown." The crown applied pressure to points corresponding to migraine pain.

In modern times, several authors have revisited the ancient concept of vessel involvement and migraine pain. In 1976, Dr. Alexander D. Rapidis, a neurosurgeon from Athens, Greece, summarized efforts made by other surgeons to treat migraine headache by vessel interventions that were met with varied success. He himself treated eight patients with superficial temporal artery excision with follow-up of 1 to 4 years. In one patient, the pain relief lasted for only 6 months, whereas the others experienced complete migraine relief.[12] More recently, Dr. Elliot Shevel, an oral and maxillofacial surgeon based in

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South Africa, demonstrated significant pain relief in migraine patients after cauterization of extracranial vessels, including the external carotid artery, maxillary artery, and superficial temporal artery.[13,14] Furthermore, Dr. Bahman Guyuron, who founded the current migraine surgery movement, has described his efforts to identify arterial signals by means of Doppler ultrasound to confirm nerve irritation by adjacent vessels as an aid to patient selection, and his technique for performing arterectomy to treat pain at this site.[15]

A newer approach to migraine headache pain involves the treatment of extracranial nerves. Drs. Bruce C. Martin and Phillip J. Fagan published the first report on the surgical therapy of occipital neuralgia in *Plastic and Reconstructive Surgery* in 1964.[16] In this series, five patients were treated by excising segments of the greater occipital nerve, lesser occipital nerve, third occipital nerve, and posterior auricular nerve with satisfactory results, although no further explanation was given (Fig. 8).[16] At the time of surgery, absolute alcohol was injected into the area after excision. Several years later, Dr. Alexander Rapidis referenced articles published between 1904 and 1955 in which treatment of migraine was described as follows: "the section of the trigeminal pathways provides relief from pain at the expense of permanent facial analgesia" and "in some limited cases the injection of alcohol in the gasserian ganglion of the affected side of the face was successful."[12] There have been further reports about contact point headache surgery in the ear, nose, and throat literature.[17] An article published in 1992 reported that 299 patients with nasal abnormality and migraines underwent septal correction, resection of the middle concha, ethmoidectomy, and sphenoidectomy. In this report, 78.5 percent of patients had complete cessation of migraine headache after surgery; 11.5 percent had a sensation of pressure in the head occasionally, but no further migraines; and 11 percent continued to experience rare, mild headaches of short duration.

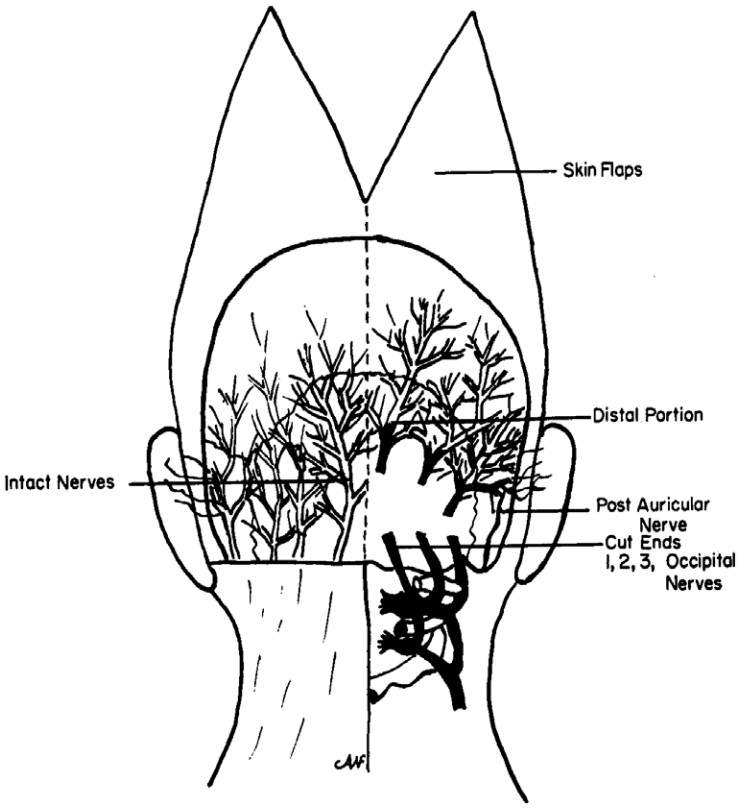

Fig. 8. Surgical therapy for occipital neuralgia. In 1964, B. C. Martin and P. J. Fagan published the first report on the surgical therapy of occipital neuralgia in *Plastic and Reconstructive Surgery* (Martin BC, Fagan PJ. The surgical therapy of certain occipital headaches. *Plast Reconstr Surg*. 1964;33:266–268). (Permission for use granted from Wolters Kluwer Health, Inc., *Plastic and Reconstructive Surgery*.)

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Since the first description of surgical interventions for migraine headache, migraine surgery has become much more sophisticated. Importantly, in 2000, Dr. Bahman Guyuron developed and promoted a theory that migraine pain can be triggered by nerve compression at specific points across the skull.[18] Since then, multiple anatomical studies have elucidated the anatomy of pericranial sensory nerves and confirmed entrapment in bone, muscle, fascia, and vessels.[15,19–34] This led to identification of trigger sites and improvement in detection of nerve compression at these sites through clinical assessment and imaging studies.[15,18,35–48] Current reported triggers are categorized as follows: frontal (first; supraorbital and supratrochlear nerves), temporal (second; zygomaticotemporal nerve), rhinogenic (third), occipital (fourth; greater occipital nerve), auriculotemporal (fifth), lesser occipital (sixth), and nummular (seventh). Guyuron further described the surgical treatment of trigger sites, which has since evolved to include open, endoscopic, and minimal incision techniques. Neurovascular structures are now addressed by decompression, neurectomy, arterial ligation, and arterectomy depending on the anatomical location and underlying pathophysiology.[20,23,31,35,39,40,43,46–61] With current techniques, numerous clinical outcome articles report success rates between 68 and 95 percent for patients undergoing migraine surgery.[18–20,23,24,31,33,35,36,38,39,41,43,44,46–51,54,56–74] Based on a large body of literature and Dr. Guyuron's work, several international groups have been able to replicate his results, and migraine surgery has become a treatment modality available to patients who suffer from migraine around the world.[21,31,57,61,63,65,68,71–76]

DISCUSSION

Interest in the surgical treatment of migraine headache has increased with mounting evidence that certain patients have extracranial triggers that can be addressed surgically.[77–80] Although the future of migraine surgery and the extracranial pathophysiology of migraine remain unclear, it is fascinating to explore and learn from the past. From Al-Zahrawi to Bahman Guyuron, two recurrent themes have emerged among doctors and surgeons who have tried to intervene on behalf of migraineurs. The first is treatment of pain by compression, cauterization, ligation, excision, leeching, or blood-letting from vessels. These techniques are centuries old, yet some are still practiced today.[14,15,79] The second is transection or decompression of nerves to improve migraine headache pain, which represents a newer theory. Although nerve decompression is by far the more popular technique, nerve transection is still used for especially severe cases.[51]

Of note, some of the techniques described in this article were intended to exclusively treat either vessels or nerves, but it is likely these approaches addressed both structures simultaneously. It is intriguing to hypothesize that, when Aretaeus incised the crown of the head down to the bone to excise the vessels, he likely decompressed or even transected nerves during the procedure.[9] Similarly, when Drs. Martin and Fagan excised all the occipital sensory nerves and injected absolute ethanol into the surgical bed, these vessels were unlikely to escape injury.[16]

From all appearances, both vessels and nerves play a role in the surgical treatment of migraine. Nevertheless, despite a long history of surgical intervention, a clear consensus has not evolved. Many anatomical studies have shown that nerves can be compressed by different tissues such as bone, muscle, fascia, fascial bands, and vessels, depending on the site.[76] However, only some of these tissues have been investigated for their involvement in migraine pain.

Although most current articles focus on treatment of nerves, vessel involvement has been investigated. Ducic et al. treated 25 patients with bilateral occipital neuralgia with decompression of the greater occipital nerve and collected a segment of the occipital artery for pathologic evaluation. None of the arteries showed vasculitis. They concluded that irritation of the nerve was caused by mechanical compression by the vessel rather than inflammation of the vessel.[81] On the contrary, Del Fiacco et al. showed that the arterial wall of scalp arteries of patients with chronic migraine demonstrated a significant increase in TRPV1-LI nerve fibers (nociceptor) compared to controls. They concluded that an increase of periarterial nociceptive fibers may represent a structural condition favoring migraine by causing a higher sensitivity to algogenic agents, such as substance P and calcitonin gene-related peptide.[80]

Clinically, Dr. Guyuron compared 55 patients who had undergone occipital artery resection to controls and reported that occipital artery resection lowered the success of occipital surgery, suggesting that routine removal may not be necessary.[50] On the contrary, Raposio and Caruana reported that in patients with visible intraoperative dilation of the occipital artery, ligation alone produced better postoperative results in comparison with ligation of the artery and decompression

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of the nerve combined.[82] Furthermore, Shevel and Spierings, who exclusively treat arteries by ligation or cauterization, report encouraging results.[13,14]

Most recently, basic scientific data have shown involvement of different pericranial structures in migraine pain. Guyuron et al. performed electron microscopy and proteomics of nerves removed during migraine surgery and reported axonal abnormality and deregulation of the myelination process in patients with migraine headache versus controls.[83] In addition, new evidence has surfaced that the calvarial periosteum in chronic migraineurs demonstrates significantly increased expression of proinflammatory markers and decreased expression of genes that suppress inflammation and immune cell differentiation.[78] The authors conclude that when the structural environment surrounding periosteal nerve fibers is inflamed, it activates trigeminovascular nociceptors that reach the periosteum through intracranial meningeal nociceptors and/or extracranial nerves, such as the occipital nerve. This finding is further supported by human and animal data showing that sensory and pain fibers cross the calvarial bones through cranial sutures and connect intracranial and extracranial axons.[84–87]

This raises the question: Which part of our ancestors' procedures were important for pain relief? Arteriotomy? Nerve excision? Or cutting down to bone?

What we do know, is that we have come very far from the first description of interventions for migraine by our predecessors. In 2000, a new era of migraine surgery began with detailed anatomical, basic scientific, and clinical studies published to describe and advance surgery for the treatment of migraines. Based on close to 20 years of peer-reviewed published articles, migraine surgery is now considered safe and effective in the treatment of a select group of migraine patients with extracranial triggers.

CONCLUSIONS

Two common themes of the past and present have emerged involving the extracranial treatment of nerves and vessels, with no consensus among current practitioners as to which structure is involved. With new research tools and technologies, it is an exciting time to elucidate the mechanism behind the success or failure of surgical therapies. Keeping history in mind will help guide our efforts in the future. One thing is clear: Where we are going, there are no roads. At least not yet.

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REFERENCES

1. Karenberg A, Leitz C. Headache in magical and medical papyri of ancient Egypt. *Cephalalgia* 2001;21:911–916.
2. Ahmad Z. Al-Zahrawi, the father of surgery *ANZ J Surg.* 2007;77:A83.
3. Abū al-Qāsim Khalaf ibn ʻAbbās al-Zahrāwī. *Octauii Horatiani rerum medicarum lib. quatuor:Albucasis chirurgicorum omnium primarij, lib. tres*; 1532. The Center for the History of Medicine, Countway Library of Medicine, Harvard University.
4. Abū al-Qāsim Khalaf ibn ʻAbbās al-Zahrāwī. *Albucasis on Surgery and Instruments: A Definitive Edition of the Arabic Text with English Translation and Commentary.* Berkeley: University of California Press; 1973.
5. Ambroise Paré. *The Works of Ambrose Parey, Chyrurgeon to Henry II, Francis II, Charles IX, and Henry III, Kings of France.* London: J. Hindmarsh; 1691.
6. Hernigou P. Ambroise Paré's life (1510-1590): Part I. *Int Orthop.* 2013;37:543–547.
7. Tekiner H. Aretaeus of Cappadocia and his treatises on diseases. *Turk Neurosurg.* 2015;25:508–512.
8. Aretaeus. *De causis et signis acutorum et chronicorum morborum; De therapia acutorum et chronicorum morborum.* Berlin: Akademie-Verlag; 1958.
9. Koehler PJ, van de Wiel TW. Aretaeus on migraine and headache. *J Hist Neurosci.* 2001;10:253–261.
10. Koehler PJ, Boes CJ. A history of non-drug treatment in headache, particularly migraine. *Brain* 2010;133:2489–2500.
11. Möllendorff W. Ueber Hemikranie. *Arch Pathol (Virchow's)* 1867;41:385–395.
12. Rapidis AD. The therapeutic result of excision of the superficial temporal artery in atypical migraine. *J Maxillofac Surg.* 1976;4:182–188.
13. Shevel E, Spierings EH. Role of the extracranial arteries in migraine headache: A review. *Cranio* 2004;22:132–136.
14. Shevel E. A new minimally invasive technique for cauterizing the maxillary artery and its application in the treatment of cluster headache. *J Oral Maxillofac Surg.* 2013;71:677–681.
15. Guyuron B, Riazi H, Long T, Wirtz E. Use of a Doppler signal to confirm migraine headache trigger sites. *Plast Reconstr Surg.* 2015;135:1109–1112.
16. Martin BC, Fagan PJ. The surgical therapy of certain occipital headaches. *Plast Reconstr Surg.* 1964;33:266–268.
17. Novak VJ, Makek M. Pathogenesis and surgical treatment of migraine and neurovascular headaches with rhinogenic trigger. *Head Neck* 1992;14:467–472.
18. 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 435–437.
19. Totonchi A, Pashmini N, Guyuron B. The zygomaticotemporal branch of the trigeminal nerve: An anatomical study. *Plast Reconstr Surg.* 2005;115:273–277.

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20. Sanniec K, Borsting E, Amirlak B. Decompression-avulsion of the auriculotemporal nerve for treatment of migraines and chronic headaches. *Plast Reconstr Surg Glob Open* 2016;4:e678.
21. Peled ZM, Pietramaggiori G, Scherer S. Anatomic and compression topography of the lesser occipital nerve. *Plast Reconstr Surg Glob Open* 2016;4:e639.
22. Mosser SW, Guyuron B, Janis JE, Rohrich RJ. The anatomy of the greater occipital nerve: Implications for the etiology of migraine headaches. *Plast Reconstr Surg.* 2004;113:693–697; discussion 698–700.
23. 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.
24. 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.
25. Lee M, Brown M, Chepla K, et al. An anatomical study of the lesser occipital nerve and its potential compression points: Implications for surgical treatment of migraine headaches. *Plast Reconstr Surg.* 2013;132:1551–1556.
26. Janis JE, Hatef DA, Thakar H, et al. The zygomaticotemporal branch of the trigeminal nerve: Part II. Anatomical variations. *Plast Reconstr Surg.* 2010;126:435–442.
27. Janis JE, Hatef DA, Ducic I, et al. The anatomy of the greater occipital nerve: Part II. Compression point topography. *Plast Reconstr Surg.* 2010;126:1563–1572.
28. Janis JE, Hatef DA, Ducic I, et al. Anatomy of the auriculotemporal nerve: Variations in its relationship to the superficial temporal artery and implications for the treatment of migraine headaches. *Plast Reconstr Surg.* 2010;125:1422–1428.
29. Janis JE, Ghavami A, Lemmon JA, Leedy JE, Guyuron B. The anatomy of the corrugator supercilii muscle: Part II. Supraorbital nerve branching patterns. *Plast Reconstr Surg.* 2008;121:233–240.
30. Janis JE, Ghavami A, Lemmon JA, Leedy JE, Guyuron B. Anatomy of the corrugator supercilii muscle: Part I. Corrugator topography. *Plast Reconstr Surg.* 2007;120:1647–1653.
31. Hagan RR, Fallucco MA, Janis JE. Supraorbital rim syndrome: Definition, surgical treatment, and outcomes for frontal headache. *Plast Reconstr Surg Glob Open* 2016;4:e795.
32. Fallucco M, Janis JE, Hagan RR. The anatomical morphology of the supraorbital notch: Clinical relevance to the surgical treatment of migraine headaches. *Plast Reconstr Surg.* 2012;130:1227–1233.
33. Dash KS, Janis JE, Guyuron B. The lesser and third occipital nerves and migraine headaches. *Plast Reconstr Surg.* 2005;115:1752–1758; discussion 1759–1760.
34. Ducic I, Moriarty M, Al-Attar A. Anatomical variations of the occipital nerves: Implications for the treatment of chronic headaches. *Plast Reconstr Surg.* 2009;123:859–863; discussion 864.
35. Guyuron B, Kriegler JS, Davis J, Amini SB. Comprehensive surgical treatment of migraine headaches. *Plast Reconstr Surg.* 2005;115:1–9.
36. Guyuron B, Kriegler JS, Davis J, Amini SB. Five-year outcome of surgical treatment of migraine headaches. *Plast Reconstr Surg.* 2011;127:603–608.
37. Guyuron B, Nahabet E, Khansa I, Reed D, Janis JE. The current means for detection of migraine headache trigger sites. *Plast Reconstr Surg.* 2015;136:860–867.
38. 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.
39. Guyuron B, Tucker T, Davis J. Surgical treatment of migraine headaches. *Plast Reconstr Surg.* 2002;109:2183–2189.
40. Janis JE, Hatef DA, Reece EM, McCluskey PD, Schaub TA, Guyuron B. Neurovascular compression of the greater occipital nerve: Implications for migraine headaches. *Plast Reconstr Surg.* 2010;126:1996–2001.
41. 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.
42. Becker D, Amirlak B. Beyond beauty: Onobotulinumtoxin A (BOTOX) and the management of migraine headaches. *Anesth Pain Med.* 2012;2:5–11.
43. 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.
44. Gfrerer L, Guyuron B. Surgical treatment of migraine headaches. *Acta Neurol Belg.* 2017;117:27–32.
45. Hwang L, Dessouky R, Xi Y, Amirlak B, Chhabra A. MR neurography of greater occipital nerve neuropathy: Initial experience in patients with migraine. *AJNR Am J Neuroradiol.* 2017;38:2203–2209.
46. 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.
47. 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.
48. Larson K, Lee M, Davis J, Guyuron B. Factors contributing to migraine headache surgery failure and success. *Plast Reconstr Surg.* 2011;128:1069–1075.
49. Chepla KJ, Oh E, Guyuron B. Clinical outcomes following supraorbital foraminotomy for treatment of frontal migraine headache. *Plast Reconstr Surg.* 2012;129:656e–662e.
50. 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.
51. Ducic I, Felder JM III, Khan N, Youn S. Greater occipital nerve excision for occipital neuralgia refractory to nerve decompression. *Ann Plast Surg.* 2014;72:184–187.
52. Ducic I, Larson EE. Posttraumatic headache: Surgical management of supraorbital neuralgia. *Plast Reconstr Surg.* 2008;121:1943–1948.
53. Ducic I, Sinkin JC, Crutchfield KE. Interdisciplinary treatment of post-concussion and post-traumatic headaches. *Microsurgery* 2015;35:603–607.
54. Edoardo R, Giorgia C. Frontal endoscopic myotomies for chronic headache. *J Craniofac Surg.* 2015;26:e201–e203.
55. Raposio E, Bellini E, Bertozzi N, Simonacci F. A new minimally invasive surgical technique for the treatment of nerve-triggered occipital headaches. Paper presented at: 28th Annual Meeting of the European Association of Plastic Surgeons; May 24–27, 2017; Pisa, Italy.
56. 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.
57. Gfrerer L, Maman DY, Tessler O, Austen WG Jr. Nonendoscopic deactivation of nerve triggers in migraine headache patients: Surgical technique and outcomes. *Plast Reconstr Surg.* 2014;134:771–778.

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58. Guyuron B, Son JH. Transpalpebral corrugator resection: 25-year experience, refinements and additional indications. *Aesthetic Plast Surg.* 2017;41:339–345.
59. 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.
60. 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.
61. Peled ZM. A novel surgical approach to chronic temporal headaches. *Plast Reconstr Surg.* 2016;137:1597–1600.
62. Egan KG, Israel JS, Ghasemzadeh R, Afifi AM. Evaluation of migraine surgery outcomes through social networking sites. *Plast Reconstr Surg.* 2015;136:66–67.
63. Egan KG, Israel JS, Ghasemzadeh R, Afifi AM. Evaluation of migraine surgery outcomes through social media. *Plast Reconstr Surg Glob Open* 2016;4:e1084.
64. Faber C, Garcia RM, Davis J, Guyuron B. A socioeconomic analysis of surgical treatment of migraine headaches. *Plast Reconstr Surg.* 2012;129:871–877.
65. Farmer R, Afifi AM. A systematic review of functional rhinoplasty and improvement in facial pain and headache. Paper presented at: Midwestern Association of Plastic Surgeons Annual Meeting; April 15, 2017; Chicago, Ill.
66. 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.
67. 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.
68. 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.
69. Molavi S, Zwiebel S, Gittleman H, Alleyne B, Guyuron B. The effect of preoperative migraine headache frequency on surgical outcomes. *Plast Reconstr Surg.* 2014;134:1306–1311.
70. Gfrerer L, Lans J, Faulkner HR, Nota S, Bot AGJ, Austen WG Jr. Ability to cope with pain puts migraine surgery patients in perspective. *Plast Reconstr Surg.* 2018;141:169–174.
71. Dirnberger F, Becker K. Surgical treatment of migraine headaches by corrugator muscle resection. *Plast Reconstr Surg.* 2004;114:652–657; discussion 658–659.
72. Ducic I, Felder JM III, Fantus SA. A systematic review of peripheral nerve interventional treatments for chronic headaches. *Ann Plast Surg.* 2014;72:439–445.
73. 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.
74. Poggi JT, Grizzell BE, Helmer SD. Confirmation of surgical decompression to relieve migraine headaches. *Plast Reconstr Surg.* 2008;122:115–122; discussion 123–124.
75. Caruana G, Bertozzi N, Boschi E, Pio Grieco M, Grignaffini E, Raposio E. Endoscopic forehead surgery for migraine therapy: Personal technique. *Ann Ital Chir.* 2014;85:583–586.
76. Janis JE, Barker JC, Javadi C, Ducic I, Hagan R, Guyuron B. A review of current evidence in the surgical treatment of migraine headaches. *Plast Reconstr Surg.* 2014;134:131S–141S.
77. Burstein R, Blake P, Schain A, Perry C. Extracranial origin of headache. *Curr Opin Neurol.* 2017;30:263–271.
78. Perry CJ, Blake P, Buettner C, et al. Upregulation of inflammatory gene transcripts in periosteum of chronic migraineurs: Implications for extracranial origin of headache. *Ann Neurol.* 2016;79:1000–1013.
79. Shevel E. Intracranial and extracranial arteries in migraine. *Lancet Neurol.* 2013;12:847.
80. Del Fiacco M, Quartu M, Boi M, et al. TRPV1, CGRP and SP in scalp arteries of patients suffering from chronic migraine. *J Neurol Neurosurg Psychiatry* 2015;86:393–397.
81. Ducic I, Felder JM III, Janis JE. Occipital artery vasculitis not identified as a mechanism of occipital neuralgia-related chronic migraine headaches. *Plast Reconstr Surg.* 2011;128:908–912.
82. Raposio E, Caruana G. Tips for the surgical treatment of occipital nerve-triggered headaches. *Eur J Plast Surg.* 2017;40:177–182.
83. Guyuron B, Yohannes E, Miller R, Chim H, Reed D, Chance MR. Electron microscopic and proteomic comparison of terminal branches of the trigeminal nerve in patients with and without migraine headaches. *Plast Reconstr Surg.* 2014;134:796e–805e.
84. Zhao J, Levy D. The sensory innervation of the calvarial periosteum is nociceptive and contributes to headache-like behavior. *Pain* 2014;155:1392–1400.
85. Kosaras B, Jakubowski M, Kainz V, Burstein R. Sensory innervation of the calvarial bones of the mouse. *J Comp Neurol.* 2009;515:331–348.
86. Schueler M, Neuhuber WL, De Col R, Messlinger K. Innervation of rat and human dura mater and pericranial tissues in the parieto-temporal region by meningeal afferents. *Headache* 2014;54:996–1009.
87. Schueler M, Messlinger K, Dux M, Neuhuber WL, De Col R. Extracranial projections of meningeal afferents and their impact on meningeal nociception and headache. *Pain* 2013;154:1622–1631.

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