A Comparison of Decompression Size and Craniectomy Speed of Reverse Question Mark Versus Retroauricular Incisions for Decompressive Hemicraniectomy: A Cadaver Study

Matthew K. McIntyre, MD, Miner Ross, MD, MPH, Jamila Godil, MD, Christina Gerges, MD, Erin A. Yamamoto, MD, Dominic Siler, MD, PhD, Josiah Orina, MD, James Wright, MD

Department of Neurological Surgery, Oregon Health and Science University, Portland, Oregon, USA

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Correspondence: James Wright, MD, Department of Neurological Surgery, Oregon Health and Science University, 3303 S Bond Ave Building 1 8th Floor, Portland, OR 97239, USA. Email: wrighjam@ohsu.edu

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BACKGROUND AND OBJECTIVES: Decompressive hemicraniectomy is a common emergent surgery for patients with stroke, hemorrhage, or trauma. The typical incision is a reverse question mark (RQM); however, a retroauricular (RA) incision has been proposed as an alternative. The widespread adoption ofthe RA incision has been slowed by lack of familiarity and concerns over decompression efficacy. Our goal is to compare the RA vs RQM incisions regarding decompression safety and to examine skill acquisition among resident neurosurgeons.

METHODS: Six cadaveric heads were randomized to first receive either RQM or RA decompressive hemicraniectomy, which was followed by use of the other incision on the contralateral side. Primary endpoints were decompression circumference and time to bone flap removal. Resident neurosurgeon (postgraduate year 3 through 7) confidence and operative times were compared.

RESULTS: All craniectomies yielded decompression diameters >13 cm (RQM: 13.5-15.5 cm; RA: 13.0-16.5 cm) and residual temporal bone heights <1.5 cm (RQM: 0.5-1.3 cm; RA: 0.5-1.5 cm). There were no differences between the RA and RQM groups in decompression circumference (P = .6605), residual temporal bone height (P = .7121), or time from incision until bone flap removal (P = .8452). There was a nonsignificant trend toward a shorter incision length with RA (RQM: 37.7 ± 0.7 cm vs RA: 35.1 ± 0.9; P = .0729). Regardless of which incision was performed first, operative time significantly improved from the first craniectomy to the second (−174.6 seconds, P = .0186). Surgeon confidence improved more with the RA incision, and there was a linear association with experience and time to bone flap removal in the RQM (P = .04) but not the RA (P = .95) groups.

CONCLUSION: The RA incision may provide adequate operative exposure without significant changes in operative time. Cadaveric labs improve skill acquisition and should be considered during implementation of novel surgical approaches into practice.

KEY WORDS: Cadaver, Decompressive hemicraniectomy, Retroauricular, Stroke, Trauma

Frontotemporoparietal decompressive hemicraniectomy (DHC) is a common neurosurgical procedure performed, often emergently, to alleviate malignant intracranial hypertension and decompress the brain following stroke, hemorrhage, or trauma.

ABBREVIATIONS: DHC, decompressive hemicraniectomy; **EAC,** external auditory canal; **PGY,** post graduate years; **RA,** retroauricular; **RQM,** reverse question mark; **STA,** superficial temporal artery.

The most commonly used incision for DHC is a reverse question mark (RQM) that endangers the superficial temporal artery (STA), which often must be sacrificed if injured. While STA sacrifice during DHC is safe, impaired perfusion may endanger wound healing at the index surgery and at subsequent cranioplasty. As such, wound complication rates for DHC using the typical RQM incision have been reported between 8% and 35%.[1-3] A recently described alternative is the retroauricular (RA) incision for DHC, which may protect the STA and therefore theoretically improves wound perfusion; in addition, it may provide for larger decompression than the RQM incision.[4-8]

Existing retrospective studies are encouraging as to the advantages of the RA incision, but there remains a paucity of evidence comparing the extent of decompression between the two incisions. Given the nature of the DHC as an emergent procedure, prospective clinical studies are challenging. This study examines, in human cadavers, the efficacy (ie, the extent of decompression and speed of a simulated procedure) of the RQM vs the RA incision for DHC in a controlled setting. Our hypothesis was that the RA and RQM incisions will have similar decompression sizes and therefore both may be safe to use for DHC. Given the lack of widespread adoption of the RA incision, we also investigated surgeon confidence and learning curve in a cadaver model of both incision types.

METHODS

Study Design

Six fresh, nonfixed cadaver heads were donated to the Oregon Health & Science University simulation program and approval for this project was obtained through the body donation program. Given that the cadaver heads are nonlive human subjects, no institutional review board approval was required. Cadavers were freely donated with expressed consent for research and education in accordance with local laws and regulations. Images were individually approved by the body donation program for use in this publication. All surgeons who participated agreed for their data to be included and are authored on this publication.

Five resident surgeons (postgraduate years [PGY] 3-7) received education on the technical nuances of the two incisions from a surgeon experienced with both incision types. Each resident was assigned a single head apart from one PGY-7 resident who performed craniectomies on both sides of two heads.

Cadaver Setup and Procedure

Each head's occipital-frontal circumference was measured before incision to normalize decompression size to head size. Cadaver heads were randomized to begin either on the right or left side and either with the RA or the RQM incision. Once the first DHC was completed, the skin was closed with the bone flap in place and the head was turned over. The same surgeon then performed a hemicraniectomy on the contralateral side with the alternative incision.

Heads were placed on a headblock in a semi-lateral position. The RA incision was planned from the ipsilateral mastoid tip and curved superiorly and medially, arcing posterior to the parietal boss ending at the hairline near but lateral to the midline (Figure 1). The periosteum and temporalis muscle were mobilized as a single myocutaneous flap. Care was taken not to violate the external auditory canal (EAC). Burr holes were then placed using either a perforator or acorn drill bit per surgeon preference but kept constant for both sides. After epidural dissection, a side-cutting craniotome was used to complete the bone flap. The bone flap was elevated off the dura and the field irrigated. Rongeurs or the drill was used to remove any remaining squamous temporal bone. Dura was opened in stellate fashion. The RQM incision was planned in the standard fashion starting 1 cm anterior to the tragus, arching above the ear around the parietal boss to the hairline anteriorly just lateral of midline. The periosteum and temporalis were mobilized as a single myocutaneous flap, and the craniectomy was completed as described above. The number of burr holes was left up to the surgeon preference; however, all craniectomies in this study were completed with four.

Data

Primary endpoints were decompression circumference and time from incision to removal of the bone flap. Additional data collected included: largest defect diameter; decompression size (antero-posterior length × height); height from the middle fossa floor to the top of remaining temporal bone; unintentional entry into the mastoid, frontal sinus, superior sagittal sinus, or EAC; and total incision length. We attempted to evaluate the integrity of the STA, occipital artery, and posterior auricular artery. If each artery was not clearly identifiable within the incision, it was assumed to be uninjured. Before each craniectomy, each surgeon was asked on a 10-point Likert scale survey how confident they felt about making the incision (1 = not confident; 10 = very confident). After each craniectomy, the surgeon was asked about the subjective difficulty of the incision (1 = very easy; 10 = very hard) and comfort with performing it on a patient. Surgeon PGY year and total cranial trauma cases logged were also recorded.

Statistics

The calculated skull diameter was derived from the measured occipital-frontal circumference divided by π. To account for variability in head size, like Dowlati et al,[8] a normalized defect size was calculated by dividing the raw defect size by the calculated skull diameter. Decompression area was calculated by multiplying the measured defect height and the width. Time until bone flap removal was plotted against attempt number, left vs right side, and surgeon PGY and trauma case number. Continuous variables are shown with mean ± standard error of the mean and were compared between the two incisions using paired *T*-tests after normality was established using Shapiro-Wilk tests. For non-normally distributed data a Wilcoxon matched-paired signed rank test was used. Pairing was between the two sides of the same head with the craniectomy performed by the same surgeon. Binary endpoints are shown with number and the percent of total and compared using Fisher exact tests. Analysis was conducted using Graphpad Prism 10.

RESULTS

Twelve craniectomies were performed on 6 cadaver heads (one incision for each side), with equal numbers starting on the left vs the right side. Likewise, 3 of the first-trial craniectomies started with the RA and 3 with the RQM incision; the second-trial craniectomy was performed with the opposite (Figure 2). There were no differences in decompression circumference or time between those who started with RA and those who started with RQM first ($P > .05$). All craniectomies yielded decompression diameters >13 cm (RQM: 13.5-15.5 cm; RA: 13.0-16.5 cm) and residual temporal bone heights <1.5 cm (RQM: 0.5-1.3 cm; RA: 0.5-1.5 cm). There were no significant differences found in paired analysis between RA and RQM by any measurement ($P > .05$), residual temporal bone height ($P = .7121$), or time from incision until bone flap removal ($P = .8452$) (Table). There was a

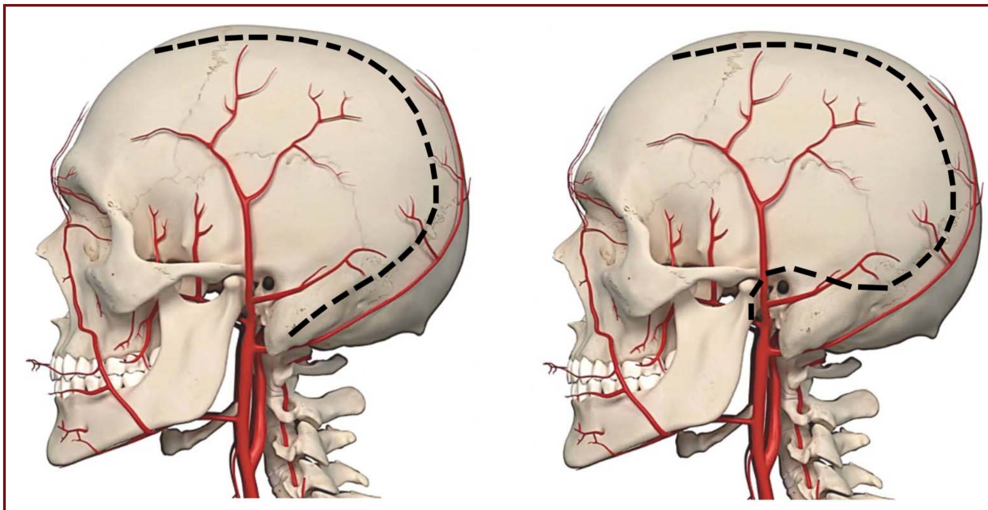

FIGURE 1. *Schematic of the retroauricular (left) and reverse question mark (right) incisions. 3-dimensional images used through an enhanced license from https://stock.adobe.com.*

nonsignificant trend toward shorter incision length with the RA incision (RQM: 37.7 ± 0.7 cm vs RA: 35.1 ± 0.9; P = .0729) and no violations of the EAC, transverse-sigmoid or superior sagittal sinuses in either group. No RA incision was confirmed to injure the STA while 2/6 RQM incisions did (Table). The RA group also had a nonsignificant increase in definitive occipital and posterior auricular artery injury compared with RQM incisions.

For each head, 2 craniectomies were performed sequentially by the same resident surgeon. Regardless of first incision randomization, from the first trial to the second, there was a significant improvement in time for all surgeons (mean decrease: 174.6 seconds, P = .0186) (Figure 3A), but no difference in decompression circumference (P = .1141). There was a linear relationship between PGY and time for the RQM incision (r^2 = 0.691; P = .004) but not the RA incision (r^2 = 0.001; P = .95) (Figure 3B). Similar findings were seen when comparing surgeons by operative trauma experience (Figure 3C). No such relationship existed between PGY and decompression circumference for the RQM incision (r^2 = 0.3539; P = .2130) or RA incision (r^2 = 0.007; P = .8774). Before the study, surgeons tended to report a nonsignificantly lower level of confidence in the RA incision (RQM: 8.0 ± 0.9 vs RA: 6.2 ± 1.6, P = .2500). After the study, all found the 2 incisions to be of equivalent difficulty (RQM: 4.0 ± 0.5 vs RA: 4.2 ± 0.5; P = .6109) and all reported they would be comfortable performing the incision in a live patient.

DISCUSSION

Decompressive hemicraniectomy is a common neurosurgical procedure, which is often performed in emergent situations. The typical RQM incision used for DHC can result in inadvertent

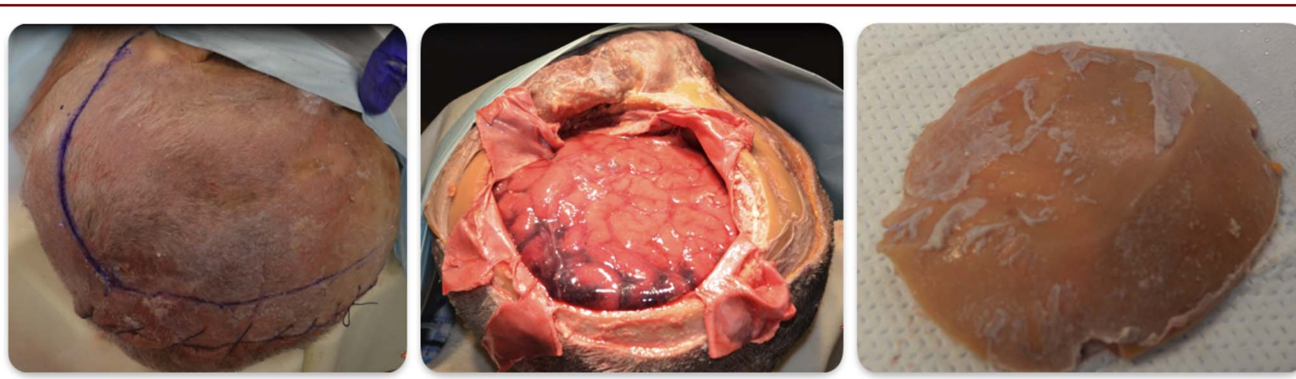

FIGURE 2. *Cadaveric specimens illustrating retroauricular incision planning (left), completed decompression (middle), and bone flap (right).*

TABLE. Outcomes by Incision Type

Variable	Reverse question mark (n = 6)	Retroauricular (n = 6)	Mean difference (CI)	*P* value
Largest defect diameter (cm)	14.6 ± 0.4	14.4 ± 0.5	−0.27 (−1.66 to 1.13)	.6439
Normalized defect diameter	0.82 ± 0.02	0.81 ± 0.03	−0.01(−0.09 to 0.06)	.6479
Defect circumference (cm)	40.8 ± 1.2	40.3 ± 0.7	−0.55 (−3.58 to 2.48)	.6605
Decompression area (cm^2)	187.9 ± 11.5	182.5 ± 9.3	−5.37 (−48.6 to 37.8)	.7621
Residual temporal bone height (cm)	1.1 ± 0.1	1.0 ± 0.2	−0.07 (−0.51 to 0.37)	.7121
Incision length (cm)	37.7 ± 0.7	35.1 ± 0.9	−2.58 (−5.52 to 0.35)	.0729
Time to bone flap removal (seconds)	666.2 ± 72.3	650.7 ± 73.0	−15.5 (−209.2 to 178.2)	.8452
Injury/involvement				
Superficial temporal artery	2/6 (33.3%)	0/6 (0.0%)	—	.4545
Occipital artery	1/3 (33.3%)	3/3 (100%)	—	.4000
Posterior auricular artery	0/1 (0%)	3/5 (60%)	—	>.9999
Mastoid air cells	2 (33.3%)	0 (0.0%)	—	.4545
Frontal sinus	1 (17%)	0 (0.0%)	—	>.9999
Superior sagittal sinus	0 (0.0%)	0 (0.0%)	—	>.9999
External auditory canal	0 (0.0%)	0 (0.0%)	—	>.9999

Continuous variables are shown with mean ± standard error of the mean.

sacrifice of the STA and thereby risk poor wound healing from the index surgery and in any future cranioplasty. Several groups have recently described a RA incision as an alternative to the RQM,[9] but its efficacy has not been established and the incorporation of this incision into clinical practice has been slow. Herein reported is the first cadaveric study comparing both incisions directly and showing no significant difference regarding decompression size, time until decompression, or residual temporal bone height. We also used this opportunity to evaluate resident skill acquisition for both incisions in a controlled environment.

The Brain Trauma Foundation guidelines provide level IIA recommendations for decompressive craniectomy size to be at least 12 × 15 cm or 15 cm in overall diameter.[10] This conclusion was based on 2 randomized trials, which were limited by comparison to much smaller craniectomies.[11,12] In ischemic stroke, Lehrieder et al[13] showed in patients with malignant middle cerebral artery infarction that those who received a craniectomy <14 cm in diameter (average 12.8 cm) had similar functional outcomes and mortality to those who received craniectomies greater than 14 cm (average 15.8 cm). Likewise, the

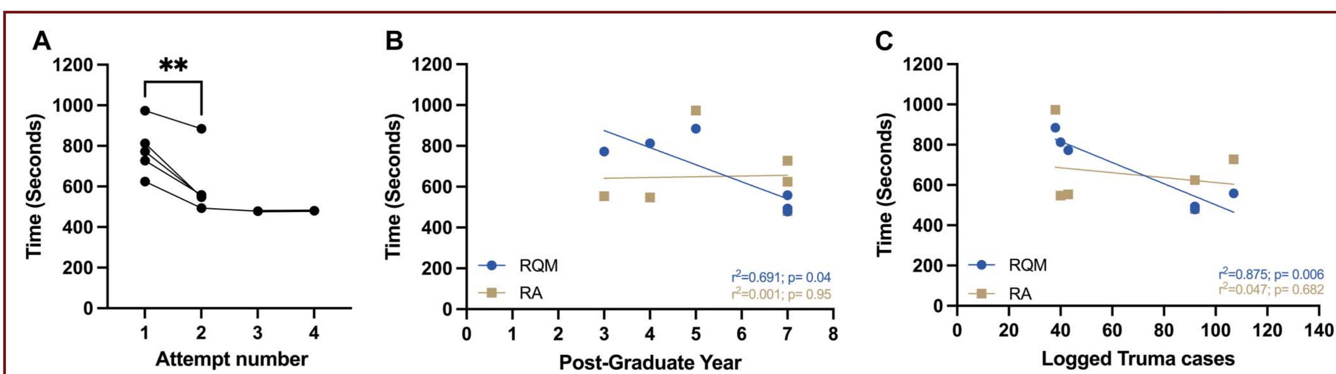

FIGURE 3. *Time from incision to bone flap removal by attempt number* **A**, *postgraduate year* **B**, *and operative experience* **C**. *One surgeon performed 4 craniectomies on 2 heads and their data are shown as attempts 1-4 in Figure 2A. **P < .01. RA, retroauricular; RQM, reverse question mark.*

European Stroke Organization guidelines recommend a decompression diameter of at least 12 cm.[14] All decompressions in this cadaveric study were >13 cm in diameter.

Dowlati et al[8] retrospectively examined the utility of the RA vs the RQM incision for DHC and showed among 63 patients that the RA incision allowed for a larger skull defect, with a nonsignificant decrease in surgical site complications but no difference in blood loss, survival, or overall complications after craniectomy. As noted by the authors, the high mortality of DHC resulted in limited statistical conclusions regarding wound complications rates and only 21/43 RA patients underwent cranioplasty, which further limited discussion of post-cranioplasty wound complications.[8] In their study, normalized skull defect size was significantly larger in the RA group than the RQM group (0.81 vs 0.77). Using similar methodology, this study shows the normalized defect diameter to be equivalent: 0.81 for RA and 0.82 for RQM. Given the large myocutaneous flap raised in the RA incision, one potential concern is the extent of temporal fossa decompression after RA-DHC.[9] This concern had led some groups to conclude that the RA may not be appropriate for all patients including those with very frontal or low temporal lesions, and such as in the case of subdural hematoma, where a more minimally invasive approach may be appropriate.[8,15]

Früh et al compared the distance from the craniectomy to the temporal base between 27 RA and 42 RQM incisions finding no significant difference between the incisions. We also found no such difference between the incisions. However, our absolute values for residual temporal bone were slightly larger (10 mm for RA) compared with the Früh group's (7.2 mm), which may reflect hand measurement of residual (vs computed tomography scans) and performance of the procedure by resident surgeons.[16] Another potential concern with the RA incision is the increased scalp exposure over the transverse sinus compared with the RQM incision.[9] While we did not observe any violations to venous sinuses in our study, this increased risk should not be minimized. Surgeons should have careful awareness of the intersection of the zygomatic root and the inion as surface landmarks of the transverse sinus as to avoid this potential complication. Together, we showed no significant difference regarding decompression size (by any measure), middle fossa decompression, or time until craniectomy between the 2 incisions, which suggests that the RA incision for DHC may be a safe alternative to the RQM.

As DHC is often an emergency procedure, we investigated the time until craniectomy for each incision and found no significant difference between the two incision types. Other groups, however, have shown between a 6.3[17] and 14 minute[18] decreased operative time with the RA incision.[17] Contrary to this, Dowlati et al[8] found that the RA incision had longer operative time by 20.2 minutes but demonstrated a 36.9 minute difference between the first and second halves of the study. In that study, the majority (65.1%) of the RA procedures were performed by a single neurosurgeon, suggesting that experience is a factor in operative time. We show no significant difference in time to decompression; however, this is less generalizable given the simulated nature of the procedures. Surgeon experience was controlled for by having a single surgeon perform both procedures on the same specimen under identical conditions with randomization in the order the craniectomies were performed. Our data agree with the conclusion by Dowlati et al in showing a learning curve to the RA incision and suggests that cadaveric modeling may improve skill acquisition before its incorporation into practice.

Wound complication rates for DHC are reported between 8% and 35%,[1-3] which is significantly higher than the rates for typical elective craniotomies (1.94%).[19] One purported advantage of the RA incision is preservation of the STA, injury to which may otherwise impair wound perfusion and healing. Dowlati et al,[8] while limited by sample size, found the surgical site complication (any operative revision of the wound postcraniectomy) to be nonsignificantly reduced from 14.0% with a RQM incision to 8.3% with a RA incision. Similarly, Veldeman et al[5] showed that the RA incision was associated with a significantly lower rate (6.3% vs 18.4%) of cranioplasty surgical site infections compared with the RQM, though there was no difference in primary surgical site infection. In this study, none of the RA incisions appeared to result in STA injury, while in the RQM incisions the STA was definitively injured in 2/6 subjects. We also found a nonsignificant trend toward a shorter incision (mean difference 2.6 cm) in the RA group without a decrease in decompression size. The total incision length has not been reported by previous studies but may play a role in decreased wound-related complications with the RA incision.

To date, the only other cadaveric study investigating the RA incision was by Zhao et al,[20] who showed in a single embalmed head that adequate middle fossa and overall decompression can be achieved using the RA incision. We expanded on this finding and showed with resident neurosurgeons that similar decompression is achievable with either the RA or RQM incision in a controlled environment. We used this opportunity to investigate resident skill acquisition and report a significant reduction in operative time between first and second procedures, but no difference in operative time comparing the two incisions. Surgeon confidence improved more with the RA than with the RQM during this exercise. As expected, we also report a significant correlation with postgraduate year of training and time to complete a RQM DHC but not a RA DHC, likely reflecting familiarity with the former procedure. Nevertheless, all residents reported that they would feel comfortable performing the RA incision after the single cadaver session. These findings are similar to those of Kim et al,[21] who demonstrated that cadaver labs can significantly increase surgical confidence and independence even when performing a procedure for the first time. Likewise, Lobel et al[22] found that trauma craniotomy simulation improves trainee craniotomy size and time to complete the procedure, especially among junior residents. This suggests that there is utility in cadaveric practice with this incision before implementation in clinical settings.

Limitations

This study was limited by availability of fresh cadaveric heads that were not embalmed, nor latex injected, which limited the evaluation of scalp artery integrity. This limited sample size could have led to type II statistical errors in our results. While both incisions are planned to terminate just behind the hairline, the anterior-posterior extent of each incision was not evaluated in this study. Pre- and postprocedural imaging (eg, computed tomography) was not obtained as in other studies; all measurements were obtained by hand on the cadaveric specimens by a single person. Cadaver simulation does not reflect all aspects of a real surgical procedure; notably, there is no bleeding to control, tissue laxity is altered, and there is no pathology (eg, fracture, hematoma, or edema), which would alter the characteristics of the operation in a live patient.

CONCLUSION

The RA incision for DHC may provide adequate operative exposure without significant changes in operative time. Cadaveric simulation improves skill acquisition and should be considered during implementation into practice.

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