Outcome after decompressive craniectomy for the treatment of severe traumatic brain injury.

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Outcome After Decompressive Craniectomy for the Treatment of Severe Traumatic Brain Injury

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Background: Using decompressive craniectomy as part of the treatment regimen for severe traumatic brain injury (STBI) has become more common at our Level I trauma center. This study was designed to examine this practice with particular attention to long-term functional outcome.

Methods: A retrospective review of prospectively collected data was performed for patients with STBI admitted from January 1, 2003 to December 31, 2005. Our institution manages patients using the Brain Trauma Foundation Guidelines. Data collected from patients undergoing decompressive craniectomy included: age, Injury Severity Score, admission and follow-up Glasgow Coma Score, timing of, and indication for decompressive craniectomy, and procedure-related complications. The Extended Glasgow Outcome Scale (GOSE) was performed by a experienced trauma clinical research coordinator using a structured phone interview to assess long-term outcome in the survivors. Student's *t* test and χ^2 were used to examine differences between groups.

Results: Forty STBI patients were treated with decompressive craniectomy; 24 were performed primarily in conjunction with urgent evacuation of extra-axial hemorrhage and 16 were performed primarily in response to increased intracranial pressure with 4 of these after an initial craniotomy. Decompressive craniectomy was very effective at lowering intracranial pressure in these 16 patients (35.0 mm Hg ± 13.5 mm Hg to 14.6 mm Hg ± 8.7 mm Hg, $p = 0.005$). Twenty-two decompressive craniectomy patients did not survive to hospital discharge, whereas admission Glasgow Coma Score and admission pupil size and reactivity correlated with outcome, age, and Injury Severity Score did not. At a mean of 11 months (range, 3–26 months) after decompressive craniectomy, 6 survivors had a poor functional outcome (GOSE 1–4), whereas 12 survivors had a good outcome (GOSE 5–8). Therefore, 70% of these patients had an unfavorable outcome (death or severe disability), and 30% had a favorable long-term functional outcome. Fifteen of 18 survivors went on to cranioplasty, whereas 4 of 18 had cerebrospinal infection.

Conclusion: The majority of survivors after decompressive craniectomy have a good functional outcome as analyzed by GOSE. Overall, 30% of patients with STBI who underwent decompressive craniectomy had a favorable long-term outcome. Improving patient selection and optimizing timing of this procedure may further improve outcome in these very severely brain injured patients.

Key Words: Craniectomy, Decompressive craniectomy, Severe traumatic brain injury, Trauma, Long-term, Functional outcome, Outcome.

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Traumatic brain injury (TBI) affects up to 2% of the population per year, and constitutes a major cause of death and disability among young people.[1] The treatment of TBI has become more refined in recent years as our diagnostic imaging modalities, medical management, and surgical interventions have improved. The management of severe traumatic brain injury (STBI) has been aided by the Brain Trauma Foundation (BTF) guidelines.[1] Accordingly, these guidelines outline an approach to management of STBI using a combination of medical and surgical treatments. Surgical interventions used in the management of STBI include ventriculostomy for drainage, craniotomy for evacuation of mass lesion, and decompressive craniectomy for refractory increased intracranial pressure (ICP). Previous reports have demonstrated that intracranial hypertension, functional outcome, and mortality may all be improved by decompressive craniectomy.[2,3]

Decompressive craniectomy is becoming increasingly used in the treatment of STBI at our Level I trauma center. This study was undertaken to better understand our indications for performing decompressive craniectomy, and, more importantly, to analyze long-term functional outcome in these severely brain injured patients.

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PATIENTS AND METHODS

A retrospective review of prospectively collected trauma registry data was performed on all patients admitted with an abbreviated injury severity score (AIS) head of 4 and 5 from January 1, 2003 to December 31, 2005. The BTF guidelines (Fig. 1) are used at our institution for the management of STBI.[1] From this database we analyzed which patients un-

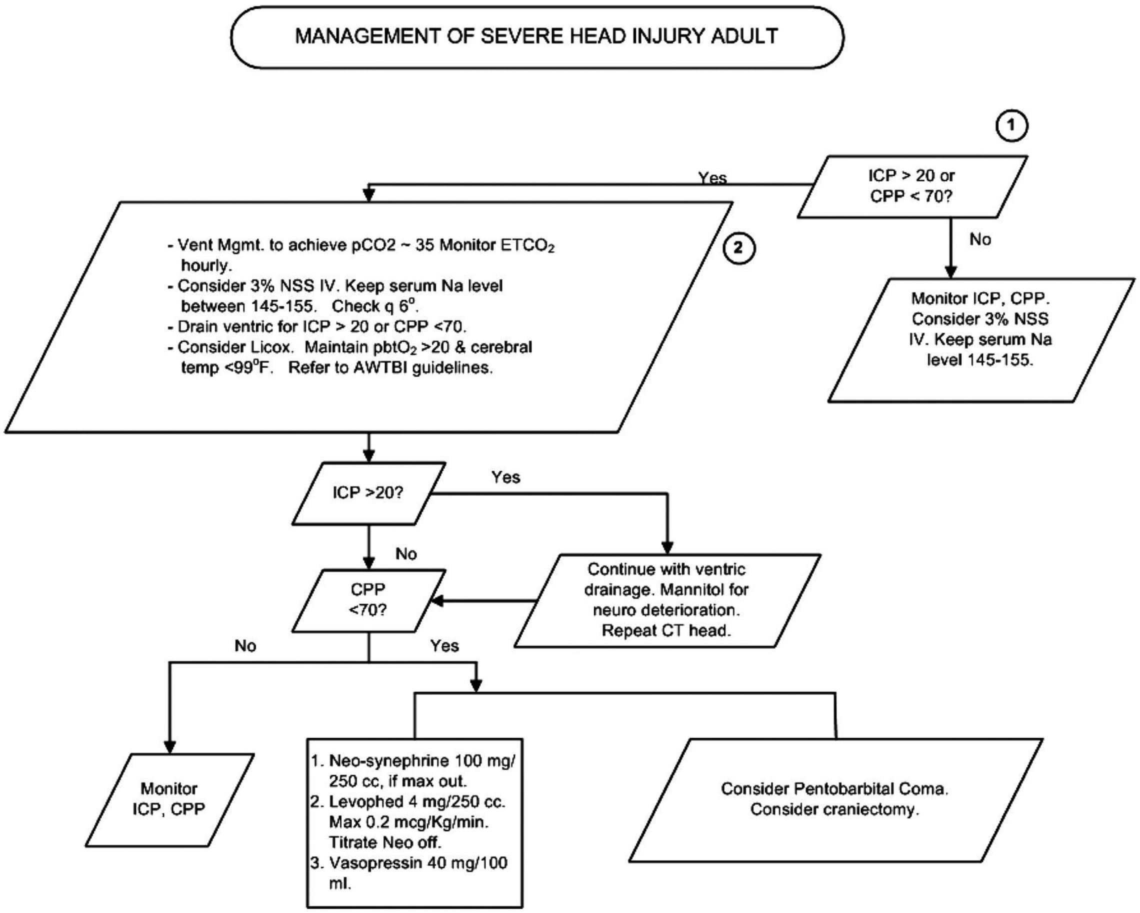

Fig. 1. *Brain Trauma Foundation treatment algorithm for management of traumatic brain injury.*[1]

derwent craniotomy or craniectomy or both. Chart review was performed on all patients who underwent decompressive craniectomy specifically noting age, mechanism of injury, admission Glasgow Coma Score (GCS), abbreviated injury score (AIS) head, Injury Severity Score (ISS), indications for craniectomy, timing of craniectomy, and 28-day mortality. All patients who underwent decompressive craniectomy had a standard sized frontotemporoparietal (FTP) craniectomy.

Available and reliable ICP and cerebral perfusion pressure (CPP) data were also recorded for those patients who had ICP monitors in place.

The Extended Glasgow Outcome Score (GOSE) (Table 1) was used to analyze long-term functional outcome. The GOSE of each survivor was obtained using a structured phone interview. This interview was conducted by an experienced trauma clinical research coordinator. Permission to conduct this interview was given by the Institutional Review Board (IRB). We also reviewed the patients who went on to cranioplasty, reviewing operative notes and cerebrospinal fluid (CSF) cultures. Positive CSF cultures in and around the time of cranioplasty were used to define the complication of infection.

Differences between groups were tested with student's *t* test for continuous data or χ^2 testing for dichotomous variables when applicable. This study was approved by the IRB.

Table 1 **Extended Glasgow Outcome Scale (GOSE)**

Score	Outcome Category
1	Dead
2	Vegetative State
3	Lower Severe Disability
4	Upper Severe Disability
5	Lower Moderate Disability
6	Upper Moderate Disability
7	Lower Good Recovery
8	Upper Good Recovery

Patient's overall rating is based on lowest outcome category indicated on the scale.

RESULTS

From January 1, 2003 to December 31, 2005, we admitted 1,176 patients to our trauma center with an AIS head of 4 or 5. The mortality rate in this group of patients was 19.2%. Of these patients, 152 had a craniotomy and 40 had a decompressive craniectomy. Four patients had a craniotomy followed by a craniectomy. It is this cohort of decompressive craniectomy patients that forms the basis for this study. Figure 2 demonstrates this distribution of STBI patients admitted to our trauma center with an AIS head 4 or 5 over this time period. The mortality rate for patients who underwent decompressive craniectomy was 55% (22 of 40). There was

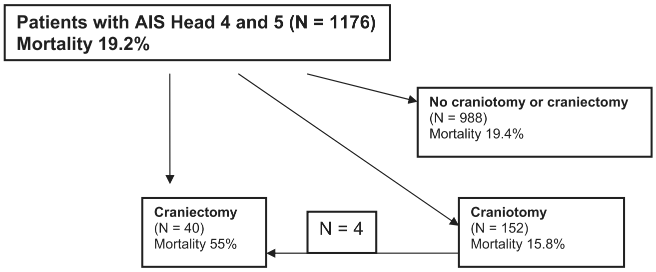

Fig. 2. *Patients with STBI, AIS head 4 and 5, treated at our institution from 2003 through 2005.*

no difference in mortality in decompressive craniectomy patients with an AIS of 4, 4 of 11 (36.4%) versus AIS of 5, 14 of 29 (48.3%).

Of the 40 patients who underwent decompressive craniectomy, 24 were performed during the initial urgent neurosurgical procedure associated with evacuation of an extra-axial hematoma. Based on the CT scan, clinical presentation and intraoperative findings, it was the clinical judgment of the neurosurgeon to leave the FTP bone flap off in these patients. The other 16 patients had a decompressive craniectomy performed after placement of an ICP monitor and 4 of these patients were after a craniotomy. The decompressive craniectomy was performed on day 1.2 ± 0.4 (range, 0–6) after placement of the ventriculostomy with 12 of the 16 decompressive craniectomies being performed within 48 hours of ventriculostomy placement. The primary indication for decompressive craniectomy in this group of patients was elevated ICP refractory to maximal medical management. Predecompressive and postdecompressive craniectomy ICP readings were recorded in all 16 patients. Not surprisingly, decompressive craniectomy was quite effective in lowering ICP in these patients. Predecompressive craniectomy ICP was 35.0 mm Hg ± 13.5 mm Hg and postdecompressive craniectomy ICP was 14.6 mm Hg ± 8.7 mm Hg (p = 0.005).

Twelve of 18 survivors had a good functional outcome with a GOSE of 5 to 8, whereas 6 of 18 had a poor functional outcome with GOSE of 1 to 4. An unfavorable outcome, defined as death or follow-up GOSE 1 to 4, occurred in 28 of the 40 (70%) decompressive craniectomy patients. The mean follow-up time was 11 months with a range of 3 months to 26 months. Table 2 demonstrates that patients with a favorable outcome had a higher GCS and smaller pupils at admission compared with patients with an unfavorable outcome. Not surprisingly, nonreactive pupils on admission predict an unfavorable outcome (Table 2). Although ISS tended to be lower in favorable outcome patients (p = 0.07), there appeared to be no difference in age or distribution of AIS head between patients with favorable or unfavorable outcomes (Table 2). Only 7 of 40 decompressive craniectomies were performed after 48 hours and appeared to have no bearing on mortality or functional outcome.

At the time of publishing, 15 of 18 had presented for cranioplasty. CSF infections were documented in 4 of 18 patients. One of these documented infections was deemed clinically significant resulting in postinfection impairment and lowering of the patients GOSE.

DISCUSSION

Decompressive craniectomy has been historically considered a salvage procedure.[4] In a review article by Hutchinson and Kirkpatrick,[5] a wide range of outcomes after decompressive craniectomy were reported. Because of the lack of class I evidence, decompressive craniectomy was solely used for medical treatment failures. Although there have been no randomized, controlled trials completed studying decompressive craniectomy for STBI, there have been many analyses published. Several of the recent published retrospective studies are listed in Table 3. A direct comparison of these analyses is difficult because of different measured endpoints and surgical methods. The retrospective studies that have been published show that a significant percentage of patients experienced a favorable outcome, ranging from 16% to 69%[3,6–12] (Table 3). In a large prospective randomized trial, Jiang et al.,[12] examined outcomes in patients who had a "limited" craniectomy and compared them to patients who underwent a "standard" frontal temporal parietal craniectomy. There was a higher percentage of patients with a poor functional outcome in the "limited" craniectomy group. Indeed, all the craniectomies in our study were "standard" size frontotemporoparietal craniectomies.

Our study shows that two-thirds of patients surviving decompressive craniectomy have a favorable outcome. By defining unfavorable outcome as death or severe disability (which in our study is analyzed by a GOSE 1–4), we demonstrate a 70% unfavorable: 30% favorable outcome for decompressive craniectomy. These outcomes are similar to those reported in the studies listed in Table 3. In addition, at our institution the use of BTF guidelines to manage STBI has been our standard protocol since 1995. It has been shown that following this standard treatment protocol in treating TBI has been linked to better outcomes.[13]

Table 2 **Comparison of Favorable (GOSE 5–8) vs. Unfavorable (Death or GOSE 1–4) Outcomes in Decompressive Craniectomy Patients**

	Age	Admit GCS	Admit Pupil size	% Admit Pupils Nonreactive	ISS	AIS Head 4:AIS Head 5
Favorable N = 12	28.2 ± 16.2	6.1 ± 5.1	3.4 ± 1.8	16.7	29.4 ± 1.0	4:8
Unfavorable N = 28	33.6 ± 17.6	3.6 ± 1.6	4.2 ± 1.0	60.7	34.5 ± 10	8:20
P value	NS	0.04	0.02	0.01	0.07	NS

Table 3 Literature Review of Outcomes in Decompressive Craniectomy Performed for STBI

	N	Unfavorable* (%)	Favorable (%)
US-Maryland 2006[3]	50	60	40
China 2005[12]	241	60.2	39.8
Turkey 2005[9]	100	84	16
France 2003[6]	40	75	25
US-Hopkins 2003[10]	18	67	33
US-UCLA 2002[11]	24	37.5 (mortality only)	?
Berlin 2002[7]	62	70.9	29.1
UK-Cambridge 2001[8]	26	31	69

* Unfavorable outcome is defined as death or severe disability.

Patients with increased ICP after TBI have been shown to have worse outcomes. Czosnyka et al.,[14] showed that an ICP of greater than 20 mm Hg for longer than 6 hours was predictive of an unfavorable outcome. The mean ICP after decompressive craniectomy has also been shown be an accurate predictor of outcome.[15] Decompressive craniectomy has been shown to lower ICP after TBI.[3,7,8,16,17] Likewise, there was a significant lowering of the ICP in our 16 patients who had a decompressive craniectomy after placement of an ICP monitor. This ICP lowering effect of decompressive craniectomy has been used as an argument to perform this intervention early to prevent unnecessary increases in ICP and minimize the effects of the secondary damage associated with increased ICP.[18] The lowering of ICP improves cerebral perfusion pressure. After decompressive craniectomy is performed, cerebral perfusion pressure has been shown to increase and be maintained at levels that are ideal for maximal benefit.[7,16] Jaeger et al.,[17] also demonstrated that the partial pressure of oxygen in brain tissue was improved by decompressive craniectomy as well, although in their experience this did not predict a favorable outcome. This study was limited because of its small size of three patients.

Ideally, a subset of patients could be identified in which decompressive craniectomy would be most beneficial. In our analysis, admission GCS and pupil size appeared to correlate with outcome in these severely brain injured patients. Although admission GCS for patients with a favorable outcome had a mean of only 6.5, it was a full 2.5 points higher than patients with an unfavorable outcome. Although the difference in mean pupil size was only 0.8 mm, this difference did reach clinical significance when the two groups were compared (Table 2). Not surprisingly, admission pupil nonreactivity did correlate with mortality in our study. Other studies have shown similar findings. Ucar et al.,[9] showed that patients with a higher GCS on presentation were more likely to have a favorable outcome after decompressive craniectomy. Their study followed 100 patients with TBI and grouped these patients according to GCS on presentation. All patients had an initial GCS $<$8. Patients with GCS of 6 to 8 were more likely to have a functionally acceptable outcome. Recently, Aarabi et al.,[3] showed that patients with admission GCS scores of 6 to 15 were 10 times more likely to experience a favorable outcome when compared with patients with a lower GCS.

Ucar et al.,[9] also found that the presence of other injuries was not predictive of outcome in patients who had undergone decompressive craniectomy. In our study, ISS tended ($p = 0.07$) to be lower in decompressive craniectomy patients with a favorable outcome (Table 2). This seems reasonable and would support the idea that patients with a higher ISS would be at higher risk for secondary brain injury. We think that it is very important to address all injuries in a timely and coordinated fashion and minimization of the potential contribution of other injuries to secondary brain injury should always be an important goal for the trauma team.

Age did not seem to relate to outcome in our analysis (Table 3). Overall the decompressive craniectomy patients are a relatively young group of patients. Eleven of our patients were 18 years of age or younger, and an additional 10 patients were 30 years of age or younger. Polin et al.,[2] found that 8 (44%) of 18 patients had good outcomes after bifrontal decompressive craniectomy compared with only a 15% favorable outcome in adults. Rutigliano et al.,[19] reported on six pediatric patients ($<$20 years old) who underwent decompressive craniectomy for traumatic brain injury. All six patients survived and were sent for rehabilitation.

Timing of decompressive craniectomy is likely to be important in determining outcome. There were seven patients who had a "late" decompressive craniectomy, i.e., after 48 hours of admission. There was no correlation noted in outcome if "late" is defined as $>$48 hours after admission. Guerra et al.,[15] maintained that decompressive craniectomy should be performed early in the course of STBI before brain tissue hypoxia and irreversible damage has occurred. Ziai et al.,[10] analyzed that surgery for decompressive craniectomy should not be performed when preoperative CT findings suggest transtentorial and uncal herniation have already occurred. In an analysis by Albanese et al.,[6] 19% of patients who underwent early decompressive craniectomy in less than 24 hours had good recoveries (social rehabilitation), 8 (30%) patients remained in a persistent vegetative state or with a severe disability, and 14 (52%) died. On the other hand, the performance of late decompressive craniectomy in the case of medical treatment failure was followed by social rehabilitation in 5 patients (38%) and death in 3 patients (23%). A persistent vegetative state or a severe disability was observed in 5 patients (38%).

Many complications of craniectomy have been reported: subdural hygromas, bone resorption, bone flap infections, CSF infections, and parenchymal lucencies. Albanese et al.,[6] reported meningitis or cerebral abscesses in 6 (15%) of 40 patients after decompressive craniectomy. In the recent report by Aarabi et al.,[3] complications were seen at varying times postoperatively. Some patients had complications, such as swelling associated with hemorrhagic contusions as early as 18 hours postoperatively. Other complications such as bone resorption present after discharge.[3] In our experience, the complication rate after decompressive craniectomy was low. Fifteen (83%) of 18 survivors had presented for cranioplasty, and CSF infections were documented in four patients, with only one infection that resulted in a change in clinical outcome.

Multiple reports have been generated regarding outcome follow-up after decompressive craniectomy. The Glasgow Outcome Scale is the most widely used system for evaluation of a patients' functional status after decompressive craniectomy. However, the GOSE has been shown to be the most reliable of all outcome measures. The GOSE is the most reproducible, it ensures the most inter-rater reliability, and is the most sensitive to change in those with mild to moderate traumatic brain injury.[20–22] Our follow-up data were gathered in a structured phone interview by an experienced trauma clinical research coordinator. All patients were contacted by the same interviewer. A verbal consent, given by telephone, was preapproved by our IRB and was obtained to complete the GOSE standard questionnaire. In the cases of children and the moderately and severely disabled, family members, significant others, or other proxy served to give confirmatory responses. Using the GOSE and conducting structured interviews with reliable personnel gives us a high level of confidence in our outcome statistics. Our analysis is unique in that we have long-term follow-up using GOSE, the most reliable method, to date, for assessing functional outcome after STBI.

Decompressive craniectomy has become an accepted part of the armamentarium to resolve malignant cerebral edema, to reduce refractory intracranial hypertension, and for the evacuation of mass lesions after trauma. This is evidenced by the increasing number of craniectomies performed at our institution since 2003. In the year 2005, we evaluated and treated 441 trauma patients with AIS head of 4 or 5. During this year there were 36 craniotomies and 24 craniectomies performed, i.e., craniectomy has come to represent a substantial portion of our neurosurgical intervention for STBI.

Although no prospective randomized trials have been completed, there are two studies underway worldwide. The Randomized Evaluation of Surgery with Craniectomy for Uncontrollable Elevation of ICP, RESCUEicp trial is underway with the lead site in Cambridge, UK. This study currently has 24 sites enrolling patients. These patients with severe STBI and elevated ICP refractory to medical management without barbiturates are randomized to either decompressive craniectomy or continued medical management including barbiturate coma. Primary endpoint is the Glasgow Outcome Scale on discharge and the GOSE at 6 months. The study plans to enroll a total of 500 patients. To date, there are no US sites participating in this trial. Another multicenter trial is also being conducted with the lead site in Victoria, Australia. The DECRA Trial: Early Decompressive Craniectomy for patients with STBI has a very similar design to the RESCUEicp trial and currently has two US sites participating.

CONCLUSIONS

Decompressive craniectomy lowers ICP and raises cerebral perfusion pressure. There are data to support the early institution of decompressive craniectomy before irreversible ischemia can occur. The timing from injury to decompressive craniectomy is controversial, but may be optimal within 24 hours after injury. Our study demonstrated that patients with an unfavorable outcome had a significantly lower admission GCS compared with patients with a favorable outcome. Systemic injuries may contribute to secondary brain injury but should not preclude decompressive craniectomy. Although past studies have had questionable results with decompressive craniectomy, many recent analyses have shown that the mortality rate is acceptable for the degree of the patient injury and that the majority of survivors return to a reasonably high level of function, i.e., moderate disability or good recovery. Our finding, that overall 30% of decompressive craniectomy patients had a long-term favorable outcome, is in keeping with other reports. In fact, our study demonstrated that most survivors after decompressive craniectomy had a favorable long-term functional outcome. We would suggest participation of more US sites in the two multicenter randomized controlled trials currently underway (RESCUEicp and DECRA) or a similar trial be conducted in the United States to better understand what effect decompressive craniectomy has on long-term functional outcome for patients with STBI.

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DISCUSSION

Dr. Vincente Gracias (Philadelphia, Pennsylvania): I do want to congratulate Dr. Cipolle and his colleagues on their report to us today, a retrospective examination of their institutional experience with decompressive craniectomy for severe traumatic brain injury and intractable intracranial hypertension. The manuscript is well written and was provided to me in a timely fashion. Dr. Cipolle's work presents us with a novel long-term follow up of patients treated with decompressive craniectomy and report an overall favorable outcome for patients who survive long term.

They should be commended for adding this very important and real look at an effective surgical option for devastating cerebral vascular injury. Well done and I have three questions.

First, your results indicate that twenty-eight of forty patients had an unfavorable outcome and twelve of forty had a favorable outcome with GCS of 14 and 15. You only report twelve as having acceptable extended Glasgow Outcome Score, the extended scores that you used, and according to the manuscript, this was reported as a favorable outcome.

By convention, a GOSE of 1 to 4 is considered unfavorable, but you had some GCS of 14 and 15 that you rated as unfavorable and if you could explain that to us, that would be great.

Second, there are multiple types of decompressive craniectomy procedures available, including extended unilateral, unilateral, bifrontal, et cetera. Are you able to tell us if one particular type of craniectomy was used and had a more favorable outcome than another particular type?

Third, and most important, the most crucial component of decompressive craniectomy involves the time of application, with several reviews recognizing that early application has a far better result than late. Most of your craniectomies were performed within the first forty-eight hours after presentation. Can you give us a breakdown that will further allow us a comprehensive report with regard to outcomes?

I would like to see your results broken down by twelve-hour increments and resultant outcomes data associated with it. We're in the middle of trying to decide whether or not decompressive craniectomy should be done in the first twelve, twenty-four hours, or if we should wait longer. Again, congratulations on the tenacity this work must have required.

Dr. Mark Cipolle (Allentown, Pennsylvania): Thank you, Dr. Gracias, for those kind comments. I think the first question is exactly why we did this trial. We were beginning to look at the data when these patients came back to the neurosurgery office and we saw that most of them were awake, but can they tie their shoes and what does it mean?

We felt even more compelled to determine functional outcome and so indeed, there are patients who are awake, but do have a poor functional outcome. I will say that mostly—I can't remember the number off of the type of my head, but we were also impressed that most patients had good recovery. Most patients did score an 8 on their GOSE and so that's exactly why we pursued the functional outcome, is because just being awake is not enough to know.

The second question, I believe our database—I believe we only had one craniectomy that was other than a unilateral frontal temporal parietal craniectomy and so we certainly didn't have enough mix in each group to make any statements, but most—I think virtually all the patients were the standard FTP craniectomy.

Finally, timing, yes, that's a good question. After we kind of got done with our analysis, we said the exact same thing. We said forty-eight hours is—We need to look sooner and so we can indeed go back to our database and hopefully be able to tease that out a little more rigorously.

I will make a comment that the last slide I showed, the Rescue ICP Trial, really isn't going to address this. Those patients are going to be patients who have failed maximal medical management for intracranial pressure management and so most of those patients will probably be done later. Yet, while I think that it's worthwhile participating in the trial, it won't answer that specific real early upfront question.

Dr. Samuel A. Tisherman (Pittsburgh, Pennsylvania): This was a very nice presentation and a nice study. If I understand correctly, this was not just patients with isolated head injuries and if that's true, do you have a sense of why these patients died? Was it related solely to the head injury or was there other trauma?

In that vein, when you think about the issues about decompressive craniectomy in the face of other injuries, how does that play into the decision to do this or not do it?

Dr. Mark Cipolle (Allentown, Pennsylvania): If you do look at the ISS data, most of the ISS can be accounted for by the abbreviated injury score they had. In other words, if you square that, you pretty much get their ISS. These patients are, for the most part, isolated severe closed head injury.

One of the things that is, of course, important in managing these patients with multiple trauma is the timing of when you address what, but most of these patients are isolated closed head.

Dr. Thomas E. Knuth (Mahomet, Illinois): This is a great paper for a military session and I'll tell you why. The skills to do a decompressive craniectomy and especially the judgment as to when and when not to do one, which I think is what your paper pertains to, are essential skills for a military general surgeon.

We taught these skills at the Army Trauma Training Center and general surgeons were required to scrub in on a few of these during that training and I know of no general surgeon who has come back from the Iraq war having not done at least one of these and in some cases, up to ten and fifteen craniectomies and mostly on local national patients. But, of course, follow up over there may be impossible. Don Jenkins could speak to that better, but I would love to see a paper to put together the military experience along the lines of what you've done and follow up these patients from the Iraq war and perhaps next year present that and that would be terrific and I applaud your efforts to lead that effort and thank you.

Dr. Mark Cipolle (Allentown, Pennsylvania): Thank you. I will make a comment that in the era of acute care surgery that we urge all our residents to scrub with the neurosurgeons and to learn these procedures and it's actually pretty straightforward. I'm not a neurosurgeon, but it looks like a pretty straightforward procedure to me.

Dr. Edward Kelly (Boston, Massachusetts): I would also like to say that I think the paper is very interesting and very forward looking to the era of treating intracranial hypertension much along the lines of the lessons that have been learned with intraabdominal hypertension and I think one of the key factors in managing that was the idea that you can patch the abdomen and make it larger.

In any of these decompressive craniectomies, were dural patches used, such as AlloDerm or other prosthesis, to enable the brain to swell and to still maintain a compliant compartment?

Dr. Mark Cipolle (Allentown, Pennsylvania): As far as I know, no. There are patients who have had in their cranioplasty they've had to have adjunctive things done because they had bone reabsorbtion, but to the best of my knowledge, no. It's just the scalp coverage over the—

Dr. Edward Kelly (Boston, Massachusetts): You had mentioned there was one infection and it may be possible that a better barrier to infection might be a more stable cover.

Dr. Mark Cipolle Allentown, Pennsylvania): I like your analogy. Vince and I were talking yesterday and he used the term "damage control craniectomy" several times and that's basically what we've begun to look at this, with our—It's basically a parallel scheme with the way we are managing abdomens now.

Dr. Nathaniel McQuay (Bethlehem, Pennsylvania): This was a nice study. I know this is a military forum and I notice in your patient population the average age was pretty young, just like most of the trauma population, but in northeast Pennsylvania, as you well know, we have a significant geriatric portion to the population. Have you looked at the experience in the geriatric population, i.e., age greater than sixty-five, or is that a contraindication at your institution for doing this procedure?

Dr. Mark Cipolle (Allentown, Pennsylvania): We, of course, did not have many geriatric patients in this database. You're right that it represents a very young—In fact, I think fourteen of our patients were in the pediatric age group.

I would tend to say that our neurosurgeons would probably not be this aggressive with an elderly patient. We had a few elderly patients with a poor outcome, of course. The other thing is these patients have more room in their brain when they get injured and so the decompressive craniectomy is usually not quite in the mix, at least early on, and by the time they would need one, I think most people would not be offering it to a geriatric patient.