Combined internal uncusectomy and decompressive craniectomy for the treatment of severe closed head injury: experience with 80 cases

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Object. Transtentorial brain herniation is a major cause of morbidity and death following severe closed head injury. The purpose of this study was to evaluate the efficacy of selective uncoparahippocampectomy and tentorial splitting as an adjuvant method of treating otherwise uncontrollable elevated intracranial pressure (ICP) while attempting to prevent or minimize the devastating consequences caused by transtentorial herniation.

Methods. The authors retrospectively reviewed data from a series of 80 consecutive cases of severe closed head injury (Glasgow Coma Scale [GCS] score < 8) treated in their neurosurgical unit. All patients had elevated ICP and downward transtentorial herniation, as documented with ICP monitoring, and clinical examination and computed tomography, respectively. Given the evidence of acute and ongoing neurological deterioration, all patients were treated with selective uncoparahippocampectomy and tentorial edge incision followed by wide decompressive craniectomy and dura-plasty.

Results. All injuries were caused by blunt trauma with signs of acute and/or progressive increased ICP causing downward transtentorial herniation. Fifty-eight patients were male and 22 were female with a mean age of 35 years and a mean preoperative GCS score of 5. Based on the current American Association of Neurological Surgeons guidelines for head trauma, an intraparenchymal ICP device (Camino, Integra) was placed in all patients who had a GCS score < 8, and ICP was consistently > 20 cm H2O. Whenever possible, risks and benefits were explained to family members, and then surgery was performed within 3–16 hours (median 6 hours). At a mean follow-up of 30 months, the outcome was favorable (Glasgow Outcome Scale [GOS] score of 4 or 5) in 60 patients (75%) and unfavorable (GOS score of 3) in 8 (10%), whereas the remaining 12 patients (15%) died at some point during the postoperative course. There was no survivor patient in a vegetative state. A younger age had a significant effect on positive outcome (p = 0.0005), as did an earlier operation (p < 0.04). The preoperative neurological status as assessed using the GCS as well as pupillary reactivity had no significant effect on outcome (p = 0.054 and p > 0.05, respectively).

Conclusions. A selective uncoparahippocampectomy with a tentorial edge incision and a wide decompressive craniectomy with duraplasty can be an effective adjuvant form of aggressive treatment to improve outcome in patients with severe closed head injury, especially in those who are younger if they are treated promptly.

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Key Words • decompressive craniectomy • raised intracranial pressure • transtentorial incision • severe head trauma • transtentorial herniation • uncoparahippocampectomy

Elevated ICP and brain herniation are major causes of death and severe morbidity following a major head injury. Current and widely accepted modalities for the treatment of increased ICP with or without brain herniation include first prompt removal of the lesion causing mass effect (that is, subdural hematomas and large contusions), supplemented or not by osseous decompression with concomitant medical management of the raised ICP including hyperventilation, osmotic diuresis, cerebrospinal fluid drainage, and barbiturate-induced coma. In general, more effort is devoted to controlling ICP; however, successfully decreasing ICP without relieving brain shift may not be a satisfactory measure. In fact, a herniated temporal lobe undergoes necrotic changes within a few hours, and in the worst case scenario, can expand, causing compression of the brainstem as well as the CNs and vascular structures. Direct surgical decompression of the temporal lobe can relieve pressure from the oculomotor nerve, midbrain, posterior cerebral artery, and anterior choroidal artery. Few authors, to our knowledge, have discussed the role of immediate direct temporal lobe decompression in patients with severe brain injury. The purpose of this study was to evaluate the efficacy of selective
uncoparahippocampectomy and tentorial splitting as an adjuvant method of treating otherwise uncontrollable elevated ICP while attempting to prevent or minimize the devastating consequences due to transtentorial herniation.

Clinical Material and Methods

Patient Population

We retrospectively reviewed data in a series of 80 consecutive patients suffering from severe closed head injury with acute or progressive elevated ICP and downward transtentorial herniation caused by acute brain swelling and/or mass effect due to acute subdural hematoma or large brain contusions. All patients were treated in the neurosurgery department of Parma University Hospital between March 2000 and February 2005. All patients had suffered a blunt head trauma causing acute subdural hematoma with or without a brain contusion and/or malignant hemispheric edema. Excluded from this study were patients with acute brain swelling not related to closed head injury such as subarachnoid hemorrhage, spontaneous ICH, penetrating trauma, and massive ischemic strokes. The selection criteria for direct selective uncoparahippocampectomy with tentorial edge splitting and wide craniectomy with duraplasty were as follows: 1) acute and/or progressive clinical signs of elevated ICP with transtentorial herniation (third CN deficits with dilated pupil[s] and no light responses); 2) CT evidence of advanced transtentorial herniation (Figs. 1A, 2A, and 3 left), such as compression and displacement of the midbrain, obliteration of the perimesencephalic cistern, and enlargement of the contralateral temporal horn; and 3) a GCS score between 3 and 8.

Several other patients were not included in the study because of CT evidence of midbrain and pons hemorrhagic lesions (also known as “Duret hemorrhage”), which are related to irreversible coma or death as a consequence of severe damage of the respiratory and cardiac centers of the brainstem. Outcome was evaluated using the GOS. A statistical analysis of different preoperative variables was conducted to determine a relationship with the final outcome in our study group.

Surgical Technique

Each patient was positioned supine with a roll below the ipsilateral shoulder, and the head was turned to the opposite side of 45° and secured with 3-point head fixation. A large trauma flap was planned beginning ~ 1 cm anterior to the tragus directly above the zygomatic arch, curving slightly posterior over the ear and turning anteriorly toward the midline; whenever possible, the incision was made within the hairline. This flap is an excellent way to expose the temporal fossa as well as a large portion of the frontoparietal area. The scalp flap, including the periosteum, was then turned to the level of the supraorbital ridge. A large frontotemporoparietal craniectomy was fashioned. The temporal squama was rongeured off to reach the floor of the temporal fossa.

Wide exposure of the brain surface allows immediate recognition of subdural and intracerebral hematomas, which were evacuated, as was the contused brain tissue. Under microscopic magnification, a temporal lobectomy was performed, always sparing the superior temporal gyrus and, whenever possible, most of the middle and inferior temporal gyri, depending on brain swelling. At this stage, the white matter was dissected until the temporal horn of the lateral ventricle was identified and entered, because it represents an important landmark for proceeding to removal of the mesial temporal structures. At this point, a brain retractor was positioned subtemporally to expose and respect the fusiform gyrus, uncus, and parahippocampal gyrus via a subpial approach to avoid damage to the oculomotor nerve, posterior cerebral artery, anterior choroidal artery, and midbrain. The parahippocampal gyrus was in-

![Figure 1](Fig. 1. Case 1. A: Preoperative axial CT scan showing right downward transtentorial herniation. B: Postoperative axial CT scan showing the right uncus and partial parahippocampal gyrus removal with the brainstem decompressed. C: Postoperative axial T1-weighted MR image demonstrating removal of the right uncus and partial parahippocampal gyrus and ipsilateral brainstem decompression.)
cised ~ 3 cm from the uncus, and the amygdala and hippocampus were left intact in situ. Finally, the tentorial edge as well as the mesial arachnoid was split to completely free the oculomotor nerve and midbrain, in this way allowing cerebrospinal fluid circulation between the infra- and supratentorial compartments, indicating visibly that the brainstem has been decompressed (Figs. 1–3). At the end of the procedure, to avoid persistent elevated ICP caused by expected postoperative brain swelling, a wide duraplasty is completed to accommodate further brain herniation.

Results

Of the 80 patients in this series, 58 were male and 22 were female with a mean age of 35 years (range 16–61 years). The mean preoperative GCS score was 5 (range 3–7). Unilateral dilated nonreactive pupil was seen in 57 cases, and bilateral fixed pupils in 23. At a mean follow-up of 30 months (range 12–60 months), the outcome was favorable (GOS Scores 4 and 5) in 60 patients, unfavorable (GOS Score 3) in 8, and the remaining 12 patients died in the postoperative course; there were no survivors in a permanent vegetative state (Table 1). Patients with a favorable outcome had a mean age of 29 years, whereas those with an unfavorable outcome had a mean age of 48 years; this difference was statistically significant (p < 0.0005). All patients who underwent an early surgery (within 6 hours) had a more favorable outcome compared with those who underwent surgical intervention beyond 6 hours; this difference was also statistically significant (p < 0.04; Table 2). In contrast, preoperative neurological status and pupil reactivity had no significant effect on outcome (p = 0.054 and p > 0.05, respectively). Postoperatively, improvement of oculomotor nerve palsy (resolution of pupil fixation) was recorded in 36 patients. The patients who had an unfavorable outcome (8 patients) and 21 of those who had a favorable outcome had some kind of complication. As expected, most complications were related to a long intensive care unit stay and prolonged immobilization. The most common complications included pneumonia, which developed in 21 patients, followed by acute renal failure, deep venous thrombosis, and nonfatal pulmonary embolism. The mean hospital stay was 39 days (range 23–111 days).

Discussion

Severe brain injury, especially if responsible for tentorial herniation, carries a very poor prognosis and is associated with a high mortality rate. Removal of injured brain in these patients is not a new concept; it has been widely described. Subtemporal decompression for the relief of increased ICP was first described by Cushing in 1908. Since then, various decompressive procedures have been used to treat these acute events. Although most of these procedures have been shown to decrease brain shift, the mortality and morbidity rates have remained between 30 and 80%.

Keeping in mind the factors just mentioned, different direct surgical decompression techniques were developed to treat tentorial herniation in the premicroneurosurgical era but failed to show satisfactory results. Displacement from one intracranial compartment to another due to sudden brain expansion determines a pressure gradient be-

<table>
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<tr>
<th>Outcome following treatment for severe closed head injury in 80 patients</th>
<th>No. (%)</th>
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<tbody>
<tr>
<td>full recovery</td>
<td>44 (55)</td>
</tr>
<tr>
<td>moderate disability</td>
<td>16 (20)</td>
</tr>
<tr>
<td>severe disability</td>
<td>8 (10)</td>
</tr>
<tr>
<td>vegetative state</td>
<td>0 (0)</td>
</tr>
<tr>
<td>death</td>
<td>12 (15)</td>
</tr>
<tr>
<td>total</td>
<td>80 (100)</td>
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tween different compartments; the mechanism lies in the obliteration of the subarachnoid space and cisterns and subsequent hemorrhagic and ischemic brain damage. Rapid expansion of a supratentorial mass lesion causes distortion of the brain and is associated with elevated ICP and downward transtentorial herniation, which is a common and clinically significant type of brain herniation. In cases of tentorial herniation, the mesial temporal structures remain trapped in the tentorial incisura and undergo compressive damage; thus, simply evacuating a hematoma with or without osseous decompression may not alleviate brain herniation that has already occurred. Until recently, all efforts have been focused on controlling increased ICP by using mainly medical measures. This strategy has certainly helped to improve patient outcomes, although not as much as expected.

Based on these data, we performed selective uncopar- hippocampectomy with tentorial edge splitting in a series of 80 consecutive patients with clinical and radiological evidence of acute and/or progressive brain herniation to avoid the usual poor outcome caused by irreversible brainstem damage. It is well known that the mortality rate among patients with signs of hyperacute transtentorial herniation is between 30 and 80%, and that a large majority of survivors still experience devastating neurological deficits. Bearing in mind the neurofunctional importance of the mesial temporal structures, we tried to select the best patients for surgical management based on clinical evidence of acute and/or progressive increased ICP and transtentorial herniation with a third CN deficit (dilated pupil[s] with loss of light reflex), CT evidence of advanced transtentorial herniation (such as compression and displacement of the midbrain, obliteration of the perimesencephalic cistern, and enlargement of the contralateral temporal horn; Figs. 1–3), and a GCS score between 3 and 8. All patients with CT evidence of brainstem hemorrhagic lesions (Duret hemorrhage) were excluded from the study given their known poor outcome related to severe damage of the brainstem’s vital cardiac centers. In our series, the mortality rate was 15% (12 of 80 patients). Eight patients (10%) had an unfavorable outcome of severe disability (GOS Score 3); in 6 of these patients, the offending lesion had been located in the dominant hemisphere, and all deficits were related to this hemisphere. The remaining 60 patients (75%) had an excellent outcome (GOS Scores 4 and 5); 32 of them were discharged to home directly from the hospital with a GOS score of 5, and 28 required inpatient rehabilitation.

We propose the described surgical technique as a life-saving procedure; the results are more encouraging than even we expected. With regard to the deficits that can be experienced by patients undergoing surgery in the dominant hemisphere, we are convinced that this technique is especially suitable for this subgroup given that the microsurgical technique may allow sparing of functionally important brain structures. An analysis of our data demonstrates that although the majority of patients had an excellent outcome, some fared better than others. Therefore, we evaluated some of the preoperative variables to reveal any relationship with postsurgical outcome. In a multivariate analysis of the data we considered the patient’s age, preoperative neurological function, pupillary reactivity, and the interval of time between injury and surgery. Results of this analysis showed that all patients with a favorable outcome had a mean age of 29 years, and those with an unfavorable outcome had a mean age of 48 years. The difference was highly significant (p < 0.0005). Moreover, patients who underwent an early surgery (≤ 6 hours from

Fig. 3. Case 3. Left: Preoperative axial CT scan revealing right downward transtentorial herniation. Right: Postoperative axial CT scan displaying the right uncus and partial parahippocampal gyrus removal and ipsilateral brainstem decompression.
injury) had a more favorable outcome compared with those who underwent a delayed operation ($p < 0.04$). In contrast, the preoperative neurological status and pupillary reactivity had no significant statistical effect ($p = 0.054$ and $p > 0.05$, respectively).

With regard to the surgical technique, we noted that 42 patients underwent surgery at a very acute stage (within 6 hours) when the temporal lobe distortion was not so dramatic. In fact, the technique was less challenging in terms of anatomical recognition. Generally, the middle temporal gyrus approach was chosen, because temporal fossa decompression was required, making it easier to enter the temporal horn and a more safe selective removal of the uncus and parahippocampal gyrus (Figs. 1B and C, 2B and C, and 3 right). The dentate gyrus and hippocampus were left intact whenever possible unless they were obviously and severely damaged. The authors also relied on their extensive experience with epilepsy surgery. By adding an external osseous decompression procedure, we intended to minimize the effects of persistent elevated ICP due to expected postoperative brain swelling. It is a matter of fact that a significant disadvantage of selective uncoparahippocampectomy is the temporal lobe retraction during brain swelling. However, by using the microsurgical technique and by removing the middle and inferior temporal gyr when necessary (in cases of consistent edema and temporal lobe distortion), the brain retraction can be consistently minimized.

Data in this study seem to suggest the lifesaving nature of uncoparahippocampectomy with tentorial splitting in patients with acute and/or deteriorating clinical signs of transtentorial herniation. With the objective of decompressing the brainstem and relieving the pressure gradient, this operation also seems to be an effective procedure for reversing acute and/or progressive neurological deterioration due to downward transtentorial herniation. This technique combined with state-of-the-art intensive care management may improve the mortality and morbidity rates associated with transtentorial herniation.

### Conclusions

Keeping in mind the limitations of a retrospective series such as this one, data in this study seem to show that selective uncoparahippocampectomy with tentorial edge splitting added to decompressive craniectomy can be an effective treatment in patients with severe closed head injury. This procedure can especially improve outcome in younger patients who undergo early surgery. In our study population we found no statistical evidence that prognostic factors such as preoperative neurological status and pupillary reaction affect outcome, as reported in the literature. The discordance between our data and findings in the relevant literature compel us to state that our work obviously cannot be considered conclusive and that further prospective randomized studies are required to clarify these interesting aspects.

### References

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