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Clinical Study

Craniectomy-Associated Progressive Extra-Axial Collections with Treated Hydrocephalus (CAPECTH): Redefining a common complication of decompressive craniectomy

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ABSTRACT

Extra-axial fluid collections following decompressive craniectomy have been observed in a variety of patient populations. These collections have traditionally been thought to represent extra-axial signs of hydrocephalus, but they often occur even in settings where hydrocephalus has been optimally treated. This study aims to elucidate the phenomenon of extra-axial fluid collections after decompressive craniectomy in patients with treated hydrocephalus, in order to improve identification, classification, prevention and treatment. We retrospectively reviewed all patients at a single institution undergoing decompressive craniectomy for refractory intracranial pressure elevations from June 2007 through December 2009. We identified 39 patients by reviewing clinical reports and imaging. Any patient who died on or prior to the third post-operative day (POD) was excluded. The analysis focused on patients with extra-axial collections and treated hydrocephalus. Twenty-one of 34 (62%) patients developed extra-axial collections and 18 of these developed collections despite ventricular drainage. Subgroup analysis revealed that seven of seven patients (100%) with subarachnoid hemorrhage, and 11 of 14 (79%) with traumatic brain injury developed collections. Extra-axial collections may develop after decompressive craniectomy despite aggressive treatment of communicating hydrocephalus. In these patients, the term "external hydrocephalus" does not appropriately capture the relevant pathophysiology. Instead, we define a new phenomenon, "Craniectomy-associated Progressive Extra-Axial Collections with Treated Hydrocephalus" (CAPECTH), as progressive collections despite aggressive cerebral spinal fluid (CSF) drainage. Our data indicate that early cranioplasty can help prevent the formation and worsening of this condition, presumably by returning normal CSF dynamics.

1. Introduction

Decompressive hemicraniectomy (DC) has become a common operative strategy in the management of conditions causing elevated intracranial pressure (ICP) and refractory cerebral edema. Despite early studies that did not definitively supportive its effectiveness,[1–4] and even with a recent study questioning the benefit of DC in traumatic brain injury (TBI),[5] the use of this surgery for ICP management continues to increase. This increase in utilization has been driven mainly by data supporting its efficacy in stroke patients with malignant cerebral edema.[6–10] Support for this procedure has also come from studies demonstrating benefit in patients with subarachnoid hemorrhage (SAH) from ruptured aneurysms[11,12] and in those with cerebral edema from TBI.[13,14] DC is not without complication; including epidural hematomas, intra- and extra-axial hemorrhages, cerebral contusions, infections, seizures, sunken flap syndrome, and extra-axial cerebrospinal fluid (CSF) collections.[15,16]

The recent DECRA trial[17] has renewed interest in this controversial surgery. The trial demonstrated that after DC, patients had decreased ICP and the length of stay in the Intensive Care Unit but increased unfavorable outcomes. We believe the surgery remains a valuable option in appropriately identified patients; however, the DECRA trial pointed out the importance of complications in shaping the outcomes we provide to our patients. In order to improve outcomes, we as neurosurgeons must be aware of and capable of managing these complications. We present our experience with a common complication of DC and offer possible pathophysiologic mechanisms of its etiology as well as treatment algorithms. As reported, we have observed the phenomenon of continued accumulation of non-hemorrhagic extra-axial fluid collections[18–21] and reviewed a series of 39 consecutive patients who underwent DC and identified those who developed these collections.

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2. Methods

We retrospectively identified all patients who underwent a DC over a 30-month period between 1 July 2007 and 31 December 2009. The study was performed under the supervision of the Partners Healthcare and Brigham and Women's Internal Review Board. We reviewed the operative reports, clinical data, and imaging for these patients. All patients were admitted to the Brigham and Women's Hospital Neuroscience Intensive Care Unit. Thirty-nine patients with SAH, TBI, stroke, and tumor who underwent DC were identified and included.

Although the procedures were performed by different surgeons, all patients underwent a frontotemporal-parietal DC and an expansive radial durotomy to allow for brain swelling. An anterior temporal lobectomy was not performed in any patient. The dura was not closed in a watertight fashion; instead, dural substitutes were used to cover the brain.

All patients with suspected hydrocephalus received frontal ventriculostomies for treatment. CSF drainage was titrated to a goal of approximately 360 cm^3 per 24 hours. CT scans were obtained at regular intervals, averaging one imaging study every two days. All patients were followed until replacement of their cranial bone flaps or placement of a synthetic cranioplasty. No patient was lost to follow-up.

We determined the presence and resolution of extra-axial collections after review of CT scans. There is no established guideline to define the minimum thickness or volume of these extra-axial collections, so we therefore defined them as fluid collections exerting mass effect, greater than 5 mm in thickness.[22] The appearance of these collections on CT scans had densities consistent with CSF, in order to exclude post-operative hematomas. Resolution of the collections was defined as the time to the first CT scan showing disappearance of the fluid.

Any patient who did not survive past the third POD was excluded from further analysis, as in our experience it takes at least three days for collections to occur. It is possible that these collections do not appear within the first three POD because we generally place subgaleal drains for two to three days following DC. There were five deaths (four TBI and one stroke) in our cohort prior to or on the third postoperative day, yielding a total of 34 patients for further analysis.

3. Results

Our results help illustrate the previously undefined entity which we have chosen to identify as Craniectomy-associated Progressive Extra-Axial Collections with Treated Hydrocephalus (CAPECTH). This name describes a clinical entity where extra-axial CSF collections occur in the presence of hydrocephalus treated actively with external ventricular drainage (EVD). Furthermore, the extra-axial CSF collections present with a clinically aggressive course and the development of mass effect on underlying brain structures.

Of the 34 patients who underwent DC, their diagnoses were: TBI in 14 patients, malignant middle cerebral artery infarction in 11 patients, aneurysmal SAH in seven patients, and tumor-associated cerebral edema in two patients. Analysis of the entire cohort demonstrated that 21/34 (62%) patients developed extra-axial collections after DC, but only 18 of the 21 had an EVD in place and would fit the criteria for CAPECTH (Table 1). These patients averaged approximately 10 to 15 cm^3 of CSF drainage per hour. ICP control was not a significant issue in any of the patients with the combination of a DC and aggressive CSF drainage. There were transient ICP spikes above 20 mmHg in five patients, but no episode was sustained for over 10 minutes. This raises the issue of the meaning of ICP readings for patients with DC, but given these limitations, none of our patients had problems with ICP control. Since the patients with strokes and tumors did not have evidence of hydrocephalus, they were not included in the final analysis. Seven of seven patients (100%) with SAH, and 11 of 14 (79%) with TBI developed these collections despite ventricular drainage. When combined, 18/21 (86%) patients with either SAH or TBI developed extra-axial collections. A detailed list of characteristics, cause, progression and resolution of those 18 patients is presented in Table 2.

Table 1
Incidence of Craniectomy-Associated Progressive Extra-axial Collections with Treated Hydrocephalus (CAPECTH)

Diagnosis	No. of patients	Incidence of CAPECTH (%)
TBI	14	11/14 (79)
SAH	7	7/7 (100)
Ischemic stroke	11	0/11 (0)
Tumor	2	0/2 (0)

SAH = subarachnoid hemorrhage from aneurysm or arteriovenous malformation, TBI = traumatic brain injury, including subdural hematoma

3.1. Traumatic brain injury

The average age of patients in the TBI group was 41 years (range 16–79 years) with 79% male and 21% female patients. Of the 14 patients who presented with TBI, six underwent immediate surgery for removal of a subdural hematoma and the bone flap was left off to allow for brain swelling. The remaining eight patients with TBI presented with generalized cerebral edema without a mass lesion, and did not undergo immediate surgery. They received a ventriculostomy for CSF drainage and ICP monitoring as well as aggressive medical management for ICP control. Medical therapy included placing the head of the bed at 30° to maximize venous outflow from the cranium, temperature control below 36.7 °C (98 °F), sedation and use of hyperosmotic therapy (20% mannitol and/or 23.4% sodium chloride). Failure of medical therapy was considered when all of these measures were exhausted with maximal CSF drainage, mild hypothermia, maximal sedation, serum osmolarity >320 mOsm/kg, sodium of >160 meq/L, and persistently elevated ICP above 25 mmHg. The decision to operate was made by the neurosurgeon in conjunction with the critical care team. CAPECTH was observed in 11 of these 14 patients (78.5%) post-operatively.

3.2. Subarachnoid hemorrhage

In the group of patients with SAH, the average age was 52 years (range 33–65 years), with a female predominance (71%). DC was performed immediately in conjunction with aneurysm clipping in three patients. The decision to perform the DC at the same time as the aneurysm clipping was made based on the neurosurgeon's observation of the degree of cerebral edema. Four of the seven patients with SAH had the DC in a delayed fashion relative to the aneurysm clipping (on POD 4, 5, 5 and 6) secondary to intractable edema. All the patients were treated with an EVD prior to aneurysm clipping. Full medical management of elevated ICP was performed as previously described. No patient who had a DC at the time of original aneurysm clipping required further decompression. CAPECTH was observed in seven of the seven patients (100%) post-operatively.

3.3. Stroke

A total of 11 patients underwent DC for ischemic stroke (eight women and three men with an average age of 56 years [range 42–72 years]). The mean time from stroke to DC was three days