Intracranial Pressure Monitors

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KEYWORDS

• Traumatic brain injury • Intracranial pressure monitor • External ventriculostomy • Cerebrospinal fluid

KEY POINTS

- Intracranial pressure monitors are indicated in patients with severe traumatic brain injury and a Glasgow Coma Scale score between 3 and 8 or for acute hydrocephalus.
- These monitors can easily be inserted at the bedside, and these devices provide accurate measurements of intracranial pressure that can guide management and treatment plans.
- There are few major complications after placement of intracranial pressure monitors, including infection, misplaced monitor, hemorrhage, and inaccurate intracranial pressure recording over time.

Introduction

The first documented external ventriculostomy (EVD) for elevated intracranial pressure (ICP) was performed in 1744 using a wick to drain cerebrospinal fluid (CSF) after a ventricular puncture, but it was not until 1881 that the first sterile EVD was performed. By the 1950s, the overall drainage system had not significantly changed. The most common early use for ICP monitoring and CSF drainage was Reye's syndrome. EVDs are now frequently used in trauma patients with severe head injuries, patients with obstructive hydrocephalus after subarachnoid hemorrhage, large strokes, or other large structural lesions.[1–3]

ICP monitoring is considered a mainstay for the management of acute brain injury. The brain is enclosed by the skull and is a fixed container. Thus, based on the Monro-Kellie doctrine, any addition to this space, such as a hematoma, will increase ICP. Normal intracranial pressure is less than 20 to 25 mm Hg, and sustained pressures from 20 to 30 mm Hg are associated with increased mortality.[4] Most neurocritical care specialists and trauma surgeons base their medical management on maintaining cerebral perfusion pressure, which is calculated by subtracting the ICP from the mean arterial pressure.[5,6] Several studies have shown that close ICP monitoring leads to either medical or surgical interventions, resulting in decreased mortality.[7,8]

About 50% of patients with severe traumatic brain injury and abnormal computed tomography (CT) scans have elevated intracranial pressure; thus, the most recent set of Brain Trauma Foundation guidelines recommends ICP monitor placement in any patient with a severe head injury who has an abnormal CT scan. These patients are defined as having a Glasgow Coma Scale score of 3 to 8 after adequate cardiopulmonary resuscitation. Abnormal CT scan findings include hematomas, contusions, and generalized edema. Additionally, there is grade 3 evidence for ICP monitor insertion in patients with a normal CT scan if the patient has at least 2 of the following criteria: (1) age greater than 40 years, (2) motor posturing, and (3) systolic blood pressure less than 90 mm Hg.[6,9–12]

ICP monitoring and CSF drainage are also commonly used in the setting of acute hydrocephalus, which may be caused by subarachnoid hemorrhage, intraventricular hemorrhage, or mass lesions. A ventriculostomy insertion allows for ICP monitoring and CSF drainage, thus alleviating intracranial pressure. Furthermore, EVDs may be useful in patients with meningitis who have hydrocephalus both for CSF drainage and antibiotic delivery.[1,2]

There are 2 basic types of ICP monitors: those that provide ICP data only (commonly referred to as a *bolt*) and those that allow for concurrent drainage of cerebrospinal fluid while measuring ICP (external ventriculostomy or intraventricular catheter). Monitors that drain CSF detect changes in pressure based on flow through a fluid-filled system and are most accurate when the system is closed to drainage. The combination of a ventriculostomy with a closed drainage system is also known as an external ventricular drain or EVD. Bolts use fiberoptic technology that allows for continuous ICP monitoring without CSF drainage. The fiberoptic type of catheter can be placed in the subdural space or in the brain parenchyma, whereas the EVD is not accurate unless it is located in the intraventricular space.

The external drainage catheter is a cerebrospinal fluid diversion device that also measures intracranial pressure. The catheter tubing is translucent with depth markings and contains a radiopaque barium sulfite strip. ICP readings are based on a fluid-filled transduction system that transmits changes in intracranial pressure through a saline-filled tube to a diaphragm on a strain gauge transducer.[6,13,14] This monitor must be leveled with the Foreman of Monro (approximately the level of the external auditory canal) after insertion and should be zero balanced daily. The level of the drain can be adjusted to allow more or less CSF drainage. These monitors can be left in place for several days, but most manufacturers recommend replacing the fiberoptic monitors after about 5 days to ensure accurate ICP readings. ICP monitors can be removed easily at the bedside, and the entry point is closed with sutures to prevent CSF leaks.

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Surgical technique

Preoperative planning

All patients should have a CT scan of their head before placement of an ICP monitor. CT scans allow the surgeon to decide which monitor to place, where to place the monitor, and whether their insertion point needs to be adjusted for midline shift, hematomas, or other mass lesions. Preoperative laboratory tests should include coagulation studies such as prothrombin time, partial thromboplastin time, and international normalized ratio. Many patients with head injuries have a coagulopathy, and the abnormal results should be corrected before insertion of any type of ICP monitor.[15]

Preparation and patient positioning

ICP monitors are commonly inserted at the bedside in either the intensive care unit or in the emergency department. The patient is positioned with the vertex of their head at the edge of the bed in the neutral position. The hair on the side of the head to be used (most commonly the right side) is clipped and cleaned with chlorhexidine or any other available sterile cleaner. Most hospitals carry cranial access kits containing all the necessary supplies for ICP monitor insertion. If not, one will need:

- Sterile drapes
- Sterile 4 × 4s
- Sterile saline flushes
- Number 10 blade scalpel
- Number 11 blade scalpel
- Small self-retaining retractor
- Hand-held twist drill
- Ventricular catheter and drainage system
- 3-0 nylon sutures
- Sterile 4 × 4 and tegaderm for dressing

Surgical approach

External ventriculostomies are traditionally inserted at Kocher's point on the right side. After the hair is clipped, a ruler is used to measure 10 cm from the nasion along the midline. From this point, one should measure 3 cm laterally, which is approximately the midpupillary line. A linear incision approximately 1.5 to 2 cm is then planned at this point. A line marking the medial canthus and the external auditory meatus can be marked at Kocher's point to help guide the trajectory of the catheter once the patient is draped.[16]

Surgical procedure

1. After the incision has been planned as described above, the skin is prepared around the proposed incision site. The skin preparation should also incorporate 2 to 3 cm around the incision to allow a sterile exit site for the catheter.
2. The surgical site is then sterilely draped.
3. The incision is injected with a local anesthetic such as 1% lidocaine. Note this step should be skipped if there is concern for a dural breach, as lidocaine can potentiate seizure activity.
4. The incision is then opened down the skull with a number 10 blade scalpel.
5. The blade should be protected, and the reverse end can be used to remove the periosteum.
6. A self-retaining retractor is inserted.
7. A hand-held twist drill is included in most ICP monitoring kits and is used to drill a hole through the skull. Before use, a drill stop, which is included in the kit, should be secured in place to prevent the drill bit from plunging through the dura into the brain.
8. The bony fragments should be irrigated from the field before dural opening.
9. The dura is then incised in a cruciate fashion using a number 11 blade scalpel.
10. At this point, the catheter should be passed with the stylet in place. The tip of the catheter should be perpendicular to the brain surface and in line with the medial canthus line and the external auditory meatus. The catheter is advanced until spontaneous CSF flow is visualized in the tube (approximately 5—7 cm depth).
11. The stylet is then removed and the distal catheter end attached to the trocar.
12. The catheter is then tunneled posteriorly and laterally about 2 cm under the skin and the trocar removed. Spontaneous CSF flow from the drain should be confirmed.
13. The end of the drain is then capped and the catheter secured to the skin at the exit site using 3 to 0 nylon suture. Additional anchoring sutures along the length of the catheter are helpful to ensure the catheter is not accidentally pulled out.
14. The incision is then closed with 3 to 0 nylon suture and a sterile dressing is placed over the incision and catheter exit site.
15. The catheter should then be sterilely attached to the drainage bag, and an opening ICP can be obtained by clamping the system. A good pressure waveform confirms proper catheter positioning; however, a postprocedure CT scan is recommended to verify proper catheter position.

When inserting a fiberoptic ICP monitor, steps 1 to 10 are followed as described above; however, the location of the bur hole does not necessarily need to be at Kocher's point and is more accurate if placed in normal brain parenchyma. The monitor must also be zero balanced before inserting it into the brain parenchyma.

Caveats/potential complications

The 2 most common complications associated with insertion of all types of intracranial pressure monitors include infection and hemorrhage. Despite use of sterile technique during insertion, the risk of meningitis and wound infection ranges from 1% to 27% and is more common with external ventriculostomy insertion. Fiberoptic monitors have a lower risk of infection ranging from 0% to 1.7%.[6,7,15,17] Most infections are caused by gram-positive organisms such as *Staphylococcus* species.

All surgical procedures are associated with a risk of hemorrhage. Patients who undergo ICP monitor insertion may subsequently get an intraparenchymal hematoma surrounding the catheter trajectory or subdural hematomas. The rate of hemorrhage varies by type of ICP monitor; subdural monitors are associated with an approximately 5% rate of hemorrhage, although there is a 4% and 1.1% risk with intraparenchymal and ventricular catheters, respectively.