Continuous Intracranial Pressure Monitoring in Patients with Brain Injury: Technique and Application*

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In 1971, a twist drill technique for measuring intracranial pressure (ICP) in patients with severe brain injuries was introduced at the Medical College of Virginia (1). Shortly thereafter continuous ICP monitoring utilizing the ventricular catheter technique of Lundberg was begun (2). It rapidly became evident that knowledge of the ICP in this group of patients speeded definitive diagnosis, provided an early warning of developing mass lesions before clinical signs appeared, and provided an objective assessment of therapy directed against brain edema; however, continuous monitoring by the Lundberg technique was cumbersome to perform and carried a significant risk of meningitis. In 1972, a new method of monitoring ICP was developed at our institution (3). The new method was based on the establishment of a fluid connection with the cerebral subarachnoid space by means of a special hollow screw. The technique proved much simpler and safer than the Lundberg technique. The development of this technique combined with the completion of a seven-bed neurosurgical intensive care unit extended ICP monitoring to all patients at our institution with significant head injuries. The morbidity and mortality for severe head injury have steadily declined as the scope of patient monitoring has increased over the last three years. We now consider ICP monitoring an essential part of head injury management.

Methods. Head injury patients are divided into 3 categories upon arrival at the emergency room based on their level of consciousness. Patients who are comatose upon arrival or patients with whom no verbal communication can be established are designated as severe (grade 3). Patients who are lethargic, but with whom verbal communication can be established, are classified as moderate (grade 2). Patients who are fully awake are classified as mild (grade 1). The presence of any focal neurologic signs increases the severity by one grade.

Grade 3 patients have an immediate twist drill ICP measurement. A twist drill hole three-sixteenths of an inch in diameter is made at the level of the coronal suture under local anesthesia. A ventricular tap is then performed with an 18 gauge blunt ventricular needle. ICP is measured by connecting the needle to a water manometer. After obtaining the ICP, 5–10 cc of air are exchanged into the ventricles and a brow-up ventriculogram is obtained to assess shift of the midline structures. Further management of these patients is based on the results of this examination. If the ICP is greater than 10 mm Hg and the midline structures are shifted, the patient is given 1 gm/kg of mannitol and is taken to the operating room for an exploratory craniotomy. If the ICP is greater than 10 mm Hg and the midline structures are not shifted, the patient is taken to the angiographic suite for angiography. If the ICP is below 10 mm Hg and the midline structures are not shifted, the patient is taken to the intensive care unit and an elective angiogram is obtained. Continuous ICP monitoring

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is performed on all grade 3 patients after they arrive at the intensive care unit.

Grade 2 patients are taken to the angiographic suite for immediate angiography. If a surgical mass lesion is discovered, the patient receives 1 gm/kg of mannitol and is taken to the operating room for a craniotomy. If no surgical mass lesion is found, the patient is taken to the intensive care unit. Continuous ICP monitoring is performed in all grade 2 patients after they arrive at the intensive care unit.

Grade 1 patients are admitted for close observation. If any clinical deterioration is noted, they are managed like grade 2 patients.

Continuous ICP monitoring is performed by means of a special hollow screw which permits fluid contact to be made with the cerebral arachnoid space. The screw is shown in Figure 1. The screw is inserted by threading it into the skull through a one-fourth-inch twist drill hole, after the dura has been removed with a small angled curette under direct vision. This is illustrated in Figure 2. ICP is monitored by connecting the lumen of the screw to a transducer by means of saline-filled tubing. The screw is shown in place in the x-ray of a postoperative patient in Figure 3. A typical ICP record, along with the blood pressure, central venous pressure, and EKG, is shown in Figure 4. The ICP is displayed at each bedside on a wall mounted oscilloscope, and it is written out at a central station on a strip chart for a permanent record.

A maximum effort is made in grade 3 patients, after they arrive at the intensive care unit, to keep the important systemic physiologic parameters within normal ranges. All patients in this grade are placed on a regimen of thorazine, 25 mg IM every 6 hours, to help accomplish this. All patients in this category have endotracheal tubes or tracheostomies. They are placed on volume respirators and nursed in the level position on heat exchange mattresses. On this regimen, blood pressure can usually be adjusted by raising or lowering the head of the bed, blood gases and pH can be regulated by adjusting the respirator, and the temperature is easily regulated with the heat exchange mattress.

Patients who have progressive brain edema, manifested by a steadily rising ICP after correction of any systemic abnormalities, in whom surgical mass lesion has been ruled out angiographically, are treated with ventriculostomy drainage and hyperventilation to a P_{CO_2} of 25 mm/Hg. If this fails to control the ICP, the patient is cooled to 30°C. If ICP still cannot be controlled, a mannitol infusion at a rate of

Fig. 1

0.1–0.3 gm/kg/hr is begun provided the serum osmolarity does not exceed 320 mOsm/L (4).

Results. In 1973, twist drill ICP measurement and ventriculogram were used in 96 grade 3 head trauma patients to establish a working diagnosis. On only one occasion was there failure to tap the ventricle. There were no recognizable complications related to the procedure. The average time required to perform the procedure was 10–15 minutes including the taking of x-rays. Fifty-eight of the 96 patients had elevated ICP and a shift of the ventricular system. All 58 patients had a surgical mass lesion confirmed at operation. Eleven patients had normal ICP and a midline ventricular system. None of these patients developed a surgical mass lesion. Twenty-seven

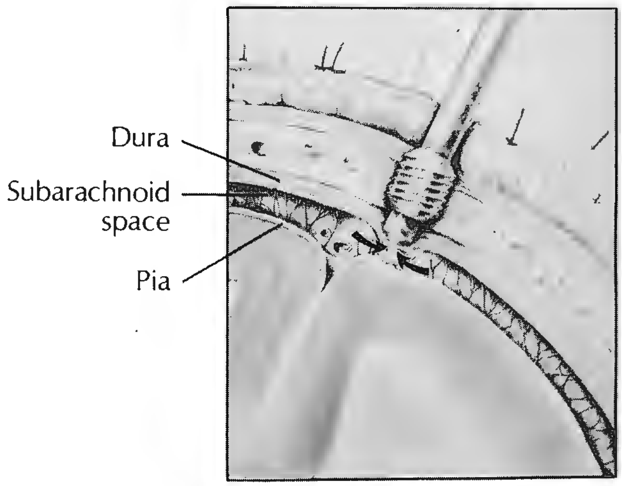

Fig. 2

Fig. 3

patients had elevated ICP and a midline ventricular system. Twenty-six of the 27 did not have surgical mass lesions by angiography. One patient in this group had an acute subdural hematoma on one side and a brain contusion with edema on the other side, giving him elevated ICP but a midline ventricular system.

Since November 1972, ICP monitoring using the hollow screw technique has been performed 161 times. It has been performed 102 times for head trauma. In the vast majority of cases, a satisfactory recording of the ICP has been obtained, manifested by a good wave form on the oscilloscope trace. The average patient was monitored for seven days. The complications to date consist of four patients with superficial scalp infections, requiring local debridement, one CSF leak, requiring revision of a scalp incision, and one subdural hematoma, which occurred in a patient who developed a bleeding disorder after insertion of the monitor.

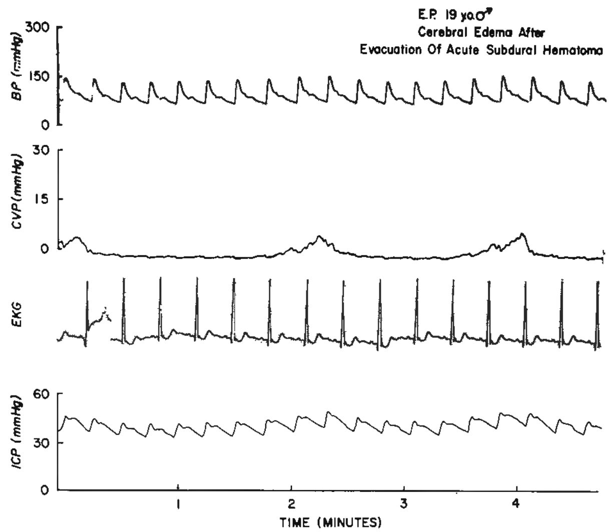

Fig. 4

The ICP monitor provided warning of developing mass lesions in all cases where such lesions developed. Even though grade 3 patients were heavily sedated, which tended to obscure the clinical picture, no case of unsuspected mass lesion occurred. The use of high doses of morphine and thorazine made the management of the group 3 patients much easier. Problems of temperature control, severe hyperventilation on a neurogenic basis, and erratic blood pressure swings, for the most part, were eliminated. With improved control of systemic physiologic parameters, the need to resort to special regimens for the control of progressively increasing intracranial pressure was obviated. In 1972, 18 of these regimens were employed. In 1973, only one regimen was employed, even though more grade 3 patients were seen in 1973 than in 1972.

Discussion. Twist drill ICP measurement and ventriculogram appear to significantly speed the definitive diagnosis and treatment of severe head injury patients in the emergency room. The procedure had a high accuracy for differentiating between surgical and nonsurgical mass lesion. It can be accomplished in 10–15 minutes, which is much faster than an angiogram under the best of circumstances. It is easy to perform in the patient with multiple trauma, because it does not require that the patient be moved or transported to an angiographic suite. Moreover, in some grade 3 patients, it is safer because it does not require the degree of patient restraint and positioning that an angiogram requires which may produce jugular compression, or airway obstruction.

Continuous ICP monitoring using the hollow screw technique has proven itself simple, safe, and reliable. The obvious advantage of continuous ICP monitoring is to provide early warning of developing mass lesions before clinical signs appear and to assess the effectiveness of therapy directed at brain edema. Its most important use, however, may be that it permits the use of depressant medications in these patients. Many of these patients have a marked tendency toward hyperthermia, severe hyperventilation, and erratic blood pressure swings. These tendencies can be most difficult to control with conventional treatment regimens. By sedating these patients, however, it is easy to override these tendencies with a respirator, a simple heat exchange mattress, and patient positioning. In many of these patients, all of the intracranial compensatory mechanisms for the maintenance of brain metabolism have been maximally taxed. These patients cannot tolerate the additional stress of disordered systemic physiology. At the present time, we try to hold our severe head injury patients within the following physiologic limits: cerebral perfusion pressure (blood pressure-intracranial pressure) 75 mm Hg ± 10 mm Hg; P_{O_2} 85 mm Hg ± 15 mm Hg; P_{CO_2} 30 mm Hg ± 5 mm Hg; pH 7.4 ± 0.1; temperature 37° C ± 1° C; sodium 140 ± 5; hematocrit 35 ± 5. Our preliminary data seem to indicate that if this is accomplished and if it is combined with rapid diagnosis and treatment of surgical mass lesions, most cases of progressive brain swelling can be prevented. At the present time, a prospective study of this regimen in head injury patients is underway at the Medical College of Virginia.

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