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ScienceDirect
Journal of Clinical Neuroscience 16 (2009) 237–241
Journal of Clinical Neuroscience
www.elsevier.com/locate/jocn

Clinical Study

Risk factors and complications of intracranial pressure monitoring with a fiberoptic device

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Received 16 October 2007; accepted 12 February 2008

Abstract

We prospectively investigated the complications associated with intraparenchymal intracranial pressure (ICP) monitoring using the Camino intracranial pressure device. A fiberoptic ICP monitoring transducer was implanted in 631 patients. About half of the patients ($n = 303$) also received an external ventricular drainage set (EVDS). The durations (mean ± SD) of ICP monitoring in patients without and with an EVDS were 6.5 ± 4.4 and 7.3 ± 5.1 days, respectively. Infection occurred in 6 patients with only an ICP transducer (6/328, 1.8%) and 24 patients with an EVDS also (24/303, 7.9%). The duration of monitoring had no effect on infection, whereas the use of an EVDS for more than 9 days increased infection risk by 5.11 times. Other complications included transducer disconnection (2.37%), epidural hematoma (0.47%), contusion (0.47%), defective probe (0.31%), broken transducer (0.31%), dislocation of the fixation screw (0.15%), and intraparenchymal hematoma (0.15%). In conclusion, intraparenchymal ICP monitoring systems can be safely used in patients who either have, or are at risk of developing, increased ICP.

Keywords: Complications; Fiberoptic device; Intracranial pressure; Monitoring

1. Introduction

Increased intracranial pressure (ICP) is an important predictive factor that affects patient mortality and morbidity.[1,2] Continuous ICP monitoring is routinely used in the management of neurosurgical patients at risk of intracranial hypertension.[3] Monitoring ICP values in aggressively-treated head trauma and neurologic patients has been shown to improve recovery rates.[4–7]

A variety of monitoring techniques and devices are available, each with advantages and disadvantages.[8–12] A ventricular catheter connected to an external strain gauge, the "gold standard" of ICP monitoring, is the most common system.[13] A fiberoptic probe containing a transducer in the tip, developed by Camino Laboratories (San Diego, CA, USA), has been available since 1985 for use as a parenchymal, subdural, or ventricular ICP monitor, although it is most frequently used as a parenchymal ICP monitoring system.[14] Several studies have evaluated complication rates, as well as the accuracy and handling characteristics of the Camino fiberoptic system.[14–17] ICP monitoring using the Camino system is regarded as highly accurate with a low incidence of complications (e.g. infection, dislocation, breakage of the fiberoptic system). However, these studies had small sample sizes or short observation periods. Here, we prospectively evaluated the complications and risk factors for intraparenchymal ICP monitoring with a large number of patients.

2. Methods

2.1. Study population

A total of 631 patients admitted between January 1996 and December 2006 to the Department of Neurosurgery

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doi:10.1016/j.jocn.2008.02.008

were included in this study. Patients had different intracranial pathologies and underwent ICP monitoring with a Camino fiberoptic device as part of their management. In addition, an external ventricular drainage set (EVDS; Medtronic, CA, USA) was inserted in 303/631 patients (48%).

2.2. EVDS and ICP monitoring procedures

The ICP transducer was inserted while patients were under local anesthesia in the operating room or at the bedside in the intensive care unit (ICU). Continuous monitoring of ICP was then performed. The transducers were replaced in case of any complications or surgical intervention. The transducer was introduced at a point 10 cm posterior to the glabella and 3 cm lateral to the midline on the left or right site, depending on which hemisphere was more severely affected. The same point on the right or left frontal area was used for patients who required EVDS application. Patients' hair, which was not cut, was scrubbed gently for 8 min to 10 min using a 10% povidone-iodine solution diluted 50:50 with water. The area was then dried with a sterile towel and washed a second time with 10% povidone-iodine solution (Isosol, Merkez Lab, İlaç San, İstanbul, Turkey).

The EVDS (Medtronic, CA, USA) was inserted with an initial ICP of over 20 mmHg. ICP monitoring was performed with the Camino fiberoptic device. All patients with an EVDS were treated according to the following standardized protocol.[22] The cerebrospinal fluid (CSF) was drained until the ICP fell below 20 mmHg. EVDSs were removed when the ICP decreased to below 20 mmHg for 24 hours; however, ICP monitoring was continued. All patients who had intracerebral hematoma or subarachnoid hemorrhage were routinely administrated corticosteroid agent intravenously.

No prophylactic antibiotics were used in patients who underwent only ICP monitoring; however, patients who also had an EVDS received a single dose of 1.5 g intravenous cefuroxime acetyl. For all patients with an EVDS, CSF samples were obtained during the insertion procedure for direct microscopy and for culture. Inspection and disinfection of the insertion sites were carried out daily. CSF was collected from the EVDS twice per week for culture. In cases of fever or elevated white blood cell counts in patients who had only an ICP transducer, CSF samples were taken by lumbar puncture every day, except in patients with serious ICP intracranial mass effect. During EVDS withdrawal, second samples were obtained for direct microscopy and culture. The distal portion of the EVDS was sent for a culture antibiogram.

Contraindications for ICP monitoring included a thrombocyte count below 100,000/mm^3, prior anticoagulant therapy, or pathological immune suppression. In all patients, intracranial bleeding complications related to transducer insertion were routinely confirmed within 24 hours after admission to the hospital or when clinically indicated (e.g. worsening of the pupillary status or reduced Glasgow Coma Scale [GCS] score). These patients were evaluated by cranial CT. Complications in continuous monitoring such as a dislocated transducer or bolt, a broken fiberoptic cable, or a monitor-related infection (e.g. meningitis, wound infection) were noted.

2.3. Statistics

Logistic regression analysis, a Mann-Whitney *U*-test, and receiver operating characteristic (ROC) analysis were used to statistically compare patients with ICP transducers with and without an EVDS. A p-value of < 0.05 was considered significant.

3. Results

3.1. Patient characteristics

The patient population consisted of 439 males and 192 females with a mean age (± standard deviation, SD) of 42.8 ± 20.9 years (range, 1–94). Upon admission to the hospital, the average GCS score was 7.2 ± 2.7 (range, 1–15). The leading causes of ICP monitoring were trauma (303/631, 48.1%) and intracerebral hemorrhage (170/631, 26.9%) (Table 1).

The 328 patients (52.0%) who received only an intraparenchymal fiberoptic ICP monitoring transducer were followed for an average of 6.5 ± 4.4 days (range, 1–32). Similarly, the 303 patients (48.0%) who also received an EVDS for CSF drainage were followed for 7.3 ± 5.1 days (range, 1–28).

3.2. Complications

ICP monitoring complications included dislocation, breakage of the fiberoptic cable, monitor-related infection, and intracranial hemorrhage (Table 2). The ICP transducer was inserted into the brain parenchyma in all patients without any technical problems. Monitor-related bleeding complications occurred in 7 cases (1.1%), with 3 cases of epidural hematoma (0.47%), 3 cases of contusion (0.47%), and 1 case of intraparenchymal hematoma (0.15%). In 2 patients, the epidural hematomas were evacuated surgically. Technical complications included disconnection of the transducer in 15 patients (2.37%), breakage of the fiberoptic cable in 2 patients (0.31%), dislocation of the fixation screw in 1 patient (0.15%), and probe defects

Table 1
Intracranial pathologies of patients

Diagnosis	*n*	%
Traumatic head injury	303	48.1
Intracerebral hematoma	170	26.9
Aneurysmal subarachnoid hemorrhage	108	17.1
Other	50	7.9
Total	631	100

Table 2
Complications associated with ICP monitoring

Complication	*n*	%
Infections		
Meningitis	6	4.75
Technical complications		
Disconnection of the transducer	15	2.37
Breakage of the fiberoptic cable	2	0.31
Dislocation of the fixation screw	1	0.15
Probe defective for unknown reason	2	0.31
Bleeding complications		
Epidural hematoma	3	0.47
Contusion	3	0.47
Intracerebral hematoma	1	0.15
Total	58	9.19

ICP = intracranial pressure.

of unknown cause in 2 patients (0.31%). These complications occurred during nursing maneuvers, transport to the radiological unit, or patient activity in bed. Monitor-related infections were recorded in 30 patients (4.75%). Of the 328 patients who had only the ICP transducer, 6 (2.1%) developed infection. In the EVDS group, 24 out of 303 patients (7.9%) developed infection (see Table 4).

Twenty-nine of the 30 infected patients had positive CSF cultures after removal of the fiberoptic catheter. Although the fiberoptic devices were removed aseptically, there was a possibility of contamination. For this reason, management of infections in this study depended upon positive CSF cultures. The most commonly isolated organism was *Staphylococcus epidermidis*, present in 15 patients (Table 3). Interestingly, when patients with the ICP transducer with and without infection were compared according to mean duration of ICP transducer placement, there was no difference between the 2 groups (Table 4). However,

Table 3
Causative infectious agents

Microorganism	*n*	%
Coagulase-negative staphylococcus	15	50
Coagulase-positive staphylococcus	7	23.4
Acinetobacter baumannii	6	20
Pseudomonas aeruginosa	1	3.3
No bacteria isolated	1	3.3

Table 4
Infection rates and ICP monitoring durations in patients with and without an EVDS

Experimental group	*n*	%	No. of infections	%	Monitoring duration (days)		
					Mean	Min	Max
ICP transducer	328	52	6	2.1	6.31	1	32
ICP transducer and EVDS	303	48	24	7.9	7.33	1	28

ICP = intracranial pressure, EVDS = external ventricular drainage set, Min = minimum, Max = maximum.

Table 5
Risk factors for 30 infected patients with an ICP transducer with and without an EVDS

Experimental group	Risk factors	*n*	%
ICP transducer	Rhinorrhea	2	6.6
	CSF leakage and collection in the wound area	3	10
	Operation for intracerebral hematoma	3	10
ICP transducer and EVDS	Rhinorrhea	2	6.6
	CSF leakage and collection in the wound area	2	6.6
	Operation for intracerebral hematoma	14	46.7
	Manipulation due to obstruction	1	3.4
	More than 1 VDS	3	10

ICP = intracranial pressure, EVDS = external ventricular drainage set, VDS = ventricular drainage set.

use of the EVDS for more than 9 days increased infection risk by 5.11 times ($p < 0.001$). In the 374 patients who underwent ICP transducer and/or EVDS placement in the operating room, 20 (5.34%) developed infection, whereas 11 (4.28%) of the 257 patients undergoing these procedures in the ICU developed infection ($p > 0.05$). The risk factors for complication are presented in Table 5.

4. Discussion

Guillaume and Janny performed the first intracranial pressure measurements in 1951.[18] Nine years later, Lundberg reported continuous monitoring of ICP using an intraventricular catheter in 130 neurological patients.[19] ICP monitoring provides important data for patients with an increased risk of high ICP, especially head trauma patients and thus ICP monitoring is now a standard procedure.[1,2,20,21] Patients with severe or moderate head trauma, coma due to subarachnoid or intracerebral hematoma, Reye's syndrome, and toxic metabolic encephalopathy are candidates for ICP monitoring.[2,4,6,8,9,19,21–23] Patients with GCS scores $\leqslant 8$ should be considered for this procedure. In our department, these patients undergo ICP monitoring routinely.

There are few contraindications for ICP monitoring. Monitoring should be postponed until prothrombine and partial thromboplastine time is normal or platelet count is over 100,000 in patients with coagulopathy.[19,24,25] Bleeding time and platelet count should be considered in patients with unexplained hemorrhages.[4] ICP monitoring is not suitable for pathologically or iatrogenically immune-suppressed patients since they are at high risk of infection. ICP monitoring also has risks in patients with open depressed fractures and CSF fistula.

None of the ICP monitoring techniques is ideal, since each is associated with advantages and disadvantages. Subarachnoid screws and bolts are simple, easy-to-use, and cheap. They do not require ventricular puncture and have low complication rates. However, they are associated with

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a high risk of local wound infection. As the duration of ICP monitoring increases, the reliability decreases and the likelihood that the transducer will become occluded with brain parenchyma increases.[25–27] The main problems with epidural and subdural systems are reliability and calibration because measurements can change with head movements.[28] Moreover, placement of these systems is difficult.[10,27] Ventricular monitoring systems are generally placed into the non-dominant frontal lobe. Although infection risk is high, these systems allow for CSF drainage. Fiberoptic intraparenchymal monitoring systems give accurate data, are easy to place, can be disconnected without the need for calibration during patient transport, and have a low complication rate. Disadvantages include the need for a ventriculostomy catheter in patients requiring CSF drainage, the cost, and that they can be broken easily. Another disadvantage is that these systems cannot be calibrated daily, and have to be re-placed after calibration.[29] The biggest advantage of ventricular catheters with fiberoptic transducers is their ability to provide CSF drainage along with ICP monitoring. The disadvantages of these transducers are their high infection rate and the difficulty of placement in cases with slit ventricles and midline shift.[19] Technical complications for parenchymal and ventricular catheters occur in 26% and 16% of cases, respectively, and no statistically significant difference has been found between them. In developing countries, ventricular catheters are preferred for monitoring in children due to their low cost and ability to allow CSF drainage.[14,30,31]

Infection, such as local skin infection, osteomyelitis, meningitis, ventriculitis, encephalitis, amphyema, abscess, or any combination of these, is the most common complication associated with the use of parenchymal and ventricular catheters.[19,28,32–34] Although the reported infection rates range from 0% to 22%, the infection risk associated with ventricular catheters is much greater than that for parenchymal ones. Factors that increase the risk of infection in intraventricular monitoring are increased duration of monitoring, steroid use, and accompanying ventricular catheterization in trauma patients with open depressed fractures.[32,33,35–37] In the present study, 6 patients undergoing only intraparenchymal monitoring had infections (1, rhinorrhea; 3, wound area infection accompanied by CSF leakage and collection; 2, intracerebral hematoma).

Placement of the ICP monitor is controversial. Clark et al. recommend that this procedure be performed in the operating room since serious complications can arise, in some cases necessitating transfer to ICU.[22] However, Diaz and colleagues did not find any statistically significant difference in the infection rates associated with this procedure performed in the emergency room, ICU, or operating room.[38] In accord with these findings, we did not find any significant difference in the infection rates associated with procedures performed in the ICU and the operating room. Nevertheless, we prefer to place monitors in the ICU if the monitor has not been placed post-operatively.

In the case of ventricular catheters, the duration of monitoring is closely related to infection risk. Although infection rate is minimal if monitoring lasts less than 3 days, infection rate gradually increases after the 5th day.[19,28,33,37,39] In contrast, parenchymal catheters may remain as long as monitoring is needed. Ventricular catheters are generally changed 5 days after their placement, although placement of shunts or continued use of the same ventricular catheter have been proposed.[22,30,35,40,41] In our preliminary study, there was no infection during ICP monitoring of 20 patients, but infection did occur during monitoring for 3 of 55 patients who also received an EVDS.[35] In the present study, the mean duration of ICP monitoring was 6.5 days for all patients who underwent ICP monitoring only, and 6.3 days for the 6 patients with infection, and there was no statistically significant association between duration of catheter use and infection risk. The presence of risk factors such as rhinorrhea and wound infection were the likely causes of infection. Thus, we recommend continuing monitoring for as long as needed.

Although infection is clearly a complication of EVDS use, there is still debate on prophylactic antibiotic use. We do not routinely use prophylactic antibiotics in patients undergoing ICP monitoring, but 1.5 g cefuroxime acetyl is used in patients who also undergo EVDS placement. Prabhu and coworkers extensively reviewed the use of prophylactic antibiotics in patients undergoing ICP monitoring.[42] Appropriate indications for prophylactic antibiotics have yet to be clearly established, but this remains important as the indiscriminate use of antibiotics can theoretically result in infection from resistant organisms, anaphylactic reactions, increased bleeding time, and systemic toxicity.[43] Normal bacterial skin flora frequently cause infection. In this study, infection was caused by, in decreasing frequency, coagulase-negative staphylococci, coagulase-positive staphylococci, *Acinetobacter baumannii* and *Pseudomonas aeruginosa*, which is consistent with most infections being derived from skin flora.

The most frequent complication, aside from infection, was disconnection of the transducer. This complication, only rarely reported, generally occurs during patient transport and care.[11,39] Education of nurses and other medical staff about this device would be expected to decrease such complication rates. Hemorrhage, which occurs during penetration of the catheter into the brain, is an another complication.[21] In our study only 7 patients (1.1%) had a hemorrhage (1 intracerebral hematoma, 3 with contusion, 3 with epidural hematoma). Two of these patients underwent an operation, and there was no mortality or morbidity.

In summary, ICP monitoring can be applied as a safe diagnostic and treatment approach for the management of patients either with or being at risk of developing high ICP so that secondary insults can be prevented. The complication risks are minimal, and infection can be decreased with precise cleaning of the surgical area.

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