Intracranial pressure monitoring after elective intracranial surgery

A retrospective study of 514 consecutive patients

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A retrospective study of 514 consecutive patients whose intracranial pressure (ICP) was monitored after elective supratentorial or infratentorial surgery is reported. Of the 412 patients operated on in the supratentorial region, 76 (18.4%) had a postoperative sustained ICP elevation exceeding 20 torr. Abnormally high ICP occurred after 13 (12.7%) of the 102 infratentorial operations. Risk factors for postoperative ICP elevation were: resection of glioblastoma in 27.2% of cases, repeat surgery in 42.9% of cases, and protracted surgery (>6 hours) in 41.7% of cases. Of the 89 patients with elevated ICP, 47 (52.8%) had an associated clinical deterioration. In 19 of these, the rise in ICP occurred before this deterioration was noticed, leading as a rule to quick diagnostic and management response. In eight patients clinical deterioration was noticed before the rise in ICP, and in 20 it happened simultaneously. The higher the level of ICP elevation, the greater were the chances of associated deterioration.

The most common findings on computerized tomography scanning in 35 of the 89 patients with elevated ICP were brain edema (19 cases) and bleeding in the tumor bed (15 cases). Mannitol, thiopental, additional hyperventilation, and reintubation (in patients who were previously extubated) were used to reduce ICP, in addition to surgical decompression whenever indicated. Thirteen patients with raised ICP and clinical deterioration underwent reoperation.

The postoperative infection rate was 1.2% (six cases). In only one patient could infection be attributed to ICP monitoring. It was concluded that ICP monitoring is advantageous in the immediate postoperative management after elective intracranial surgery and is almost risk-free. It should therefore be used liberally, especially when risk factors for ICP elevation can be identified prior to the end of surgery.

KEY WORDS • brain neoplasm • intracranial pressure monitoring • elective neurosurgery • postoperative complication

While intracranial pressure (ICP) monitoring is considered by many to be mandatory in the management of severe head trauma, controversy exists regarding the indications for its use after elective cranial surgery. The controversy is based on considerations related to the balance between the benefits that may be associated with the use of ICP monitoring and the possible risks (primarily infection).

This present study was undertaken to answer several questions that pertain to the benefits and risks of ICP monitoring after elective intracranial surgery. Which intracranial procedures are most likely to be associated with postoperative intracranial hypertension? How sensitive is ICP monitoring in detecting clinically relevant neurological deterioration in the immediate postoperative period? What are the consequent alterations in management of patients following detection of ICP elevation, and what is the immediate fate of these patients? Finally, what are the risks of ICP monitoring?

The aim of this retrospective study was to formulate an optimal policy for postoperative ICP monitoring following elective cranial surgery based on the answers to the preceding questions.

Clinical Material and Methods

This study comprised 514 consecutive patients who underwent an elective supra- or infratentorial cranial...
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operation between 1980 and 1986. Only those patients who had received ventriculostomies, ventriculoperitoneal shunts, or other cerebrospinal fluid (CSF) drainage procedures were excluded. Of the 514 patients, 412 underwent supratentorial craniotomy and 102 infratentorial craniotomy (Table 1). Among those with supratentorial craniotomies the most prevalent tumors were meningiomas and glioblastomas, while in those with tumors in the infratentorial area acoustic neurinomas, meningiomas, and astrocytomas were most frequently found.

During the period of the study it was routine procedure to leave a No. 5 French feeding catheter (with multiple distal perforations) in the ipsilateral subdural space prior to closure of the dura for ICP monitoring. It was exteriorized via a separate scalp incision. After surgery, the catheter was connected to a pressure transducer,* and the ICP was continuously recorded, zeroing the pressure at the height of the ear. A purse-string suture was left to prevent CSF leakage after the catheter was removed. Since June, 1982, all patients have received a single intraoperative dose of intravenous gentamicin (2 mg/kg) and vancomycin (10 mg/kg). All catheter tips were routinely cultured after removal. In patients without ICP elevation or significant clinical deterioration, the ICP was monitored until noon of the 1st postoperative day when the patients left the intensive care unit (ICU). The overall mean duration of ICP monitoring was 1.3 days (range 1 to 9 days).

For each of the 514 patients, data were obtained from the 24-hour flow sheets in the ICU until the ICP catheter was removed. For the purpose of this study ICP elevation was defined as a level higher than 20 torr that was sustained for at least 2 hours. Clinical deterioration was defined as a decline of at least 2 points on the Glasgow Coma Scale and/or a new sustained major focal neurological deficit. Statistical significance was obtained by calculating the p value with the binomial test.

Results

Risk Factors for Postoperative ICP Elevation

Among the 514 patients in this series, 89 (17.3%) exhibited postoperative elevation of ICP. The mean peak ICP level in these patients occurred at 16.1 ± 12.5 hours (± standard deviation) after surgery. The mean duration of ICP elevation was 28.2 ± 18.1 hours. Table 2 shows the incidence of ICP elevation in the postoperative period for the different histological tumor types. In patients with surgery in the supratentorial area, the overall incidence of ICP elevation was 18.4% (76 of 412 cases), while in those with surgery in the infratentorial area it was 12.7% (13 of 102 cases). The difference between the two areas was not statistically significant.

Operations for malignant glioma were associated with a significantly higher (p < 0.05) incidence of ICP elevation as compared to the mean incidence for the rest of the group (27.2% vs. 15.5% of cases). The occurrence of ICP elevation in 17.5% of patients undergoing operations for supratentorial meningiomas was not different from the rest of the group. When further subdivided, however, meningiomas at the base of the skull and in the parasagittal area seemed to be associated with a somewhat higher incidence of ICP elevation (21.8% of cases), but this was not statistically significant. The higher incidence of postoperative intracranial hypertension was found in cases where reoperation was required (15 of 35 cases; 42.9%) and in cases in which the patients had been subjected to prolonged surgery, defined as over 6 hours (20 of 48 cases; 41.7%). Both were found to be highly significant risk factors as compared to the rest of the group (p < 0.001).

There were no defined subgroups of either higher or lower risk for ICP elevation after infratentorial surgery.

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* Pressure transducer, Model 800, manufactured by Bentley Laboratories, Irvine, California.

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**TABLE 2**

Incidence of postoperative ICP elevation in the various histological tumor types

<table>
<thead>
<tr>
<th>Tumor Type</th>
<th>Total Cases</th>
<th>ICP Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>supratentorial region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>meningioma</td>
<td>166</td>
<td>17.5</td>
</tr>
<tr>
<td>glioblastoma</td>
<td>103</td>
<td>27.2†</td>
</tr>
<tr>
<td>low-grade astrocytoma</td>
<td>28</td>
<td>21.4</td>
</tr>
<tr>
<td>others</td>
<td>115</td>
<td>11.3</td>
</tr>
<tr>
<td>total</td>
<td>412</td>
<td>18.4</td>
</tr>
<tr>
<td>infratentorial region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>acoustic neurinoma</td>
<td>35</td>
<td>11.4</td>
</tr>
<tr>
<td>meningioma</td>
<td>18</td>
<td>5.6</td>
</tr>
<tr>
<td>astrocytoma</td>
<td>15</td>
<td>20.0</td>
</tr>
<tr>
<td>medulloblastoma</td>
<td>9</td>
<td>11.1</td>
</tr>
<tr>
<td>others</td>
<td>25</td>
<td>16.0</td>
</tr>
<tr>
<td>total</td>
<td>102</td>
<td>12.7</td>
</tr>
</tbody>
</table>

† Operations for malignant glioma had a significantly higher (p < 0.05) incidence of ICP elevation as compared to the rest of the group.
Neither the age of the patient nor the exact location of the tumor was found to influence the rate of postoperative intracranial hypertension.

ICP Elevation and Clinical Deterioration

Table 3 summarizes the relationship between ICP and clinical deterioration. Forty-two (47%) of the 89 patients with postoperative intracranial hypertension did not demonstrate any associated clinical deterioration. The 47 remaining patients (53%) in whom elevated ICP correlated with clinical deterioration can be further subdivided into three groups according to the temporal relationship between the ICP elevation and clinical deterioration. In 19 patients, ICP rose before deterioration was noticed, with a mean interval of 5.2 ± 4.0 hours. In eight patients, clinical deterioration was noticed before ICP rose (with a mean interval of 2.4 ± 1.2 hours). In 20 patients, the deterioration and ICP rise occurred simultaneously.

In 21 (4.1%) of the 514 patients, deterioration occurred without an associated elevation of ICP. In at least four of these, a computerized tomography (CT) scan was suggestive of elevated ICP; thus, 21 (30.9%) of the 68 patients who developed significant postoperative clinical deterioration had no associated rise in ICP. In 36 of the 89 patients with elevated postoperative ICP, the peak rise in pressure never exceeded 30 torr. Figure 1 suggests that the higher the rise in ICP, the more likely it is to be associated with clinical deterioration. All of the patients who exhibited intracranial hypertension of over 50 torr had an associated neurological deterioration.

Management of Patients With Elevated ICP

This retrospective study indicates that elevated ICP prompted the treating physicians to respond to that rise in 30% of the patients, even when clinical deterioration was not evident. The response rate exceeded 95% in patients who demonstrated both an elevated ICP and clinical deterioration. Of the 89 patients who had elevated ICP, 35 were promptly taken for CT scanning. In these, CT scanning was performed before clinical deterioration was noted. Brain edema and tumor-bed bleeding were the most common CT findings (Table 4). Epidural and subdural hematomas, pneumocephalus, and hydrocephalus were also found on CT scans.

Augmented hyperventilation, intravenous mannitol and Pentothal (thiopental), and reintubation in patients who were already extubated were used as medical means to reduce elevated ICP. At least some of these treatments were started before clinical deterioration was noticed (Table 5). Thirteen of the 89 patients with postoperative elevated ICP were returned to the operating room after CT scanning. In these, evacuation of tumor-bed, epidural, and subdural hematomas was the most frequent operation performed (Table 6). Ventic-
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uloperitoneal shunting, ventriculostomy, and frontal lobectomy were also performed in one case each. All of the 13 patients who were taken back to surgery already had clinical deterioration prior to reoperation. In three, however, CT scanning was carried out before clinical deterioration developed. Presumably, decision-making was faster and time delay before the second operation was minimized (see illustrative case report below).

Postoperative Infection

Only six (1.2%) of the 514 patients exhibited either intracranial or wound infection. Of these, two had meningitis (Pseudomonas aeruginosa and Proteus mirabilis) and four had an isolated wound infection, all with Staphylococcus aureus. In only one instance (0.2%) did culture of the catheter tip show the same organism as the associated infection (P. mirabilis meningitis).

Illustrative Case Report

This 63-year-old woman was admitted to Hadassah University Hospital because of the recent occurrence of epilepsy. The attacks usually started as left-sided Jacksonian seizures which quickly progressed to typical grand mal seizures. Physical examination revealed mild left-sided hemiparesis. Computerized tomography scanning demonstrated a right frontoparietal enhancing space-occupying lesion surrounded by brain edema. Angiography showed that the lesion was avascular.

A gross subtotal removal of necrotic tumor was performed through a right frontal craniotomy. Pathological examination revealed glioblastoma multiforme. After surgery she was transferred to the ICU, where she was fully conscious and the paresis of her left hand improved rapidly. Her ICP levels were normal, and she was extubated a few hours after arrival in the ICU. About 20 hours after surgery her ICP rose to 35 torr. Although at that time there was no associated clinical deterioration, she was immediately reintubated and intravenous mannitol treatment was initiated. ACT deterioration developed. Presumably, decision-making was faster and time delay before the second operation was minimized (see illustrative case report below).

Operative procedures in 13 patients undergoing reoperation

<table>
<thead>
<tr>
<th>Procedure</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>evacuation of tumor-bed hematoma</td>
<td>7</td>
</tr>
<tr>
<td>evacuation of epidural hematoma</td>
<td>2</td>
</tr>
<tr>
<td>evacuation of subdural hematoma</td>
<td>1</td>
</tr>
<tr>
<td>ventriculoperitoneal shunt</td>
<td>1</td>
</tr>
<tr>
<td>ventriculostomy</td>
<td>1</td>
</tr>
<tr>
<td>frontal lobectomy</td>
<td>1</td>
</tr>
<tr>
<td>total</td>
<td>13</td>
</tr>
</tbody>
</table>

TABLE 6

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she gradually improved, regaining consciousness, with improved muscle strength in her left side. She was released from the hospital in good condition 12 days after the initial surgery.

Discussion

Few studies in the past have investigated the incidence of raised ICP following elective intracranial surgery. None of these reports defined risk factors for ICP elevation in the immediate postoperative period or looked at the clinical course and management of the patients who developed intracranial hypertension.

Our results show that as many as one-sixth of patients (17.3%) undergoing elective craniotomy develop postoperative elevation of ICP. Three major risk factors for the occurrence of postoperative intracranial hypertension were found. Following surgery for glioblastoma, approximately one in every four patients (27.2%) demonstrated ICP elevation. This is probably related to the invasive nature of this tumor, as well as to its tendency to be surrounded by peritumoral edema. Furthermore, surgery for this tumor is often limited to a debulking procedure. Residual tumor may then swell or bleed to fill the bed of tumor resection. Repeated surgery for recurrent tumor and protracted operations led to ICP elevation in almost half of the patients (42.9% and 41.7%, respectively). It seems that these are selected groups of patients in whom tumor excision and hemostasis are more difficult. In these procedures, forceful and prolonged retraction, as well as the need for coagulation of draining veins, may have contributed to subsequent brain edema.

Interestingly, advanced age or location of the tumor was not found to be a significant risk factor in the occurrence of postoperative intracranial hypertension. Since brain tissue compliance decreases with age, a higher incidence of postoperative ICP elevation was expected in old age. However, this effect may well be neutralized in this age group by the presence of brain atrophy and increased CSF volume.

The detection of ICP elevation was found to be a sensitive and reasonably specific indicator of associated clinical deterioration. In 69.1% of the patients who had clinical deterioration there was also elevated ICP, while 53% of the patients who had increased ICP deteriorated clinically. In 19 patients (3.7% of the total and 21.2% of the patients who exhibited ICP elevation), intracranial hypertension preceded clinical deterioration. The mean interval of 5.2 hours before clinical deterioration allowed CT scanning and hastened the decision-making process before patients were returned to the operating room or medical treatment was initiated to reduce ICP.

Twenty-one patients had clinical deterioration that was not associated with a measured rise in ICP. This may be the result of either technical failures in the measurement system or functional alterations not associated with raised tissue pressure, such as ischemia not accompanied by edema. It is also possible that because of local ICP gradients, pressure at the cathe-

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Intracranial pressure measurement can never replace vigilant clinical monitoring. It may, however, complement it. This is especially true in situations when clinical examination is impractical, such as immediately after surgery when the patient is still under the persisting effect of anesthetic drugs or in the restless disoriented patient in whom sedative drugs are required. Another advantage of ICP monitoring over clinical judgment alone is that it is an objective measurement which, if properly carried out, is easily followed with time and may be monitored by less trained personnel. The monitoring of ICP further permits evaluation of the effects of procedures and drugs employed in the postoperative period. Hyperventilation, when needed, can be adjusted and titrated, and weaning from the ventilator can be carried out more intelligently. Dosage and timing of drugs such as mannitol and Pentothal are easily individualized. Attention must be drawn, however, to the danger of a false sense of security in the presence of a normal ICP reading. Clinical deterioration in the absence of ICP elevation must never be ignored.

This retrospective study did not evaluate the effect of ICP monitoring on long-term morbidity and mortality. For this purpose a prospective, large-scale, controlled study is necessary. The negligible rate of infection that may be related to ICP monitoring reduces the fear of associated risks. We believe that our low infection rate is due to meticulous technique, the use of prophylactic antibiotics during surgery, and the purse-string suture that was used to prevent CSF leakage, as well as early removal of the ICP catheter when it was no longer needed. The results of this work prompt us to conclude that ICP monitoring is advantageous in the immediate postoperative management following elective intracranial surgery. It is almost risk-free, and should therefore be used liberally, especially in the presence of risk factors for ICP elevation.

Acknowledgment

The authors gratefully recognize the contribution of the nursing staff of the intensive care unit in collecting data for this study, and acknowledge the thoughtful advice of Prof. A. Beller in reviewing the manuscript.

References


Manuscript received January 4, 1988.
This paper was presented in part at the Eighth European Congress of Neurosurgery, Barcelona, Spain, in 1987.
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