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Effects of Neck Position and Head Elevation on Intracranial Pressure in Anaesthetized Neurosurgical Patients: Preliminary Results

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Summary:

This study reports the collective effect of the positions of the operating table, head, and neck on intracranial pressure (ICP) of 15 adult patients scheduled for elective intracerebral surgery. Patients were anesthetized with propofol, fentanyl, and maintained with a propofol infusion and fentanyl. Intracranial pressure was recorded following 20 minutes of stabilization after induction at different table positions (neutral, 30° head up, 30° head down) with the patient's neck either 1) straight in the axis of the body, 2) flexed, or 3) extended, and in the five following head positions: a) head straight, b) head angled at 45° to the right, c) head angled at 45° to the left, d) head rotated to the right, or e) head rotated the left. For ethical reasons, only patients with ICP <= 20 mm Hg were included. Intracranial pressure increased every time the head was in a nonneutral position. The most important and statistically significant increases in ICP were recorded when the table was in a 30° Trendelenburg position with the head straight or rotated to the right or left, or every time the head was flexed and rotated to the right or left—whatever the position of the table was. These observations suggest that patients with known compromised cerebral compliance would benefit from monitoring ICP during positioning, if the use of a lumbar drainage is planed to improve venous return, cerebral blood volume, ICP, and overall operating conditions.

Many intracranial lesions reduce the intracranial compliance (1). The consequences may be detrimental to cerebral oxygen delivery and affect the quality of surgical field exposure.

During intracranial surgery, optimal oxygen delivery to the brain depends mainly on cerebral perfusion pressure (CPP) (1–3). Cerebrospinal fluid (CSF) drainage, head elevation, and neck positioning are mechanical means used to reduce intracranial pressure (ICP) and to diminish cerebral venous flow obstruction. Inadequate head or neck positioning before the beginning of a neurosurgical procedure may contribute to increased cerebral blood volume and cerebral CSF and counteract the reduction of ICP provided by other means.

In clinical practice, this may occur when the operating table and/or the patient's neck or body are not maintained in an axial alignment with the head. This randomized prospective study was designed to assess the collective effects of head, neck, and operating table positions on ICP of patients undergoing intracranial surgery.

PATIENTS AND METHODS

Following institutional review board approval and informed consent, 18 adult patients scheduled for elective intracranial surgery were included in the study. All patients with a Glasgow Coma Scale score below 15, reported to have tomographic evidence of increased CSF volume, and/or presenting clinical symptoms of elevated ICP before surgery were excluded. Patients demonstrating an ICP recording higher than 20 mm Hg following induction of anesthesia were also excluded for ethical reasons.

All patients fasted and received a premedication with 0.1 mg/kg of midazolam orally. Upon arrival to the operating room, routine monitoring devices were placed, which consisted of electrocardiogram (ECG), pulse oximeter, side-stream end-tidal CO_2, and a temperature probe. An indwelling arterial pressure catheter was used for each patient before the induction of anesthesia. Anesthesia was induced under 100% O_2 with propofol 1–3 mg/kg titrated until loss of eyelash reflex. Fentanyl 2 μg/kg was administered to ensure analgesia and pancuronium 0.1 mg/kg was given to facilitate tracheal intubation. Intermittent positive pressure ventilation was instituted to achieve normo-to mild hypocapnia, which was confirmed by arterial blood gas analysis (32 –38 mm Hg $PaCO_2$, maintained stable for each patient throughout the study). Anesthesia was maintained with a propofol infusion 3–10 mg/kg/h. Immediately after induction of anesthesia and stabilization of the patient, a 20-gauge malleable spinal needle was inserted into the L3–L4 space in order to monitor the ICP and subsequently to allow peroperative CSF drainage when indicated (4). The Quekenstedt maneuver as well as the computerized tomography (CT) scans were used to confirm the free CSF circulation from the central to the peripheral compartment. Furthermore, during measurements, transmission of respiratory oscillations on the ICP curve always had to be present. A central venous catheter was placed into the right jugular vein for continuous recording of the central venous pressure (CVP). The administration of mannitol to further improve brain compliance was postponed until the end of the study period. Intravenous fluids were limited to 500 mL of 6% starch until the measurements were completed. A period of 20 minutes was then allowed for the patients to reach a state of equilibrium before the beginning of the study period.

Intracranial pressure was recorded after 3 minutes following each position change to reach stabilization of the ICP wave. Mean arterial pressure (MAP), CVP, and heart rate (HR) were recorded every time the position of the table was modified. The effect of the position of the operating table on ICP was studied for three consecutive randomized positions: a) horizontal (0°), b) head-up (30°), and c) head-down (30°). Following the positioning of the operating table, the patient's head and neck were placed in the following positions (Figure 1):

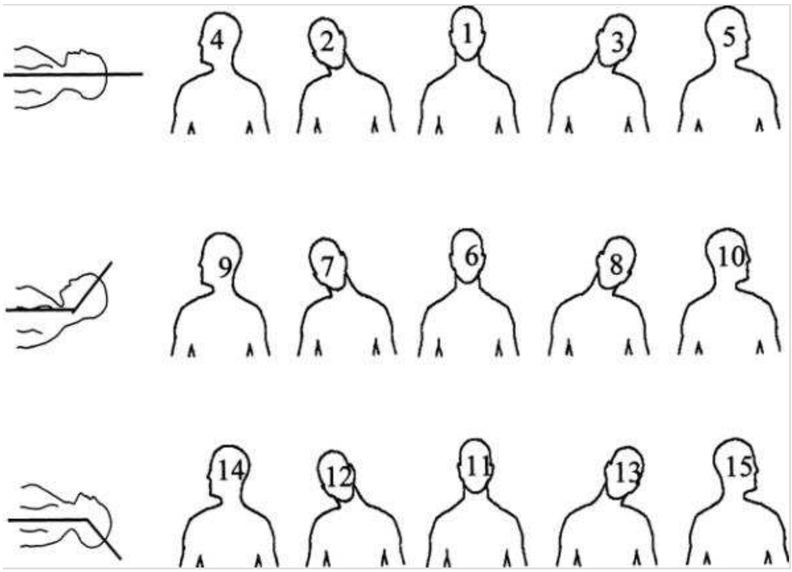

FIG. 1. Fifteen head orientations with the table positioned either horizontally, 30° head-up or 30° head-down were studied. Each number represents the final head and neck position and corresponds to: 1) head straight in the axis of the body, 2) head angled at 45° to the right, 3) head angled at 45° to the left, 4) head rotated to the right, 5) head rotated to the left, 6) head flexed straight, 7) head flexed and angled at 45° to the right, 8) head flexed and angled at 45° to the left, 9) head flexed and rotated to the right, 10) head flexed and rotated to the left, 11) head extended straight, 12) head extended and angled at 45° to the right, 13) head extended and angled at 45° to the left, 14) head extended and rotated to the right, and 15) head extended and rotated to the left.

1) head straight in the axis of the body,
2) head angled at 45° to the right,
3) head angled at 45° to the left,
4) head rotated to the right,
5) head rotated to the left,
6) head flexed straight,
7) head flexed and angled at 45° to the right,
8) head flexed and angled at 45° to the left,
9) head flexed and rotated to the right,
10) head flexed and rotated to the left,
11) head extended straight,
12) head extended and angled at 45° to the right,
13) head extended and angled at 45° to the left,
14) head extended and rotated to the right,
15) head extended and rotated to the left.

The transducer used to measure ICP was calibrated and zeroed to the level of the external auditory meatus each time a new position was achieved.

STATISTICAL ANALYSIS

Demographic and parametric data are expressed as means ± SD (x ± SD). The value of ICP recorded while the head of the patient was in the neutral position was used as baseline (Figure 1, position 1, table horizontal). Statistical analysis of the effect of table, head, and neck positioning on ICP was performed using a one-way analysis of variance (ANOVA) to evaluate differences in ICP values. If there was a significant difference in the means between measurements, a paired Student *t* test with the Bonferroni correction for multiple comparisons was performed for intragroup head and neck positions (for each table position). The hemodynamic variables were analyzed using a paired Student *t* test. Statistical significance was accepted as $P < .05$.

RESULTS

Eighteen patients were enrolled. Three could not be included in the study because of an ICP>20 mm Hg. Finally 15 patients (9 men, 6 women), aged between 46 and 70 years (58 ± 11 years) were included in the study. The weight of the patients was 74 ± 13 kg, with no patient being overweight. The hemoglobin concentration was 131.4 ± 16.4 g/l and the hematocrit was 39 ± 5%. Twelve patients had surgery for intracranial tumor and three for unruptured aneurysm.

The arterial blood gases obtained after intubation were similar in our patients. Intermittent positive pressure ventilation was used with a FiO_2 of 1.0 for each patient before and during the study period. The corresponding PaO_2 was 357 ± 58 mm Hg (range 297 –464 mm Hg). Mild hypocapnia was achieved with a $PaCO_2$ of 37.1 ± 2.3 mm Hg (range 34–41 mm Hg). No patient had a modification of his end-tidal CO_2> 2 mm Hg over the study period. The ICP value at the beginning of the study period for all patients was 8.8 ± 2.5 mm Hg (range 5–18 mm Hg).

Mean arterial pressure was 83.1 ± 10.1 mm Hg at the beginning and 82.0 ± 9.8 mm Hg at the end of the study. Heart rate was stable at 69 ± 18/min initially and 67 ± 11/min at the end of the study. Central venous pressure measured at the beginning of the study period was 3.9 ± 2.3 mm Hg and 3.8 ± 1.9 mm Hg at the end (range 2–10 mm Hg). Mean arterial pressure and CVP were also analyzed before and after modifying the position of the table. Mean arterial pressure (and CPP = MAP-ICP) did not change significantly (87 ± 10.3 in the head-down position and 79 ± 9.9 in the head-up position. However, mean CVP, which was 3.9 ± 2.3 mm Hg in the neutral position, increased to 8.4 ± 2.4 in the head-down position ($P < .05$). It decreased to 2.9 ± 2.1 (nonsignificant) in the head-up position.

The collective effect of the positions of the table, head, and neck on ICP is presented in Table 1. The position of the table with the head in the neutral position affected ICP in the 30° head-down position (position 1). Rotation of the head caused the most important increases in ICP, reaching statistical significance in positions 4 and 5 (right and left rotation, head neither flexed nor extended, with table 30° head-down), and in positions 9 and 10 (right and left rotation, head flexed, with the table in the three positions). The increase in ICP did not reach statistical significance with the head extended, nor when it was angled at 45° to the right or left laterally whatever the position of the table was.

Head and neck position		Position	Table	Table	Table
Neck	Head	(Fig 1.)	horizontal 0°	head-up +30°	head-down −30°
	Straight	1	8.8 ± 2.5	7.0 ± 3.3	13.3 ± 2.9*
	Right lat. flexion	2	11.6 ± 4.3	10.0 ± 4.1	14.6 ± 5.1
Flat	Left lat. flexion	3	11.9 ± 4.3	10.4 ± 4.0	14.9 ± 5.9
	Right rotation	4	13.6 ± 4.6	12.5 ± 4.3	15.4 ± 3.6*
	Left rotation	5	12.9 ± 3.8	12.5 ± 3.3	16.2 ± 3.0*
	Straight	6	13.8 ± 4.7	12.2 ± 5.0	17.3 ± 5.7
	Right lat. flexion	7	14.7 ± 5.0	13.2 ± 5.0	18.2 ± 6.7
Flexed	Left lat. flexion	8	14.5 ± 5.1	13.1 ± 5.3	18.9 ± 6.9
	Right rotation	9	16.2 ± 3.9*	16.0 ± 3.2*	19.1 ± 3.8*
	Left rotation	10	15.8 ± 3.8*	15.4 ± 3.4*	19.2 ± 3.8*
	Straight	11	10.7 ± 4.0	9.4 ± 5.0	13.4 ± 4.9
	Right lat. flexion	12	12.0 ± 3.4	11.0 ± 4.5	14.4 ± 4.5
Extended	Left lat. flexion	13	11.5 ± 4.8	11.6 ± 5.3	14.1 ± 4.9
	Right rotation	14	12.8 ± 4.0	11.2 ± 4.8	15.6 ± 5.5
	Left rotation	15	13.2 ± 4.5	11.5 ± 5.9	15.3 ± 5.5

*$P < .05$ vs. the neutral position (1) with the table horizontal.

TABLE 1. *ICP (mean ± SD) in each head and neck position with the table in the three positions** $P < .05$ vs. the neutral position (1) with the table horizontal.

DISCUSSION

This study was designed to evaluate the collective effect of modifying the position of the operating table and the head and neck orientation on the ICP of patients anesthetized for intracranial surgery. In the present study, there was an increase in ICP only in the head-down position or when the head of the patient was rotated and/or flexed, but not when it was extended.

Undoubtedly, the patients with abnormal ICP would have yielded the most relevant information and would have strengthened the results. For ethical reasons, however, and in order to measure the mechanical effects of head positioning on ICP, only patients with ICP <= 20 mm Hg, located on the horizontal part of the intracranial compliance curve and representing the major proportion of neurosurgical patients scheduled for elective intracranial surgery, were studied. Our patients, however, all had either a tumor or an unruptured aneurysm, which means that their normal ICP did not necessarily imply normal compliance. This makes our group of patients a group with an "intermediate" compliance, which certainly underestimates the effect of positioning on ICP.

The review of the literature on this topic is somewhat confusing because of the meaning of the terminology used. "Head position" and "neck position" have been used to describe similar anatomical angulation of head with reference to the trunk and "head elevation" and "table position" or "bed position" to describe the inclination of the entire trunk in relation to the floor (5–9). To facilitate the comprehension of the terminology used in the present study, a drawing to describe the head, neck, and table positions is shown in Figure 1. In the present study, the positions described are related to the final position of the head in relation to the neck of the patient.

Concerning ICP measurements, most studies included patients in the intensive care unit and included those with normal and elevated ICP in the same study group (5–7). Previous observations of the effect of head, neck, and table position can be divided into two groups of studies. The first group of studies reported the effect of changing the position of the table on ICP, CPP, and cerebral compliance (5–9). Rosner et al. studied 18 patients with varying degrees of intracranial hypertension and suggested that ICP decreases 1 mm Hg for every 10° in "head elevation" from 0° to 50° and concluded that 0° head elevation maximizes CPP and reduces the severity and frequency of pressure-wave occurrence (6). Feldman et al. studied 22 head-injured patients and reported similar findings when the head of the patients was raised up to 30°(5). Cerebral profusion pressure and cerebral blood flow (CBF) recorded at 0° were unchanged during head elevation (5). Other studies in adult patients showed variable results in terms of CPP and cerebral oxygenation when the head was elevated up to 45°. All reported similar decreases in ICP when the head was elevated (7–9). The interpretation of these studies is limited by the fact that patients with normal and elevated ICP were combined, leading to uncontrolled observation and important variability in the data. In the present study, when the table was changed from 0° to a 30° head-up position, ICP decreased. This trend was amplified when the ICP values were compared between the table in the head-down position to values with the table in the head-up position. These observations may become clinically important in patients with raised ICP who are on the steep part of the pressure-volume curve. The second group of studies focused on the influence of head and neck rotation with the trunk. Here again, different results were obtained (10–13). Most studies showed significant increases in ICP when head and neck were placed in a nonneutral position (flexion, extension, rotation, or lateral flexion of the head). As an example, rotation of the head has an important impact on the diameter of the jugular veins (13). However, these studies included a mixed population of patients with normal and elevated ICP.

In our patients, CPP as well as MAP were not significantly modified by the study. One conclusion that can be drawn is that the best surgical exposure in terms of direct access to the lesion may be impeded by brain congestion secondary to compromised venous and CSF drainage.

Monitoring of ICP was achieved with the insertion of a lumbar 20-gauge malleable spinal needle connected to a pressure transducer. This device is also used to withdraw CSF when indicated during the procedure. This is a standard technique in our institution. Takizawa et al. demonstrated that lumbar CSF pressure represent a reliable measurement of ICP when values are less than 20 mm Hg (4).

In summary, in this small series of 15 patients with ICP<= 20 mm Hg, head position affected ICP especially when patients were positioned with their head rotated to the right or left and/or flexed. Neither $PaCO_2$, MAP (the so-called vasodilatory cascade (14)), nor weight in excess in our patients can explain these results. Could body position interfere with CSF circulation and/or absorption? Maybe just by impeding translocation of CSF between the intracranial and the spinal areas in the head-down position. This leaves us with one major logical mechanism: the increase in CVP in head-down position may impede cerebral venous drainage, resulting in an increase in cerebral venous blood volume and increase in ICP. The mechanism is the same for rotation and flexion of the head (shift to the steep part of the intracranial compliance curve (13)). This implies that specific consideration must be given during positioning of high risk patients; indeed when looking at the steep part of the pressure-volume curve one may speculate that patients with compromised intracranial compliance are more affected during identical maneuvers than patients with normal compliance. Clinically, the potential increase in ICP suggests the use of close monitoring of ICP during positioning of patients with potentially compromised compliance requiring lumbar drainage of CSF. This recommendation may be helpful to improve cerebral venous drainage, cerebral blood volume, ICP, and overall operating conditions.

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Key Words: Anesthesia: neurosurgery; Monitoring: intracranial pressure; Position: head, neck, operating table

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IMAGE GALLERY

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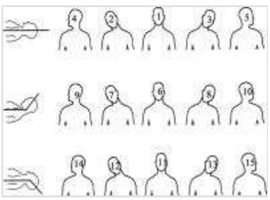
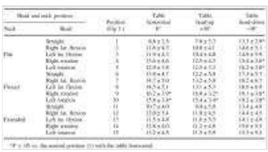


☐ Fig. 1



☐ Table 1

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