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Original article

Determining an Accurate External Reference Point for Zeroing an External Ventricular Drain (EVD) as an Intracranial Pressure Monitoring System

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BACKGROUND: Monitoring of intracranial pressure is a highly valued tool in neurosurgical practice. There is no consensus about the exact outer zero point for correlation with the brain center while measuring the intracranial pressure using external ventricular drainage system.

OBJECTIVE: The aim of this study was to evaluate the accuracy of using the top of the head serving as the zero-reference point of the intracranial pressure monitoring device and correlate its relation to the foramen of Monro at clinically used positions of the head.

PATIENTS AND METHODS: The study included 30 patients who were candidates for invasive intracranial pressure monitoring with external ventricular drain for different pathological reasons. We compared two points as a zero-reference point; the glabella and the tragus as approximation to the foramen of Monro in different head positions.

RESULTS: Readings while using the tragus were slightly higher than those while using the glabella as regards the intracranial pressure and drained higher cerebrospinal fluid volumes, with no statistically significant difference.

CONCLUSION: Our study revealed that a zero point at the foramen of Monro was found to be insignificantly different from using the glabella as the zero-reference point when the head of the patient was positioned either supine or elevated 45◦.

KEYWORDS: External ventricular drain, Intracranial pressure, Zero point.

INTRODUCTION

Intracranial pressure (ICP) monitoring is widely used in neurosurgical practice and has become an important tool despite the obstacles facing it as an invasive tool.[1] It is important in monitoring different cases from hemorrhage, trauma, perioperative and different medical conditions.[2]

Each one of the monitoring systems has its pros and cons, and the external ventricular drain (EVD) is the most widely used one as it has more benefits allowing cerebrospinal fluid (CSF) drainage in addition to the monitoring.[3] There should be a surface point of zero reference that correlates with the center of the brain or the foramen of Monro, but there is no consensus about this point. Some use the external auditory meatus as the surface point of Monro foramen, midpoint of the orbito-meatal line and the top of the head when lying supine, while in the lateral position, nose tip is an option as a zero point in ICP monitoring and the top of the head.[4,5] The idea of these points is being accurate in correlation to the center of the brain and easy to use in measurements in different head positions.[4,6]

The aim of this study was to evaluate the accuracy of using the top of the head as the zero-reference point of the ICP monitoring device and correlate its relation to the foramen of Monro at clinically used positions of the head.

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PATIENTS AND METHODS

We conducted a randomized clinical trial over 30 patients with no age or gender selection criteria. All 30 patients were candidates of invasive ICP monitoring with EVD for different pathological reasons. Several predetermined variables were documented for each patient, including the patient's age, sex, associated medical comorbidities, etiology of hydrocephalus, burr hole site, type of EVD inserted, complications, the need for long-time CSF diversion and, when applicable, duration of EVD placement and patient's fate. The study was conducted in Cairo university hospitals in Egypt over the period from December 2020 to April 2021. The study complied with the institution's ethical guidelines and was approved by the Ethical Committee of Cairo University (Code: MS-431-2020). The patients or their legal guardians gave their written consent for operation and publication.

Two types of EVDs were inserted; Becker external drainage and monitoring system manufactured by Medtronic and Ramathibodi EVD collecting device (RAMA EVD), a locally made device of sterilized intravenous soluset and connecting components.[7] We compared two points, as a zero-reference point, the glabella and the tragus as an approximation to the foramen of Monro. After implantation of an external ventricular drain, postoperative brain computed tomography (CT) scan was done and ICP was monitored. Opening pressure and one- day follow up readings were measured two times; one using the glabella as the point of zero reference and the other using the foramen of Monro at two distinct head positions. The ICP zero level was adjusted at the level of foramen of Monro for the first 12 hours and the amount of CSF drainage was observed, then re-adjusted at the level of glabella and the volume of drained CSF was recorded.

Data collection was performed by one investigator to reduce bias and measurement variance sources. The investigator zeroed the ICP initially at the level of the tragus of the ear to roughly correspond to the Monro foramen. Heads of the patients were in flat position, and for one minute the patient stayed in that Accurate external reference point for zeroing an EVD Ismail et al posture, before the reading was recorded. Then, he leveled the ICP transducer to the glabella and waited for one minute before recording the reading. Next, the same steps were repeated but with the patient's head elevated at 45◦ and ICP were recorded. These actions were carried out once per day for two consecutive days. Then at the Monro foramen, the ICP transducer was leveled and left for 12 hours and the amount of CSF drained was recorded and the same was done after leveling the transducer to the glabella.

The study included different patients from different age groups who were candidates of ICP monitoring for different pathological reasons and the level of the EVD was adjusted according to each case and changed according to the measures and drained CSF criteria and volumes. Any factor that can affect the readings made the case excluded from the study such as leakage from the insertion site, poor flow in the EVD line and any intervention through the EVD as drug injection or disconnection at any level. The EVD was closed an hour before taking readings every time and reclosed while changing head position to take readings in different head positions to avoid pressure changes from volume changes. The decision where to level the EVD and the next step depends on the readings taken every day.

The statistical package for social sciences (SPSS) version 24, a statistical tool for social science, was utilized for data analysis, while Microsoft Excel 2013 was employed for data entry. Frequencies were employed for qualitative data, while simple descriptive statistics were used for summarizing normal quantitative data (arithmetic mean and standard deviation) and aberrant quantitative data (median and interquartile range). Bivariate relationships were shown in cross tabulations, and where necessary, Fisher's exact tests and the chi-square test were used to compare proportions. Mann Whitney was used for skewed data, whereas T-independent was used to compare quantitative data that was regularly distributed. A value of less than 0.05 was deemed statistically significant in the p value calculation used to evaluate statistical significance.

RESULTS

In this study, 30 patients had EVD used for monitoring of ICP comparing two references zero points, the tragus (foramen of Monro) and the glabella. There was no specified age among study population with age range from 3 days to 74 years with male predominance (60%). The most commonly used site for EVD insertion was the right frontal burr hole in 80% of the patients. The locally made EVD system was more commonly used for the availability and cost issues in comparison with the Becker system (70% and 30%, respectively). Most EVDs were inserted after tumor excision (47%) followed by other causes like CSF infection (30%) and intraventricular hemorrhage (23%). Most of the patients were medically free (80%). Eighteen out of the 30 patients passed away with 50% of the surviving patients requiring permanent CSF diversion with ventriculoperitoneal shunt. These mortalities were related to the original pathology for which the EVD was inserted with no complications associated with the EVD procedure itself. As regards the ICP and the drained CSF volumes in different head positions over 2 days assessment when the foramen of Monro and the glabella were compared as zero-reference point, there was no statistical difference of significance **(Table 1).**

Table 1: The ICP values and CSF volumes in different head positions over 2 days with p-values

Reference Point	Mean	Median	Minimum	Maximum	Std. D.	Percentile 25	Percentile 75	P-value
ICP at Monro supine 1st day	15	14	4	35	8	9	18	0.084
ICP at Glabella Supine 1st day	11	11	1	31	8	5	14	
ICP at Monro supine 2nd day	13	11	4	34	7	8	17	0.092
ICP at Glabella supine 2nd day	10	9	1	28	7	5	12	
ICP at Monro head 45 1st day	17	16	5	39	8	12	22	0.084
ICP at Glabella head 45 1st day	14	12	2	35	8	8	17	
CSF Volume at Monro 1st day	54	43	20	180	37	28	54	0.063
CSF Volume at Glabella 1st day	37	25	8	160	32	19	37	

DISCUSSION

The cerebrospinal fluid space's anatomy provides a longitudinally communicating, semi-open, water-filled system.[1] Consequently, depending on the measurement site, intracranial pressure varies with body posture.[8] There has been continuous search for the best monitoring tool, method and numerical value required to maximize brain perfusion and improve patient outcomes. The majority of ICP-related papers exclude information concerning the transducer's zero-reference point, head position, or transducer location that is necessary for calculating cerebral perfusion pressure (CPP).5 In our comprehensive review of literature, no study discussed the zero-reference point in detail except the work of Reinstrup et al. in 2019. They determined that there are two commonly utilized approaches to acquire a strict brain center (BC) zero point; using the meatus when the patient is supine, or using the glabella when the patient is in a lateral posture. When the patient's head was positioned supine without head elevation, a zero point at the meatus was discovered to be optimal. The glabella was the optimum BC zero point when the head was in a strict lateral posture. Regardless of the reference point used, the level of an external transducer must be modified with each shift in the head's position.[4]

In our study, as previously described, opening pressure and one-day follow up readings were measured two times; one using the glabella as the zero-reference point and the other using the foramen of Monro at different positions of the head; supine and elevation of head 45◦. The ICP zero level was adjusted at the level of Monro for the first 12 hours and the amount of CSF drainage was observed, then re-adjusted at the level of glabella and the volume of drained CSF was recorded. Provided the patient's head remained positioned supine and not elevated, the data acquired using the foramen of Monro as a point of reference were 2–5 mm Hg higher when compared to readings obtained with the glabella as reference location. While readings obtained using the foramen of Monro as reference point were 2–6 mm Hg higher when compared to readings obtained with the glabella as reference location with the head elevated at 45◦. CSF volumes recorded using the foramen of Monro as reference point for 12 hours were 4-37 ml higher in contrast to measurements made with the glabella as reference location for the next 12 hours. Follow-up readings obtained during the second day using the foramen of Monro as reference point were 1–6 mm Hg higher when compared to readings obtained with the glabella as reference location with the head in the supine position. The results demonstrated that there was no significant statistical difference between both ICP readings ($p=0.084$ for the 1st day and $p=0.092$ for the 2nd day) with the head at supine position nor with the head elevated at 45◦ ($p=0.084$) in addition to the volume of CSF drained for 12 hours ($p=0.063$). Thus, it provided data to adequately refute the theory that ICP measurement based on these two anatomical reference locations was not equivocal and highlight that the two reference points were interchangeable for clinical practice.

Despite Reinstrup et al. work studied the two reference points by applying precise calculations with the aid of imaging modalities; their work did not examine the significant difference between their results.[4] These results add to the discussion on the variability of the best place to assess ICP. Although the forementioned research has shown variability in ICP measurement between locations, this is the first to quantify these variances and indicates that they are not statistically significant. Right now, there is no agreement on how to apply any correction factor or where to put the pressure transducer. Global standardization of the process would be necessary.[5]

One of the limitations of this study is assessing intracranial pressure only once per day for two days in a row due to the constant fluctuations in physiological variables. It was crucial to record paired readings simultaneously rather than trending all paired values over time, though, as the goal was to find discrepancies. Variations in the kind of external drain across locations constituted a second constraint. The validity of readings may be impacted by the fact that sites were not required to utilize the same type of EVD. To guarantee reliable results, all equipment was calibrated both before and after usage. We regard the study's inclusion of patients with varying reasons for ICP monitoring in both sexes and at any age as strength since it lowers the possibility of systematic error.

CONCLUSION

The gold standard method of monitoring ICP is by invasive methods such as EVD. In clinical use, the meatus and glabella are well-defined anatomical sites that are frequently utilized as the ICP gauge's zero reference points. The evidence is not strong enough in the literature to support the recommendation of standard location for ICP readings. The validity of research is also challenged by the heterogeneity of assessment, which leads to persistent variances in practice and an uncertain influence on patient outcomes. There is so much emphasis for national and worldwide standards established by specialists to direct the practice towards this clinical dilemma.

Our study revealed that a zero point at the foramen of Monro was found to be insignificantly different from using the glabella as the zero-reference point when placing the patient's head either supine or elevated 45◦. Lastly, it is important to keep in mind that measuring ICP is not a treatment in and of itself; rather, it is a method for monitoring and diagnosing the brain pathology, which may help choose the most appropriate course of medication or surgery.

List of abbreviations

BC: Brain center.
CPP: Cerebral perfusion pressure.
CSF: Cerebrospinal fluid.

CT: Computerized tomography.
EVD: External ventricular drain.
ICP: Intracranial pressure.
SPSS: Statistical package for social sciences.

Disclosure

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