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Indirect Measurement of Perioperative Intracranial Pressure - Eye and Orbitary Ultrasound Utility

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Abstract: Aims: To measure changes in optic nerve diameter during lower extremity trauma surgery and to compare changes in patients under general and spinal anesthesia. Methods: A prospective observational study was conducted on 50 patients undergoing lower extremity trauma surgery, of whom 26 received general anesthesia and 24 received spinal anesthesia. Data on basic patient profile, surgery, anesthesia, and optic nerve diameter were collected before surgery, 10 minutes after dural puncture or induction of anesthesia, and 10 minutes after recovery from motor block. Descriptive statistical analysis and Spearman's index were used to study the correlation between the two groups (general and spinal anesthesia). Results: The study population consisted of 25 males and 25 females, age 63.40 ± 16.36 years, weight 77 ± 10.66 kg, duration of surgery 93.20 ± 23.659 min. 28 cases required ischemic management, duration 58.15 ± 10.57 min. Preoperative optic nerve measurements were 5.06 ± 0.89 mm in the right eye and 4.45 ± 0.7955 mm in the left eye; intraoperatively: 5.70 ± 0.77 mm in the right eye and 4.84 ± 0.75 mm in the left eye; and postoperatively: 4.91 ± 0.88 mm in the right eye and 4.46 ± 0.64 mm in the left eye. The data were similar in both groups. Preoperative ($p<0.01$) and postoperative data were bilaterally statistically significant between the two groups. Conclusions: The optic nerve diameter increased after both spinal and general anesthesia and it returned to preoperative data in the immediate postoperative period.

Key words: point of care ultrasound; perioperative medicine; optic nerve sheath; intradural anesthesia

1. Introduction

Bedside ultrasonography (POCUS) is undergoing great development as it is a powerful tool for patient monitoring [1]. Intracranial pressure can be measured invasively (subarachnoid or intraparenchymal manometry) or noninvasively (fluid dynamic, ophthalmic and otic methods, electrophysiology, nuclear magnetic resonance, transcranial Doppler ultrasound, cerebral blood flow velocity measurement, infrared spectroscopy). Measurement of the optic nerve diameter at the retrobulbar level by ultrasonography [2, 3] should be part of perioperative monitoring, together with cardiac, pulmonary, hemodynamic, abdominal and airway ultrasound [4-7].

Spinal anaesthesia is contraindicated in intracranial hypertension, but cases of intradural obstetric analgesia for delivery in patients with intracranial hypertension after lumbar drainage of cerebrospinal fluid have been described without complications [8].

Several anesthetic surgical factors have been associated with increased intracranial pressure, which leads to a higher risk of neurological complications, longer postoperative recovery time and worse outcomes. These factors include: abdominal surgery, anesthetic technique, intubation or extubation maneuvers, aspiration of bronchial secretions, mechanical ventilation (PEEP), laparoscopic surgery. Currently, the use of epidural/rachidian anesthesia is usually associated with general anesthesia, but its use remains under discussion in patients with intracranial hypertension [9].

Based on the hypothesis that noninvasive intracranial pressure monitoring (by measuring the optic nerve diameter at retrobulbar level) should be part of the perioperative study, especially in case of spinal anesthesia, several study objectives were set. The main objective was to measure sonographic variations in optic nerve diameter (indirect parameter of intracranial pressure) in patients undergoing lower extremity trauma surgery. Other objectives were to compare the changes recorded at different perioperative times between patients operated under general anesthesia or spinal anesthesia.

2. Patients and Methods

Design: Prospective cohort study in patients who underwent scheduled lower extremity trauma surgery and who accepted and signed an informed consent form for participation in the study. The study is part of the project on the "Usefulness of POCUS in the perioperative period", which was approved by the Ethics Committee of the Hospital Clínico Universitario de Valladolid with code PI 17-634. It was carried out between May 2 and July 15, 2020.

Inclusion criteria: Patients over 18 years of age with physical status ASA I-III, scheduled for lower limb surgery under spinal or general anesthesia, with written informed consent to participate in this study.

Exclusion criteria: Not meeting inclusion criteria, contraindication to the technique, history of cranioencephalic or ocular trauma, or chronic intracranial hypertension, previous neurosurgery, brain tumor or known neurological or ophthalmic diseases.

All patients underwent an ultrasound study of the optic nerve diameter at 3 mm posterior to the eyeball, using the Mindray Diagnostic Ultrasound System Model Z6 in B-mode with a high-frequency linear transducer (6-12 MHz). The parameters were set with a thermal index less than 1 and a mechanical index less than 0.2, and the focus was placed 1-2 cm from the entrance of the optic nerve into the eyeball. Scanning was performed three times: before surgery, 10 minutes after dural puncture or induction, and 10 minutes after recovery of motor block in the awakening room or prior to discharge from this unit in case of general anesthesia, as summarized in Figure 1.

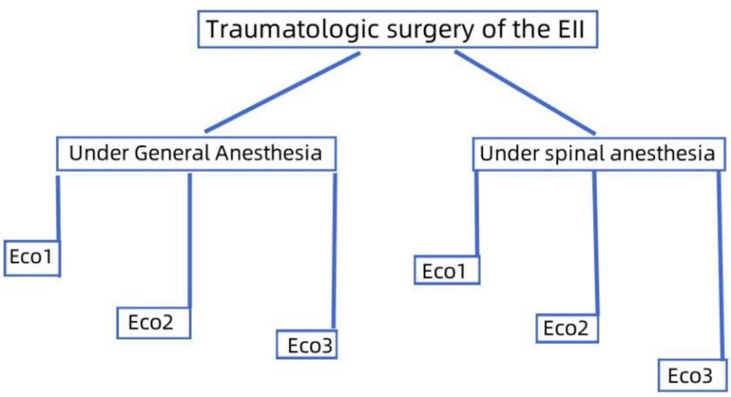

Figure 1. Summary of the study methodology. Echo 1: preoperative. Echo 2: 10 minutes after dural puncture in case of spinal anesthesia or induction and intubation in case of general anesthesia. Echo 3: once recovered from anesthesia, upon discharge from the Post-Surgical Recovery Unit (without motor block or at least with knee mobility).

The ultrasound examination was performed with the patient in supine decubitus with head in neutral position (neck flexion and head extension) and eyes closed. The operator was positioned at the patient's bedside. The ultrasound probe was gently rested on the upper eyelid, after applying abundant echogenic gel, on the transverse axis of the eyeball, rotating it until the image of the optic nerve was found, as shown in Figure 2. The diameter of the optic nerve was measured 3 mm after its entry into the eyeball.

Figure 2. Placement of linear probe and image of the eyeball and ultrasound image of the eyeball. The ultrasound study was performed with a B-mode ultrasound device, setting parameters of thermal index less than 1 and thermal index less than 0.2. The focus was placed 1-2 cm below the target (origin of the optic nerve in the eyeball).

3. Procedure

The first ultrasound study (Echo 1) was performed in the preanesthesia room, after obtaining verbal and written consent to perform the technique and the study, and after cannulating a venous line in the upper extremity contralateral to the lower extremity to be operated on, and after basic monitoring (pulse oximetry, electrocardiogram and noninvasive blood pressure). All images were collected by anesthesiologists with accredited experience in ultrasound. Secondly, in the operating room, the indicated anesthetic technique (general anesthesia or spinal anesthesia) was performed as usual:

-Intradural anesthesia group (RA group). With the patient in lateral decubitus on the pathological lower extremity or susceptible to surgery and standard monitoring, aseptic intradural puncture was performed with a 26G Whitacre-tipped needle, injecting 10-12.5 mg of bupivacaine 0.5% hyperbaric. After verifying the presence of motor and sensory blockade adequate for the intervention, the patient was placed in supine decubitus and at that moment an ultrasound of the eyeball (Echo 2) was obtained following the technique explained in the previous section. Immediately afterwards, the patient was positioned for the operation: supine decubitus or lateral decubitus on the side contralateral to the limb to be operated on. In case of any adverse event (hypotension with mean arterial pressure below 55 mmHg, bradycardia), the patient was treated with serum therapy or inotropic and vasoconstrictor drugs, as indicated.

-General anesthesia group (AG group). The patient was induced with intravenous anesthesia using Propofol 2 mg/kg, and rocuronium (0.6mg/kg) with the patient in supine position, followed by direct laryngoscopy for orotracheal intubation. Anesthesia maintenance is performed using 1.5-2% inhaled sevoflurane for Sedline PSI levels ® 30-40. If blood pressure or heart rate increases by more than 20% from baseline, intravenous fentanyl (0.05 mg) is administered. If muscle relaxation is required, intravenous rocuronium bromide (0.1 mg/kg) is administered.

The ocular ultrasound (Echo 2) was performed in the supine decubitus position as indicated above. If it was necessary to reposition the patient in lateral decubitus to start the procedure, this was done once the ultrasound study had been completed. Once the procedure was completed, muscle relaxation was reversed with Sugammadex® at 2 mg/kg intravenous. All patients received 1 g of paracetamol and antiemetic prophylaxis with intravenous dexamethasone 0.1

mg/kg after induction.

Once the operation was completed, anesthesia was reversed and the patient was extubated (in the general anesthesia group) and transferred to the Post Surgical Recovery Unit (PACU) where the usual monitoring and treatment was carried out and a third ultrasound study (Echo 3) was performed before the patient was discharged, always once he had recovered from the motor block.

4. Data Collection

Data were collected on filiation (age, sex, weight), anesthetic-surgical data (type and duration of surgery, understanding surgical time as that between incision and removal of ischemia or the last stitch for skin closure; anesthetic block time: between puncture and recovery of the motor block until knee flexion), and retrobulbar diameters of the left and right eye at the three moments described in Figure 1.

5. Statistical Analysis

The data were entered into an Excel® database (Microsoft Office, Microsoft, USA) and analyzed using the PASW® v22.0 statistical package (SPSS, Inc., Chicago, IL, USA). Descriptive study of the variables are analyzed. Quantitative variables are presented with the mean, maximum and minimum values and standard deviation. Qualitative variables were presented according to their frequency distribution. The Kolmogorov Smirnov test was used to test for normality. Spearman's Rho index for nonparametric tests was used to study the correlation between the optic nerve diameters measured in the two groups (general and spinal anesthesia) at the three time points of the study. Bilateral asymptotic significance was calculated between the measured variables. Those p values < 0.05 were considered statistically significant.

6. Results

Data were recorded for 52 patients, two of whom were excluded from the study because retinal detachment and intracranial hypertension were suspected and subsequently diagnosed on preoperative ocular ultrasound. In the case of intracranial hypertension, a temporal intraparenchymal hemorrhage was detected on MRI.

Data from 50 patients were analyzed: 24 under spinal anesthesia and 26 under general anesthesia. General anesthesia was performed due to impossibility of puncture (5), presence of headache (3), treatment with antiplatelet agents (10) or patient preference (8).

Data from 25 males and 25 females were studied, with a mean age of 63.40 years and standard deviation of 16.365 (range between 34 and 85), a mean weight of 77 kg with standard deviation of 10.656 (range between 60 and 92), and a surgical time of 93.20 minutes (range between 49 and 130) and standard deviation of 23.659.

The surgical technique performed required ischemia in 28 cases, and had a duration of 58.15 minutes with standard deviation of 10.57 and range between 30 and 95. The surgeries were as follows: total hip replacement in 8 cases, partial replacement in 3 cases, total knee replacement in 20 cases, tibial valguizant osteotomy in 6 cases, replacement of artificial knee joint in 5 cases, and knee ligament reconstruction in 8 cases. The engine lockout time ranges from 0 to 160 minutes, with an average of 112.50 minutes and a standard deviation of 60.519 minutes. Both groups (GA and RA) have comparable parameters.

Perioperative complications were noted in three patients (all in the spinal anesthesia group): two cases of postoperative infection and one persistent headache after puncture. The data obtained from the optic nerve measurement are summarized in Table 1 and Figure 3.

Table 1. Optic nerve diameter measurements at 3 mm from its entry into the eyeball

Item	Optic nerve diameter (cm) (minimum)	Optic nerve diameter (cm) (maximum)	Optic nerve diameter (cm) (mean)	Optic nerve diameter (cm) (standard deviation)
Eco1 OD	0.45	0.73	0.5060	0.06947
Eco1 OI	0.42	0.57	0.4520	0.06955
Eco2 OD	0.45	0.78	0.5700	0.07700
Eco2 OI	0.41	0.67	0.4840	0.07575
Eco3 OD	0.45	0.72	0.4910	0.08825
Eco3 OI	0.42	0.62	0.4460	0.06415

Note: In right eye (OD) and left eye (OI), at three moments: Echo 1 (preoperative), Echo 2 (after induction/rachianesthesia) and Echo 3 (in immediate postoperative period after complete recovery of motor block).

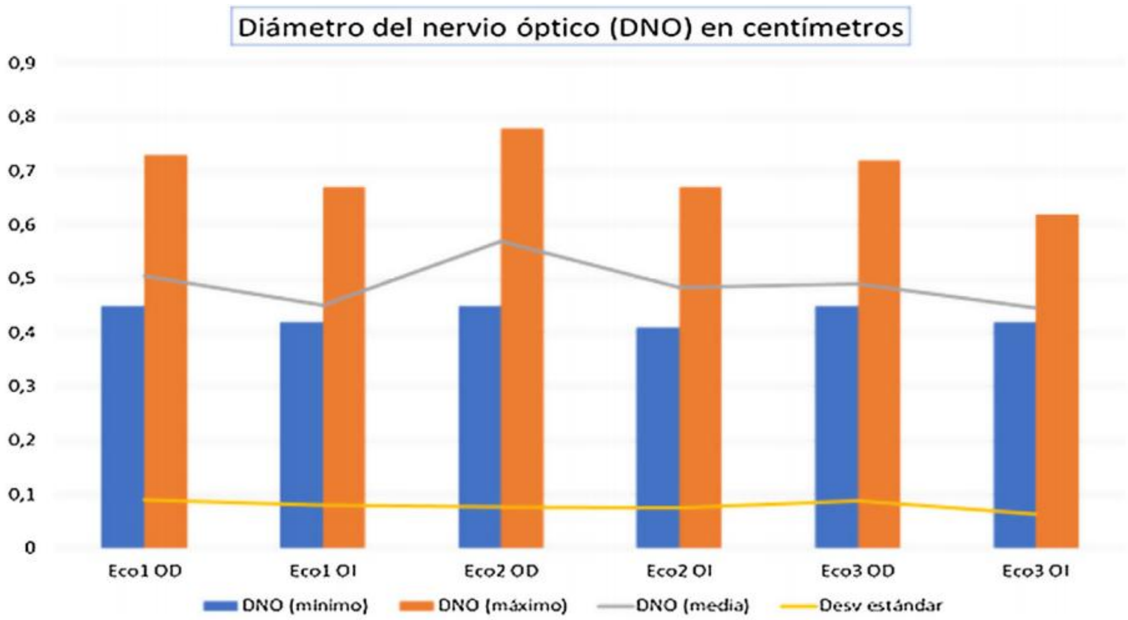

Figure 3. Optic nerve diameters at the three moments of the study: maximum, minimum, mean and standard deviation. Echo 1 OD (preoperative echo in right eye), Echo 1 OI (preoperative echo in left eye), Echo 2 OD (intraoperative echo in right eye), Echo 2 OI (intraoperative echo in left eye), Echo 3 OD (postoperative echo in right eye) and Echo 3 OI (postoperative echo in left eye). Measurements are in centimeters (cm).

When applying Spearman's Rho correlation coefficient, bilateral statistical significance was found ($p < 0.01$) when comparing the values recorded in the preoperative period in the general anesthesia group, in the spinal anesthesia group and in the postoperative values ($p < 0.05$). No statistically significant difference was found between the values obtained intraoperatively. Likewise, the maximum correlation (index of 1) was reached when comparing the measurements obtained in the right and left eye, at each moment of the study.

7. Discussion

The results of this work demonstrate the usefulness of ocular ultrasound in the diagnosis of ophthalmologic (retinal detachment) or neurologic (intracranial hypertension secondary to intracranial hemorrhage) pathologies in the preoperative period, which would indicate postponing the intervention or a non-spinal anesthetic technique, as indicated in the management guidelines for various neurological pathologies such as cranioencephalic trauma, hydrocephalus, subarachnoid hemorrhage, intracranial hematoma or idiopathic intracranial hypertension in adults [10].

Likewise, the recording of intracranial pressure increase in the intraoperative period could prevent and treat serious neurological pathologies such as optic nerve ischemic neuropathy, by immediately monitoring the effect of measures applied to optimize cerebral blood flow, either to decrease intracranial pressure (ICP) or to increase blood pressure [11].

The study presented here coincides with several publications that have highlighted the performance of optic nerve ultrasonography to diagnose elevated intracranial pressure, complementing the clinical examination, a priority in sedoanalgesia or patients under general anesthesia and muscle relaxation [12].

In general, higher optic nerve sheath diameter values were recorded in the right eye versus the left eye. Optic nerve sheath diameter increased after induction or intradural injection of anesthetic, to regain baseline levels after reaching full recovery from anesthesia or motor block. These results are in agreement with the literature in indicating optic nerve diameter monitoring as a noninvasive tool both in perioperative monitoring and in the critically ill patient [13], of choice over invasive intracranial pressure monitoring [14, 15].

Ultrasound measurement of optic nerve sheath diameter at 3 mm normal retrobulbar depth is less than 5 mm, which would be equivalent to intracranial pressure (ICP < 20 mmHg) [12, 16]. Several studies have demonstrated immediate reduction in intracranial pressure and optic nerve diameter due to decreased papilledema, either immediately [17], or 30 minutes after lumbar puncture [18]. Although values higher than this figure were recorded in this study, they were modified after repositioning the patient; however, they are not reflected in the study because they were not the objective of comparison, they were not associated with clinical symptoms, and baseline levels were recovered postoperatively in all cases.

The association between anesthetic-surgical factors and changes in intracranial pressure have been widely documented. Thus, laparoscopic surgery has been associated with increases in intracranial pressure that are intensity proportional to the duration of surgery, the Trendelemburg position [19], or the anesthetic used to maintain anesthesia, with propofol being more effective in protecting against surgical factors that increase intracranial pressure than sevoflurane® [20, 21].

The limitations of the study include the following:

First, despite abundant literature on anesthetic-surgical factors and their influence on intracranial pressure, no documented data have been found on the influence of spinal anesthesia without prior cerebrospinal fluid drainage [9]. Only optic nerve diameter measurements were recorded by placing the probe in the transverse axis of the eye, despite knowing the variability of the nerve sheath and the need to collect the diameter in longitudinal axis, however, most of the patients were wearing intraocular lenses that hindered visibility in this axis.

We should not forget the large number of perioperative factors that can influence the optic nerve sheath diameter, which is difficult to mask with a sample size such as the one presented, especially in the general anesthesia group. The authors are aware of the need to enlarge the sample size.

Finally, we did not take into account the blood pressure values at the time of the ultrasound study was performed, a key factor, together with the intracranial pressure in cerebral flow, we should not forget that invasive methods (intraventricular, subarachnoid or intraparenchymal catheter) remain as a choice in the measurement of intracranial pressure.

8. Conclusion

Optic nerve diameter increases after induction of anesthesia or intradural anesthesia, although it recovers baseline values in the immediate postoperative period. Optic nerve diameter monitoring is a useful non-invasive tool in perioperative patient monitoring.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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