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Original Article

Intraocular pressure changes in the intensive care unit: The effect of spontaneous respiration, mechanical ventilation, non-invasive CPAP and medical treatments

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Abstract

Aim: The aim of this study was to investigate the intraocular pressure (IOP) changes in patients in intensive care unit (ICU) and the parameters that cause these changes.

Material and Methods: In total, 304 eyes of 152 patients were examined. IOP and central corneal thickness (CCT) were measured. Age, sex, hospitalization (surgical/non-surgical causes), type of ventilation (spontaneous, intubated, non-invasive continuous positive airway pressure (CPAP), Glasgow coma scale, use of hypertonic solution and sedation status were evaluated.

Results: The mean age was 63.52±21.47 (range: 18–96) years, and the male/female ratio was 73/79. The mean hospitalization time was 30.91±47.80 (8-297) days, and the mean Glasgow coma scale score was 9.61±4.42. While 33 patients (21.7%) had hypertonic solution, 28 (18.4%) were sedated. The mean IOP was measured as 13.81±3.58 (6–28) mmHg. In 5 patients, the IOP was more than 20 mmHg, and in 14 patients, it was less than 10 mmHg. It was observed that gender and hospitalization diagnosis had no effect on the IOP change ($p=0.97$, $p=0.814$, respectively). When the patients were evaluated according to their respiration types, there was no statistically significant difference in IOP values between patients with spontaneous respiration and intubated patients ($p=0.261$), but non-invasive CPAP patients were significantly different from patients with spontaneous breathing ($p=0.035$) and intubated patients ($p<0.001$). In addition, the use of hypertonic solution and sedation significantly decreased IOP ($p<0.001$ in both groups).

Conclusion: Some changes in IOP were observed due to some applications in the ICU. These changes are often not significant in patients with no eye problems. However, patients with a glaucoma diagnosis or susceptibility to glaucoma, as well as patients with simultaneous IOP reduction, should be carefully monitored for IOP changes.

Keywords: Glaucoma; hypotony maculopathy; ıntensive care unit; intraocular pressure

INTRODUCTION

Aqueous humor—which provides globe integrity; delivers nutrients to the cornea, lens and trabecular network; and removes residual metabolites—contributes to the ocular immune response and creating a transparent environment for the optic system of the eye (1). Intraocular pressure (IOP) production of aqueous humor, outflow of aqueous humor and episcleral venous pressure–related changes in the complex are physiological events. Although normal IOP is considered to be 15.5±2.57 (range:10-20) mmHg, an imbalance in humoral aqueous secretion and discharging mechanisms may result in an increase or decrease in IOP (2). The optic nerve transmits visual signals from photoreceptors in the outer retina through more than 1 million nerve fibers to the visual processing areas of the occipital lobe. Increases in IOP can lead to permanent vision loss due to the effects on the axoplasmic flow and vascular bed and atrophy in the optic disc (3). Prolonged decreases in IOP may result in the development of hypotony maculopathy, which may cause severe reductions in vision (4). In contrast, increased IOP is the major risk factor for glaucoma development.

Glaucoma is a progressive, irreversible and neurodegenerative disease that can cause loss of vision in the optic nerve and ganglion cells, and it is a major cause of preventable blindness throughout the world (5). Hypotony maculopathy is a clinical picture in which papillary oedema and/or retinal and choroidal folds are

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observed when the IOP is less than 6.5 mmHg. Although it is seen after glaucoma surgery, it may also occur when the aqueous humor secretion is extremely low or the aqueous humor drainage is increased (6).

Many genetic, environmental and physiological factors have been identified that cause IOP changes. Age, gender, diurnal and postural variations, intraocular conditions, topical and systemic drugs used and the patient's metabolic status are some of these factors (7,8). Prevention of changes in IOP in the presence of certain risks is important for preventing irreversible damage to the optic disc and macula.

Intensive care units (ICUs) are clinics where patients are followed up and treated with a multidisciplinary approach. The patients in these clinics have the potential to experience altered IOP due to some applications for diagnosis and treatment and some metabolic problems during follow up. However, in ICUs, it is possible that healthcare workers focusing on correcting the patient's vital functions may ignore this factor. The aim of this study is to draw attention to the changes in IOP and the parameters that cause these changes in patients in the ICU.

MATERIAL and METHODS

Our study was conducted between September 2018 and April 2019 in Health Sciences University Diyarbakir Gazi Yasargil Education and Research Hospital Intensive Care Clinic after receiving approval from the Local Ethics Committee in accordance with the 2008 Human Rights Declaration. Patients who were older than 18 years and had no history of eye disease were followed up and treated in the ICU for more than 1 week. Patients with irregular arterial tension (above 140/90 mmHg, below 90/60 mmHg) and glucose values (above 200 mg/dl, below 60 mg/dl), corneal surface disorders that could prevent IOP measurement, a history of topical anti-glaucomatous drug use and intraocular surgeries or eye problems that could cause a secondary increase in mature cataract IOP were excluded from the study. Informed consent was obtained from the relatives of the patients. The patient data reviewed in the study included age, gender, IOP, CCT, hospitalization (non-surgical/surgical cause), length of hospitalization, type of ventilation (spontaneous/non-invasive CPAP/intubation), Glasgow coma scale value, use of sedative/neuromuscular blockade, use of intravenous hypertonic solution (20% mannitol or 3% NaCl) on the day of examination and use of drugs.

The patients' eye pressure was measured under local anesthesia (Alcaine, Proparacaine HCl 0.5%, USA) from both eyes (Reichert Tono-Pen, USA). The mean of the measurement of both eyes was entered into the database. Measurements were made at the supine position on his or her bed before noon; thus, the measurements were not affected by postural or diurnal variations. CCT was measured by ultrasonic pachymeter (MMD, P2000, USA) in both eyes under local anaesthesia (Alcaine, Proparacaine HCl 0.5%, USA).

All the data were recorded using SPSS 16 Windows (SPSS Inc., Chicago, IL, USA) package program. The numerical variables were shown as mean ± standard deviation (min–max), and the categorical variables were shown with the number of cases (n) and percentage (%). İndependent t-tests were used for comparing categorical variables between two or more groups. A p-value <0.05 was considered statistically significant.

RESULTS

In total, 304 eyes of 152 patients treated in the ICU were included in the study. The demographic data of age, sex, CCT, length of stay, hospitalization (surgical/internal causes), type of ventilation, Glasgow coma scale, use of hypertonic solution, and sedation status are summarized in Table 1.

Table 1. Demographic data and clinical characteristics of the patients

Age (years) (mean±sd) (range) (n:152)	63.52±21.47 (18-96)
Gender (male / female) (n/%) (n: 152)	73 (48%) / 79(52%)
Central Corneal Thickness (µm) (mean±SD) (range)	533.95±24.92 (474-612)
Length Of Icu Stay (days) (mean±Sd) (range) (N:152)	30.91±47.80 (8-297)
Cause of Icu Admission (non-surgical / surgical),(n/%) (n:152)	95(62.5%) / 57(37.5%)
Ventilation Type	
Intubation	65 (42.8%)
Spontaneous	46 (30.2%)
Non-invasive Cpap	41 (27%)
(n/%) (n:152)	
Glasgow Coma Scale Score (mean±SD) (n:152)	9.61±4.42 (3-15)
Use of Intravenous Hypertonic Solution - / + (n/%) (n:152)	119(78.3%) /33(21.7%)
Sedation Status sedatized / non-sedatized (n/%) (n:152)	28 (18.4%) / 124 (81.6%)

Results are denoted as 'number(percent)' of subjects, SD: Standard Deviation µm: micron meter, ICU: Intensive Care Unit, Cpap: Continous Positive Airway Pressure

IOP changes with sex, hospitalization, type of ventilation, hypertonic solution usage, and sedation status are summarized in Table 2. There was no statistically significant difference between patients with spontaneous respiration and IOP (p=0.261). However, non-invasive CPAP patients were compared with the other two groups, and the differences were statistically significant for spontaneous breathing (p=0.035) and intubated patients (p<0.001). In addition, the use of hypertonic solution and sedation showed a statistically significant difference in IOP (p<0.001 in both groups).

Table 2. Intraocular pressure results of the patients

	Intraocular Pressure (mm Hg)	P value
Mean Value (mm Hg) (mean±SD) (range)	13.81±3.58 (6-28)	
Male (mean±SD) (n:73)	13.79±3.29	P : 0.97*
Female (mean±SD) (n:79)	13.82±3.85	
Non-Surgical Causes (mean±SD) (n:95)	13.75±3.50	P : 0.814*
Surgical Causes (mean±SD) (n: 57)	13.89±3.75	
Type Of Ventilation		
Intubation(mean±SD) (n:65)	12.92±3.78	Spontaneous-cpap p : 0.035*
Spontaneous (mean±SD) (n:46)	13.77±4.13	Cpap-intubated p<0.01*
Non-invasive Cpap (mean±SD) (n:41)	15.26±1.71	Spontaneous-intubaed p : 0.261*
Use of Intravenous Hypertonic Solution		
-(mean±SD) (n:119)	14.58±3.54	p<0.001*
+ (mean±SD) (n:33)	11.03±2.07	
Sedation Status		
Non-sedatized (mean±SD) (n:124)	14.56±3.42	p<0.001*
Sedatized (mean±SD) (n:28)	10.45±2.02	

Results are denoted as 'number(percent)' of subjects , SD: Standard deviation ,* : Independent t-test mm: millimeter ,Cpap: Continous Positive Airway Pressure

DISCUSSION

Patients treated in ICUs are at increased risk of the possibility of IOP changes due to advanced age, sedation, fluid electrolyte imbalance and invasive/non-invasive mechanical ventilation (4,7,8). Monitoring of these patients for variable IOP values is important for preventing possible irreversible damage.

IOP usually increases with age. Despite the decrease in the secretion of aqueous humor, the increase in the outflow and uveoscleral flow augment has the tendency towards increased IOP (9). In the Beaver Dam Eye Study, conducted among people aged 43-86 years, IOP was found to be related to systolic and diastolic blood pressure, serum glucose level, glycosylated hemoglobin, pulse, and season and measurement time (10). In our study, the mean age of the patients was 63 years. Patients with abnormal blood pressure and serum glucose levels were excluded from the study, and this factor was eliminated. There are different views about the effect of gender on IOP; in general, it is stated that gender does not have a major effect on IOP in the population between 20 and 40 years of age, but there is an increase in women in comparison with men due to hormonal factors as age progresses (11). In the Barbados Eye Study (7), IOP was found to be higher in women than it was in men, while in another study (12), no difference was found between the two groups. We did not find any differences in IOP values between men and women in our patient group (p=0.97).

Along with IOP, CCT is a parameter used in the diagnosis and follow up of glaucoma patients. The values are with an average of 536±31 μm (13). In case of CCT values different from the mean values, the IOP value is revised as 'corrected IOP'. Although it is not a generally accepted formula, correction of 1 mmHg is made for each 12–15 μm difference in corneal thickness values from the average. (IOP is decreased by 1 mmHg in high corneal thickness values, while it is increased by 1 mmHg in low corneal thickness values) (14). In our study, the CCT was found to be 533.95±24.92 μm, and this is compatible with the literature. Corrected IOP values of patients with CCT measured to be different from the average were entered into the database, which prevented the IOP results from being affected by abnormal corneal thickness.

Several studies have shown that IOP values may vary depending on the time of day and patient's position. Although some hormonal factors that control this biological rhythm have been shown, this complex event is not fully understood (8,15). To ensure that our study was not affected by these factors, we took our measurements when the head and body were at the same level.

In ICUs, invasive and non-invasive mechanical respiratory support is preferred for many different indications. It is thought that increased vitreous pressure may increase the IOP with suppression of venous return due to the superior vena cava pressure in patients undergoing mechanical ventilation (16,17). Johnson et al. (18) reported that this increase was related to the pressure level applied in mechanical ventilation, and there were no significant changes in IOP in low pressure (7–15 cm H2O) applications; however, increased IOP was found even in short-term high pressure (60 cm H2O) applications. In the literature, a case of bilateral optic atrophy after a short period of high-level pressure mechanical ventilation has been described (19). Teba et al. (20) reported that mechanical ventilation had no effect on central venous pressure, but if the duration of mechanical ventilation was prolonged, there could be clinically insignificant increases in IOP. Non-invasive CPAP, another mode of respiratory support, also increases IOP. Although these increases are not usually clinically significant, it is recommended to avoid this practice, especially in patients with glaucoma (21). Patients with obstructive sleep apnea syndrome, in which CPAP is applied for treatment, should be followed up regularly for increased IOP and risk of glaucoma (22). In our study, no significant differences in IOP were observed in patients with spontaneous breathing compared with intubated patients (p=0.261), but IOP was significantly higher in these patients compared with the non-invasive CPAP group (p=0.035). The difference between IOP in intubated patients and patients with non-invasive CPAP was statistically significant (p<0.001). In our cases, in patients who underwent non-invasive CPAP, we observed clinically insignificant increases. No pressure was applied in any of our patients. Non-invasive CPAP was performed in four out of five cases with an IOP level over 20 mmHg, and one patient was breathing spontaneously. We think that mechanical ventilation should not follow clinically significant IOP changes in patients with no risk factors, but patients with glaucoma susceptibility or glaucoma diagnosis should be monitored for IOP increases.

In ICUs, intravenous hypertonic solutions are frequently used for treating hypovolemic shock and reducing intracranial pressure. These solutions increase the systemic blood volume, increase blood pressure, and reduce intracranial pressure by pulling liquids from the tissue into the intravascular cavity osmotically (23,24). In ophthalmology practice, in patients with high IOP, is frequently used to reduce IOP in the acute phase. These solutions provide a 20-30% reduction in IOP within 5 minutes to 2 hours (25,26). However, this application, which does not cause severe IOP reduction in patients with normal IOP, may lead to the development of hypotony maculopathy in patients with long-term sedation. Although such a case has not been described in the literature, patients with long-term use of this solution should be monitored for the development of hypotony maculopathy, especially if there is another application that may lead to a decrease in IOP. In our study, we observed that one patient who had an IOP level under 6.5 mmHg had sedation for more than 1 week and used hypertonic solution for 3 days. However, there was no finding in favor of hypotony maculopathy in this patient.

CONCLUSION

Sedation is the cornerstone of patient care in ICUs. However, it has been reported that drugs used for sedation may cause different rates of decreased IOP (27,28). It is estimated that the underlying mechanism has a direct effect on the brain centers controlling IOP and indirectly effect on the production and drainage of aqueous humor. (29). In our patient group, sedation was found to be an important parameter causing IOP reduction (p<0.001). Of the 14 patients with an IOP level below 10 mmHg, 5 were patients who were sedated for more than 1 week. These low values are not clinically relevant in most patients, but we think that these patients should be followed up for the risk of developing ocular hypotonia if other applications are performed in sedated patients, which may lead to a decrease in IOP.

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REFERENCES

1. Civan MM, Macknight AD. The ins and outs of aqueous humour secretion. Exp Eye Res 2004;78:3:625-31.
2. Leydhecker W, Akiyama K, Neumann HG. Intraocular pressure in normal human eyes(in German). Klin Monbl Augenheilkd Augenarztl Fortbild 1958;133:662-70.
3. Duke-Elder S.The problems of simple glaucoma.Trans Ophthalmol Soc U K 1962;82:307.
4. Seah SK, Prata JA Jr, Minckler DS, et al. Hypotony following trabeculectomy. J Glaucoma.1995;4:2:73-9.
5. George R, Ve RS, Vijaya L. Glaucoma in India: Estimated burden of disease. J Glaucoma 2010;19:391-7.
6. Thomas M, Vajaranant TS, Aref AA. Hypotony Maculopathy: Clinical Presentation and Therapeutic Methods. Ophthalmol Ther 2015;4:79–88.
7. Leske MC, Connell AM, Wu SY, et al. Distributıon of intraocular pressure. The Barbados Eye Study. Arch Ophthalmology 1997;115:8:1051-57.
8. Bagga H, Liu JH, Weinreb RN. Intraocular pressure measurements throughout the 24 h. Currv Opin Ophthalmology 2009;20:79-83.
9. Toris CB, Yablonski ME, Wang YL, et al. Aqueous humor dynamics in the aging human eye. Am J Ophthalmol 1999;127:407-12.
10. Klein BE, Klein R, Linton KL. Intraocular pressure in an American community. The Beaver Dam Eye Study. Invest Ophthalmol Vis Sci 1992;33:2224-8.
11. Armaly MF. On The dıstrıbutıon of applanatıon pressure. I. Statıstıcal features and the effect of age,sex and famıly history of glaucoma. Arch Ophthalmol. 1965 ;73:11-18.
12. Fukuoka S, Aihara M,Iwase A, et al. Intraocular pressure ın an ophthalmologically normal Japanese populatıon.Acta Ophthalmology 2008;86:434-39.
13. La Rosa FA, Gross RL, Orengo-Nania S. Central corneal thickness of Caucasians and African Americans in glaucomatous and nonglaucomatous populations. Arch Ophthalmol 2001;119:23-7.
14. Damji KF, Muni RH, Munger RM. Influence of corneal variables on accuracy of intraocular pressure measurement. J Glaucoma 2003;12:69-80.
15. David R, Zangwill L, Briscoe D, et al. Diurnal intraocular pressure variations: an analysis of 690 diurnal curves. Br J Ophthalmology 1992;76:280-3.
16. Spapen HD, D'Haese J, Diltoer M, et al. Bedside evaluation of intraocular pressure in critically ill patients, ventilated at different levels of positive end-expiratory pressure. Acta Anaesthesiol Belg 1993;44:39-43.

17. Pillar A, Jeng BH, Munir WM. Positive End-Expiratory Pressure as a Risk Factor for Severe Positive Vitreous Pressure During Combined Penetrating Keratoplasty and Cataract Extraction. Cornea 2016;35:1491-4.
18. Johnson DS, Crittenden DJ. Intraocular pressure and mechanical ventilation. Optom Vis 1993;70:523-7.
19. Chelluri L, Jastremski MS. Bilateral optic atrophy after cardiac arrest in a patient with acute respiratory failure on positive pressure ventilation. Resuscitation 1988 ;16:45-8.
20. Teba L, Viti A, Banks DE, et al. Intraocular pressure during mechanical ventilation with different levels of positive end-expiratory pressure. Crit Care Med 1993;21:867-70.
21. Alvarez-Sala R, García IT, García F, et al. Nasal CPAP during wakefulness increases intraocular pressure in glaucoma. Monaldi Arch Chest Dis 1994;49:394-5.
22. Cohen Y, Ben-Mair E, Rosenzweig E, et al. The effect of nocturnal CPAP therapy on the intraocular pressure of patients with sleep apnea syndrome. Graefes Arch Clin Exp Ophthalmol 2015;253:2263-71.
23. Tyagi R, Donaldson K, Loftus CM, et al. Hypertonic saline: A clinical review. Neurosurg Rev 2007;30:277-90.
24. Himmelseher S.Hypertonic saline solutions for treatment of intracranial hypertension. Curr Opin Anaesthesiol 2007;20:414-26.
25. Harju M, Kivelä T, Lindbohm N, et al. Intravenous hypertonic saline to reduce intraocular pressure. Acta Ophthalmol 2013;91:625-9.
26. Inborr PK, Harju M, Kivelä TT. Intravenous Hypertonic Saline to Lower Intraocular Pressure in Ocular Hypertension and Primary Open-angle and Exfoliation Glaucoma. J Glaucoma 2018;27:638-42.
27. Hanna SF, Ahmad F, Pappas AL, et al. The effect of propofol/remifentanil rapid-induction technique without muscle relaxants on intraocular pressure. J Clin Anesth 2010;22:437-42.
28. Oberacher-Velten I, Prasser C, Rochon J, et al. The effects of midazolam on intraocular pressure in children during examination under sedation. Br J Ophthalmol 2011;95:1102-5.
29. Jantzen JP. Anesthesia and intraocular pressure. Anaesthesist 1988;37:458-69.