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ORIGINAL ARTICLE

Can we use intraocular pressure as a non-invasive intracranial pressure monitoring?

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ABSTRACT

Background and Objectives: intracranial hypertension is widely known to be a common problem dealt in neurosurgical patients. Currently, invasive methods are used to measure or monitor the intracranial pressure(ICP). Non-invasive monitoring or method to measure ICP is yet to be used or known. Correlation between intraocular pressure and ICP via various normal anatomical connections, would be a potential method for measuring or monitoring of ICP in clinic. The noninvasive intraocular pressure as a representation of intracranial pressure still be a few papers so we try to use this method for correlation of ICP in practice which would be useful for guiding of ICP treatment in clinic.

Materials and Methods. Fifty participants were included in this study. We measured intraocular pressure (IOP) and ICP twice and analyzed with Pearson's correlation to find the correlation between IOP and ICP. Cut of point of IOP was determined to predict the occurrence of intracranial hypertension.

Results: The study result confirmed that there is a moderately strong correlation between intraocular pressure and intracranial pressure which meant IOP increase was associated with increased ICP. However, this study showed the predict amount of ICP change following the IOP change because of many factors causing interruption in measurement of IOP precisely.

Conclusions: There is a correlation of IOP change and ICP change but the usage of IOP to monitor ICP as non-invasive method was not feasible due to this method of IOP has pressure shift with ICP (Gold standard).

Keywords: intracranial pressure, intraocular pressure, intracranial hypertension, non- invasive measurement
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Background

The intracranial hypertension or increased intracranial pressure is common neurosurgical problem associated with various pathological causes. The current method of measuring intracranial pressure involves only invasive methods and there is no non-invasive method for the ICP measurement. It's known that the orbit and intracranial anatomy are well connection. The anatomical relation between the orbit and intracranial gets achieved via many structures, that includes optic canal and superior orbital fissure which makes direct connection between orbit and intracranium, and the meningeal layers covering the brain till the optic nerve. Furthermore, even the venous system of the orbit that includes superior and inferior ophthalmic vein also connects to cavernous venous sinus within the intracranium.[1,2]

In addition, a condition called "Terson Syndrome" has been known to affirm the direct effect on intraocular pressure by the raised intracranial pressure.[3] This syndrome shows an occurrence of the vitreous hemorrhage in the eye due to rise in intraocular pressure caused by sudden increase in intracranial pressure from aneurysmal subarachnoid hemorrhage.

We therefore hypothesized that intracranial pressure and intraocular pressure has a good anatomical connection and perhaps we can use intraocular pressure as a non-invasive intracranial pressure monitoring.

We reviewed literatures and found several studies showing correlation and non-correlation between IOP and ICP. The study of P Sheeran showed the correlation of ICP and IOP in critical ill patients.[2] The literature of Tomasz Czarnik, et.al found correlation between IOP and ICP in 12 patients from 22 patients,[4] However; the other study by Tim Muchnok et. Al reveal non correlation between IOP and ICP via lumbar puncture.[5] Thomas Spentzas et.al showed the lack of accuracy in monitoring of ICP via measurement of IOP in the close management of intracranial pressure in the acute posttraumatic period.[6] Therefore, the correlation of IOP and ICP is still inconclusive and this study would explore the potential correlation of them. This method would apply for clinical use in term of ICP measurement before the subtle intracranial hypertension occurring.

Materials and Methods

This study was approved by the Institutional Review Board of Mahidol University. A Cohort study was done on 50 adult (more than 15 years old) subjects admitted in neurosurgery ward and Neuro- intensive care unit. We investigated the correlation between intraocular pressure (IOP) and intracranial pressure (ICP) in various diseases and conditions, such as ruptured intracranial aneurysm, intracranial tumor, and obstructive hydrocephalus of any pathological cause which required external ventricular drainage as the part of the treatment.

The method for ICP measurement involved using the intraventricular route which is the gold standard for intracranial pressure monitoring. ICP measurement was done on two sessions. The first measurement was done after the patient and their relative had been informed and consented to join the study. The second measurement was then made at 6 to 24 hours after the first measurement. The patient was placed in recumbent position during the ICP and IOP measurement.

The intraocular pressure was measured by the handheld tonometer (Tono-Pen AVIA®). Patients who had history of glaucoma and ophthalmologic surgery were excluded. Chlortetracaine was used for local anesthesia and IOP was measured in both eyes and then mean IOP was calculated. The ICP and IOP were measured at the same time. Blood pressure was measured and mean arterial pressure (MAP) was recorded to evaluate the correlation with ICP and IOP.

After the second measurement of IOP and ICP, the difference between the first and second measurement of ICP and IOP were calculated. The difference of 1st and 2nd measurement was done to define the change in values of IOP and ICP whether it increased or decreased. For example: if the first measurement of ICP was 10 mmHg and the second was 14 mmHg, the change of ICP +4 mmHg was noted as increased and if the first time measurement of ICP was 16 mmHg and the second time was 12 mmHg, the change of ICP of -4 mmHg was noted to be decreased.

We hypothesized that IOP and ICP should has a good relation. The change in ICP should be directly proportional to IOP i.e. increase in ICP should lead to increase in IOP and decrease in ICP should lead to decrease in IOP. Pearson's correlation was used to analyze the correlation between the changing value of intracranial pressure and the changing value of the intraocular pressure. The characteristics of the subjects are shown in table 1.

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Table 1. Characteristic of patient data

Characteristics	Value
Age (Yrs)	
Mean	53
Interquatile Range(IQR)	15-85
Gender	
Male(%)	23(46)
Female(%)	27(54)
Diagnosis	
Intracerebral hemorrhage(%)	5(10)
Infection(%)	3(6)
Rupture intracranial aneurysm(%)	19(38)
Vascular malformation(%)	1(2)
Supratentorial tumor(%)	13(26)
Infratentorial tumor(%)	9(18)

Results

In this study, there was 50 participants, 23 male and 27 female. The mean age was 53.25 year. The diseases or conditions of the patient that required the external ventricular drainage were classified as, 5 intracerebral/intraventricular hemorrhage (10%), 3 infection (6%), 19 Ruptured intracranial aneurysm (38%), 1 Vascular malformation (2%), 13 Supratentorial tumor (26%) and 9 Infratentorial tumor (18%)

The mean of first time measured IOP was 14.33 mmHg (9-21.5 mmHg) and ICP was 14.15 mmHg (5-33.5 mmHg). The mean of second time measured IOP was 14.64 (7.5-22.5 mmHg) and ICP was 14.5 (4-23.5 mmHg)

We used Pearson's correlation to analyze the changing value of ICP (2^{nd} ICP- 1^{st} ICP) and changing value of IOP (2^{nd} IOP – 1^{st} IOP). As previous study, there was a good correlation of IOP (Goldman applanation tonometer) and ICP measurement via lumbar puncture.[7] We found the Correlation Coefficient at 0.570. It showed moderately strong linear correlation between change of IOP and ICP based on correlation coefficient interpreted by Colton (1974), which meant the change of IOP and ICP were directly proportional. For instance, if the rise of IOP happened the ICP trend to be increased. On the other hand, when the IOP decrease, the ICP will decrease simultaneously. (Figure 1, 2)

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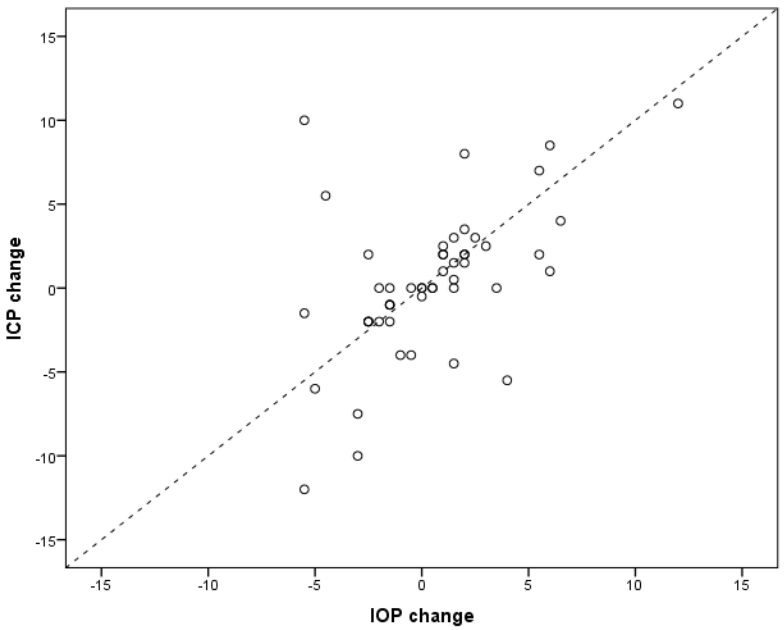
Figure 1. Spearman rank-order correlation coefficient for relation of IOP change and ICP change

			IOP change	ICP change
Spearman's rho	IOP change	Correlation Coefficient	1.000	.570
		Sig. (2-tailed)	.	.000015
		N	50	50
	ICP change	Correlation Coefficient	.570	1.000
		Sig. (2-tailed)	.000	.
		N	50	50

IOP(intraocular pressure), ICP (intracranial pressure)

Figure 2. The scatter plot of ICP change (mmHg) versus IOP change(mmHg) show positive correlation respectively



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We tried to analyze the correlation between IOP/ICP and MAP but it demonstrated no correlation. Subsequently, the MAP did not have any effect on the changing IOP or ICP. This phenomenon would be explained by the autoregulation mechanism of cerebral blood vessels.[1]
(Table 2)

However, in this study, some patients who had intracranial hypertension (>20 mmHg) had more different IOP values between both eyes than in the normal ICP patients. So we tried to analyze the correlation in patients with different IOP between both eyes (IOP difference value more than 2mmHg) and patients with equal or different IOP (IOP difference of less than 2mmHg between eyes) in both eyes.

Interestingly, those patients who had unequal IOP of both eyes with difference more than 2 mmHg, all of them had ICP more than 15 mmHg (100%) compared with patients who had equal IOP in both eyes and difference less than 2 mmHg. The latter had ICP more than 15 mmHg only in 34.8% which has statistical significance (P 0.021).
In patients who had unequal IOP of both eyes with difference more than 2 mmHg, it can be predicted that the patient had ICP more than 15 mmHg. (Sensitivity 20%, specificity 100% positive predictive value (PPV) 100% and negative predictive value (NPV) 65.2% but we have no scientific explanation in this phenomenon and still need further investigation. (Table 3)

Table 2. Correlation between IOP and MAP, ICP and MAP by Spearman rank-order coefficient

			MAP
Spearman's rho	IOP	Correlation Coefficient	.186
		Sig. (2-tailed)	.215
		N	46
	ICP	Correlation Coefficient	.058
		Sig. (2-tailed)	.703
		N	46

IOP(intraocular pressure), ICP (intracranial pressure), MAP, mean arterial pressure

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Table 3. Correlation of IOP change more than 2 mmHg between both eyes and intracranial hypertension

Chi-Square Tests	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.522[a]	1	.011		
Continuity Correction[b]	4.087	1	.043		
Likelihood Ratio	7.861	1	.005		
Fisher's Exact Test				.021	.021
Linear-by-Linear Association	6.391	1	.011		
N of Valid Cases	50				

df (degree of freedom)

We tried to analyze IOP cut of point to predict the intracranial hypertension that was associated with poor neurological outcome and required aggressive management (i.e. ICP >20 mmHg), but optimum cut of point or value of IOP to predict ICP more than 20mmHG couldn't be determined.

Discussion

We hypothesized that the orbit and intracranial anatomy has a good connection and the change in intracranial pressure have effect on intraocular pressure. As previous systematic review, they showed a good correlation between IOP and ICP, then IOP measurement may be clinically used as intracranial hypertension detection.[8] Hence question was if intraocular pressure and intracranial pressure has correlation 'can we use intraocular pressure as a non-invasive intracranial pressure monitoring'?

In this study, we enrolled 50 patients who have had the various diseases and conditions which needed external ventricular drainage. The study result confirmed that there is a moderately strong correlation between intraocular pressure and

intracranial pressure which meant IOP increasing was associated with the increased ICP. Data analysis were done to predict the exact value of ICP change when the IOP was changed from the baseline but couldn't determine it precisely. We could only observe the rise of IOP and the ICP increase, but it's change has not been as one by one. There was inaccuracy to predict amount of ICP change following the IOP change because of many factors causing interruption in measurement of IOP precisely. This factors included, patient positioning during measurement and patient squeezing their eyes during the measurement. Such factors might have caused measurement error. Though the change of IOP was seen to have correlation with change of ICP in the same direction, the change of IOP whether it was immediate after the change of ICP or was delayed couldn't be figured out. Hence it was not accurate enough to use IOP as a non-invasive ICP monitoring in critical patients. As another study demonstrated the good correlation of ICP and IOP especially in the pediatric group with severe head injury which ICP more than 20 mmHg, however, the correlation will decrease when ICP less than 20 mmHg.[6]

To predict the patient who has intracranial pressure with value more than 20mmHG and required aggressive treatment, optimum value of IOP was required to be found. However, in this study, the optimum value or cut of point of IOP to predict intracranial pressure more than 20mmHG couldn't be determined. Therefore, this study can be concluded that IOP measurement has some correlation with ICP but it couldn't determine the actual ICP, do in critical ill patient would need more accurate of ICP monitoring.

Consequently, we observed that some patients who had increased intracranial pressure from the baseline they also had increase in intraocular pressure. However, IOP increased unequally between both eyes and the difference of IOP between the eyes were more than 2 mmHg. It also noted that if patient had difference of IOP between their eyes more than 2 mmHg, all of them had ICP more than 15 mmHg. Those patients who had equal IOP on both eyes or unequal IOP with difference less than 2 mmHg, only one-third had ICP more than 15 mmHg (Sensitivity 20%, specificity 100% PPV 100% and NPV 65.2%. This increase in phenomenon was unexplainable and hence require further study.\

Limitation

The IOP measurement has a limitation in a case of eye diseases such as glaucoma, or even with eye trauma with soft tissue swelling. The IOP measurement device is not available in the emergency room or Intensive care unit.

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Conclusion

This method of IOP couldn't determine the real ICP and the change of IOP has some correlation with ICP change. We couldn't find the cut-off point of IOP which can represent the intracranial hypertension. However, we found some phenomenon of IOP difference more than 2 mmHg has relation to increased intracranial pressure more than 15 mmHg. In critical patient, we need to have a good correlation with gold standard measurement of ICP (ventriculostomy), so IOP method could have moderate strong correlation with ICP. Finally, our study revealed that IOP couldn't be used as ICP monitoring.

References

1. Czarnik T, Gawda R, Kolodziej W, Latka D, Sznajd-Weron K, Weron R. Associations between intracranial pressure, intraocular pressure and mean arterial pressure in patients with traumatic and non-traumatic brain injuries. *Injury*2009. p. 33-9.
2. Sheeran P, Bland JM, Hall GM. Intraocular pressure changes and alterations in intracranial pressure. *The Lancet*. 2000;355(9207):899.
3. McCarron M, Alberts M, McCarron P. A systematic review of Terson's syndrome: frequency and prognosis after subarachnoid haemorrhage. *Journal of Neurology, Neurosurgery, and Psychiatry*. 2004;75(3):491-493. doi:10.1136/jnnp.2003.016816.
4. Czarnik T, Gawda R, Latka D, Kolodziej W, Sznajd-Weron K, Weron R. Noninvasive measurement of intracranial pressure: is it possible? *The Journal of trauma*. 2007 Jan;62(1):207-11. PubMed PMID: 17215756.
5. Muchnok T, Deitch K, Giraldo P. Can intraocular pressure measurements be used to screen for elevated intracranial pressure in emergency department patients? *The Journal of emergency medicine*. 2012;43: 532-7. PubMed PMID: 20580516.
6. Thomas Spentzas, Jared Henricksen, Andrea B. Patters, Edward Chaum. Correlation of intraocular pressure with intracranial pressure in children with severe head injuries. *Pediatr Crit Care* Med. 2010; 11(5): 593–598.
7. Li Z, Yang Y, Lu Y, Liu D, Xu E, Jia J, et al. Intraocular pressure vs intracranial pressure in disease conditions: a prospective cohort study (Beijing iCOP study). *BMC neurology*. 2012;12: 66. PubMed PMID: 22862817. Pubmed Central PMCID: 3444958.
8. Yavin D, Luu J, James MT, Roberts DJ, Sutherland GR, Jette N, et al. Diagnostic accuracy of intraocular pressure measurement for the detection of raised intracranial pressure: meta-analysis. *J Neurosurg*. 2014;121:680-7. PubMed PMID: 24857243