

CASE STUDY

Optic nerve sheath diameter ultrasonography for elevated intracranial pressure detection

Li-Juan Wang , Hong-Xiu Chen , Ying Chen , Ze-Yang Yu  & Ying-Qi Xing 

Department of Neurology, The First Hospital of Jilin University, Changchun, China

Correspondence

Ying-Qi Xing, The First Hospital of Jilin University, Xinmin Street 1, Changchun 130021, China. Tel: 86-158430637846; Fax: 0086-431-88782762; E-mail: xingyq2009@sina.com

Funding Information

This work was supported by the National Natural Science Foundation of China (No.81801707).

Received: 21 February 2020; Revised: 13 April 2020; Accepted: 14 April 2020

Annals of Clinical and Translational Neurology 2020; 7(5): 865–868

doi: 10.1002/acn3.51054

Introduction

Elevated intracranial pressure (ICP) is considered to be a common emergency condition. High ICP is associated with poor clinical outcomes, including high mortality rates in various neurological diseases.^{1,2} Determining the ICP is essential for the diagnosis of neurological diseases and hence there is an urgent need for simple, reproducible, noninvasive ICP measurement methods. Ultrasonographic optic nerve sheath diameter (ONSD) measurement has been increasingly investigated as a non-invasive method for timely detection of elevated ICP.^{3,4,5}

This technique is based on the anatomy of the optic nerve sheath (ONS) and its surrounding structures. The ONS is an extension of the dura mater, with a subarachnoid space containing cerebrospinal fluid. Because of this communication, cerebrospinal fluid can shift between the intracranial and intraorbital subarachnoid spaces.⁶ The intraorbital subarachnoid space surrounding the optic nerve is subject to the same pressure changes as that in the intracranial subarachnoid space.⁷ In 1989, it was discovered that ONSD could be measured by B-mode

Abstract

Ultrasonographically measured optic nerve sheath diameter measurement has become a common noninvasive approach for detecting elevated intracranial pressure. We present a case of aneurysmal subarachnoid hemorrhage with elevated intracranial pressure. Postoperative arachnoiditis developed, and lumbar puncture revealed low intracranial pressure. However, ultrasonography revealed a dilated optic nerve sheath, denoting elevated intracranial pressure. This was confirmed by computed tomography showing ventricular dilation. Ophthalmoscopy revealed papilledema and hemorrhage. This case study demonstrated that noninvasive bedside ultrasonographic optic nerve sheath diameter measurement can detect elevated intracranial pressure more accurately than lumbar puncture, especially in cases with intracranial infection.

ultrasonography, which demonstrates increases in ONSD in patients with increased ICP.⁸ Other subsequent studies confirmed the correlation between ONSD and ICP.^{9,10} However, this technique has been used only to detect an elevated ICP in cases of severe traumatic brain injury.

We present a complicated case of aneurysmal subarachnoid hemorrhage with spinal arachnoiditis, severe infection, and a dramatically fluctuant ICP. Spinal arachnoiditis is a rare complication of aneurysmal subarachnoid hemorrhage.¹¹ We measured the ONSD using ultrasonography for the assessment of ICP, and found this to be a rapid, noninvasive bedside method, especially suitable in our case with severe infection.

Case Description

A 27-year-old man was admitted to the emergency department with an abrupt, severe headache and loss of consciousness for 2 hours. Physical examination revealed a moderate coma. Brain computed tomography (CT) showed frontal and ventricular high-density shadows (Fig. 1A), and computed tomography angiography (CTA)

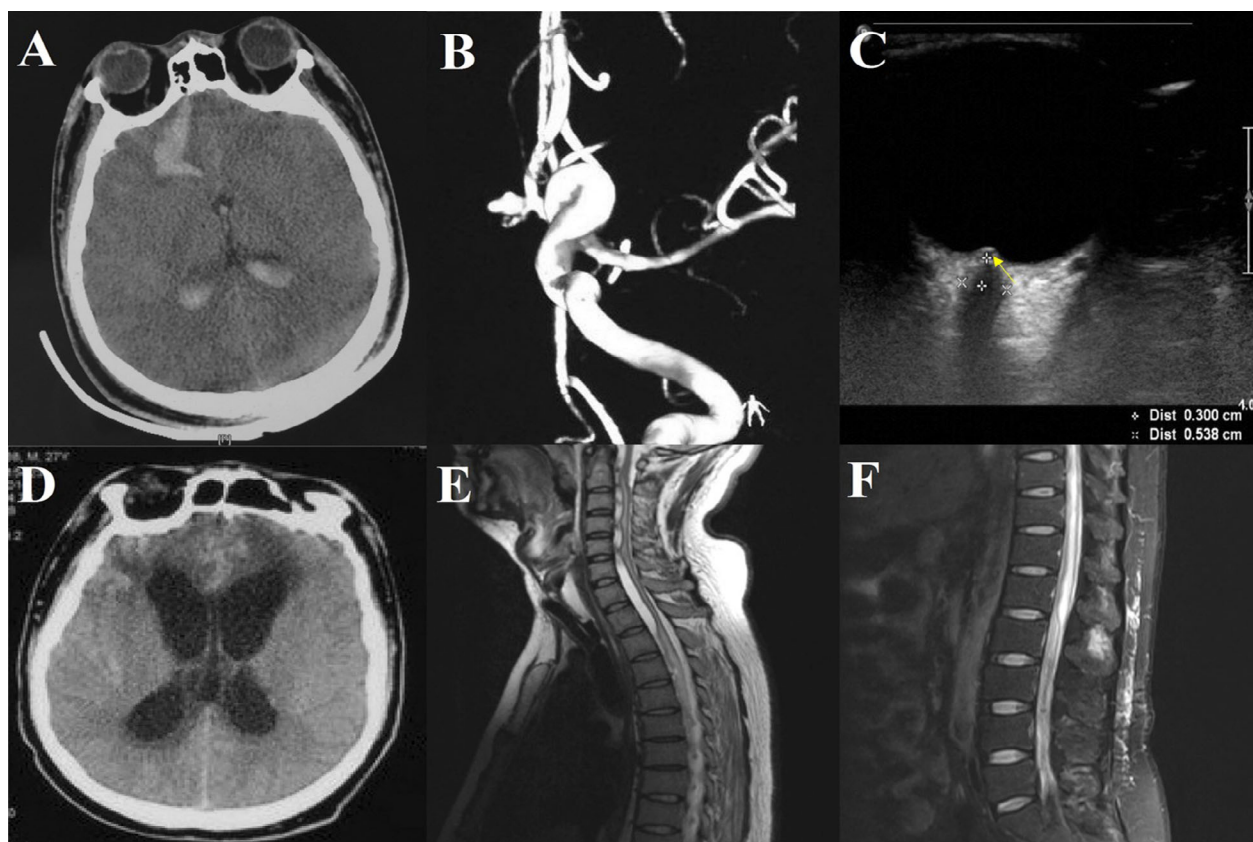


Figure 1. (A) The head CT shows frontal and ventricle high-density shadows in a patient with subarachnoid hemorrhage. (B) Computed tomography angiography (CTA) of the head shows an anterior communicating artery aneurysm. (C) After surgery, the optic nerve sheath diameter was 0.538 cm and there was papilledema (arrow). (D) A CT scan of the head shows ventricular dilation. (E) The cervicothoracic MRI shows arachnoid adhesions in the spinal cord. (F) The lumbar MRI shows lumbar spinal stenosis and subarachnoid space stenosis.

established a diagnosis of an anterior communicating artery aneurysm (Fig. 1B). The following day, the patient underwent aneurysm embolization and lumbar cistern drainage.

One week later, cerebrospinal fluid examination revealed a postoperative infection (white blood cells: $11897 \times 10^6/L$). Lumbar puncture (LP) revealed an opening pressure of 320 mmH₂O. Anti-infective and ICP lowering therapies were administered for 2 weeks. Subsequent cerebrospinal fluid examination revealed a decrease in the white blood cell count to $135 \times 10^6/L$. LP revealed an opening pressure of 180 mmH₂O. However, there was no significant symptomatic improvement. One week later, LP revealed low ICP (30 mmH₂O).

Ultrasonographic ONSD measurement was conducted to confirm the ICP value. Ultrasonography showed a dilated ONSD of 5.38 mm and papilledema consistent with elevated ICP (Fig. 1C). ICP was calculated using the mathematical equation¹⁰.

$ICP = -111.92 + 77.36 \times ONSD$ which indicated an elevated ICP (304 mmH₂O). Ophthalmoscopy showed

papilledema and hemorrhage. The patient subsequently underwent a brain CT, which revealed ventricular dilation, confirming the elevated ICP (Fig. 1D).

Finally, the patient underwent cervicothoracic and lumbar magnetic resonance imaging (MRI) examinations. The cervicothoracic MRI revealed arachnoid adhesions in the spinal cord (Fig. 1E), while the lumbar MRI revealed lumbar spinal stenosis and narrowing of the subarachnoid space (Fig. 1F).

Discussion

This case study shows that, in cases where cerebrospinal fluid pressure measurements by LP are inconsistent with the patient's symptoms, noninvasive bedside ultrasonographic ONSD measurement can serve as a viable clinical alternative for the assessment of ICP. This is particularly true in cases with concomitant infection. To the best of our knowledge, this is the first study to report that ultrasonographic ONSD measurement can detect elevated ICP more accurately than LP in more complicated cases.

This patient had arachnoid adhesions in the spinal cord, lumbar spinal stenosis, and narrowing of the subarachnoid space. Cerebrospinal fluid could not flow freely between the intracranial and lumbar subarachnoid spaces. Hence, LP could not assess the ICP accurately. In contrast, ultrasonography detected a dilated ONS, indicating elevated ICP that was subsequently confirmed by the ventricular dilation shown in the CT study. In addition, we quantitatively determined the ICP using a mathematical model based on the patient's ONSD data, which served as supplemental information of the patient's condition.

Although there are other methods of assessing ICP accurately, all of them have several disadvantages in comparison to ultrasonographic ONSD measurement. For example, while invasive ICP monitoring can provide accurate ICP assessment, it is often only available in specialist neurocritical care units.¹² Because of its invasiveness, this technique may result in complications such as hemorrhage, bacterial colonization, and pain for the patient, especially when repeated assessments are required.^{9,13} Many facilities may lack the specific, expensive instruments required for this method, and the presence of contraindications such as coagulopathy may reduce the feasibility of invasive ICP monitoring. CT and MRI can detect elevated ICP noninvasively. However, these two techniques are time-consuming and may require patient transportation, a complicated process for patients in the intensive care unit or those on mechanical ventilation or monitoring equipment. Hence, it is necessary to explore noninvasive bedside methods of assessing ICP in clinical settings.

Recent studies have confirmed that ONSD measurement via noninvasive imaging technologies can accurately evaluate elevated ICP.¹³⁻¹⁵ Thus, the rapid, noninvasive bedside method of ultrasonographic ONSD measurement is in high demand, and it might become the recommended method of detecting elevated ICP.¹⁶

Papilledema and hemorrhage identified by ophthalmoscopy is probably an indicator of elevated ICP. However, it may also indicate inflammation of the optic nerve or optic nerve compartment syndrome. Brodsky *et al.* reported that low intraocular pressures may lead to optic disc swelling even in the presence of normal ICP, and that high intraocular pressures can prevent papilledema even when ICP is elevated.¹⁷ A review article reported that the papilledema grading scale was not widely accepted, and there was considerable interobserver variability concerning normal ophthalmoscopic morphology. Moreover, optic disk swelling in cases with elevated ICP requires time to develop and therefore is not applicable in emergency conditions or when acute elevated ICP is suspected.¹⁸ Another review found similar information.¹⁹

The ONSD can rapidly change with changes in ICP. Hansen *et al.* demonstrated *in vitro* that ONSD quickly

changes by applying controlled increased and decreased pressure levels in the subarachnoid space.²⁰ Another study investigated the effects of acute ICP changes on ONSD by measuring ONSD before, during, and after tracheal manipulation, which is known to increase ICP. They found that ONSD increased with tracheal manipulation and immediately returned to baseline once manipulation was stopped.²¹ Based on these reports, it appears that ultrasonographic ONSD may be a sensitive indicator of ICP. Further assessments of the sensitivity and specificity comparing ultrasound with ophthalmoscopy are needed in a future study.

In conclusion, this was an uncommon case of aneurysmal subarachnoid hemorrhage with spinal arachnoiditis, where elevated ICP was detected more accurately using ultrasonographic ONSD measurement compared to LP. Ultrasonographic ONSD measurement can serve as a rapid, noninvasive bedside method for ICP assessment, especially in cases of spinal arachnoiditis.

Acknowledgments

The authors thank the patient and the patient's family for their cooperation and contributions to this study. This work was supported by the National Natural Science Foundation of China (No.81801707).

Author Contributions

Y-QX and L-JW conceived and designed the manuscript. Y-C performed the examinations of optic nerve sheath diameter by ultrasound. Z-YY collected the patient information. L-JW and H-XC were the major contributor in writing the manuscript. All the authors read and approved the final manuscript.

Ethical approval and patient consent for publication

This study was approved by the ethics committee of The First Hospital of Jilin University. And the patient provided written informed consent.

Conflict of Interest

The authors declare no competing interest.

References

1. Juul N, Morris GF, Marshall SB, *et al.* Intracranial hypertension and cerebral perfusion pressure: influence on neurological deterioration and outcome in severe head injury. The Executive Committee of the International Selfotel Trial. *J Neurosurg* 2000;92:1-6.

2. Balestreri M, Czosnyka M, Hutchinson P, et al. Impact of intracranial pressure and cerebral perfusion pressure on severe disability and mortality after head injury. *Neurocrit Care* 2006;4:8–13.
3. Shirodkar CG, Rao SM, Mutkule DP, et al. Optic nerve sheath diameter as a marker for evaluation and prognostication of intracranial pressure in Indian patients: An observational study. *Indian J Crit Care Med* 2014;18:728–734.
4. Newman WD, Hollman AS, Dutton GN, et al. Measurement of optic nerve sheath diameter by ultrasound: a means of detecting acute raised intracranial pressure in hydrocephalus. *Br J Ophthalmol* 2002;86:1109–1113.
5. Wang LJ, Chen LM, Chen Y, et al. Ultrasonography Assessments of optic nerve sheath diameter as a noninvasive and dynamic method of detecting changes in intracranial pressure. *JAMA Ophthalmol* 2018;136:250–256.
6. Hansen HC, Helmke K. The subarachnoid space surrounding the optic nerves. An ultrasound study of the optic nerve sheath. Surgical and radiologic anatomy. *Surg Radiol Anat* 1996;18:323–328.
7. Hayreh SS. Pathogenesis of oedema of the optic disc. *Documenta ophthalmol* 1968;24:289–411.
8. Galetta S, Byrne SF, Smith JL. Echographic correlation of optic nerve sheath size and cerebrospinal fluid pressure. *J Clin Neuro-ophthalmol* 1989;9:79–82.
9. Amini A, Kariman H, Arhami Dolatabadi A, et al. Use of the sonographic diameter of optic nerve sheath to estimate intracranial pressure. *Am J Emerg Med* 2013;31:236–239.
10. Wang LJ, Yao Y, Feng LS, et al. Noninvasive and quantitative intracranial pressure estimation using ultrasonographic measurement of optic nerve sheath diameter. *Sci Rep* 2017;7:42063.
11. Rahmathulla G, Kamian K. Compressive cervicothoracic adhesive arachnoiditis following aneurysmal subarachnoid hemorrhage: a case report and literature review. *J Neurol Surg Rep.* 2014;75:e56–61.
12. Citerio G, Bakker J, Bassetti M, et al. Year in review in Intensive Care Medicine 2014: I. Cardiac dysfunction and cardiac arrest, ultrasound, neurocritical care, ICU-acquired weakness, nutrition, acute kidney injury, and miscellaneous. *Intensive Care Med* 2015;41:179–191.
13. Geeraerts T, Launey Y, Martin L, et al. Ultrasonography of the optic nerve sheath may be useful for detecting raised intracranial pressure after severe brain injury. *Intensive Care Med* 2007;33:1704–1711.
14. Kimberly HH, Noble VE. Using MRI of the optic nerve sheath to detect elevated intracranial pressure. *Crit Care* 2008;12:181.
15. Das SK, Shetty SP, Sen KK. A novel triage tool: optic nerve sheath diameter in traumatic brain injury and its correlation to rotterdam Computed Tomography (CT) scoring. *Pol J Radiol* 2017;82:240–243.
16. Kristiansson H, Nissborg E, Bartek J Jr, et al. Measuring elevated intracranial pressure through noninvasive methods: a review of the literature. *J Neurosurg Anesthesiol* 2013;25:372–385.
17. Brodsky MC, Chen JJ, Wetjen NM. Optical coherence tomography for the noninvasive detection of elevated intracranial pressure a new role for the ophthalmologist? *JAMA Ophthalmol* 2017;135(4):329–330.
18. Raboel PH, Bartek J Jr, Andresen M, et al. Intracranial pressure monitoring: invasive versus non-invasive methods—a review. *Crit Care Res Pract* 2012;2012:950393.
19. Robba C, Bacigaluppi S, Cardim D, et al. Non-invasive assessment of intracranial pressure. *Acta Neurol Scand* 2016;134(1):4–21.
20. Hansen HC, Lagrèze W, Krueger O, et al. Dependence of the optic nerve sheath diameter on acutely applied subarachnoidal pressure—an experimental ultrasound study. *Acta Ophthalmol* 2011;89:e528–e532.
21. Maissan IM, Dirven PJ, Haitsma IK, et al. Ultrasonographic measured optic nerve sheath diameter as an accurate and quick monitor for changes in intracranial pressure. *J Neurosurg* 2015;123(3):1–5.