

Optic Nerve Sheath Diameter & Ocular Ultrasound

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Introduction:

Raised intracranial pressure (ICP) is a frequent condition in neurosurgical care and is associated with poor neurological outcome. Invasive devices are the gold standard for continuous and reliable assessment of ICP. Invasive devices for monitoring ICP, however, require expertise and normal coagulation blood tests in order to be placed safely (1, 2).

The optic nerve is surrounded by a dura mater sheath that is distensible when cerebrospinal fluid pressure rises. Measurement of the optic nerve sheath diameter (ONSD) using ocular sonography is a simple and noninvasive tool that can be performed at the patient's bedside. This method predicts raised ICP in various settings, including traumatic brain injury (3).

Anatomical background:

There are four anatomical divisions of the optic nerve: intraocular (1 mm), intraorbital (24–28 mm), intracanalicular (9 mm), and intracranial (16 mm) (3).

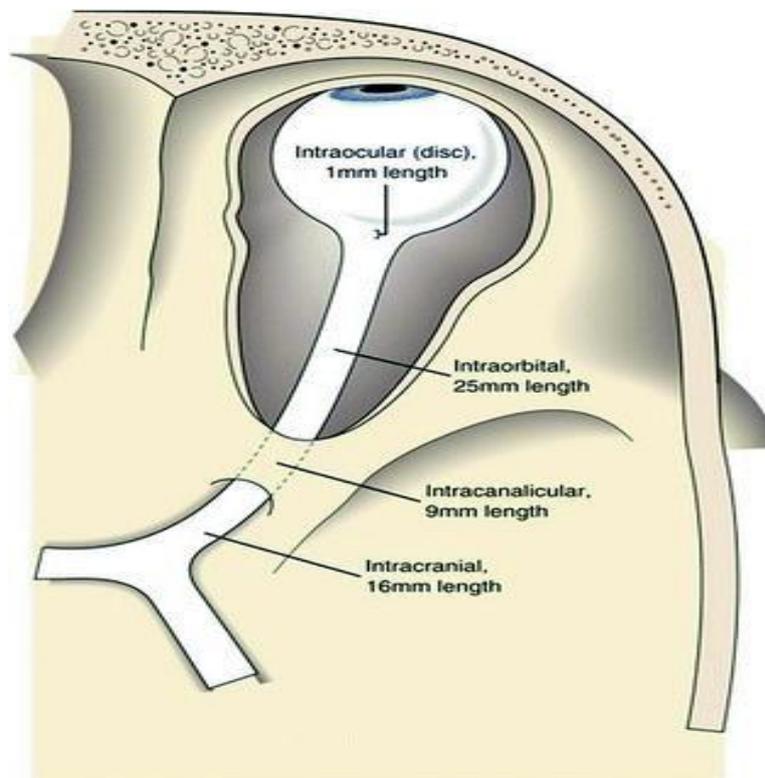


Figure (1): Optic nerve segments. From Yanoff M, Duker JS (eds) Ophthalmology, 2nd edn. St Louis, Mosby, 2004 (4)

Intraocular:

The intraocular ON is comprised of the optic disc, prelaminar area (anterior to lamina cribrosa), and lamellar area. Beginning at the optic disc, 1.2 million retinal ganglion cell (RGC) axons exit the globe through the scleral canal to form the optic nerve. The RGC axons are physically supported by the lamina cribrosa and metabolically supported by interweaving astrocytes. The lamina cribrosa is a system of 10 connective tissue plates integrated with the sclera, and axon bundles are transmitted through openings in the lamina cribrosa (5).

Intraorbital:

Posterior to the lamina cribrosa, the optic nerve fibers are myelinated by oligodendrocytes and surrounded by a meningeal sheath (pia mater, arachnoid mater, and dura mater). At this point, the optic nerve is within the muscle cone of the eye. The intraorbital part of the optic nerve is longer than the distance between the posterior globe and optic canal. This length difference allows for optic nerve laxity in the orbit and facilitates unrestricted globe rotation. Before entering the optic canal, the optic nerve passes through the annulus of Zinn (3).

The optic nerve becomes myelinated as it traverses the lamina cribrosa scleralis, doubling its diameter from approximately 1.5 mm at the optic disc to 3 mm as it leaves the scleral canal posteriorly (6).

Intracanalicular:

The optic canal travels through the lesser wing of the sphenoid bone. In the optic canal, the dural sheath surrounding the optic nerve fuses with the periosteum and immobilizes the nerve.

Intracranial:

At the transition from intracanalicular to intracranial segments, the optic nerve passes under a dural fold called the falciform ligament. The final intracranial portion of the optic nerve does not have a dural sheath. The optic nerve terminates at the optic chiasm where the neural fibers continue posteriorly as the optic tracts.

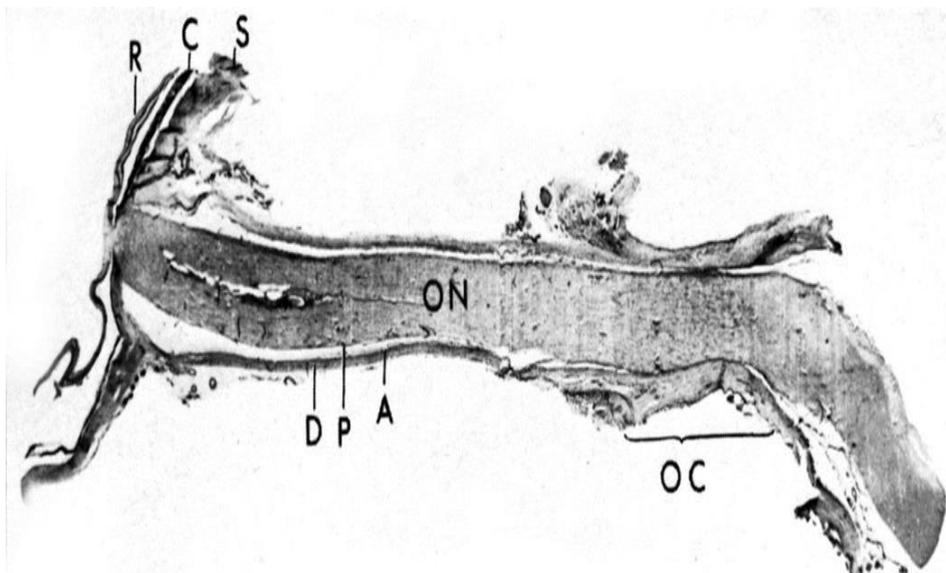


Figure (2): Longitudinal section of a normal human optic nerve showing the sheath in its different parts. Abbreviations: A= Arachnoid; C = Choroid; D = Dura, OC = Optic canal; ON = Optic nerve; P = Pia; R = Retina; S = Sclera. Reproduced from (7).

Pathophysiology:

In 1964, Hayreh showed in monkeys, that the cranial cavity communicated with the optic nerve sheath and that a rise in CSF pressure in subarachnoid space was transmitted along the optic nerve sheath (8).

As a part of the CNS, the optic nerve is surrounded by a subarachnoid space containing cerebrospinal fluid (CSF). The intra-orbital subarachnoid space surrounding the optic nerve is subject to the same pressure changes as the intracranial compartment (9).

The retrobulbar part of this sheath is surrounded only by orbital fat and is distensible when pressure in CSF increases, whereas the posterior part (optic canal) presents dense subarachnoid adhesions and is less distensible.

Edema of the optic disc results then from a chronic CSF accumulation in the retrobulbar optic nerve sheath and mechanical compression of the optic nerve. Indeed, papilloedema is an indirect and late indicator of raised ICP, whereas a pressure rise in optic nerve sheath (and the resulting ONSD enlargement) is a more dynamic process.

Those results were confirmed in cadavers, where a proportional increase in optic perineural pressure was found following direct infusion in the ventricular system, resulting in a predominantly anterior enlargement in ONSD (10).

Ocular Ultrasound:

Ocular ultrasound has been used for more than 10 years in ophthalmology and, more recently, for the detection of raised ICP in conditions including hydrocephalus in children, liver failure, traumatic brain injury and intracranial hemorrhage (11).

Method and Technique:

This noninvasive method can be performed easily in the supine position. B-mode ultrasound equipment, which is commonly used today, is safe regarding the production of a harmful temperature rise.

Awake and alert patients should be briefed on the procedure. Obtunded, intubated, or heavily sedated patients should have a gross eye evaluation for signs and symptoms of globe rupture or hyphemia. If there is evidence of globe rupture, including visible conjunctival or scleral defect, severe chemosis, 360-degree conjunctival hemorrhage, hypotony, or total hyphemia, the procedure should be aborted to avoid further herniation of intraocular contents, and an ophthalmologist should be consulted.

A high-frequency (7.5–10 MHz) linear probe, available in most ultrasound units, must be placed on the temporal area of the eye after a thick layer of gel is applied on the closed upper eyelid.

The normal sonographic aspect of the optic nerve is from center to peripheral: hypoechogenic nerve fibers closely surrounded by the echogenic pia mater; the subarachnoid space appears anechogenic or hypoechogenic and is surrounded by hyperechogenic dura mater and periorbital fat.

The retrobulbar ONSD can be measured as the distance inside dura mater, 3 mm behind the ocular globe using an electronic caliper with an angle perpendicular to the eye ball. Attention must be paid to avoid generating pressure on the eye with the probe.

Placement of the probe must be adjusted to give the best angle for display the entry of the optic nerve into the globe. Measurements can be made bilaterally and in several axes by rotating the probe (1).

After the application of a sterile dressing over a closed eye and copious ultrasound gel, the high-frequency ultrasound transducer should be placed over the eye with little to no contact with the sterile dressing in the transverse plane. The sonographer's hand should be placed on a non-compressible surface (the patient's nose, midface, or forehead) to avoid direct globe pressure, discomfort, and distortion of anatomy. Small movements

nasally and temporally followed by caudad and cephalad should be executed trying to capture the optic nerve sheath in the same plane as the AC, PC, and lens to avoid obliquing of the image. Once the anechoic streak posterior to the optic disc is visualized, the image should be captured, and measurements can be taken from the saved image (12).

If difficulty in acquiring an image during the ultrasound study is encountered, one should try to center the focal ultrasound beam transversely through the plane of the lens. The contralateral eye can be assessed to estimate the location and orientation of the pupil on the studied eye. Increasing the volume of an ultrasound gel buffer can improve the quality of the image. Increasing the gain can be helpful to enhance discernment between the actual nerve sheath and nerve. If available, color doppler can help visualize the retinal artery near the posterior globe as a reference point (13).

In emergency departments and intensive care units, there is growing evidence that ocular sonography is a useful tool for the detection of patients with raised ICP. Clinical signs of raised ICP, such as headache or vomiting, are often difficult to interpret.

Indeed, as observed by Tayal et al., clinical examination is of poor sensitivity (25%) and specificity (75%) compared with head computed tomography (CT) findings of raised ICP (12).

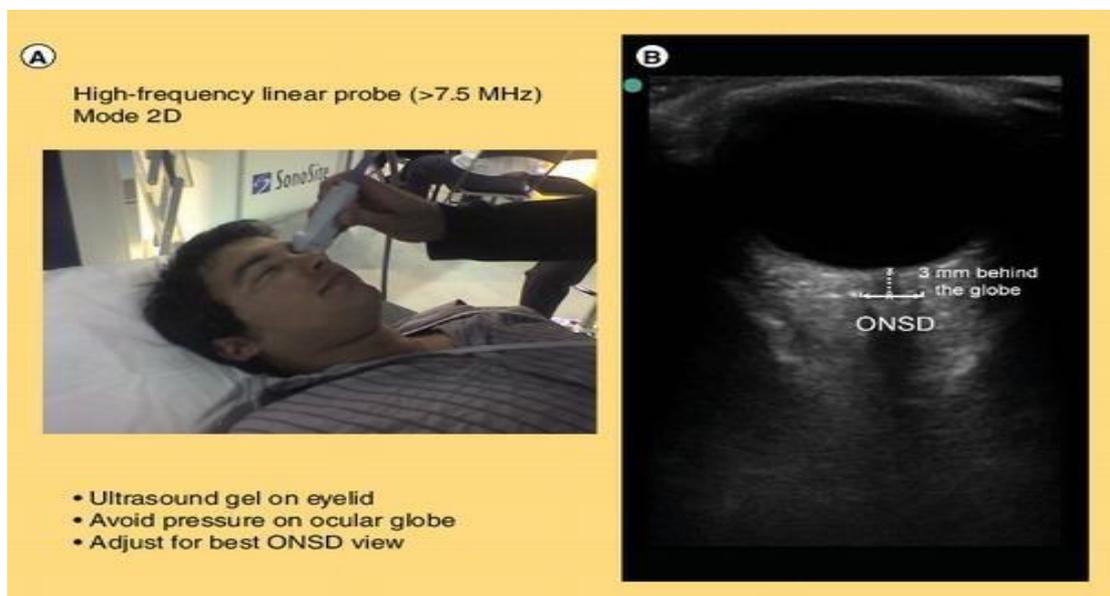


Figure (3): Ocular sonography of the optic nerve sheath. Ultrasound probe must be placed on the gel on the close eyelid (A). The normal 2D mode sonographic aspect of the optic nerve is from center to peripheral: hypoechogenic nerve fibers closely surrounded by the echogenic pia mater; the subarachnoid space appears anechogenic or hypoechogenic and is surrounded by hyperechogenic dura mater and periorbital fat (B). The retrobulbar optic nerve diameter sheath (ONSD) can be measured as the distance inside dura mater, 3 mm behind the ocular globe (14).

Measurements:

Observational studies in healthy patients confirm that normal ONSD ranges from about 2.2–5mm (15).

Once the optic nerve sheath diameter is determined, it requires evaluation in the overall clinical context. Earlier studies have most commonly used a cutoff of 5.0 mm with excellent sensitivity as well as positive and negative predictive values, but cutoffs correlating to elevations of ICP greater than 20 mm Hg have varied from less than 5 mm to greater than 6 mm in different papers. One meta-analysis of 12 studies that compared optic nerve sheath values to CT evidence of elevated ICP yielded a specificity of 92.3% and a sensitivity of 95.6% utilizing a 5 mm cutoff in adult patients (13).

Advantages:

Ocular ultrasound has the advantage of being non-invasive and avoids the risk of infection, hemorrhage, or ionizing radiation that are inevitable with intracranial monitors and computed tomography (CT). ONSUS can also be used as a tool to help “rule out” elevated ICP in non-acute trauma settings such as troubleshooting of a malfunctioning intraventricular device, before or following lumbar punctures, or while evaluating the safety of neuraxial anesthesia in patients with a previous history of elevated ICP (16).

Complications and Contraindications:

Ocular ultrasound is safe and benign in the absence of an open globe. If an open globe injury is suspected, however, there is potential for further ocular injury (17).

Surface ultrasound remains a safe modality with little to no risk to adult patients. If an open globe injury is suspected, however, there is potential for further ocular injury, and the study should not proceed without consultation or assistance from an ophthalmologist (18).

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