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Non-Invasive Sonographic Detection of Intracranial Hypertension in Severe Brain Injury

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In brain injury, elevated Intracranial Pressure (ICP) is usually established as an acute situation, which may reduce blood perfusion and oxygen delivery to the brain, leading to ischemia and progression towards brain tamponade. An intracranial catheter inserted through a craniotomy remains the gold standard modality for the diagnosis of intracranial hypertension; however the application of this highly invasive technique in all patients with head trauma is clearly inappropriate. Even in hospitalized patients, the invasive measurement of the ICP may be unfeasible not due to lack of a neurosurgeon or contraindications including coagulopathy and thrombocytopenia. In such cases, intracranial hypertension can be established by the combination of clinical examination, which has low sensitivity and specificity, computed tomography, which is time-consuming and requires the transfer of critically-ill patients and supporting devices to the imaging department, and ophthalmoscope, which requires trained personnel and can only establish the diagnosis with a certain delay.

In recent years, Transcranial Doppler Sonography (TCD) and Optic Nerve Sonography (ONS) have been enjoying increasing popularity for the detection of intracranial hypertension and can be used for rapid non-invasive bedside evaluation of patients with head trauma. On TCD, the velocity parameters reflect the resistance to blood flow in the parenchymal territory of the insonated vessel. After performing bilateral TCD of the middle cerebral arteries, the estimated ICP (eICP) from each side is calculated using the formula eICP=ABPm×(1- FVd/FVm)−14(where ABPm=Mean Arterial Blood Pressure, FVd=End Diastolic Flow Velocity, FVm=Mean Flow Velocity), or the formula eICP=10.93×PI - 1.28 (where PI=Pulsatility Index). Intracranial hypertension is highly suspected when the average value of eICP between the two sides exceeds 20 mmHg. Alternatively (and more rapidly), elevated ICP can be detected by measuring the Optic Nerve Sheath Diameter (ONSD) using conventional B-mode sonography. When ICP rises, cerebrospinal fluid flows towards the subarachnoid space which surrounds the optic nerve, and increases the pressure around the latter, thereby resulting in expansion of the dural sheath and an increase in the ONSD. This expansion mainly affects the anterior segment of the dural sheath 3 mm behind the globe, and this is the level where ONSD measurements should be performed. Most authors have suggested that the upper normal value of ONSD is 5 mm, and values ONSD values above this threshold should alert the clinician to the presence of raised ICP.

As with all ultrasound examinations, the quality of ONS and TCD relies heavily on the skill and diligence of the observer. Standardization of the examinations is of great importance, whereas inappropriate technique may lead to significant errors and reduce the benefit of the modalities. It is therefore mandatory that all examinations are performed by trained personnel only.

ONS and TCD may alert the clinician to the presence of intracranial hypertension and the need for immediate intervention or transport to a specialized centre. The techniques could be applied as additional diagnostic tools in emergency and intensive care settings, particularly in cases where the invasive ICP evaluation is contraindicated and/or is not available.

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