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Case Report

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Transcranial Doppler in a child: A most valuable imaging modality

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Abstract

Introduction: Pediatric brain injury is a common cause of emergency department (ED) referral. Although severe traumatic brain damage is less frequent, it could be primarily managed by non-pediatric critical care physicians called in for advice. Clinical evaluation is important, but radiology is of particular value in the case of severe brain injury. Transcranial Doppler may help the physician through neuromonitoring.
Case Report: We report the case of a 3-year-old male child brought into the pediatric ED for a moderate head injury. His neurological status deteriorated rapidly, making endotracheal intubation and mechanical ventilation necessary. Computed tomography (CT) of the head revealed brain contusion and post-traumatic subarachnoidal hemorrhage.
Discussion: Transcranial Doppler was performed at the standard transtemporal evaluation window, and it showed normal vascularization of the entire anterior brain. This result permitted performance of the control CT scan to be postponed. In this case, basic knowledge of transcranial ultrasound proved to be useful, and we believe it could also be useful to other colleagues faced with similar situations even if they are not dedicated to pediatric critically ill patients.
Conclusion: Doppler ultrasound in the pediatric population is a valuable bedside tool. Together with clinical evaluation and radiology, it completes the set of techniques necessary for continuous neuromonitoring.

Keywords

Head injury, transcranial Doppler ultrasound, neurocritical care, children, radiology

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Introduction

Head injuries constitute a non-negligible cause for emergency department (ED) referrals in young children, with nearly 700,000 evaluations made in the United States each year.[1]

Fortunately, mild traumatic brain injury (TBI) constitutes >95% of all head traumas.[2]

Information about the mechanism of trauma and meticulous neurological examination is fundamental, as is selection of the most appropriate diagnostic imaging technique.[3]

The majority of children suffering a head trauma are treated in pediatric emergency departments (PED), and only a very small minority of these present severe head injuries, which require immediate detailed clinical assessment and treatment, and are subsequently admitted to the Pediatric Intensive Care Unit.[4]

Computed tomography (CT) must be performed in cases of TBI associated with a Glasgow Coma Scale (GCS) score <14, thus exposing the child to ionizing radiation. The aim of subsequent diagnostics is to review the extent of the damage and the patient's progress, to whom multimodal monitoring could be applied in case of worsening clinical condition.[3,4]

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Transcranial Doppler (TCD) represents a non-invasive bedside monitoring tool used in both adults and children that provides clinicians an additional method with which to estimate intracranial pressure (ICP).[5]

ICP values, especially in TBI, are used to define the patient's treatment and outcome.

This case report emphasizes the possible role of TCD as a monitoring method for brain injury in a child admitted to a general intensive care unit (ICU) not dedicated to pediatric care.

The case report and imaging also highlight how TCD is simple to perform in pediatric populations given the easy penetration of ultrasound through the skull, which is still relatively thin.

Case report

A healthy 3-year-old boy who had tumbled down a flight of stairs was transported by the emergency medical service to the PED, where he was assessed for potential head trauma. The parents reported no loss of consciousness. He presented with a GCS of 13 (Eyes 2, Verbal 5, Motor 6), a frontal hit, and a wound to the chin.

The patient underwent an immediate CT head scan, which demonstrated a right frontobasal contusion, a thin blood layer along the interhemispheric fissure, and a thin subarachnoidal hemorrhage along the Sylvian cistern and cortical grooves (Figure 1). He also had fractures to the frontal bone, the greater wing of the sphenoid, and the lamina papyracea.

Following the CT scan, the child's neurological status deteriorated rapidly to a GCS of 7 (Eyes 1, Verbal 2, Motor 4), requiring endotracheal intubation and admission to ICU.

Six hours later, a second CT head scan (Figure 2) was performed to monitor the trauma's evolution, which demonstrated a slight decrease in contusion dimensions.

The patient was kept sedated using propofol (3–5 mg kg^{-1} $hour^{-1}$) and remifentanil (0.1–0.15 mcg kg^{-1} $minute^{-1}$) for 24 hours. While the patient was under deep sedation in ICU, several transcranial color Doppler (TCCD) examinations using a phased array 2 MHz transducer (Philips Affinity 70, Milan, Italy) were performed to monitor the evolution of the head injury (Figure 3). The anesthesiologist performing TCD had less than 5 years' experience but encountered no difficulties in performing the examinations under the supervision of a senior colleague (>10 years' experience).

Considering the child's age, the expected cerebral blood flow velocities would be as follows (expressed as means $\pm$ SD):[6] for the middle cerebral artery (MCA), peak systolic velocity (PSV) 147 $\pm$ 17 cm/s, mean flow velocity (MFV) 94 $\pm$ 10 cm/s, and end diastolic velocity (EDV) 65 $\pm$ 9 cm/s; for the anterior cerebral artery (ACA), PSV 104 $\pm$ 22 cm/s, MFV 71 $\pm$ 15 cm/s, and EDV 48 $\pm$ 9 cm/s.

In our case, TCD demonstrated the following values in the MCA: PSV 169 cm/s, MFV 95 cm/s, and EDV 58.4 cm/s. In the homolateral ACA, PSV was 112 cm/s, MFV was 66 cm/s, and EDV was 42.7 cm/s. The pulsatility index (PI) was 1.16 in the MCA and 1.05 in the ACA. These results allowed us to withdraw osmotherapy with mannitol given that there were no signs of

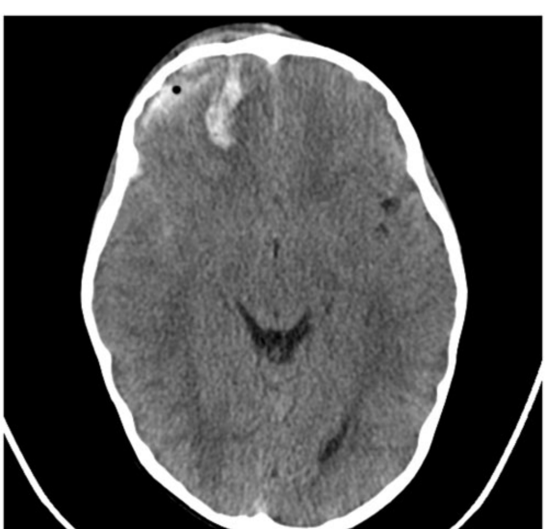

Figure 1. First CT scan obtained just after the patient's admission to PED showing a right frontobasal contusion.

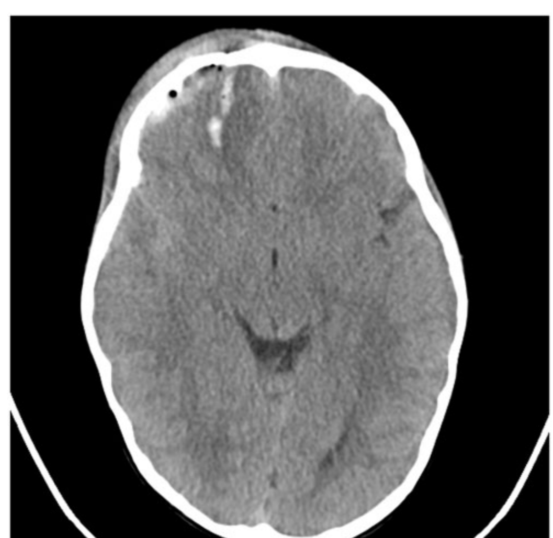

Figure 2. Second CT scan performed 6 hours later to evaluate the evolution of trauma inside brain parenchyma.

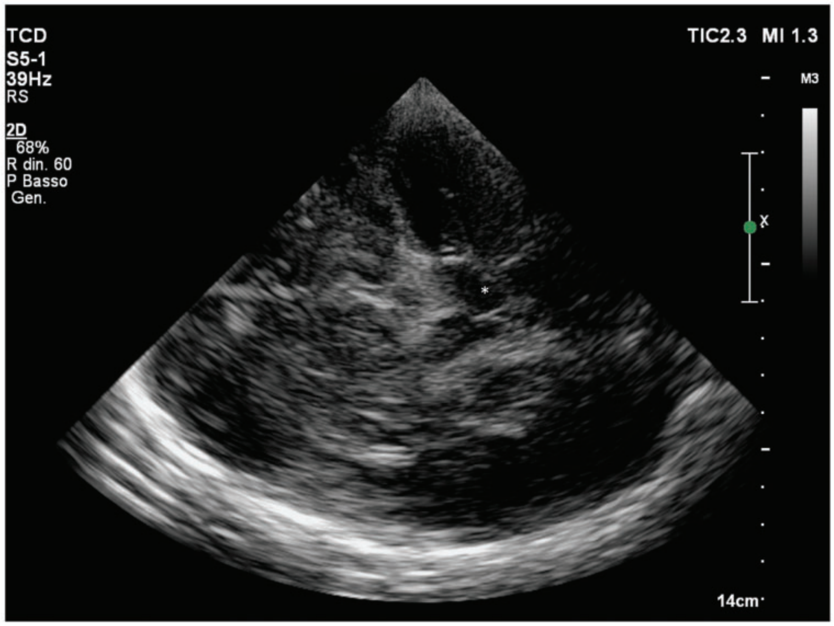

Figure 3. Transcranial view of the brain parenchyma obtained through the right transtemporal window. *indicates the midbrain. This image allows the practitioner to obtain anatomical and vascular information on the circle of Willis.

intracranial hypertension developing. These results also permitted us to avoid CT scan repetition 24 hours after the trauma onset and to delay the control CT scan. As a consequence, TCCD reduced the child's overall exposure to ionizing radiation.

Although brain access through the transtemporal fossa was easy (Figure 4), access through the frontal bone provided us with an extremely good anatomical image of the Willis polygon (Figure 5). TCD examinations were repeated at least three times a day during the first 2 days with the aim of detecting promptly any potentially problematic modifications to cerebral hemodynamics.

Twenty-four hours after ICU admission, considering the favorable progression of TBI evaluated by TCD, the child was gently awoken. He demonstrated no focal neurological deficits, but was moderately agitated, and as a consequence was re-sedated.

The patient was finally extubated 24 hours later, transferred to a pediatric ward, and finally discharged home a further 72 hours later in the absence of any neurological sequelae.

Discussion

Pediatric head injuries make a significant contribution to child morbidity and mortality rates. The cost of treatment for a head injury in the United States is estimated to range from $4,000 for mild trauma to $40,000 in the case of severe trauma.[7] All efforts should be made to deliver the best treatment to improve outcome and optimize resources.

The most severe trauma cases requiring ICU admission are at high risk of intracranial hypertension, the incidence of which enhances the chances of so-called secondary damage, mainly caused by ischemia, thus leading to a poor outcome. Monitoring the evolution of brain injury is mandatory to optimize medical therapy and enhance balanced brain oxygen delivery.[3,5]

Depending on the local resources and organization, critically ill patients may need to be managed in the general ICU by intensivists who are not specialized in neuropediatric medicine. However, this should not correlate with substandard care, but instead constitute a drive to ensure high levels of care. TCD is a tool that can help achieve this due to its wide availability and ease of use.

There are many neuromonitoring tools available, which vary in their degree of invasiveness. CT constitutes an important tool with the potential to obtain detailed anatomical images of the brain extremely rapidly. However, a CT scan is a picture taken at a given moment and not a continuous monitoring tool. Moreover, it exposes the patient to ionizing radiation, which was of particular concern in the present case, given the patient's very young age.

Neurocritical care requires rapid, easy-to-use, repeatable bedside tools able to provide pertinent information for guiding patient management.[8,9]

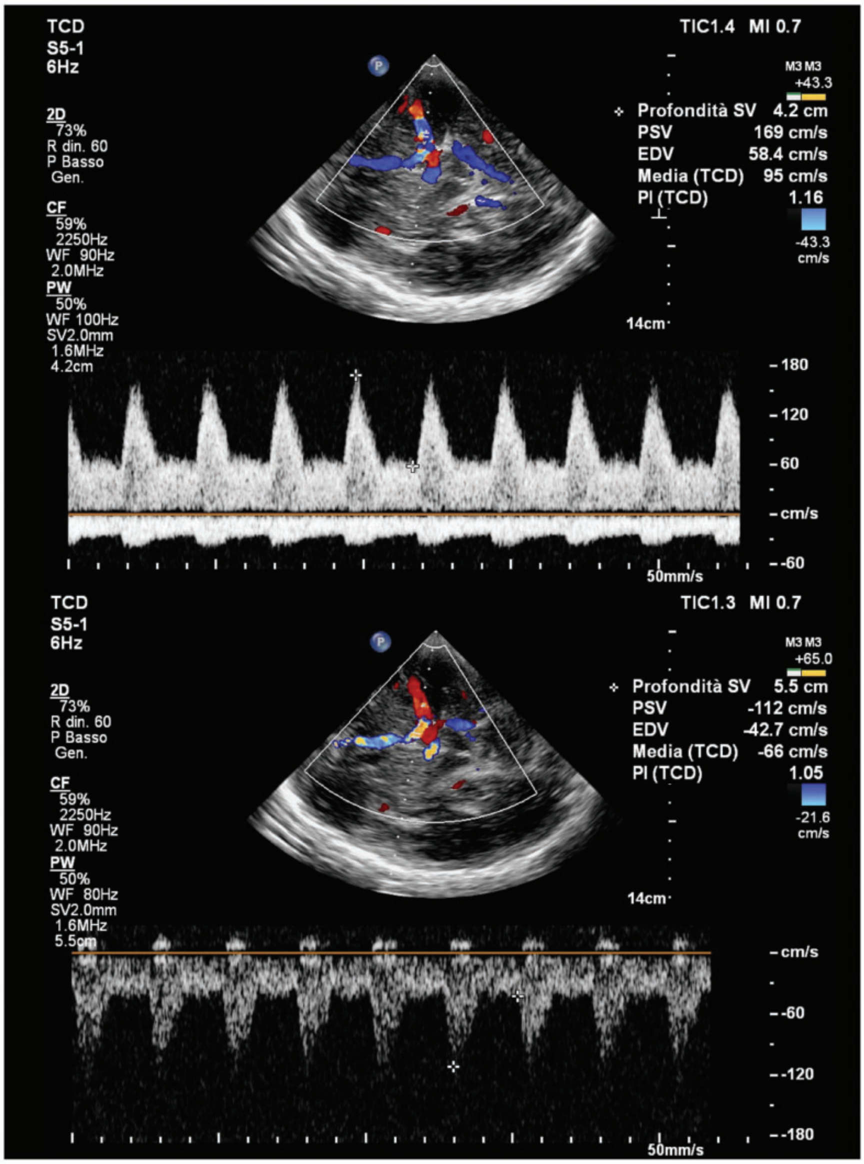

Figure 4. Upper part of the figure shows color Doppler sample of the right middle cerebral artery. The lower part displays sampling of the right anterior cerebral artery. Both PI values are reassuring and exclude severe intracranial hypertension thus allowing us to avoid implementation of neuromonitoring and to postpone another CT scan.

TCD has become a widespread and irreplaceable tool for the management of head trauma patients. Its non-invasive and non-ionizing characteristics make it particularly suitable for the pediatric population. Also, children make ideal patients to apply TCD: the thin skull bone allows for easier penetration of ultrasound, enabling access to the brain from unusual windows, as demonstrated here.

In our case, it was the TCD blood flow velocities, in addition to the CT findings, that enabled us to decide not to increase the neuromonitoring level, for example to measure pressure by means of an intracranial probe. According to Melo et al., an EDV > 25 cm/s and a PI < 1.31 have a 95% negative predictive value of an ICP > 20 mmHg in children.[10] However, TCD cannot and should not replace a CT scan, but it can help guide the timing of subsequent CT scans.[11,12]

Conclusion

Non-TCD experts and physicians not dedicated to pediatric ICU may, with minimal training, utilize TCD: basic knowledge is easy to acquire and can

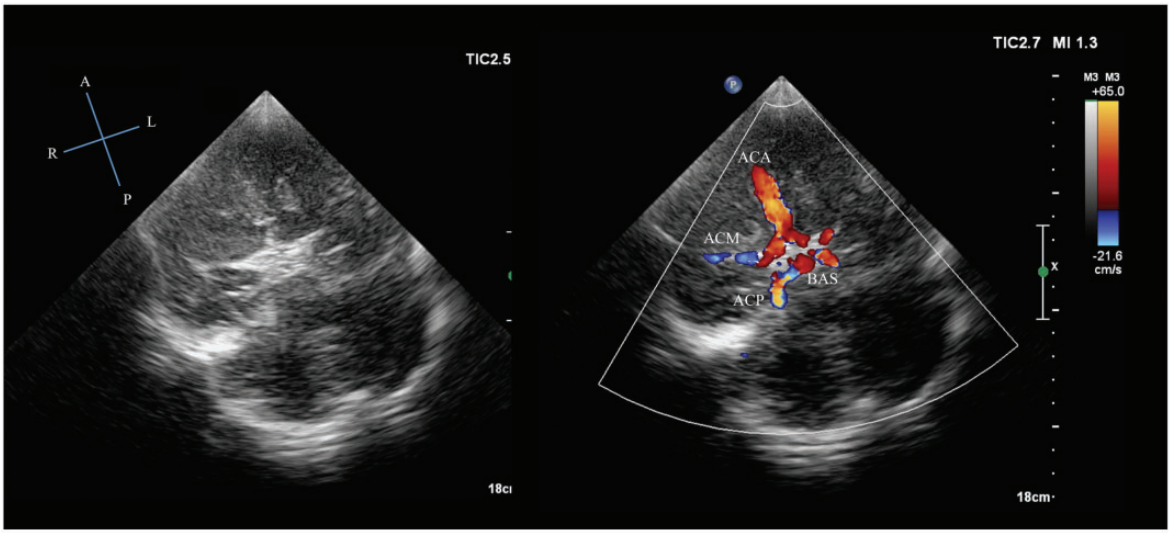

Figure 5. The brain parenchyma visualization with transcranial ultrasound via the frontal bone is shown on the left. On the right, the circle of Willis visualized by applying color Doppler.
A: anterior; ACA: anterior cerebral artery; ACM: middle cerebral artery; ACP: posterior cerebral artery; BAS: basilar artery; L: left; P: posterior; R: right.

enable the user to obtain important cerebrovascular information in both adults and children.[9]

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None to declare.

Ethics Approval

Consent to publish this anonymized case was obtained from the child's parent.

Declaration of conflicting interests

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