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Transcranial Doppler (TCD) Examination is One of the Ancillary Investigations Used to Establish the Diagnosis of Brain Death

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Abstract. Background: The determination of brain death relies primarily on clinical neurological assessment; however, ancillary investigations are often required when standard examination or apnea testing cannot be fully performed. Transcranial Doppler (TCD) ultrasonography offers a noninvasive bedside method to assess cerebral hemodynamics and may provide supportive evidence of severely impaired cerebral perfusion. Case Presentation: We report a serial case of critically ill patients with severe neurological impairment following cardiac arrest, in whom TCD was performed as part of the evaluation for suspected brain death. TCD examinations focused on intracranial arterial flow patterns, particularly within the middle cerebral artery. The observed waveforms demonstrated high-resistance pulsatile flow with markedly reduced diastolic velocities, reflecting impaired cerebral perfusion rather than immediate cerebral circulatory arrest. Serial neurological deterioration and neuroimaging findings were consistent with severe hypoxic–ischemic brain injury. Conclusion: Transcranial Doppler ultrasonography serves as a valuable ancillary tool in the assessment of suspected brain death by providing real-time information on cerebral blood flow dynamics. Although TCD should not replace clinical criteria, its bedside availability and ability to demonstrate evolving high-resistance flow patterns make it a useful supportive modality in selected clinical situations.

Keywords: Ancillary Investigation; Brain Death; Cerebral Circulatory Arrest; Intracranial Pressure; Transcranial Doppler

1. INTRODUCTION

The determination of brainstem death is a critical clinical process that requires a high degree of accuracy, particularly in situations where standard neurological examination or apnea testing cannot be fully performed due to patient-related constraints. In such circumstances, ancillary investigations that provide indirect information on cerebral perfusion status become essential. Transcranial Doppler (TCD) ultrasonography has emerged as a valuable supportive modality by enabling bedside assessment of cerebral hemodynamics, thereby complementing clinical evaluation in suspected brainstem death. (Monteiro LM et al., 2006a) (SM H, H D, K N, 2016a)

From a pathophysiological perspective, irreversible elevation of intracranial pressure to levels approaching or exceeding systemic arterial pressure may lead to progressive reduction of effective cerebral blood flow. On transcranial Doppler ultrasonography, this process can manifest as increasing pulsatility with attenuation or loss of diastolic flow, and in advanced stages, the emergence of characteristic oscillating or reverberating waveforms. These patterns reflect to-and-fro blood movement within the rigid cranial vault without net forward perfusion. Standard evaluation typically targets the middle cerebral arteries and the vertebrobasilar system, as bilateral involvement of both anterior and posterior circulations has been associated with global cerebral circulatory arrest in appropriate clinical contexts (Li Y et al., 2016).

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In addition to oscillating flow, the presence of small systolic peaks, also known as systolic spikes, represents another TCD waveform pattern described in the context of brainstem death. These signals consist of brief, low-velocity systolic components without accompanying diastolic flow, reflecting transient ventricular ejection against a markedly noncompliant intracranial compartment. Several studies have reported frequent observation of these patterns in patients with confirmed brainstem death, highlighting their potential supportive value when observed persistently and bilaterally (SM H, H D, K N, 2016a) (Morelli N et al., 2023).

TCD offers important practical advantages, including its noninvasive nature, repeatability, and feasibility for bedside application in intensive care settings. Nevertheless, its accuracy is influenced by operator expertise and the adequacy of acoustic windows, with a small proportion of patients presenting technical limitations. Consequently, TCD findings must be interpreted in conjunction with established clinical criteria, serving as supportive evidence rather than a standalone determinant in the diagnosis of brainstem death (Chang JJ et al., 2016) (Kasapoğlu US et al., 2019).

Case 1

The patient was admitted to the intensive care unit following cardiac arrest with successful return of spontaneous circulation after one cycle of cardiopulmonary resuscitation. Despite comprehensive intensive care support, the patient remained in a deep coma with persistently low Glasgow Coma Scale scores (E1M1V1) and absent pupillary light reflexes. Serial neurologic examinations showed no meaningful improvement. Brain computed tomography demonstrated diffuse cerebral edema with a white cerebellum sign, consistent with severe hypoxic–ischemic encephalopathy. Given the irreversible neurologic injury and lack of clinical recovery, evaluation for brainstem death was considered, and transcranial Doppler ultrasonography was performed as an ancillary investigation.

Transcranial Doppler ultrasonography was performed to assess cerebral perfusion as an ancillary examination. The calculated mean arterial pressure was 53.3 mmHg. The pulsatility index was 1.5, indicating increased distal cerebrovascular resistance. Estimated intracranial pressure was approximately 15.8 mmHg. The Doppler waveform demonstrated preserved diastolic flow without oscillating or reverberating patterns, findings consistent with impaired cerebral perfusion rather than cerebral circulatory arrest in the setting of severe post–cardiac arrest hypoxic brain injury.

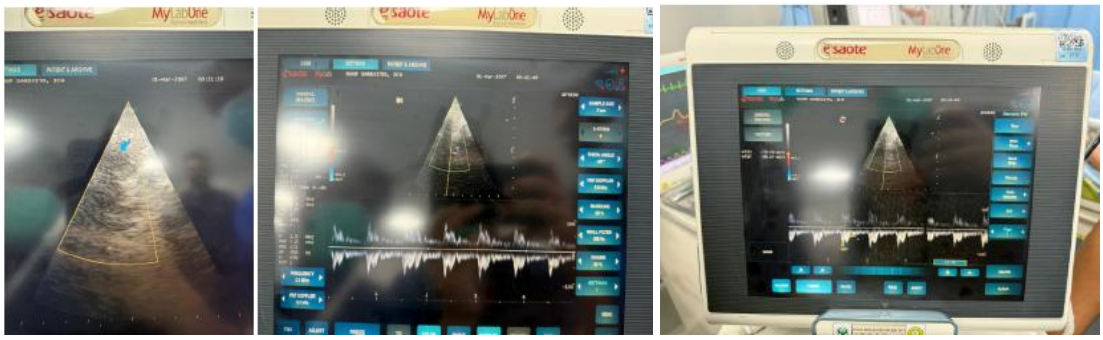

Figure 1. Documentation.

Transcranial Doppler waveform demonstrating a high-resistance pulsatile flow patern with reduced diastolic velocity, consistent with impaired cerebral perfusion.

Case 2

The patient was admitted to the intensive care unit following spontaneous intracerebral hemorrhage involving the left temporal lobe and underwent neurosurgical intervention. Despite definitive management and postoperative intensive care, the patient developed persistent coma with severely depressed levels of consciousness and absent brainstem reflexes on serial neurologic examinations. Neuroimaging demonstrated extensive intracranial pathology consistent with severe brain injury. Given the lack of neurologic improvement and the clinical suspicion of brainstem death, ancillary evaluation using transcranial Doppler ultrasonography was performed.

Transcranial Doppler ultrasonography of the right middle cerebral artery was performed through the transtemporal window. The Doppler waveform demonstrated a markedly pulsatile pattern with reduced diastolic flow, indicating increased distal cerebrovascular resistance. No oscillating or reverberating flow and no isolated systolic spikes were observed. These findings are consistent with severely impaired cerebral perfusion but do not fulfill criteria for cerebral circulatory arrest, and therefore serve as supportive rather than confirmatory evidence in the evaluation of suspected brainstem death. In this case, transcranial Doppler assessment was limited to the right middle cerebral artery, and bilateral or posterior circulation insonation could not be performed.

Figure 2. Documentation.

Transcranial Doppler examination of the right middle cerebral artery via the transtemporal window demonstrating a markedly pulsatile waveform with reduced diastolic flow, consistent with increased distal cerebrovascular resistance. These findings represent severely impaired cerebral perfusion and are presented as an ancillary supportive finding in the overall evaluation of suspected brainstem death.

2. DISCUSSION

Transcranial Doppler (TCD) ultrasonography is a valuable ancillary modality in the evaluation of suspected brainstem death (BD), providing indirect information on cerebral hemodynamics when standard neurological examination or apnea testing is limited. Under conditions of markedly elevated intracranial pressure, TCD may demonstrate characteristic flow alterations, including reduced or absent diastolic flow, oscillating (reverberating) flow, or isolated small systolic peaks, which reflect severely impaired cerebral perfusion (Monteiro LM et al., 2006) (SM H, H D, K N, 2016b). Representative examples of oscillating and reverberating Doppler flow patterns associated with cerebral circulatory arrest are illustrated in Figure 3.

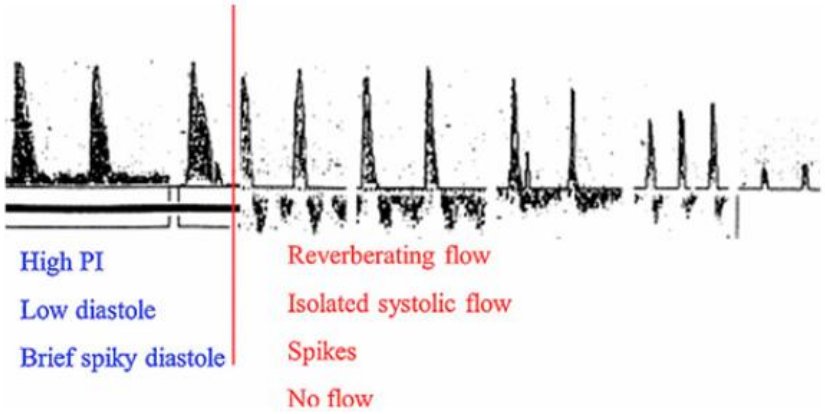

Figure 3. Documentation.

3. RESEARCH METHODS

TCD patterns associated with progressive increase of intracranial pressure (blue) and patterns of brain death (red) (Cardona P et al., 2012). In clinical practice, TCD assessment typically targets major intracranial arteries, most commonly the bilateral middle cerebral arteries via transtemporal windows, with additional evaluation of the vertebrobasilar circulation through the suboccipital window. The presence of oscillating or reverberating flow, characterized by alternating forward and reverse flow within a single cardiac cycle and a net flow volume approaching zero, has been associated with advanced intracranial hypertension. Importantly, such patterns must be demonstrated persistently and bilaterally in both anterior and posterior circulations to reliably indicate cerebral circulatory arrest, thereby distinguishing them from high-resistance flow patterns observed in earlier or incomplete stages of cerebral hypoperfusion (Monteiro LM et al., 2006) (Li Y et al., 2016).

In the first case of this series, TCD demonstrated a pulsatile waveform with a relatively high systolic peak and reduced but preserved diastolic flow. The elevated pulsatility index indicated increased distal cerebrovascular resistance, while the absence of flow reversal, oscillating flow, or isolated systolic spikes suggested that cerebral circulatory arrest had not yet occurred. These findings are consistent with previously described high-resistance flow patterns associated with severe cerebral injury and impaired compliance rather than definitive brainstem death, underscoring the need for cautious interpretation of single time-point TCD results (Monteiro LM et al., 2006) (Li Y et al., 2016). Typical transcranial Doppler waveforms observed in patients with brain death, including short systolic spikes and alternating flow patterns, are shown in Figure 4.

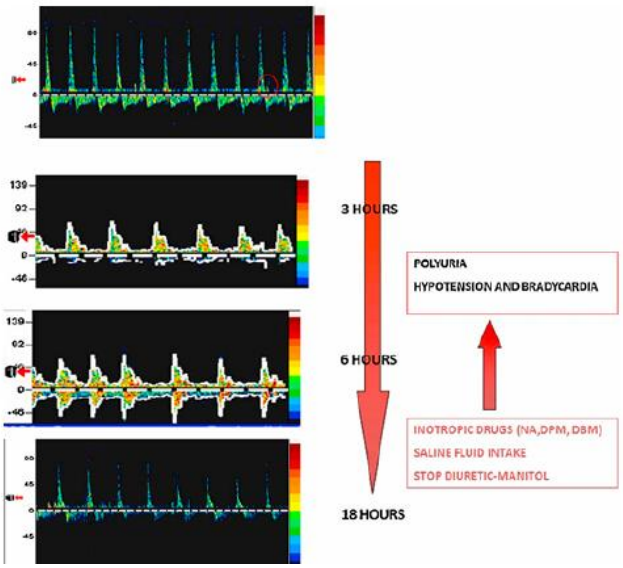

Figure 4. Documentation.

TCD showing reverberating flow (top image), but with brief diastolic positive spikes, that was incompatible with brain death. After a few hours TCD showed improvement of diastolic flow with a high and positive pattern possibly related to the polyuric phase and use of inotropic drugs. The last Doppler image shows isolated brief systolic flow with spikes. At that moment the patient was diagnosed of brain death (Cardona P et al., 2012).

Small systolic spikes represent a more advanced Doppler waveform pattern described in confirmed cases of brainstem death when observed persistently and bilaterally. These brief, low-velocity systolic signals without accompanying diastolic forward flow are thought to reflect extreme intracranial hypertension exceeding arterial pressure. However, prior studies emphasize that such findings should be interpreted strictly within the appropriate clinical context and in conjunction with established diagnostic criteria, as residual forward flow may still be present in transitional stages of cerebral circulatory compromise (SM H, H D, K N, 2016) (Morelli N et al., 2023) (Chang JJ et al., 2016) (Dosemeci L et al., 2001). A comparison between transcranial Doppler findings and radionuclide cerebral perfusion imaging in brain death is demonstrated in Figure 5.

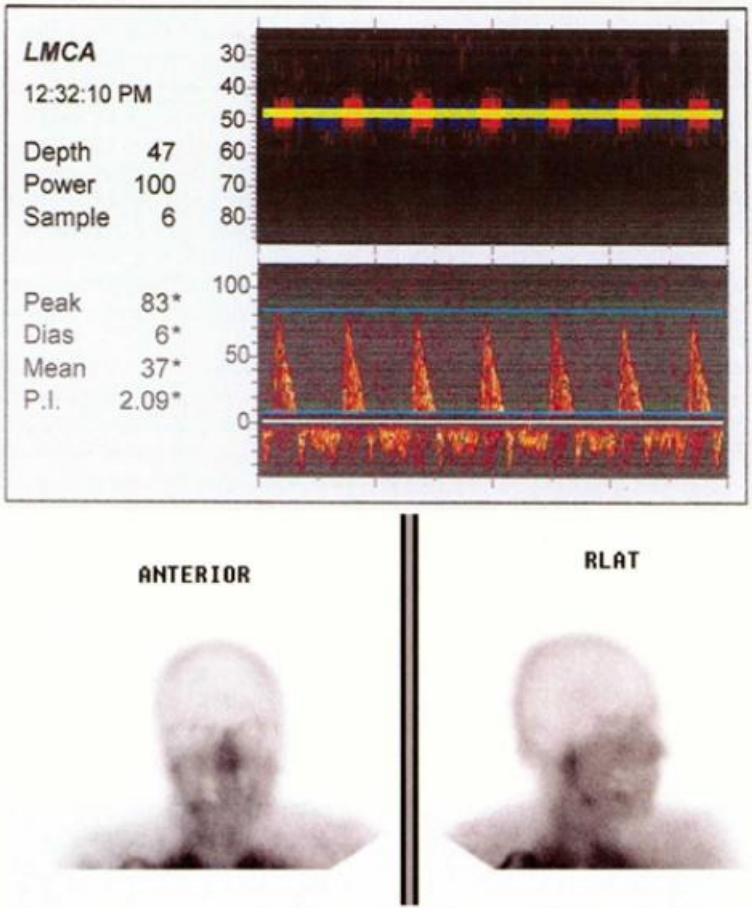

Figure 5. Documentation.

Transcranial Doppler (TCD) tracing and Tc 99m hexamethylpropyleneamine oxime (HMPAO) planar images of a 67-year-old woman with bacterial meningitis and extensive cerebral infarcts. The TCD tracing demonstrates systolic spikes with reversal of diastolic flow in the left middle cerebral artery. The radionuclide images, performed approximately 2 hours after TCDs, show absence of intracranial blood flow (Kramer AH, 2015).

Technical considerations play a critical role in the reliability of TCD as an ancillary test. Adequate patient preparation, including stable hemodynamics, normothermia, and minimization of sedative or neuromuscular blocking agents, is essential to reduce confounding effects on cerebral blood flow dynamics. Standardized insonation techniques using a 2-MHz pulsed-wave Doppler probe, appropriate depth settings, and careful optimization of gain and filter parameters are required to ensure accurate waveform interpretation (Kasapoğlu US et al., 2019) (Reynolds AS et al., 2025).

Current TCD protocols for BD evaluation recommend systematic and sequential insonation of intracranial vessels, beginning with bilateral middle cerebral arteries and extending to the anterior cerebral, terminal internal carotid, and vertebrobasilar arteries when feasible. The demonstration of absent flow, oscillating flow, or isolated systolic spikes across multiple insonated vessels increases diagnostic confidence. When initial findings are equivocal, repeat TCD examinations after an appropriate interval are advised to improve specificity and reduce false interpretation related to transient hemodynamic fluctuations (Reynolds AS et al., 2025) (Naqvi J et al., 2013).

In the present case series, TCD findings consistently demonstrated highresistance cerebral blood flow patterns rather than definitive cerebral circulatory arrest at the time of assessment. Preserved diastolic flow and markedly pulsatile waveforms highlight an intermediate stage of cerebral hypoperfusion, illustrating the limitations of relying on a single TCD examination for BD confirmation. These observations reinforce the concept that TCD should be regarded as a supportive ancillary investigation rather than a standalone determinant of brainstem death, particularly in complex clinical scenarios (Reynolds AS et al., 2025) (Loomis AL & Chakko MN, 2022). [10,12] Additional representative Doppler patterns illustrating progressive impairment of cerebral blood flow are presented in Figure 6.

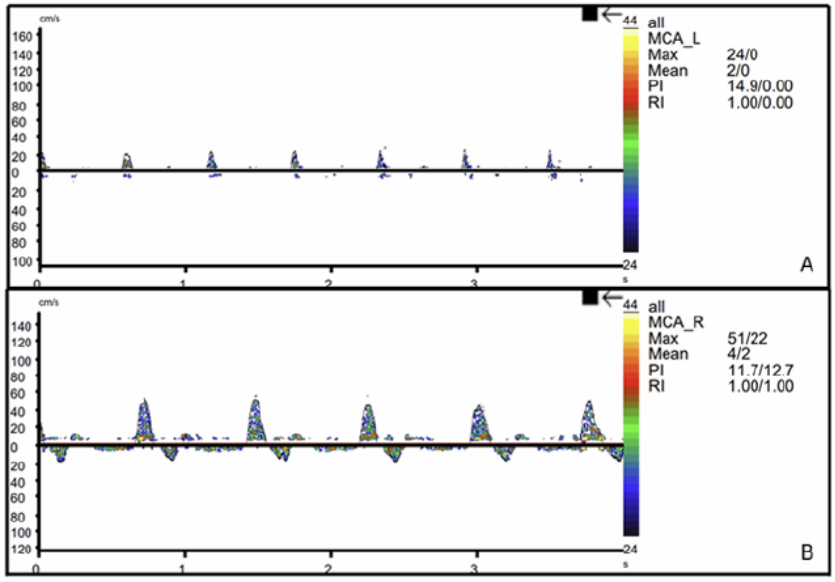

Figure 6. Documentation.

TCD in patients with brain death. (A) short systolic peak in MCA. (B) alternating flow in MCA. MCA – middle cerebral artery; TCD – Transcranial Doppler (Albuquerque CRC de et al., 2025). Compared with invasive confirmatory tests such as four-vessel cerebral angiography, TCD offers significant practical advantages, including bedside feasibility, noninvasiveness, and suitability for serial monitoring in critically ill patients. The ability to perform repeated assessments without patient transport is especially valuable in unstable conditions and resource-limited settings, where access to advanced imaging modalities may be constrained (Chang JJ et al., 2016) (Reynolds AS et al., 2025). When integrated appropriately within established diagnostic frameworks, TCD contributes meaningful supportive information while minimizing procedural risk. Illustrative examples of high-resistance cerebral blood flow patterns across different stages of intracranial hypertension are summarized in Figure 7.

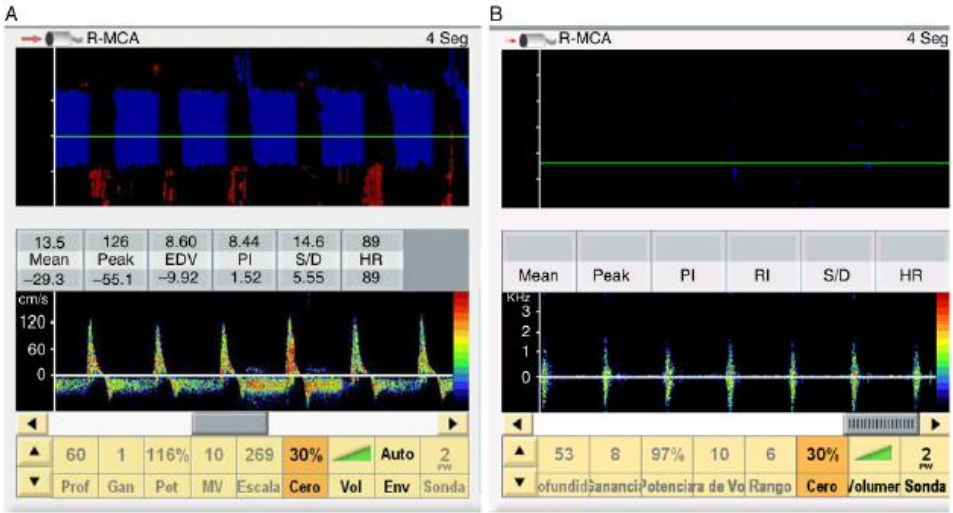

Figure 7. Documentation.

Middle cerebral artery explored through the temporal window with an inverted diastolic flow pattern (A) and systolic spikes (B), exhibiting a systolic peak of under 50 cm/s, characteristic of cerebral circulatory arrest (Escudero D et al., 2015).

4. CONCLUSION

Transcranial Doppler (TCD) ultrasonography represents a useful ancillary modality in the evaluation of suspected brainstem death by providing indirect assessment of cerebral hemodynamics at the bedside. In the present case series, TCD demonstrated high-resistance cerebral blood flow patterns with increased pulsatility and reduced, yet preserved, diastolic flow, reflecting severely impaired cerebral perfusion rather than definitive cerebral circulatory arrest at the time of examination.

These findings highlight that TCD patterns may evolve dynamically along a continuum of cerebral hypoperfusion and should be interpreted cautiously within the broader clinical context. The absence of classic terminal Doppler waveforms, such as persistent oscillating flow or isolated systolic spikes across both anterior and posterior circulations, underscores the limitation of relying on a single TCD examination for confirmation of brainstem death.

Accordingly, TCD should be regarded as a supportive ancillary investigation rather than a standalone determinant of brainstem death. When applied using standardized protocols and integrated with clinical assessment and, when necessary, repeat examinations, TCD may contribute valuable complementary information, particularly in critically ill patients or settings where other confirmatory tests are limited or impractical.

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