

# Transcranial Doppler in brain death assessment

## *Perspective and implications in the Saudi Arabian health system*

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### ABSTRACT

تعد الأشعة فوق الصوتية أو "دوبلر" عبر الجمجمة طريقة تصوير غير غازية، غير مؤينة الإشعاع والتي تحتاج منحى تعلم قصير. والمهم فيها أنه يمكن أن يؤديها الطبيب ويفسرها دون الحاجة إلى نقل المريض من مكانه مما يجعلها وسيلة قيمة في تأكيد تشخيص حالات الوفاة الدماغية. تأكيد الموت الدماغية مبكراً يمكن الأطباء المعالجين في تقديم المشورة وصنع القرار مع الأسرة في وقت مبكر نحو رعاية أفضل بما في ذلك خيار التبرع لزراعة الأعضاء في الوقت المناسب. نوصي بهذه الطريقة لإدراجها كجزء من معايير تشخيص موت الدماغ لدى نظام الرعاية الصحية في المملكة العربية السعودية والاستفادة منها في مستويات نظم المستشفيات السعودية المختلفة.

Transcranial Doppler is a non-invasive, non-ionizing ultrasound-based imaging modality that is inexpensive with a short learning curve. It can be performed and interpreted at the bedside. This review explores the value of the transcranial Doppler technique as a confirmatory tool for brain death. The early confirmation of brain death enables the treating physicians in early decision-making and family counseling toward better care approaches, including the option of organ donation for transplantation at the appropriate time. We recommend this modality be incorporated as part of the brain death criteria in the Saudi Arabian health care system guidelines and utilized in different tiers of our hospital system.

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With the improvement and refinement of critical care medicine and care of trauma victims, there are compelling ethical and practical reasons for physicians to be acquainted with the criteria of brain death and apply them precisely. This is for the most part due to the fact that our aggressive medical management of patients in critical conditions tends to be preferentially protective of the organ systems other than the brain. The determination of brain death has assumed its importance for the dramatic alteration it implies in the care of our patients, and the overwhelming need for organ donations for transplantation.<sup>1-3</sup> Many families would probably benefit from a short period of time to accept the sudden tragedy and cope with the hopelessness of the situation prior to being introduced to the idea of organ donation.<sup>4,5</sup> They may need this opportunity also to develop trust in their physician and their diagnosis.

Brain death as a concept was first introduced in 1959 with the term coma "depassé" (beyond coma) that was reappraised as "irreversible cessation of all functions of the entire brain."<sup>6,7</sup> The assessment of brain death starts by excluding factors that may alter consciousness such as; temperature changes, O<sub>2</sub> desaturation, blood pressure changes, electrolyte disorders, and intoxication.<sup>3,7</sup> Brainstem assessment as represented by pupillary, corneal, and oculocephalic reflexes, and corticospinal motor response assessment must be performed.<sup>1,7</sup> If these examinations are suggestive of brain death, then the more aggressive caloric and apnea testing are performed. The evaluation of brain death is highly variable among different institutions and bodies of practice.<sup>1,3,7-11</sup> The key clinical elements of brain stem reflexes and apnea testing are dependant on the expertise of the evaluating physician and the

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allied health professionals involved in performing the tests, and on the general clinical status, and the values of the biochemical tests of each patient, in addition to the significant hemodynamic risks associated with the apnea test.<sup>12</sup>

The protocols and logistics of repeat testing vary worldwide, reflecting the cultural and religious predispositions of different regions as well as the variability in the medical technology available in each medical system.<sup>13-16</sup> International bodies of neurology and critical care medicine recognize, in order to minimize false positive brain death diagnoses, that a repeat brain death assessment is required for confirmation.<sup>17,18</sup> Recent reports argue against repeat testing because of its lack of added confirmatory benefits, with the significant potential for patient hemodynamic deterioration that could lead to loss of organ preservation for donation.<sup>17,19</sup>

**Confirmatory testing in brain death.** To be able to confirm the clinical assessment of brain death, several ancillary tests are suggested for confirmation of brain death.<sup>20,21</sup> The available confirmatory tools for evaluation are either difficult to interpret at the bed side due to confounding factors, or not readily available at every medical institution.<sup>22</sup> These include electroencephalography, CT with stable xenon, MR spectroscopy, positron emission tomography, 3D CT angiography, somatosensory evoked potentials, and brain stem auditory evoked potentials, and ultimately digital subtraction angiography.

An EEG can be obtained at the bedside with minimal risk to the patient, and may be instrumental in evaluating the overall cortical activity supporting the diagnosis of brain death. The new and improved units offer mobility to this test, combined with experienced and dedicated neurologists who are vital in confirming the diagnosis. Brain death confirmed by documenting the absence of electrical activity during at least 30 minutes of recording with a minimum sensitivity of at least 2 microvolt/mm is the minimal technical criteria for EEG recording in suspected brain death as adopted by the American Electroencephalographic Society, including 16-channel EEG instruments.<sup>23</sup> It is important to recognize that EEG assesses cortical electrical discharges and does not assess brainstem function, and it might still show activity when patients meet the clinical criteria of brain death. To overcome this pitfall, somatosensory evoked potentials were used in combination with brain stem auditory evoked potentials and were found to be helpful in the evaluation of comatose patients. Median somatosensory evoked potential involves the stimulation of the median nerve distally with recording electrodes along the sensory

pathway at: the Erb point overlying the brachial plexus, at the second cervical vertebra posteriorly where gracile and cuneatus nuclei are, and on the scalp overlying the parietal lobe contralateral to the stimulated limb. Recorded waves are P9, N13, N20/P22 sequentially. Brain death is confirmed by bilateral absence of the N20-P22 response.<sup>24</sup> Although cerebral electrical activity precludes the diagnosis of brain death, cerebral electrographic silence does not exclude reversible coma, such as from intoxication or hypothermia, which has to be diligently ruled out by the evaluating team.

Other neuroimaging tests include CT angiography and CT perfusion,<sup>25</sup> MRI and MR angiography, and more recently the MR diffusion-weighted imaging.<sup>26-28</sup> However, the utilization of these imaging modalities is hindered by the cumbersome setup required to transfer a critically-ill patient to the imaging scanner and back, in addition to the high startup cost, which limits the widespread use of these tests in the diagnosis of brain death. Cerebral angiography is considered the gold standard test for confirmation of brain death; however, it has not gained popularity because of the risks associated with it; namely, the risk of contrast-induced renal failure and the theoretical risk of interference with residual brain function.<sup>2,29-31</sup>

**Transcranial Doppler in brain death determination in the Saudi health system.** In the Saudi Arabian health system, the potential for organ donation exists, but one of the major impediments is the lack of ability to confirm brain death due to complexity of the logistics to conduct such assessment. In a recent report, Aldawood et al<sup>32</sup> reported the protocol of determination of brain death in a tertiary care center in Saudi Arabia. In their report, they presented the criteria of brain death, including 2 brain death assessments at least 6 hours apart, and they relied on EEG, brain nuclear scan or digital subtraction angiography as their ancillary tests without the implementation of the non-invasive transcranial Doppler in their study. This fact reflects the current practice in brain death assessment in leading medical centers in Saudi Arabia.

Transcranial Doppler (TCD) application is non-invasive, and a simple method of evaluating the cerebrovascular circulation.<sup>33-35</sup> It is an ultrasound-based technology that measures blood flow velocity in the major intracranial arteries. This technique uses a low frequency ultrasonic signal with the ability to penetrate the acoustic windows of the skull within the thin temporal bone squama.<sup>36,37</sup> In TCD, spectral analysis of the reflected ultrasound signal uses the Doppler shift principle to calculate the velocity of intracranial blood flow. The TCD has the advantage

of being a safe examination with no contrast material or ionizing radiation. Furthermore, it is portable and may be performed in the emergency room, intensive care unit, wards, radiology department, and even in the operating room. The TCD has proven to have a short learning curve. This combined with the relatively lower purchase and operation costs, make it an ideal test to incorporate on a large scale among different tiers of health care facilities. One of the drawbacks of TCD is being operator-dependant. This can greatly influence the interpretation of the examination through faulty identification of vessels or lack of accurate interpretation and identification of Doppler patterns. This is important for interpretation when we consider the confounding effect of age, PaCO<sub>2</sub>, and cardiac output as well as the angle of insonation on the interpretations of the TCD velocity and patterns. Another difficulty with TCD is the lack of insonation window in 10-15% of the population due to thickened temporal bones obscuring the acoustic windows and hindering the TCD.<sup>37,38</sup> The Therapeutic and Technology Assessment Subcommittee of the American Academy of Neurology established that TCD is of value in detecting severe stenosis with simultaneous assessment of the patterns and extent of collateral circulation, in monitoring for vasospasm after subarachnoid hemorrhage, and detecting arteriovenous malformation, and studying their feeding arteries and flow patterns as well as its utilization in brain death assessment.<sup>39</sup> Recent reports have addressed TCD as a promising and reliable test in brain death, but TCD has yet to be included in the routine criteria for brain death evaluation.<sup>2,20,40</sup> We conducted a prospective study to evaluate the current use and the specificity and sensitivity of transcranial Doppler in confirming brain death.<sup>41</sup> In patients who are diagnosed clinically to be brain dead, 90% of them had characteristic high-resistance to-and-fro waveform abnormality in their TCD's.

Studies have demonstrated a characteristic pattern of blood flow velocity on TCD in patients with increased intracranial pressure who are clinically brain dead, including systolic spikes, to-and-fro pattern, reverberating, and flat Doppler spectrum with no signal on serial examination previously detecting flow patterns.<sup>2,42-44</sup> Measurements are easily performed at the bedside and can be repeated or continuously monitored (using dedicated head-holding systems) to follow up the trend of the tracing of the TCD. This proves valuable in cases where the clinical exam does not conform to the rest of the biochemical and neuroimaging workup, as in the case of intoxication or hypothermia.

Given its versatility and practical discriminatory specificity, we recommend the incorporation of the TCD as a non-invasive and informative test for the diagnosis of brain death. Given our vast country and complex referral patterns, we recommend the training of critical care physicians in secondary and tertiary care facilities on the performance and interpretation of TCD's to better identify patients in whom escalation of therapy is detrimental, yet are candidates for organ donation. This practice paradigm shift will facilitate the process of family discussion towards organ donation in an efficient and expedient manner and prove of great benefit to our health care system. If widely implemented in the Saudi medical centers, this would allow for early prediction of case outcome. In a well-organized clinical protocol, this would enable the reliable confirmation of brain death assessment, providing valuable information to the brain dead-patients' relatives and expedite communication with the Saudi center for organ transplant for possible organ donation.

In conclusion, the use of transcranial Doppler in the ancillary testing for brain death confirmation is a promising tool that fits the needs and setup in the health care system in Saudi Arabia. Widespread implementation would allow for better family discussions regarding critical issues such as organ donation and allocation of health care resources.

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## References

1. Benzel EC, Mashburn JB, Conrad S, Modling D. Apnea testing for the determination of brain death: a modified protocol. Technical note. *J Neurosurg* 1992; 76: 1029-1031.
2. Monteiro LM, Bollen CW, van Huffelen AC, Ackerstaff RG, Jansen NJ, van Vught AJ. Transcranial Doppler ultrasonography to confirm brain death: a meta-analysis. *Intensive Care Med* 2006; 32: 1937-1944.
3. Black PM. Conceptual and practical issues in the declaration of death by brain criteria. *Neurosurg Clin N Am* 1991; 2: 493-501.
4. Flodén A, Kelvered M, Frid I, Backman L. Causes why organ donation was not carried out despite the deceased being positive to donation. *Transplant Proc* 2006; 38: 2619-2621.
5. Valks K, Mitchell ML, Inglis-Simons C, Limpus A. Dealing with death: an audit of family bereavement programs in Australian intensive care units. *Aust Crit Care* 2005; 18: 146, 148-151.
6. Wijdicks EF. The diagnosis of brain death. *N Engl J Med* 2001; 344: 1215-1221.
7. Guidelines for the diagnosis of brain death. Canadian Neurocritical Care Group. *Can J Neurol Sci* 1999; 26: 64-66.
8. Ebata T, Watanabe Y, Amaha K, Hosaka Y, Takagi S. Haemodynamic changes during the apnoea test for diagnosis of brain death. *Can J Anaesth* 1991; 38: 436-440.

9. Gawlowski J, Hassler W. Is TC-Doppler sonography a useful method for the determination of brain death? *Neurosurg Rev* 1989; 12 Suppl 1: 307-310.
10. Hassler W, Steinmetz H, Pirschel J. Transcranial Doppler study of intracranial circulatory arrest. *J Neurosurg* 1989; 71: 195-201.
11. Wang MY, Wallace P, Gruen JP. Brain death documentation: analysis and issues. *Neurosurgery* 2002; 51: 731-735.
12. Lang CJ, Heckmann JG. Apnea testing for the diagnosis of brain death. *Acta Neurol Scand* 2005; 112: 358-369.
13. Hornby K, Shemie SD, Teitelbaum J, Doig C. Variability in hospital-based brain death guidelines in Canada. *Can J Anaesth* 2006; 53: 613-619.
14. Wijdicks EF. Brain death worldwide: accepted fact but no global consensus in diagnostic criteria. *Neurology* 2002; 58: 20-25.
15. Powner DJ, Hernandez M, Rives TE. Variability among hospital policies for determining brain death in adults. *Crit Care Med* 2004; 32: 1284-1288.
16. Practice parameters for determining brain death in adults (summary statement). The Quality Standards Subcommittee of the American Academy of Neurology. *Neurology* 1995; 45: 1012-1024.
17. Lustbader D, O'Hara D, Wijdicks EF, MacLean L, Tajik W, Ying A, et al. Second brain death examination may negatively affect organ donation. *Neurology* 2011; 76: 119-124.
18. Souter M, Van Norman G. Ethical controversies at end of life after traumatic brain injury: defining death and organ donation. *Crit Care Med* 2010; 38 (9 Suppl): S502-S509.
19. Sung G, Greer D. The case for simplifying brain death criteria. *Neurology* 2011; 76: 113-114.
20. Young GB, Shemie SD, Doig CJ, Teitelbaum J. Brief review: the role of ancillary tests in the neurological determination of death. *Can J Anaesth* 2006; 53: 620-627.
21. Djuric S, Djuric V, Zivkovic M, Milosevic V, Stamenovic J, Djordjevic G, et al. Diagnostic value of neurophysiological tests in the diagnosis of brain death--do we need changes in national guidelines? *Rev Neurosci* 2009; 20: 181-186.
22. Roberts DJ, MacCulloch KA, Versnick EJ, Hall RI. Should ancillary brain blood flow analyses play a larger role in the neurological determination of death? *Can J Anaesth* 2010; 57: 927-935.
23. Guideline three: minimum technical standards for EEG recording in suspected cerebral death. American Electroencephalographic Society. *J Clin Neurophysiol* 1994; 11: 10-13.
24. Wijdicks EF, Varelas PN, Gronseth GS, Greer DM. Evidence-based guideline update: determining brain death in adults: report of the Quality Standards Subcommittee of the American Academy of Neurology. *Neurology* 2010; 74: 1911-1918.
25. Escudero D, Otero J, Marqués L, Parra D, Gonzalo JA, Albaiceta GM, et al. Diagnosing brain death by CT perfusion and multislice CT angiography. *Neurocrit Care* 2009; 11: 261-271.
26. Selcuk H, Albayram S, Tureci E, Hasiloglu ZI, Kizilkilic O, Cagil E, et al. Diffusion-weighted imaging findings in brain death. *Neuroradiology* 2012; 54: 547-554.
27. Karantanas AH, Hadjigeorgiou GM, Paterakis K, Sfiras D, Komnos A. Contribution of MRI and MR angiography in early diagnosis of brain death. *Eur Radiol* 2002; 12: 2710-2716.
28. Ishii K, Onuma T, Kinoshita T, Shiina G, Kameyama M, Shimosegawa Y. Brain death: MR and MR angiography. *AJNR Am J Neuroradiol* 1996; 17: 731-735.
29. Mason RA, Arbeit LA, Giron F. Renal dysfunction after arteriography. *JAMA* 1985; 253: 1001-1004.
30. Guimaraens L, Vivas E, Fonnegra A, Sola T, Soler L, Balaguer E, et al. Transient encephalopathy from angiographic contrast: a rare complication in neurointerventional procedures. *Cardiovasc Intervent Radiol* 2010; 33: 383-388.
31. Krol AL, Dzialowski I, Roy J, Puetz V, Subramaniam S, Coutts SB, et al. Incidence of radio contrast nephropathy in patients undergoing acute stroke computed tomography angiography. *Stroke* 2007; 38: 2364-2366.
32. Aldawood A, Al Qahtani S, Dabbagh O, Al-Sayyari AA. Organ donation after brain-death: experience over five-years in a tertiary hospital. *Saudi J Kidney Dis Transpl* 2007; 18: 60-64.
33. Newell DW, Grady MS, Sirota P, Winn HR. Evaluation of brain death using transcranial Doppler. *Neurosurgery* 1989; 24: 509-513.
34. McMenamin JB, Volpe JJ. Doppler ultrasonography in the determination of neonatal brain death. *Ann Neurol* 1983; 14: 302-307.
35. Rigamonti A, Ackery A, Baker AJ. Transcranial Doppler monitoring in subarachnoid hemorrhage: a critical tool in critical care. *Can J Anaesth* 2008; 55: 112-123.
36. Sarkar S, Ghosh S, Ghosh SK, Collier A. Role of transcranial Doppler ultrasonography in stroke. *Postgrad Med J* 2007; 83: 683-689.
37. Kwon JH, Kim JS, Kang DW, Bae KS, Kwon SU. The thickness and texture of temporal bone in brain CT predict acoustic window failure of transcranial Doppler. *J Neuroimaging* 2006; 16: 347-352.
38. Jarquin-Valdivia AA, McCartney J, Palestrant D, Johnston SC, Gress D. The thickness of the temporal squama and its implication for transcranial sonography. *J Neuroimaging* 2004; 14: 139-142.
39. Sloan MA, Alexandrov AV, Tegeler CH, Spencer MP, Caplan LR, Feldmann E, et al. Assessment: transcranial Doppler ultrasonography: report of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology. *Neurology* 2004; 62: 1468-1481.
40. Rasulo FA, De Peri E, Lavinio A. Transcranial Doppler ultrasonography in intensive care. *Eur J Anaesthesiol Suppl* 2008; 42: 167-173.
41. Sheikh B, Al-Jehani H. Implementing transcranial Doppler as confirmatory test in brain death criteria. *Pan Arab Journal of Neurosurgery* 2008; 12: 46-49.
42. Petty GW, Mohr JP, Pedley TA, Tatemichi TK, Lennihan L, Duterte DI, et al. The role of transcranial Doppler in confirming brain death: sensitivity, specificity, and suggestions for performance and interpretation. *Neurology* 1990; 40: 300-303.
43. Ropper AH, Kehne SM, Wechsler L. Transcranial Doppler in brain death. *Neurology* 1987; 37: 1733-1735.
44. Rózsa L, Hassler W. Investigations on oscillating flow spectra as a Doppler ultrasonographic sign of intracranial circulatory arrest. *Acta Neurochir (Wien)* 1991; 112: 113-117.