The 2023 American Academy of Neurology, American Academy of Pediatrics, Child Neurology Society, and Society of Critical Care Medicine Pediatric and Adult Brain Death/Death by Neurologic Criteria Determination Consensus Guidelines: What the Critical Care Team Needs to Know*

Matthew P. Kirschen, MD, PhD[1,2]
Ariane Lewis, MD[3,4]
David M. Greer, MD, MA[5]

ABSTRACT: Guidelines for brain death/death by neurologic criteria (BD/DNC) determination were revised to provide a consistent and updated approach to BD/DNC evaluation across all ages by the American Academy of Neurology, American Academy of Pediatrics, Child Neurology Society, and Society of Critical Care Medicine. This article is intended to complement the guidelines and highlight aspects relevant to the critical care community; the actual guidelines should be used to update hospital protocols and dictate clinical practice. Because BD/DNC evaluations are conducted in the ICU, it is essential for members of the critical care community to familiarize themselves with these guidelines. The fundamental concept of BD/DNC has not changed; BD/DNC is permanent loss of function of the brain as a whole, including the brain stem, resulting in coma, brainstem areflexia, and apnea in the setting of an adequate stimulus. The BD/DNC evaluation requires a sufficient observation period to ensure there is no chance of recovery, followed by exclusion of potentially confounding conditions like hypothermia, hypotension, severe metabolic disturbances, or medication effects. Specific guidance is provided for patients who were treated with therapeutic hypothermia or medical or surgical interventions to manage intracranial hypertension. The guidelines outline a structured and meticulous neurologic examination and detail the responses consistent with BD/DNC. A protocol is provided for how to safely perform apnea testing, including modifications needed for patients on extracorporeal membrane oxygenation. Controversial issues such as consent, BD/DNC evaluation in pregnancy, preservation of neuroendocrine function, and primary posterior fossa injuries are addressed. The ultimate goal is to ensure a consistent and accurate approach to BD/DNC evaluation in patients of all ages, fostering public trust in the medical community's ability to determine death. By adhering to these guidelines, critical care clinicians can confidently navigate the challenging aspects of BD/DNC determination.

KEYWORDS: ancillary test; apnea test; brain death; critical care; death by neurologic criteria; end-of-life

The American Academy of Neurology (AAN), American Academy of Pediatrics (AAP), Child Neurology Society (CNS), and Society of Critical Care Medicine (SCCM) collaborated to update and combine the 2010 AAN brain death/death by neurologic criteria (BD/DNC) guideline for adults and the 2011 AAP/CNS/SCCM BD/DNC guideline for infants and

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children into a single document to describe BD/DNC determination for individuals of all ages and address controversies related to the prior guidelines (1–3). This process was informed by the minimum standards for BD/DNC determination described in 2020 by the World Brain Death Project and available evidence at the time of publication (4). The goal in creating these updated guidelines was to ensure a consistent, meticulous, and highly reliable approach to BD/DNC determination among providers and across hospitals, and to provide guidance for how to perform the BD/DNC evaluation in situations that were not addressed in prior guidelines.

The guidelines, and a summary of changes compared with prior guidelines, were published in journals primarily targeting neurologists, but it is imperative that members of the critical care community familiarize themselves with these updates as they are integrally involved in the care of patients with acute brain injury and in the BD/DNC evaluation process (3, 5). BD/DNC evaluations must be performed in intensive care settings with critical care teams that have expertise in caring for patients with acute brain injury and dealing with end-of-life issues. In many institutions, intensivists independently perform BD/DNC evaluations. In others, neurologists perform the clinical evaluation, but intensivists are asked to perform or supervise the apnea test given the potential cardiopulmonary complications.

To maintain public trust in our ability to accurately determine death, it is essential that BD/DNC evaluations are performed accurately and consistently. Reviews of BD/DNC protocols from adult and pediatric hospitals in the United States demonstrated variability and incomplete alignment with published standards (6, 7). There is likely further variability in clinical practice related to how providers implement hospital protocols at the bedside. In this article, we review key aspects of the revised BD/DNC guidelines relevant to the critical care community and highlight important areas of difference with prior guidelines. This article is intended as a compendium of the formal guideline document itself, which should be used to update hospital protocols and inform clinical practice (3).

Definition of BD/DNC

The Uniform Determination of Death Act (UDDA), which was written in 1981, is the legal foundation for declaration of BD/DNC in the United States (8). It states, "An individual who has sustained either (1) irreversible cessation of circulatory and respiratory functions, or (2) irreversible cessation of all functions of the entire brain, including the brain stem, is dead." The guidelines define BD/DNC as the "permanent loss of function of the brain as a whole, including the brain stem, resulting in coma, brainstem areflexia, and apnea in the setting of an adequate stimulus." (3) The word "permanent" was chosen to indicate that brain function would neither resume spontaneously nor would interventions be used in an attempt to restore brain function.

The UDDA states that "a determination of death must be made in accordance with accepted medical standards." Multiple medical societies previously agreed that the 2010 AAN adult and 2011 AAP/CNS/SCCM pediatric guidelines were the accepted medical standards for BD/DNC determination (9). The updated guidelines were authored by the same societies and endorsed by several additional societies. Thus, these should now be considered the accepted medical standards for BD/DNC determination in the United States, unless otherwise stated by local laws.

Overarching Principles in BD/DNC Determination

The guidelines are intended to both prevent false-positive BD/DNC determination (i.e., the conclusion that a patient meets criteria for BD/DNC when they do not) and be practical to ensure the BD/DNC evaluation can be conducted in all ICUs in the United States. To minimize cognitive and other inherent biases, the BD/DNC evaluation should be undertaken with the presumption that a patient has brain function. The goal of the standardized BD/DNC evaluation is to detect brain function. If no evidence of brain function is identified, the patient meets criteria for BD/DNC.

The BD/DNC evaluation for adults and children has been combined into a single document with most guidance applicable independent of age. There are some recommendations that differ for children based on age-dependent pathophysiological responses to brain injury, anatomical considerations for infants with open fontanels and unfused sutures, and historical precedent. For purposes of BD/DNC determination, a child is defined as any patient who is at least 37 weeks corrected gestational age and younger than 18 years.

An interactive, online flowchart is provided with the guidelines on the AAN website (aan.com) to help clinicians navigate the intricacies of the BD/DNC evaluation process. A free checklist is also provided on the website to help reduce diagnostic errors (10, 11).

The guidelines emphasize that communication between clinicians and families about BD/DNC should be clear and concise, using simple terminology, and avoiding medical jargon. Clinicians should provide appropriate empathetic care, support, and guidance as families process catastrophic brain injury, in general, and BD/DNC, in particular. Some families have difficulty in understanding the concept of BD/DNC or maintain hope for recovery, leading to informational, emotional, or principled objections to BD/DNC determination (12). Having families observe the BD/DNC evaluation can help improve understanding of the severity and permanence of the brain injury, the concept of BD/DNC, and the finality of the determination (13).

Credentials to Perform BD/DNC Evaluations

The guidelines specify that clinicians performing BD/DNC examinations should have specific education and demonstrate competency in performing the BD/DNC evaluation. For members of the critical care community, education should occur during critical care training and be supplemented by in-person or online courses (14). Although many of these courses (e.g., the Neurocritical Care Society's Brain Death Determination Course) require completion of written examinations, there is no universal evaluation or certification process (15). Simulation-based courses can provide valuable hands-on training and experience with examination techniques, and standardized patients can be used to educate about communication strategies related to BD/DNC (16–20). Trainees may not perform BD/DNC evaluations independently and must be directly supervised by an attending clinician. Advance practice providers may perform BD/DNC evaluations independently if permitted by local laws and institutional standards, after adequate training and demonstration of competency in performing the BD/DNC evaluation.

Prerequisites for the BD/DNC Evaluation

It is essential to ensure the etiology of brain injury is known, that it is permanent with no possibility of recovery, and conditions that could confound the assessment or interpretation of the BD/DNC evaluation have been excluded. Neuroimaging studies, if performed, should be consistent with the mechanism and severity of brain injury. However, for patients with a primary posterior fossa process, neuroimaging should also demonstrate evidence of catastrophic supratentorial injury before initiating the BD/DNC evaluation. Patients should not undergo evaluation for BD/DNC if they have not sustained catastrophic brain injury from an identifiable etiology, or if they display any evidence of consciousness, intact brainstem reflexes, spontaneous respiratory effort, or have motor movements not consistent with spinal origin.

In general, the prerequisite conditions are unchanged from prior guidelines, but additional guidance is provided to improve the accuracy and consistency of the BD/DNC evaluation process (**Table 1**).

Observation Period Between Brain Injury and BD/DNC Evaluation. The guidelines emphasize the importance of observing patients closely to ensure there is no evidence of brain function and no possibility of recovery of brain function before initiating a BD/DNC evaluation. The observation period should be based on the patient's age and the pathophysiology of brain injury. For infants and children younger than 24 months, clinicians should wait at least 48 hours after the brain injury before BD/DNC evaluation. The only other finite observation period delineated is for global hypoxic-ischemic brain injury, after which it is recommended that clinicians wait at least 24 hours (in patients 24 mo and older) before BD/DNC evaluation.

The observation period for patients who receive neuroprotective treatments (e.g., targeted temperature management) or medical or surgical interventions aimed at treating increased intracranial pressure (e.g., hyperosmolar therapy, external ventricular drain placement, decompressive hemicraniectomy) should allow sufficient time after these therapies to detect recovery of brain function before initiating a BD/DNC evaluation.

In general, it is reasonable to observe patients for evidence of recovery of brain function for a minimum of 24 hours after completion of a neuroprotective intervention, normalization of blood pressure or temperature, or clearance of a metabolic factor or toxin/medication before initiating a BD/DNC evaluation. However, this time should be individualized based on the mechanism of brain injury, the patient's age, the

TABLE 1.
Prerequisite Conditions for Brain Death/Death by Neurologic Criteria Evaluation

Prerequisite Conditions
Age ≥ 37 wk corrected gestational age
Etiology of brain injury must be known • Neuroimaging should be consistent with the mechanism and severity of brain injury • Primary posterior fossa injury: ensure concurrent catastrophic supratentorial injury
Observe for sufficient time to determine the severity and permanency of the brain injury • < 24 mo old: wait > 48 hr independent of brain injury etiology • ≥ 24 mo old: wait > 24 hr after hypoxic-ischemic brain injury • After medical or surgical interventions to treat intracranial hypertension, wait sufficient time to ensure no recovery of brain function
Core body temperature • ≥ 36°C • If temperature ≤ 35.5°C, wait >24 hr after rewarming to ≥ 36°C
Blood pressure • Adults: SBP ≥ 100 mm Hg and MAP ≥ 75 mm Hg • Children: SBP and MAP greater than or equal to fifth percentile for age • VV ECMO: same as for non-ECMO • VA ECMO: MAP ≥ 75 mm Hg (adults) or ≥ fifth percentile for age (children)
Toxicology • Ensure toxicology (urine and blood) screening, if clinically indicated, is negative • Alcohol blood level ≤ 80 mg/dL
Medications • Confirm medication levels (when available) are in therapeutic or subtherapeutic range • Allow at least five half-lives to pass • Consider age-dependent metabolism • Consider a longer elimination period if the patient has renal or hepatic dysfunction • Consider a longer elimination period if the patient is obese or is hypothermic
Exclude severe metabolic, acid-base, and endocrine derangements • Sodium: < 130 mmol/L or > 160 mmol/L • Glucose: < 70 mg/dL or > 300 mg/dL • Blood urea nitrogen: > 75 mg/dL • Calcium (iCa): < 7 mg/dL or > 11 mg/dL (< 1 mmol/L or > 1.3 mmol/L) • Magnesium: < 1.5 mg/dL or > 4 mg/dL • pH: < 7.3 or > 7.5 • Total T4[a]: < 3 mg/dL or > 30 mg/dL; free T4[a]: ≤ 0.4 ng/dL or > 5 ng/dL • Ammonia[a]: > 75 µmol/L

ECMO = extracorporeal membrane oxygenation, MAP = mean arterial pressure, SBP = systolic blood pressure, VA = venoarterial, VV = venovenous.

[a]Routine measuring of thyroid and ammonia values may not be necessary unless clinically indicated.

Exclude effect of pharmacologic paralysis through train-of-four stimulator or demonstration of deep tendon reflexes.

severity of derangement (e.g., higher medication dose administered for a longer duration, severity and duration of hypothermia or hypotension, etc.), and comorbid medical conditions (e.g., hepatic or renal dysfunction). In some situations, longer observation periods may be indicated.

Temperature Management. For all patients, the core body temperature must be maintained greater than or equal to 36˚C before performing a BD/DNC evaluation. If the core body temperature has been less than or equal to 35.5˚C for any reason (e.g., environmental exposure, induced hypothermia for neuroprotection, hypothalamic dysfunction), clinicians should wait a minimum of 24 hours after the patient's core temperature has achieved and been maintained at greater than or equal to 36˚C before initiating the BD/DNC evaluation. Consider maintaining a temperature greater than 36˚C (e.g., 36.5˚C) before initiating the BD/DNC evaluation to reduce the possibility of the patient becoming hypothermic when exposed for the neurologic examination and apnea test.

Blood Pressure Management. Because hypotension can suppress brain function, it is necessary to maintain systolic blood pressure (SBP) greater than or equal to 100 mm Hg and mean arterial pressure (MAP) greater than or equal to 75 mm Hg in adults, and greater than or equal to fifth percentile for age in children. Goal blood pressure can be achieved with parenteral fluid boluses or vasopressors. For patients supported on venoarterial ECMO, MAP should be maintained greater than or equal to 75 mm Hg for adults and greater than or equal to the fifth percentile for age in children. Patients on venovenous (VV) ECMO should be maintained with the same blood pressure parameters as those not on ECMO. In patients with chronically elevated blood pressures, it is reasonable to maintain SBP and MAP at or above their chronic baseline. Once target blood pressures have been achieved, patients should be observed for recovery of brain function before BD/DNC evaluation.

Toxins, Medications, and Metabolic Derangements. It is essential to ensure that toxic and metabolic factors that can suppress brain function and lead to a false-positive BD/DNC determination are excluded.

1) *Toxins*: If a substance that can suppress brain function is identified on toxicology screening, the patient should be observed until this toxin is cleared. Repeat toxicology screen testing may be required.
2) *Medications*: Some medications can suppress brain function and lead to coma and even loss of brainstem reflexes. It is essential to ensure all confounding medication effects have been excluded before BD/DNC evaluation. The guidelines provide a comprehensive table that summarizes medication half-lives. After clearance of medications has been established, the patient should be observed and reevaluated to ensure there is no recovery of brain function. Ancillary testing should not be used to hasten the BD/DNC evaluation if there are possible residual medication effects. Rather, the patient should be observed to ensure there is no recovery of brain function after appropriate medication clearance. This is particularly relevant for patients who have received pentobarbital, for which the level must be less than 5 μg/mL or below the lower limit of detection before BD/DNC evaluation. In this situation, it may be necessary to send daily pentobarbital levels until the level is appropriate before initiating the BD/DNC evaluation. There are some laboratories that report pentobarbital levels on the same day, which may decrease delays in BD/DNC evaluation.
3) *Metabolic, acid-base, and endocrine disturbances*: The guidelines recommend ensuring that patients do not have severe metabolic, acid-base, or endocrine disturbances before BD/DNC evaluation. Ranges for electrolyte, acid-base, and endocrine values are intended to provide practical guidance and are not evidence-based. If possible, these values should be corrected, followed by an observation period to monitor for recovery of brain function. In circumstances where it is neither feasible nor ethically appropriate to correct these values (e.g., initiating dialysis if inconsistent with the patient's goals of care), ancillary testing is required.

Neurologic Examination

The basic components of the BD/DNC neurologic examination have not changed with the updated guidelines; however, additional clinical guidance is provided to standardize technique, delineate responses consistent with BD/DNC, and offer clinical considerations to assist with conducting the examination, interpreting findings, and avoiding common pitfalls (**Table 2**). Ancillary testing is indicated if any component of the examination is unable to be completed or the response cannot be assessed adequately (e.g., in patients with neuromuscular disorders, spinal cord injuries, severe sensory neuropathies, or facial trauma). In this situation, the remainder of the examination (and the apnea test) must still be completed and be consistent with BD/DNC.

As part of the neurologic examination, clinicians must ensure the patient does not have any motor responses that either occur spontaneously or are

TABLE 2.
Components of Brain Death/Death by Neurologic Criteria Neurologic Examination

Examination Component	Guidance on the Performance of Examination Maneuvers	Response Consistent With Brain Death/Death by Neurologic Criteria
Coma	Visual: blink to visual threat Auditory: clapping and yelling the person's name loudly Tactile: deep pressure to bilateral condyles at the level of the temporomandibular joints, supraorbital notch, nasal tickle, sternum, all 4 extremities proximally and distally	No response to visual, auditory, and noxious tactile stimulation
Motor responses of face and limbs	Tactile noxious stimulation as above	Noxious stimuli should not produce grimacing, facial muscle movement, or motor response of the limbs other than spinally mediated reflexes
Pupillary light reflex	Shine a bright light into each eye looking for pupillary constriction and measuring pupil diameter Consider using a magnifying glass and/or quantitative pupilometer	Both pupils are midsize or dilated with no response to light Small pupils <2mm should alert the clinician to possible drug intoxication
Corneal reflex	Touch the cornea of each eye with a cotton swab on a stick at the external border of the iris, applying light pressure	No eyelid movement, other than that directly caused by the stimulus
Oculocephalic reflex	Confirm integrity of the cervical spine and skull base Secure endotracheal tube Rotate the head briskly horizontally to both sides	Absence of eye movements relative to the head (i.e., the eyes follow the head movement exactly, staying mid-position the entire time)
Oculovestibular reflex	Examine auditory canals for patency and intact tympanic membranes Elevate head to 30° to place horizontal semicircular canals in optimal orientation Using a catheter attached to a syringe placed inside one of the auditory canals, irrigate 50–60mL of ice water for at least 60 s and observe for extraocular movements There should be a > 5-min interval before testing opposite side to allow endolymph temperature to equilibrate	Absence of extraocular movements
Gag reflex	Stimulate posterior pharyngeal wall bilaterally with a tongue blade or rigid suction device	Absence of gag
Cough reflex	Stimulate tracheobronchial wall at the level of the carina with placement of a suction catheter through the endotracheal tube	Absence of cough
Sucking reflex (< 6-mo of age)	A gloved finger is placed inside the infant's mouth	Absence of sucking–the lips do not close around the finger and there is no rhythmic squeezing of the finger between the tongue and palate (sucking transitions from primitive reflex to voluntary around 4 mo)
Rooting reflex (< 6-mo of age)	External surface of both cheeks and corners of the mouth are stroked with a finger	No movement of the head (rooting reflex extinguishes between 3 and 6 mo)

Modified from Greer et al (3) and Greer et al (4).

elicited by noxious stimuli except those that are spinally mediated reflexes. A spinal motor reflex is a movement that is derived from spinal cord function alone without any involvement of the cerebrum or brain stem. Some classic spinal reflexes are triple flexion of lower extremities, undulating toe, "thumbs up" sign, plantar response, abdominal and cremasteric reflexes, and the constellation of Lazarus signs (4). Differentiating motor movements that are cerebrally versus spinally generated can be challenging, even for experienced clinicians. If a clinician is unsure of the origin of a motor response, the BD/DNC evaluation should be paused. The motor response can be observed over time to see if it is stereotyped and reproducible, making it more likely to be spinal. The clinician can consult an experienced practitioner for assistance in making the determination, or perform an ancillary test if the remainder of the examination and apnea test are consistent with BD/DNC and uncertainty regarding the movement's origin persists.

There are limited data to guide the number of neurologic examinations necessary to determine BD/DNC. All patients require at least one examination. Confirmation of examination findings by a second clinician may minimize the risk of a false-positive BD/DNC determination due to diagnostic error. This approach may be reasonable given the finality and implications of a BD/DNC determination. Thus, in adults, the guidelines recommend that "a second clinician may perform a separate and independent examination for BD/DNC." The interval between examinations is not prescribed. A second BD/DNC examination in adults may increase the time to death declaration and in some situations may negatively affect organ donation, but the priority throughout the evaluation should be the integrity of the BD/DNC determination, erring on the side of a patient, conservative approach (21). In pediatrics, there were no data to justify modifying the current standard of two examinations; thus, two clinicians must each perform a separate and independent BD/DNC examination and the examinations should be separated by a minimum of 12 hours. Although there are potential advantages to a mandated interval between examinations (e.g., providing families time to gather and begin grieving), the prescribed interval was determined based on historical precedent. However, the key observation period is not the inter-examination interval; rather, it is the time between the brain injury and initiation of the BD/DNC evaluation, as the permanency of the injury is established during this time.

Apnea Testing

In adults, at least one apnea test is required; in pediatrics, due to historical precedent, two are required, one with each neurologic examination. There is no physiologic reason why additional apnea testing should be necessary in children compared with adults. The guidelines do not require a different clinician to perform each apnea test in children.

The guidelines outline a detailed protocol for performing the apnea test that minimizes the risk of hypoxemia and hemodynamic instability. Apnea testing should always be performed in a critical care setting with teams trained in the management of potential cardiopulmonary complications. Some studies have attempted to elucidate risk factors for complications during apnea testing (22, 23). In general, lower blood pressure, hypoxemia, higher arterial-alveolar gradient, higher ventilator settings (e.g., mean airway pressure and F_{IO_2}), and acidemia before apnea testing are associated with a higher risk of complications. All patients should have an invasive arterial line for close hemodynamic monitoring and serial arterial blood gas (ABG) sampling. It is helpful to ensure the patient's blood pressure is sufficiently higher (~10–20%) than the minimum standards for BD/DNC evaluation (i.e., SBP ≥ 100 mm Hg and MAP ≥ 75 mm Hg in adults, and greater than or equal to fifth percentile for age in children) before initiating the apnea test to reduce the possibility of the patient becoming hypotensive during the apnea test.

The ventilator should be titrated to achieve a normal P_{aCO_2} (35–45 mm Hg) and pH (7.35–7.45) and patients should be preoxygenated with 100% F_{IO_2} for at least 10 minutes to achieve a goal P_{aO_2} greater than 200 mm Hg before initiating the apnea test. To perform the apnea test, intermittent mandatory ventilation is stopped, and the patient is disconnected from the ventilator. Apneic oxygenation is used to avoid hypoxemia while observing the patient for respiratory effort (**Fig. 1**). Because P_{aCO_2} increases by approximately 2–3 mm Hg per minute, it is recommended to check an ABG after 8–10 minutes of apnea and then every 2 minutes until the

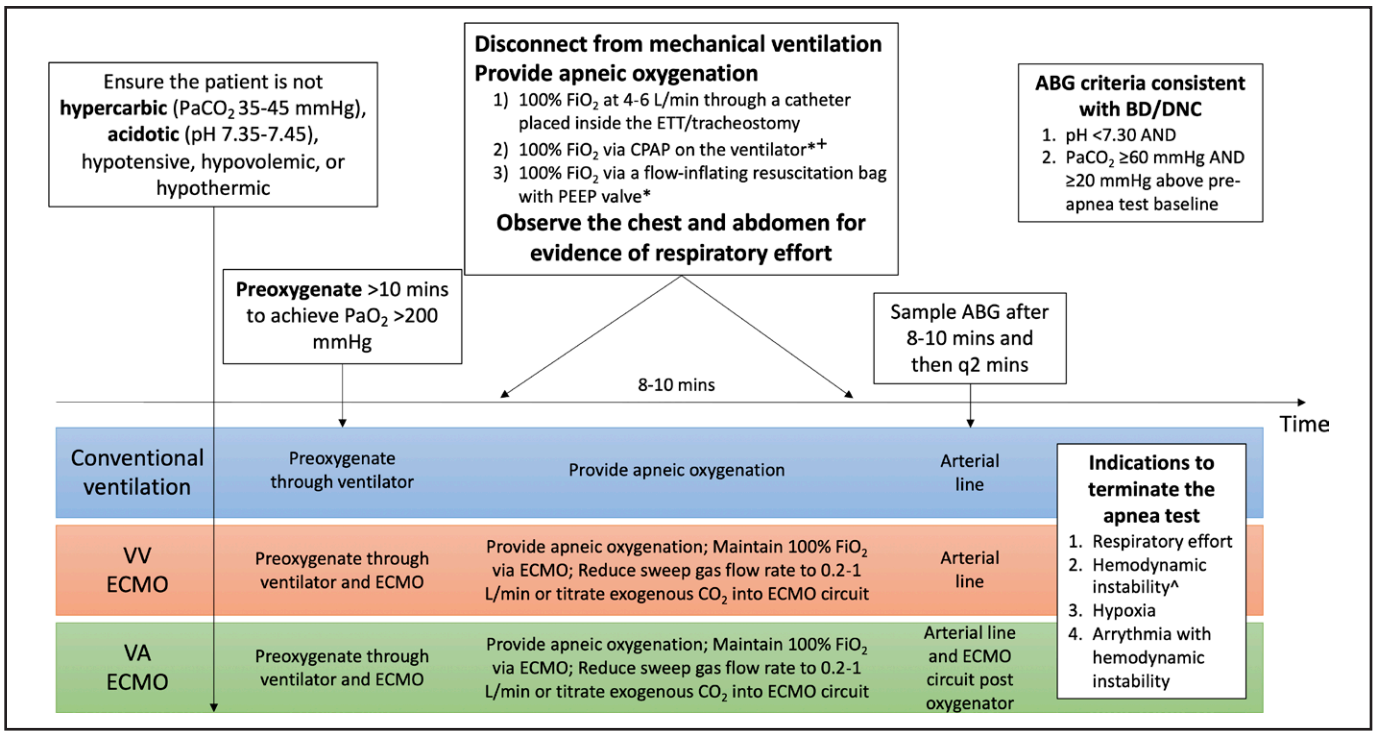

Figure 1. Clinical guidance for conducting apnea testing for patients on conventional mechanical ventilation, venovenous (VV) extracorporeal membrane oxygenation ECMO), and venoarterial (VA) ECMO. *Apneic oxygenation techniques used in children to avoid atelectasis and hypoxemia. +When conducting the apnea test on the ventilator using continuous positive airway pressure (CPAP), auto-cycling caused by cardiac pulsations or condensation in the ventilator tubing can be misinterpreted as patient-initiated breaths. ^The apnea test should be aborted if the patient has hypotension (systolic blood pressure [SBP] <100 mm Hg or mean arterial pressure [MAP] < 75 mm Hg in adults or SBP or MAP less than fifth percentile for age in children despite titration of vasopressors, inotropes, and/or IV fluids), hypoxemia (progressive decrease in oxygen saturation below 85%), or a cardiac arrhythmia with hemodynamic instability. ABG = arterial blood gas, BD/DNC = brain death/death by neurologic criteria, ETT = endotracheal tube, PEEP = positive end-expiratory pressure.

arterial pH is less than 7.30 and $Paco_2$ is greater than or equal to 60 mm Hg AND greater than or equal to 20 mm Hg above the patient's pre-apnea test baseline. If these thresholds are met and the patient has demonstrated no evidence of respiratory effort, the apnea test is consistent with BD/DNC. If patients have known or suspected CO_2 retention at baseline, this should be considered when interpreting apnea test results. After completion of the apnea test and resumption of mechanical ventilation, consider transiently increasing the minute ventilation to achieve normocapnia. Although the $Paco_2$ threshold of greater than or equal to 60 mm Hg has been used since the inception of BD/DNC, cases have been reported where patients had respiratory effort with a $Paco_2$ that exceeded 100 mm Hg (8, 24–26). Future research should focus on determining the optimal pH and $Paco_2$ thresholds and whether those values should vary based on any patient factors (e.g., age) (4).

The apnea test should be aborted if the patient has hypotension (SBP < 100 mm Hg or MAP < 75 mm Hg in adults or SBP or MAP less than fifth percentile for age in children despite titration of vasopressors, inotropes, and/or IV fluids), hypoxemia (progressive decrease in oxygen saturation below 85%), or a cardiac arrhythmia with hemodynamic instability. Ancillary testing is required if the apnea test is unable to be completed or the results are inconclusive.

It is feasible to perform apnea testing in a patient on ECMO. For patients on VV or VA ECMO, preoxygenation is achieved through both the ventilator and ECMO membrane lung. During apnea testing, patients are disconnected from mechanical ventilation, and apneic oxygenation is provided through the endotracheal tube/tracheostomy and membrane lung. The patient is observed for spontaneous respirations as their $Paco_2$ level rises. Because CO_2 is cleared efficiently by the ECMO lung, it is necessary to either reduce the sweep

gas flow rate to 0.2–1 L/min to allow CO_2 to accumulate or titrate exogenous CO_2 into the ECMO circuit.

For patients on ECMO, the pH and $Paco_2$ criteria consistent with BD/DNC are the same as for non-ECMO patients. Patients on VV ECMO should have ABGs sampled from the patient's arterial line. For patients on VA ECMO, arterial blood obtained from a distal arterial line may not fully represent the pH and $Paco_2$ in the cerebral circulation. If the patient has native cardiac output, the cerebral circulation will usually see a mixture of blood from the heart and the ECMO circuit, with the proportion dependent on cannula position, ECMO flow rates, and degree of myocardial function. Thus, for apnea testing on VA ECMO, arterial blood should be sampled from both the patient's arterial catheter and the ECMO circuit post-oxygenator. Patients cannulated centrally, via the right carotid artery, or via the right axillary artery should have the distal arterial sample obtained from the left upper extremity or either lower extremity. Patients cannulated through the femoral artery should have the distal arterial sample obtained from the right upper extremity. The pH and $Paco_2$ levels from both locations must meet the criteria for the test to be consistent with BD/DNC.

Ancillary Testing

BD/DNC is a clinical diagnosis and ancillary testing is not needed in most cases. There are a limited number of situations in which ancillary testing is required (**Table 3**). In these situations, prerequisite conditions still must be met, and the neurologic examination and apnea test completed to the fullest extent possible, with results consistent with BD/DNC. If two examinations and apnea tests are required, both should be completed before ancillary testing, such that ancillary testing is the final component of the BD/DNC evaluation. The guidelines specifically note that ancillary testing should not be used in the context of hypothermia or high levels of sedating medications. Additionally, ancillary testing is not needed solely because a patient has an open fontanel, skull fracture or defect (e.g., craniectomy), or cerebrospinal fluid diversion device that may limit the impact of intracranial hypertension.

The recommended ancillary tests are conventional four-vessel catheter angiography, radionuclide perfusion scintigraphy, and transcranial Doppler (TCD, adults only). TCD should demonstrate sharp systolic spikes and oscillating flow, and the diastolic flow should return to zero or be reversed, reflecting an intracranial pressure that is higher than the mean arterial pressure, preventing cerebral perfusion. Radionuclide perfusion scintigraphy, or cerebral blood flow/perfusion studies, should use lipophilic and brain-specific agents that cross the blood–brain–barrier, in conjunction with delayed planar or single-photon emission CT imaging, to demonstrate the absence of intracranial blood flow and cerebral perfusion. Electrophysiology-based tests are not recommended because they do not evaluate the entire brain (e.g., EEG does not assess the brain stem). Additionally, a patient with a severe metabolic encephalopathy could have an isoelectric EEG, despite

TABLE 3.
Indications for Ancillary Testing

Indications for Ancillary Testing
Ancillary testing should be used in the following situations
Injuries or abnormalities preclude accurate assessment of any component of the neurologic examination (with the notable exception of the oculocephalic reflex in the setting of cervical spine instability, provided the oculovestibular reflex can still be tested)
Inability to perform or complete the apnea test safely because of the patient's risk of cardiac or pulmonary decompensation
Inability to interpret $Paco_2$ levels in a patient with chronic hypercarbia for whom the chronic baseline $Paco_2$ level is unknown
Findings on neurologic examination that may be difficult to interpret, such as limb movements that may or may not be spinally mediated
Metabolic derangements unable to be adequately corrected

the absence of catastrophic structural brain injury. Neither CT nor MR angiography are permitted ancillary tests due to a lack of sufficient validation data.

BD/DNC Declaration

For standardization, the time of death is the time during the final apnea test that ABG results are reported and consistent with BD/DNC. If ancillary testing is performed, the time of death is when the attending clinician documents in the medical record the results are consistent with BD/DNC.

Controversial Issues in BD/DNC Determination

Finally, the guidelines address situations clinicians may find challenging or controversial (3).

Consent Before BD/DNC Evaluation. The guidelines state, "Clinicians do not need to obtain consent before an evaluation for BD/DNC unless otherwise stipulated by the institution's policy or state laws or regulations."

BD/DNC Evaluation in a Pregnant Patient. The guidelines note it is permissible to evaluate and diagnose pregnant persons with BD/DNC. Following BD/DNC determination, with input from clinicians in maternal-fetal medicine, child neurology, neonatology, and ethics, the patient's clinicians should discuss the risks and benefits to the fetus of continuing maternal organ support with surrogate decision makers.

Preservation of Neuroendocrine Function. The guidelines state it is permissible to make a BD/DNC determination despite evidence of neuroendocrine function. In clinical practice, this means that patients may undergo evaluation for BD/DNC independent of whether they have diabetes insipidus.

Patients With Primary Posterior Fossa Injury. Given the risk that patients with primary posterior fossa injury may retain some cortical viability despite an evaluation consistent with BD/DNC, the guidelines recommend clinicians ensure that the posterior fossa process has led to catastrophic supratentorial brain injury before BD/DNC evaluation.

Conclusions

This article provides members of the critical care community with a summary of the updated BD/DNC guidelines, which provide comprehensive, up-to-date, and practical guidance on BD/DNC evaluation. The guidelines outline a standardized process for BD/DNC determination and address aspects of BD/DNC evaluation that clinicians may find challenging or controversial.

1 *Department of Anesthesiology, The Children's Hospital of Philadelphia, Philadelphia, PA.*

2 *Department of Critical Care Medicine, Neurology, and Pediatrics, The Children's Hospital of Philadelphia, Philadelphia, PA.*

3 *Department of Neurology, NYU Langone Medical Center, New York, NY.*

4 *Department of Neurosurgery, NYU Langone Medical Center, New York, NY.*

5 *Department of Neurology, Boston University School of Medicine and Boston Medical Center, Boston, MA.*

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For information regarding this article, E-mail: kirschenm@chop.edu

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