Guidelines for Brain Death in Children: Toolkit

These guidelines and toolkit are based upon the available literature and consensus opinion of a panel of national experts, and may differ from individual state laws or statutes, as well as individual hospital policies and procedures. Please review all relevant hospital and state policies and regulations when utilizing the American College of Critical Care Medicine guidelines and toolkit in the assessment and declaration of brain death in children. Please use the Alt + Left Arrow to return to previous view.

Tab 1: Index

1. Revised pediatric guidelines for determination of brain death in children
   http://pediatrics.aappublications.org/content/early/2011/08/24/peds.2011-1511

Endorsing organizations:

American Academy of Pediatrics:
   Section on Critical Care
   Section on Neurology
American Association of Critical-Care Nurses
Child Neurology Society
National Association of Pediatric Nurse Practitioners
Society of Critical Care Medicine
Society for Pediatric Anesthesia
Society of Pediatric Neuroradiology
World Federation of Pediatric Intensive and Critical Care Societies
Affirmed the value of the manuscript:
American Academy of Neurology

2. Guideline summary
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   b. Apnea testing
   c. Observation period
   d. Ancillary studies
   e. Algorithm for examination *(Algorithm)*
   f. Special populations
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      ii. Teenage patients (PEDIATRIC TRAUMA PATIENTS)

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   b. Neurologic examination
      i. Examination
      ii. How to perform oculocephalic (doll's eye) testing
      iii. How to perform oculovestibular (cold water caloric) testing
      iv. How to perform an apnea test

4. Documentation
   b. Sample notes formats
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5. Other materials
   a. Drug elimination table *(Drug_elimination)*
   b. Perfusion scan

Please use the Alt + Left Arrow to return to previous view.
Tab 2: Guideline Summary

Examination criteria

- Appropriate patients for testing
  - Age >37 weeks gestation to 18 years
  - Temperature >35°C (95°F)
- Normotensive without volume depletion
  - Blood pressure measured by indwelling arterial catheter is preferable.
  - Hypotension is defined as systolic blood pressure or mean arterial pressure <2 standard deviations below normal values for age norms.
- Metabolic disturbances capable of causing coma should be identified and corrected.
- Patient should have a known irreversible cause of coma. Drug intoxication, neurotoxins, and chemical exposures should be considered in cases where a cause has not been identified.
- Medications can interfere with the neurologic examination; sedatives, analgesics, antiepileptics, and neuromuscular blocking agents require adequate time for drug clearance (Drug elimination).
  - Stop all such medications and allow adequate time for drug metabolism.
  - Organ system dysfunction and hypothermia can alter drug metabolism.
  - Obtain blood or plasma levels to confirm drug levels are in the low to mid-therapeutic range.
  - If elevated levels are noted, an ancillary test can be performed.
- Initial exam should be deferred for at least 24 hours after trauma or resuscitation event.

- Two examinations are performed by two different attending physicians.
- Observation period
  - Examinations are separated by an observation period.
  - Term newborns (>37 weeks gestational age) to 30 days: 24 hours
  - Children >30 days to 18 years: 12 hours
- Reduction of the observation periods is acceptable using an accepted ancillary (Ancillary) study.
  - When an ancillary study is used to decrease the observation interval, two examinations and two apnea tests are recommended.
  - One examination (or all components that can be completed safely) and an apnea test should be completed before the ancillary study, and the second examination (or all components that can be completed safely) and an apnea test (if able) should be completed after the ancillary study.
The second examination can occur at any time following the ancillary study in children of all ages.

- Spinal reflexes may remain intact and do not preclude a determination of brain death.
- Presence or absence of diabetes insipidus does not preclude a determination of brain death.
- Death is declared after the second neurologic examination and apnea test confirming an unchanged and irreversible condition.

**Apnea testing** (see Apnea test for detailed explanation)

- An apnea test should be performed with both exams. Both tests may be performed by the same physician. The physician performing the apnea test should be trained in ventilator management.
  
The \( \text{PaCO}_2 \) should increase \( \geq 20 \text{ mm Hg} \) above baseline and reach at least 60 mm Hg, with the patient demonstrating no respiratory effort.
  
If unable to safely perform or to complete the apnea test, an ancillary test should be performed.

**Ancillary studies** (for more detail, see [Ancillary](#))

- Ancillary testing is not required to make a determination of brain death.
- Ancillary testing is indicated in the following situations:
  
  - Unable to safely perform or to complete apnea testing
  - Unable to perform all components of the neurologic examination
  - Uncertainty exists about the neurologic examination results
  - Medication effect may be interfering with neurologic testing

- Ancillary testing may be used to reduce the intra-examination observation period.
- If ancillary tests are utilized, a second clinical examination of neurologic function and apnea testing should be performed.
- Accepted ancillary tests:
  
  - Electroencephalogram (EEG) — \( \sim 30 \) minutes of monitoring is needed
  - Radionuclide cerebral blood flow ("perfusion") study

- Studies that have not been validated as ancillary tests:
  
  - Transcranial Doppler sonography
  - Computed tomography (CT) angiography
  - Magnetic resonance imaging (MRI) angiography
Special populations

- Infants at 37 weeks estimated gestational age to 30 days of age
  Careful and repeated examination of term newborns should give particular attention to
  brainstem reflexes and apnea testing.
  Assessment of neurologic function in the term newborn may be unreliable immediately
  after an acute catastrophic neurologic injury or cardiopulmonary arrest. A period of at
  least 24 hours is recommended before evaluating for brain death.
  The observation period between examinations should be 24 hours.
  Ancillary studies in newborns are less sensitive than in older children.
  No data are available to determine brain death in infants <37 weeks estimated gestational
  age.

- Teenage trauma patients
  Variability exists for the age designation of pediatric trauma patients. In some states, the
  age is defined as <14 years of age.
  If the pediatric trauma patient is cared for in the pediatric intensive care unit, pediatric
  guidelines should be followed.
  If the older pediatric trauma patient is cared for in an adult intensive care unit, the adult
  brain death guidelines should be followed.
Tab 3: Brain death determination

Educational media

- PowerPoint slide set

Exam basics

- Order of exam – No set order, but it is more efficient to test one ear for oculovestibular function at the beginning and the other at the end, so that the first ear tested has had time to warm back to body temperature.
- **Spontaneous movement** – No spontaneous movement, even posturing, is seen in a brain-dead patient, though spinal reflexes may be present.
- **Response to pain**
  
  Method:
  
  Use trapezius squeeze, supraorbital pressure, earlobe pinching, or sternal rub.
  
  Observe for localization.
  
  In brain death, there will be no movement, excluding spinal cord events such as reflex withdrawal or spinal myoclonus.

FYI -- Do not be misled by testing for pain response on the foot as the patient may have an intact triple-flexion response, which is a spinal arc, and could be misinterpreted as localization.

- **Test cranial nerves**
  
  **Corneal reflex**
  
  Method:
  
  Hold the eyelid open.
  
  Touch the cornea with gauze, tissue, or the tip of a swab.
  
  Observe for eyelid (eyelash) movement.
  
  Repeat on other eye.
  
  In brain death, there will be no movement.
  
  Tests cranial nerves V and VII.

  **Facial grimace**
  
  Method:
  
  Apply a noxious stimulus to the face using supraorbital ridge pressure or a swab inserted into the nares with upward pressure against the turbinates.

  Observe face for grimace.

  In brain death, there will be no grimace

  Tests cranial nerves V and VII.
**Pupillary response to light**

In brain death, there is no response to light.

- Pupils may be mid-position to dilated, but fixed.
- Pupils need not be equal or dilated.

Tests cranial nerves II and III.

**Cough and gag**

Stimulate the posterior pharynx.

Suction the patient to depth of carina using an endotracheal suction catheter.

Tests cranial nerves IX and X.

**Oculocephalic test (doll’s eye reflex)**

Contraindications: Presence of cervical collar

**Physiology:** Tests the extraocular muscle movements controlled by cranial nerves III and VI

**Method:**

- Hold the eyelids open.
- The examiner moves the patient’s head from side to side forcefully and quickly.
- In brain death, the eyes always point in the direction of the nose and do not lag behind or move.

**FYI**

Even someone who is blind will have doll’s eye reflex if the brainstem is intact.

The phenomena of the doll’s eye reflex is based on old-fashioned dolls that had porcelain heads and wooden eyeballs. The wooden eyeballs would lag behind in movement when the porcelain head was turned due to inertia. Modern dolls (eg. Barbie) have eyes painted on the head.

A positive doll’s eye reflex is normal; negative is indicative of brainstem dysfunction.

**Oculovestibular test** (cold water calorics)

Note: this test may be substituted for oculocephalic testing in the patient with cervical spine injury.

- **Contraindications**
  - Ruptured tympanic membrane
  - Otorrhea
• Materials needed:
  o Container of ice water
  o 20- to 60-mL syringe
  o Intravenous tubing or 16- to 20-gauge intravenous catheter (needle removed) Emesis basin and/or absorbent pad

• Method:
  o Place absorbent pad under the patient’s head.
  o Elevate the head of the bed to 30⁰ so that the lateral semicircular canal is vertical.
  o Have someone hold the eyelids open so that the pupils can be observed.
  o Fill the syringe with ice water and attach the tubing or catheter.
  o Instill 40-60 mL of ice water into the external auditory meatus while observing for eye movement.
  o Allow at least a 5-minute interval before testing the other ear.

• Interpretation
  o Any nystagmus is not consistent with brain death.
  o Physiology:
    ▪ Ice water cools the endolymph in the semicircular canal.
    ▪ Tests cranial nerves III, VI, and VIII.
    ▪ C-O-W-S: cold opposite, warm same -- When cold fluid is instilled into the ear canal, the fast phase of nystagmus will be to the side opposite from the ear tested; in the comatose patient, the fast phase of nystagmus will be absent, as this is controlled by the cerebrum. Cold water instillation in the ear canal of a comatose patient will result in deviation of the eyes toward the ear being irrigated. When brainstem function is absent, no nystagmus will be observed.

Apnea Testing

Contraindications

Patients with high cervical spine injury
Patients requiring high levels of respiratory support

Prior to the apnea test:

Normalize PaCO₂; confirm with arterial blood gas measurements.
  In a child with chronic lung disease, the child’s baseline PaCO₂ should be used.

Confirm core temperature ≥35°C (95°F).

Normalize blood pressure.

Pre-oxygenate with 100% oxygen for 5-10 minutes.

Ensure correction of metabolic parameters and clearance of sedating pharmacologic agents. Ensure there is no recent use of neuromuscular blocking agents. Train-of-four testing may be needed to confirm absence of neuromuscular blockade.

Performing the apnea test:

Methods of administering oxygen (FiO₂ = 1.0) while not ventilating patient
T-piece connection providing O₂.

Flow-inflating anesthesia bag with positive end-expiratory pressure titrated to the desired level.

Low-flow endotracheal tube insufflation with 100% O₂. Caution: use of tracheal insufflation may be associated with CO₂ washout and barotrauma and is not recommended in the pediatric guidelines.

Use of continuous positive airway pressure via the ventilator is not recommended as apnea may not be appreciated if the ventilator reverts to an assist mode when apnea is sensed.

Monitor by direct visualization for any spontaneous respiratory effect

- In-line end tidal CO₂ monitoring can be used to measure any respiratory effort resulting in CO₂ excursion

Arterial blood gas measures should be obtained every 3-5 minutes until apnea criteria are met (increase in PaCO₂ ≥20 mm Hg and PaCO₂ ≥60 mm Hg).

Any spontaneous respiratory effort is not consistent with brain death.

FYI

In patients without significant pulmonary disease or injury, apneic oxygenation will permit the arterial oxygen saturation to remain high or change minimally. Despite no active ventilation, gas exchange continues to take place in the alveoli, with oxygen diffusing out of the alveoli and CO₂ diffusing into them. If the respiratory quotient is assumed to be 0.8, then for every 1 mL of oxygen consumed, 0.8 mL of CO₂ will be produced. As a result, there is a net entrainment of oxygen (the only gas being provided to the patient) down the tracheobronchial tree.
CO₂ rises ~4 mm Hg for every minute of apnea. The rate may be lower in the setting of brain death due to the loss of brain metabolism. At this rate, it will take at least 5 minutes of apnea for the PCO₂ to rise by 20 mm Hg; often it requires 7-9 minutes. Therefore, one may choose to draw a blood gas at minute 5-6 to of apnea, and continue the apnea observation while awaiting the results, so that another may be drawn every 2-3 minutes until the apnea criteria have been met.

Termination of apnea test:
- Draw arterial blood gas to verify appropriate CO₂ change from baseline.
- Place patient back on ventilator support.
- Document test result.
- Abort the apnea test and obtain ancillary testing if hemodynamic instability occurs or if unable to maintain SaO₂ ≥85%.

Ancillary testing
- Tests not required unless clinical examination or apnea test cannot be completed.
- Ancillary tests may not be used in lieu of clinical neurologic examination; rather, ancillary testing should be followed by a confirmatory clinical examination.
- Ancillary tests may be used to decrease the observation period. No specific recommendation is made on time to perform the second clinical examination after the ancillary study.
- If ancillary testing supports the diagnosis of brain death, then a second exam and apnea test should be performed, but repeat ancillary testing is not necessary.
- If the ancillary test is equivocal, then retesting should occur after a 24-hour waiting period.
- Imaging studies, such as CT or MRI scans, are not considered ancillary studies in the determination of brain death.
- Accepted ancillary studies
  - Both EEG and cerebral blood flow have similar confirmatory value.
  - Ancillary studies are less sensitive in newborns.
  - “Gold standard” = four-vessel cerebral angiography
    - Requires moving patient to angiography suite
    - May be used in the presence of high-dose barbiturate therapy
    - May be difficult to perform in smaller infants and children
- Cerebral blood flow study
  - Commonly used with good experience in pediatric patients
May be used in the presence of high-dose barbiturate therapy
Standards established by Society of Nuclear Medicine and Molecular Imaging
and the American College of Radiology
Example: no accumulation of tracer in non-perfused cranial vault, while scalp and
facial structures are perfused

EEG
Standards established by American Electroencephalographic Society
Low to mid-therapeutic barbiturate levels should not preclude use of EEG

- Ancillary studies not yet validated and with little to no experience in children:
  Transcranial Doppler
  CT angiography
  CT perfusion with spin labeling
  Nasopharyngeal somatosensory evoked potential studies
  MRI + magnetic resonance angiography
  Perfusion MRI
Algorithm for Determination of Brain Death in Comatose Child
(37 weeks gestational age to 18 years of age)

Does Neurologic Examination Satisfy Clinical Criteria for Brain Death?
A. **Physiologic parameters have been normalized:**
   1. Normothermic: Core temperature >35°C (95°F)
   2. Normotensive for age without volume depletion
B. **Coma:** No purposeful response to external stimuli (exclude spinal reflexes)
C. Examination reveals **absent brainstem reflexes:** Pupillary, corneal, oculovestibular (caloric), gag
D. **Apnea:** No spontaneous respirations with a measured PaCO₂ ≥60 mm Hg and ≥20 mm Hg above the baseline PaCO₂

**NO**
A. Continue observation and management
B. Consider diagnostic studies: baseline EEG, and imaging studies

**YES**

Toxic, drug or metabolic disorders have been excluded?

**NO**
A. Await results of metabolic studies and drug screen
B. Continued observation and reexamination

**YES**

**Patient Can Be Declared Brain Dead**
(by age-related observation periods*)
A. **Newborn 37 weeks gestation to 30 days:** Examinations 24 hours apart remain unchanged with persistence of coma, absent brainstem reflexes and apnea. Ancillary testing with EEG or CBF studies should be considered if any concern exists about the validity of the examination.
B. **31 days to 18 years:** Examinations 12 hours apart remain unchanged. Ancillary testing with EEG or CBF studies should be considered if any concern exists about the validity of the examination.

*Ancillary studies (electroencephalography and cerebral blood flow) are not required but can be used when (i) components of examination or apnea testing cannot be safely completed; (ii) there is uncertainty about examination; (iii) if a medication effect may interfere with evaluation or (iv) to reduce the observation period.
# Brain Death Examination for Infants and Children

Two physicians must perform independent examinations separated by specified intervals.

<table>
<thead>
<tr>
<th>Age of Patient</th>
<th>Timing of first examination</th>
<th>Examination interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Term newborn (≥37 weeks gestational age) and up to 30 days old</td>
<td>☐ First exam may be performed 24 hours after birth OR 24 hours following cardiopulmonary resuscitation or other severe brain injury</td>
<td>☐ At least 24 hours&lt;br&gt;☐ Interval shortened because ancillary study (section 4) is consistent with brain death</td>
</tr>
<tr>
<td>☐ 31 days to 18 years old</td>
<td>☐ First exam may be performed 24 hours following cardiopulmonary resuscitation or other severe brain injury</td>
<td>☐ At least 12 hours OR&lt;br&gt;☐ Interval shortened because ancillary study (section 4) is consistent with brain death</td>
</tr>
</tbody>
</table>

## Section 1. PREREQUISITES for brain death examination and apnea test

A. **IRREVERSIBLE AND IDENTIFIABLE Cause of Coma (Please check):**
   - ☐ Traumatic brain injury
   - ☐ Anoxic brain injury
   - ☐ Known metabolic disorder
   - ☐ Other (Specify) __________________

B. **Correction of contributing factors that can interfere with the neurologic examination**
   
   a. Core Body Temp is ≥95°F (≥35°C)
   b. **BP<sub>90</sub>** or MAP in acceptable range for age
      (BP<sub>90</sub> should not be less than 2 standard deviations below age appropriate norm)
   c. Sedative/analgiesic drug effect excluded as a contributing factor* 
   d. Metabolic intoxication excluded as a contributing factor
   e. Neuromuscular blockade excluded as a contributing factor

Examination One | Examination Two
---|---
☐ Yes | ☐ No | ☐ Yes | ☐ No
☐ Yes | ☐ No | ☐ Yes | ☐ No
☐ Yes | ☐ No | ☐ Yes | ☐ No
☐ Yes | ☐ No | ☐ Yes | ☐ No
☐ Yes | ☐ No | ☐ Yes | ☐ No

*If ALL prerequisites are marked YES, then proceed to section 2; if not, then defer examination. *See Section 4.

## Section 2. PHYSICAL EXAMINATION

**NOTE:** Spinal cord reflexes are acceptable

| a. Flaccid tone, patient unresponsive to deep painful stimuli |
| b. Pupils are midposition or fully dilated; light reflexes are absent |
| c. Corneal, cough, gag reflexes are absent | Examination One Date/time: | Examination Two Date/time: |
| d. Sucking and rooting reflexes are absent (in neonates and infants) |
| e. Oculovestibular reflexes are absent |
| f. Spontaneous respiratory effort while on mechanical ventilation is absent |

Explain any exam element that could not be performed: ________________________________

## Section 3. APNEA TEST

| a. Exam 1: No spontaneous respiratory efforts were observed despite final PaCO<sub>2</sub> ≥ 60 mm Hg and a ≥ 20 mm Hg increase above baseline. |
| b. Exam 2: No spontaneous respiratory efforts were observed despite final PaCO<sub>2</sub> ≥ 60 mm Hg and a ≥ 20 mm Hg increase above baseline. |

| Pre PaCO<sub>2</sub>: ________ | Pre PaCO<sub>2</sub>: ________ |
| Apnea duration: ________ minutes | Apnea duration: ________ minutes |
| Post PaCO<sub>2</sub>: ________ | Post PaCO<sub>2</sub>: ________ |

Apnea test is contraindicated or could not be completed due to: ________________________________

Ancillary study (EEG or radionuclide CBF) was performed. (See Section 4)

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Section 4. ANCILLARY TESTING is required when:
(1) components of the examination or apnea testing cannot be completed;
(2) if there is uncertainty about the results of the neurologic examination; or
(3) if a medication effect may be present.
Ancillary testing may be performed to reduce the inter-examination period however a second
neurologic examination is required.

|☐ Electroencephalogram (EEG) report documents electrocerebral silence | ☐ Yes ☐ No |
|☐ Cerebral Blood Flow (CBF) study report documents no cerebral perfusion | ☐ Yes ☐ No |

Section 5. SIGNATURES

Examiner One
I certify that my examination is consistent with cessation of function of the brain and brainstem. Confirmatory exam to follow.

(Printed Name)  (Signature)  (Specialty)  (Pager/ID #)  (Date)  (Time)

Examiner Two
I certify that my examination and/or ancillary test report confirms unchanged and irreversible cessation of function of the brain and brainstem.

(Date/Time of death: __________________________)

(Printed Name)  (Signature)  (Specialty)  (Pager/ID #)  (Date)  (Time)


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### Medications Administered to Critically Ill Pediatric Patients and Recommendations for Time Interval Between Discontinuation and Testing

<table>
<thead>
<tr>
<th>Medication</th>
<th>Infants/Children Elimination Half-Life</th>
<th>Neonates Elimination Half-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intravenous induction, anesthetic, and sedative agents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thiopental</td>
<td>Adults: 3–11.5 hrs (shorter half-life in children)</td>
<td></td>
</tr>
<tr>
<td>Ketamine</td>
<td>2.5 hrs</td>
<td></td>
</tr>
<tr>
<td>Etomidate</td>
<td>2.6–3.5 hrs</td>
<td></td>
</tr>
<tr>
<td>Midazolam</td>
<td>2.9–4.5 hrs</td>
<td></td>
</tr>
<tr>
<td>Propofol</td>
<td>2–8 mins, terminal half-life 200 mins (range, 300–700 mins)</td>
<td>4–12 hrs (77–80)</td>
</tr>
<tr>
<td>Dexamethasone</td>
<td>Terminal half-life 83–159 mins (79–81)</td>
<td>Infants have faster clearance (81–83)</td>
</tr>
<tr>
<td>Antiepileptic drugs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenobarbital</td>
<td>Infants: 20–133 hrs*; children: 37–73 hrs*</td>
<td>45–500 hrs* (79, 84, 85)</td>
</tr>
<tr>
<td>Phenobarbital</td>
<td>25 hrs*</td>
<td></td>
</tr>
<tr>
<td>Phenytoin</td>
<td>11–55 hrs*</td>
<td>63–88 hrs* (79, 86, 87)</td>
</tr>
<tr>
<td>Diazepam</td>
<td>1 month to 2 yrs: 10–50 hrs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2–12 yrs: 15–21 hrs</td>
<td></td>
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<tr>
<td></td>
<td>12–16 yrs: 18–20 hrs</td>
<td></td>
</tr>
<tr>
<td>Lorazepam</td>
<td>Infants: 40.2 hrs (range, 18–73 hrs) Children: 16.5 hrs (range, 6–17 hrs)</td>
<td>40 hrs (88)</td>
</tr>
<tr>
<td>Clonazepam</td>
<td>4–12 yrs: 5 hrs</td>
<td></td>
</tr>
<tr>
<td>Valproic acid</td>
<td>Children &gt;2 months: 7–13 hrs* Children 2–14 yrs: mean 9 hrs; range, 3.5–20 hrs</td>
<td>10–67 hrs*</td>
</tr>
<tr>
<td>Levetiracetam</td>
<td>Children 4–12 yrs: 5 hrs</td>
<td></td>
</tr>
<tr>
<td>Intravenous narcotics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morphine sulfate</td>
<td>Infants 1–3 months: 6.2 hrs (5–16 hrs)</td>
<td>7.6 hrs (range, 4.5–13.3 hrs) (79, 89–91)</td>
</tr>
<tr>
<td></td>
<td>6 months to 2.5 yrs: 2.9 hrs (1.4–7.8 hrs)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Children: 1–2 hrs</td>
<td></td>
</tr>
<tr>
<td>Meperidine</td>
<td>Infants &lt;3 months: 8.2–10.7 hrs (range, 4.9–31.7 hrs); infants 3–18 months: 2.3 hrs</td>
<td>23 hrs (range, 12–39 hrs)</td>
</tr>
<tr>
<td></td>
<td>Children 5–8 yrs: 3 hrs</td>
<td></td>
</tr>
<tr>
<td>Fentanyl</td>
<td>5 months to 4.5 yrs: 2.4 hrs (mean); 0.5–14 yrs: 21 hrs (range, 11–36 hrs for long-term infusions)</td>
<td>1–15 hrs</td>
</tr>
<tr>
<td>Suxamethonium</td>
<td>Children 2–8 yrs: 57 ± 12 mins</td>
<td>382–1,162 mins</td>
</tr>
<tr>
<td>Muscle relaxants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pancuronium</td>
<td>5–10 mins; prolonged duration of action in patients with pseudocholinesterase deficiency or mutation</td>
<td>110 mins</td>
</tr>
<tr>
<td>Vecuronium</td>
<td>41 mins</td>
<td>65 mins</td>
</tr>
<tr>
<td>Atracurium</td>
<td>17 mins</td>
<td>20 mins</td>
</tr>
<tr>
<td>Rocuronium</td>
<td>3–12 months: 1.3 ± 0.5 hrs 1 to &lt;3 yrs: 1.1 ± 0.7 hrs 3 to &lt;8 yrs: 0.8 ± 0.3 hrs Adults: 1.4–2.4 hrs</td>
<td></td>
</tr>
</tbody>
</table>

*Elimination half-life does not guarantee therapeutic drug levels for longer-acting medications or medications with active metabolites. Drug levels should be obtained to ensure that levels are in a low to midtherapeutic range before neurologic examination to determine brain death. In some instances, this may require waiting several half-lives and rechecking serum levels of the medication before conducting the brain death examination.

Modified from Ashwal and Schneider (57). Metabolism of pharmacologic agents may be affected by organ dysfunction and hypothermia. Physicians should be aware of total amounts of administered medication that can affect drug metabolism and levels.

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Example of Electronic Medical Record Documentation for Determination of Pediatric Brain Death

Pediatric Brain Death Examination Documentation 12/10/2014 7:27 PM

Note: For use with patients ≥12 weeks gestation to 18 years of age. The patient must be examined in this hospital during treatment of potentially correctable abnormalities. Determination of brain death in infants and children must be made by two attending physicians. The examining physicians will evaluate each separate component of the exam and, where appropriate, document supporting laboratory or examination data. All exams must be completed.

Have reasonable efforts been made to notify the patient’s parents/legal guardian that a determination of brain death will soon be completed? (YES/DEF/NO 23119)

Age of Patient | Inter exam interval | Timing of first exam | Timing of first exam may be performed (hours after birth):
--- | --- | --- | ---
Term neonate, ≥12 weeks gestation age up to 20 days | At least 24 hours | First exam may be performed 24 hours after birth if APGAR ≤ 4 at 10 minutes or other severe brain injury
31 days of age to 18 years | Interval shortened due to ancillary study consistent with brain death | First exam may be performed 24 hours after birth if APGAR ≤ 4 at 10 minutes or other severe brain injury

A. PREREQUISITES for Brain Death Examination

1. IRREVERSIBLE AND EVIDENTLY CAUSE OF DEATH:
   - Adult: APGAR score ≤ 4 at 10 minutes
   - Pediatric: APGAR score ≤ 3 at 10 minutes

2. Correction of contributing factors that interfere with neuro exam:
   - Normal Vital Signs
   - Normal APGAR score
   - Normal arterial blood pressure

3. Sedative/anesthetic drug effect excluded as a contributing factor
   - Within normal therapeutic range are acceptable

4. Metabolic: methodology excluded as a contributing factor
   - Venous blood gas normal

5. Neurovascular/vascular block excluded as a contributing factor
   - Normal carotid Doppler

IF ALL prerequisites are marked YES, then proceed to Section II (Physical Exam), or if conflicting variable(s) present, proceed to Section IV (Ancillary Study):

II. Physical Exam (Please check)

- Spinal cord reflexes are acceptable
- Pupil midposition or dilated and light reflexes are absent
- Corneal, cough, gag reflexes are absent
- Spontaneous respiratory effort is absent

If all elements of the Physical Exam are complete, proceed to Section III (Apnea Test). If an element of the Physical Exam cannot be performed, proceed to Section IV (Ancillary Study).

III. APNEA Test - May be performed by same physician for both exams

- Preoxygenate patient with 100% oxygen for 5 minutes. Once preoxygenated, change mechanical ventilation to continuous positive pressure ventilation or a Mapleson circuit while observing for any spontaneous respiratory movements. PaCO2 must be allowed to rise to ≥ 50 torr and ≥ 20 torr over baseline PaCO2. If no respiratory effort noted at PaCO2 = 50 torr and ≥ 20 torr above baseline, documentation of apnea consistent with neurologic death is noted. The patient is placed back on mechanical ventilation until death is confirmed with a repeat clinical examination or ancillary testing.

- If no spontaneous respiratory efforts were observed despite final PaCO2 ≥ 60 mmHg and ≥ 20 mmHg increase above baseline

- Apnea test is contraindicated or could not be performed because of...

- Ancillary study was therefore performed to document brain death (Section IV)

IV. ANCILLARY testing is required when any of the components of the exam or apnea test cannot be completed; if there is uncertainty about the results of the neurologic exam; or, if a medication effect may be present.

- Electroencephalogram (EEG) report documents electrocerebral silence
- Cerebral Blood Flow (CBF) Study report documents no cerebral perfusion

If all components of the exam or apnea test cannot be completed, proceed to Section IV (Ancillary Study).
Electronic Medical Record: Sample Note

(Parenthetical information included as drop-down lists for selection; see next page for list contents. ***used to allow for free text entry.)

Neurological Function Exam {PICU INITIAL/CONFIRMATORY}

The irreversible identifiable cause of coma include: {PICU CAUSE OF COMA}.

The following criteria have been evaluated:
- Core body temperature >35°C: {YES/NO}
- BP or MAP in acceptable range: {YES/NO}
- Sedative/analgesic drug effect excluded as a contributing factor: {YES/NO}
  - Phenobarbital: {PICU PHENOBARBITOL}
  - Pentobarbital: {PICU PENTOBARBITAL}
- Metabolic intoxication excluded as a contributing factor: {YES/NO}
- Neuromuscular blockers excluded as a contributing factor: {YES/NO}

Exam:

Cortical Function

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Brainstem Function

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Oculovestibular response: {OCULOVESTIBULAR RESPONSE}. Oculocephalic response (doll’s eye): {PICU OCULOCEPHALIC RESPONSE}.
Respiratory drive: {PICU RESPIRATORY DRIVE}.

Ancillary tests (not required in any age group, but may decrease exam interval): {PICU ANCILLARY TEST}.

This exam demonstrates irreversible cessation of all activity in the cerebral hemispheres and brainstem {PICU NEURO EXAM DISPOSITION}.

Signature________________________________ Date/Time________________________
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<th><strong>EMR choice descriptor</strong></th>
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| (PICU INITIAL/CONFIRMATORY)              | • Initial  
• Confirmatory                                                                                                                                 |
| (PICU CAUSE OF COMA)                     | • Traumatic brain injury  
• Anoxic brain injury  
• Known metabolic disorder  
• ***                                                                                                                                |
| (PICU PHENOBARBITOL)                     | • Not used in this patient  
• Level = *** at ***  
• ***                                                                                                                                |
| (PICU FENTOBARBITAL)                     | • Not used in this patient  
• Level = *** at ***  
• ***                                                                                                                                |
| (OCULO-VESTIBULAR RESPONSE)              | • Absent  
• Absent left (unable to test right)  
• Absent right (unable to test left)  
• Unable to test due to CSF leak  
• ***                                                                                                                                |
| (PICU OCULOCEPHALIC RESPONSE)            | • No response (negative)  
• N/A - unable to perform secondary to spine immobilization or facial injuries  
• ***                                                                                                                                |
| (PICU RESPIRATORY DRIVE)                 | • Not yet performed  
• N/A - unable to test secondary to concurrent cardiopulmonary dysfunction  
• Absent as evidenced by an apnea test. Pretest pCO2 was ***. Patient was pre-oxygenated with FiO2 = 1.0 for several minutes. Patient was then placed on CPAP (no breaths) via ETT. After *** minutes, a blood gas was drawn. Pulse oximetry and hemodynamics were stable throughout. Blood gas result: pH ***, pCO2 ***, pO2 ***, indicating a pCO2 increase of *** mm Hg  
• Apnea test being performed by another physician, see additional note                                                                                                                                |
| (PICU ANCILLARY TEST)                    | • Not indicated at this time  
• EEG: (PICU EEG)  
• Cerebral Perfusion Study: (PICU CEREBRAL PERFUSION STUDY)                                                                                                                                |
| (PICU EEG)                               | • Ordered  
• In progress  
• Perinding reading  
• Electrocerebral silence  
• ***                                                                                                                                |
| (PICU CEREBRAL PERFUSION STUDY)          | • Ordered  
• Absent cerebral blood flow  
• ***                                                                                                                                |
| (PICU NEURO EXAM DISPOSITION)            | • A confirmatory exam will be performed in approximately 24 hours by a second physician, given the child’s age is less than 31 days  
• A confirmatory exam will be performed in approximately 12 hours by a second physician, given the child’s age is greater than or equal to 31 days  
• An ancillary test is planned, a confirmatory test will be performed in *** hours  
• Results discussed with family.  
• Time of death ***                                                                                                                                |
Neurological Function Exam - PICU

Name: 
Hospital #: 
Room/Bed: 
Medical Record #: 
Admission Date: 
Attending Provider: 
Date of Birth: 
Age: 

Irreversible and identifiable causes of coma include:

- Traumatic brain injury
- Anoxic brain injury
- Known metabolic disorder

The following criteria have been evaluated:

1. Core body temperature >35°C:
   - Yes
   - No

2. Systolic BP or MAP in acceptable range:
   - Yes
   - No

3. Sedative/analgesic drug effect excluded as a contributing factor:
   - Yes
   - No

   Phenobarbital:
   - Not used in this patient
   - Level *** at ***

   Pentobarbital:
   - Not used in this patient
   - Level *** at ***

4. Metabolic intoxication excluded as a contributing factor:
   - Yes
   - No

5. Neuromuscular blockers excluded as a contributing factor:
   - Yes
   - No
Exam:

Cortical Function:

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Oculovestibular response:

- Absent
- Absent left (unable to test right)
- Absent right (unable to test left)
- Unable to test due to CSF leak

Oculocephalic response (doll's eye):

- No response (negative)
- N/A - unable to perform secondary to spine immobilization or facial injuries

Respiratory drive:

- Not yet performed
- N/A - unable to test secondary to concurrent cardiopulmonary dysfunction

Absent as evidenced by apnea test. Pretest P<sub>CO₂</sub> was ***. Patient was pre-oxygenated with F<sub>IO₂</sub> = 1.0 for several minutes. Patient was then placed on CPAP (no breaths) via ETT. After *** minutes, blood gas was drawn. Pulse oximetry and hemodynamics were stable throughout. Blood gas result: pH ***, P<sub>CO₂</sub> ***, P<sub>O₂</sub> ***, indicating a P<sub>CO₂</sub> increase of *** mm Hg.
Apnea test being performed by another physician, see additional note
***

Ancillary Tests (not required in any age group, but may decrease exam interval):
Not indicated at this time
EEG:

- Ordered
- In progress
- Pending reading
- Electrocerebral silence
  ***

Cerebral perfusion study:

- Ordered
- Absent cerebral blood flow
  ***

This exam demonstrates irreversible cessation of all activity in the cerebral hemispheres and brainstem.

A confirmatory exam will be performed in approximately 24 hours by a second physician, given
the child's age is <31 days
A confirmatory exam will be performed in approximately 12 hours by a second physician, given
the child's age is ≥31 days
An ancillary test is planned
A confirmatory test will be performed in *** hours
Results discussed with family
Time of death ***

Attending performing exam:
DEFINITION

- Circulatory death: Cessation of cardiac activity
- Brain death: Irreversible cessation of function of the entire brain, including the brain stem
First introduced in a 1968 report authored by a special committee of the Harvard Medical School

Adopted in 1980, with modifications, by the President's Commission for the Study of Ethical Problems in Medicine and Biomedical Research, as a recommendation for state legislatures and courts

The "brain death" standard was employed in the legislation known as the *Uniform Determination of Death Act*, which has been enacted by a large number of jurisdictions and has been endorsed by the American Bar Association.

In 1987, the first pediatric guidelines were published

Revised in 2011 for children 37 weeks to 18 years

Endorsed by:
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- Section on Critical Care, American Academy of Pediatrics
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- Cerebrum
  - Controls memory, consciousness, and higher mental functioning
- Cerebellum
  - Controls various muscle functions
- Brainstem, consisting of the midbrain, pons, and medulla, extends downwards to become the spinal cord
  - Controls respiration and various basic reflexes (e.g., swallow and gag)
Deep coma
- Unresponsive to most external stimuli
- Has a dysfunctional cerebrum but, by virtue of the brainstem remaining intact, is capable of spontaneous breathing and heartbeat

PVS – persistent vegetative state
- Eyes may move
- May have sleep-wake cycles
Heart
- Needs O\textsubscript{2} to survive and without O\textsubscript{2} will stop beating
- Not controlled by the brain but is autonomous

Breathing
- Controlled by vagus nerve, located in the brain stem
- Main stimulant for vagus nerve is \( \uparrow \) CO\textsubscript{2} in the blood
  - Causes the diaphragm & chest muscles to expand
  - Spontaneous breathing can not occur after brainstem death

With artificial ventilation, the heart may continue to beat for a time after brainstem death

Time lag between brain death and circulatory death in the unsupported patient is generally \(~2-10\) days, but much longer in those with fully supported organ function.
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Clinical or radiographic evidence of an acute catastrophic cerebral event consistent with diagnosis of brain death

Exclusion of conditions that confound clinical evidence (i.e., metabolic)

Confirmation of absence of drug intoxication or poisoning
  - Barbiturates, neuromuscular blockers, etc.

Core body temp >35 °C (95 °F)
Cerebral motor response to pain
- Supraorbital ridge, nail beds, trapezius
- Motor responses may occur spontaneously during apnea testing (spinal reflexes)
- Spinal reflex responses occur more often in young
- If patient received paralytic, then test with train-of-four

Spinal arcs are intact!
- Example: Triple flexion response of legs
Round, oval, or irregularly shaped

- Midsize (3-6 mm), but may be totally dilated
- Absent pupillary light reflex
  - Although drugs can influence pupillary size, the light reflex remains intact only in the absence of brain death
  - IV atropine does not markedly affect reactivity, but does affect size
  - Topical administration of drugs and eye trauma may influence pupillary size and reactivity
  - Pre-existing ocular anatomic abnormalities may also confound pupillary assessment in brain death
  - Paralytics do not affect pupillary size or response
  - Dilated pupils suggest anticholinergic drugs (tricyclic antidepressants, neuroleptics) or sympathomimetic drugs (cocaine, amphetamines, theophylline)
Oculocephalic reflex = doll’s eyes
- Not based on Barbie-type dolls with painted eyes
- But on old-fashioned type dolls with wooden eyes in porcelain heads

Vestibulo-ocular = cold caloric test
Contraindication
- Presence of cervical collar – oculovestibular testing (“cold calorics”) may still be done

Physiology
- Tests the extraocular muscle movements controlled by cranial nerves III and VI

Method
- Hold the eyelids open
- Examiner moves the patient’s head from side to side forcefully and quickly
In brain death, the eyes always point in the direction of the nose and do not lag behind or move.

**FYI**

Even someone who is blind will have doll’s eye reflex if the brainstem is intact.
Example: Head turned abruptly to right

Negative doll’s eyes
-- Eyes continue to point straight forward despite head turn
-- Equates to brainstem dysfunction

Positive doll’s eyes
-- You have them!
Contraindication:
- Ruptured tympanic membrane
- Otorrhea

Method:
- Elevate head of bed 30° to properly orient the semicircular canal
- Irrigate tympanic membrane with 40-60 mL ice water. Check 1 ear at beginning of exam and 1 at end to allow endolymph temperature to equilibrate
- Observe patient for 1 minute after each ear irrigation, with a 5-minute wait between testing of each ear
Ice water cools the endolymph in the semicircular canal.

Tests cranial nerves III, VI, and VIII.

C-O-W-S: cold opposite, warm same. When cold fluid is instilled into the ear canal, the fast phase of nystagmus will be to the side opposite from the ear tested.

- In the comatose patient, the fast phase of nystagmus will be absent, as this is controlled by the cerebrum. Cold water instillation in the ear canal of a comatose patient will result in tonic deviation of the eyes toward the ear being irrigated.
- In the brain dead patient, no nystagmus will be observed.
Movement only of eye on side of stimulus
- Internuclear ophthalmoplegia
- Suggests brainstem structural lesion

Tonic deviation of both eyes
- Coma

No eye movement
- Brainstem injury / brain death
- Facial trauma involving the auditory canal and petrous bone can also inhibit these reflexes
FACIAL SENSORY & MOTOR RESPONSES

- Corneal reflexes are absent in brain death
  - Corneal reflexes - tested by using a cotton-tipped swab
  - Grimacing in response to pain can be tested by applying deep pressure to the nail beds, supraorbital ridge, temporomandibular joint, or by swab in nose
  - Severe facial trauma can inhibit interpretation of facial brainstem reflexes
Both gag and cough reflexes are absent in patients with brain death

- Gag reflex can be evaluated by stimulating the posterior pharynx with a tongue blade, but the results can be difficult to evaluate in orally intubated patients
- Cough reflex can be tested by using suction catheter deep, past end of endotracheal tube
**Contraindications:**
- Patients with high cervical spine injury
- Patients requiring high levels of respiratory support

**Goal:**
- $\text{PaCO}_2$ levels $\geq 60$ mmHg
- $\geq 20$ mmHg over baseline
  - In a child with chronic lung disease, the child’s baseline $\text{PaCO}_2$ should be used
Pre-oxygenate with 100% oxygen for several minutes

Allow baseline $\text{PaCO}_2$ to be $\sim 40$ mmHg

Place patient on T-piece or flow-inflating bag

- Titration of positive end-expiratory pressure (PEEP) via a flow-inflating bag may assist in preventing alveolar collapse and derecruitment
- Use of continuous positive airway pressure (CPAP) via the ventilator is not recommended as apnea may not be appreciated if the ventilator reverts to an assist mode when apnea is sensed

Observe for respiratory effort for $\sim 6-10$ minutes
**APNEA TESTING**

- CO₂ rises ~4 mm Hg for every minute of apnea
  - The rate may be lower in the setting of brain death due to the loss of brain metabolism
- At this rate, it will take at least 5 minutes of apnea for the PaCO₂ to rise by 20 mm Hg; often it requires 7-9 minutes
- Therefore, may choose to draw an arterial blood gas at minute 5-6 of apnea, and continue the apnea observation while awaiting the results. Repeat gas every 2 minutes until the apnea criteria have been met or the test must be aborted.
- Abort testing if the SpO₂ falls below 85% or hemodynamic instability is present
In patients without significant pulmonary disease or injury, apneic oxygenation will permit the arterial oxygen saturation to remain high or change minimally.

Despite no active ventilation, gas exchange continues to take place in the alveoli, with oxygen diffusing out and CO$_2$ diffusing in.
If the respiratory quotient is assumed to be 0.8, then for every 1 mL of oxygen consumed, 0.8 mL of CO₂ is produced.

As a result, there is a net entrainment of oxygen (the only gas being provided to the patient) down the tracheobronchial tree.
CONFIRMATORY TESTING

- Gold standard: 4 vessel angiography
  - Rarely done
- Cerebral blood flow = perfusion scan

- EEG
  - Standards established by American Electroencephalographic Society
  - Low to mid-therapeutic barbiturates levels should not preclude use of EEG
Say “dead”, not “brain dead”

Say “artificial or mechanical ventilation”, not “life support”

Time of death = time of second examination, including apnea and/or ancillary test completion. When a patient meets all criteria for brain death, he/she is legally dead.
  - NOT when ventilator removed
  - NOT when heart beat ceases

State law and local institutional policies should be reviewed and followed.

Ask staff not talk to the patient as if still alive.
BRAIN DEATH

Jana Stockwell, MD, FCCM

2014
Circulatory death: Cessation of cardiac activity
Brain death: Irreversible cessation of function of the entire brain, including the brain stem
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  - 1987: Required, but how many not specified
  - 2011: 2 required unless clinically contraindicated

- **Final Pco₂ threshold:**
  - 1987: Not specified
  - 2011: ≥60 mmHg & ≥20 mmHg above baseline

- **Ancillary study:**
  - Age 7d to 2 mo: 2 EEGs separated by 48 h
  - Age 2 mo to 1 y: 2 EEGs separated by 24 h, or a cerebral blood flow study instead of second study
  - Age >1 y: none
  - 2011: Required only if unable to complete exam and apnea test

- **Time of death:**
  - 1987: Not specified
  - 2011: Time of second exam and apnea test or ancillary study
Clinical or radiographic evidence of an acute catastrophic cerebral event consistent with diagnosis of brain death

Exclusion of conditions that confound clinical evidence (i.e., metabolic)

Confirmation of absence of drug intoxication or poisoning
  - Barbiturates, neuromuscular blockers, etc.

Core body temp >35 °C (95 °F)
Cerebral motor response to pain

- Supraorbital ridge, nail beds, trapezius
- Motor responses may occur spontaneously during apnea testing (spinal reflexes)
- Spinal reflex responses occur more often in young
- If patient received paralytic, then test with train-of-four

Spinal arcs are intact!

- Example: Triple flexion response of legs
- Round, oval, or irregularly shaped
- Midsize (3-6 mm), but may be totally dilated
- Absent pupillary light reflex
  - Although drugs can influence pupillary size, the light reflex remains intact only in the absence of brain death
  - IV atropine does not markedly affect reactivity, but does affect size
  - Topical administration of drugs and eye trauma may influence pupillary size and reactivity
  - Pre-existing ocular anatomic abnormalities may also confound pupillary assessment in brain death
  - Paralytics do not affect pupillary size or response
  - Dilated pupils suggest anticholinergic drugs (tricyclic antidepressants, neuroleptics) or sympathomimetic drugs (cocaine, amphetamines, theophylline)
Oculocephalic reflex = doll’s eyes
- Not based on Barbie-type dolls with painted eyes
- But on old-fashioned type dolls with wooden eyes in porcelain heads

Vestibulo-ocular = cold caloric test
Contraindication
- Presence of cervical collar – oculovestibular testing (“cold calorics”) may still be done

Physiology
- Tests the extraocular muscle movements controlled by cranial nerves III and VI

Method
- Hold the eyelids open
- Examiner moves the patient’s head from side to side forcefully and quickly
In brain death, the eyes always point in the direction of the nose and do not lag behind or move.

FYI

Even someone who is blind will have doll’s eye reflex if the brainstem is intact.
Example: Head turned abruptly to right

- Negative doll’s eyes
  - Eyes continue to point straight forward despite head turn
  - Equates to brainstem dysfunction

- Positive doll’s eyes
  - You have them!
Contraindication:

- Ruptured tympanic membrane
- Otorrhea

Method:

- Elevate head of bed 30° to properly orient the semicircular canal
- Irrigate tympanic membrane with 40-60 mL ice water. Check 1 ear at beginning of exam and 1 at end to allow endolymph temperature to equilibrate
- Observe patient for 1 minute after each ear irrigation, with a 5-minute wait between testing of each ear
Ice water cools the endolymph in the semicircular canal
Tests cranial nerves III, VI, and VIII
C-O-W-S: cold opposite, warm same. When cold fluid is instilled into the ear canal, the fast phase of nystagmus will be to the side opposite from the ear tested

- In the comatose patient, the fast phase of nystagmus will be absent, as this is controlled by the cerebrum. Cold water instillation in the ear canal of a comatose patient will result in tonic deviation of the eyes toward the ear being irrigated.
- In the brain dead patient, no nystagmus will be observed.
Movement only of eye on side of stimulus
- Internuclear ophthalmoplegia
- Suggests brainstem structural lesion

Tonic deviation of both eyes
- Coma

No eye movement
- Brainstem injury / brain death
- Facial trauma involving the auditory canal and petrous bone can also inhibit these reflexes
Corneal reflexes are absent in brain death

- Corneal reflexes - tested by using a cotton-tipped swab
- Grimacing in response to pain can be tested by applying deep pressure to the nail beds, supraorbital ridge, temporomandibular joint, or by swab in nose
- Severe facial trauma can inhibit interpretation of facial brainstem reflexes
Both gag and cough reflexes are absent in patients with brain death

- Gag reflex can be evaluated by stimulating the posterior pharynx with a tongue blade, but the results can be difficult to evaluate in orally intubated patients
- Cough reflex can be tested by using suction catheter deep, past end of endotracheal tube
Contraindications:
- Patients with high cervical spine injury
- Patients requiring high levels of respiratory support

Goal:
- $\text{PaCO}_2$ levels ≥ 60 mmHg
- ≥20 mmHg over baseline
- In a child with chronic lung disease, the child’s baseline $\text{PaCO}_2$ should be used
Pre-oxygenate with 100% oxygen for several minutes

Allow baseline $\text{Paco}_2$ to be $\sim 40 \text{ mmHg}$

Place patient on T-piece or flow-inflating bag

- Titration of positive end-expiratory pressure (PEEP) via a flow-inflating bag may assist in preventing alveolar collapse and derecruitment
- Use of continuous positive airway pressure (CPAP) via the ventilator is not recommended as apnea may not be appreciated if the ventilator reverts to an assist mode when apnea is sensed

Observe for respiratory effort for $\sim 6-10$ minutes
- CO₂ rises ~4 mm Hg for every minute of apnea
  - The rate may be lower in the setting of brain death due to the loss of brain metabolism
- At this rate, it will take at least 5 minutes of apnea for the PaCO₂ to rise by 20 mm Hg; often it requires 7-9 minutes
- Therefore, may choose to draw an arterial blood gas at minute 5-6 of apnea, and continue the apnea observation while awaiting the results. Repeat gas every 2 minutes until the apnea criteria have been met or the test must be aborted.
- Abort testing if the SpO₂ falls below 85% or hemodynamic instability is present
In patients without significant pulmonary disease or injury, apneic oxygenation will permit the arterial oxygen saturation to remain high or change minimally.

Despite no active ventilation, gas exchange continues to take place in the alveoli, with oxygen diffusing out and CO$_2$ diffusing in.
If the respiratory quotient is assumed to be 0.8, then for every 1 mL of oxygen consumed, 0.8 mL of CO₂ is produced.

As a result, there is a net entrainment of oxygen (the only gas being provided to the patient) down the tracheobronchial tree.
CONFIRMATORY TESTING

- Gold standard: 4 vessel angiography
  - Rarely done
- Cerebral blood flow = perfusion scan

- EEG
  - Standards established by American Electroencephalographic Society
  - Low to mid-therapeutic barbiturates levels should not preclude use of EEG
Say “dead”, not “brain dead”
Say “artificial or mechanical ventilation”, not “life support”
Time of death = time of second examination, including apnea and/or ancillary test completion. When a patient meets all criteria for brain death, he/she is legally dead.
- NOT when ventilator removed
- NOT when heart beat ceases
State law and local institutional policies should be reviewed and followed.
Ask staff not talk to the patient as if still alive.