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# DEATH BY NEUROLOGICAL CRITERIA

2023 GUIDELINES

## TERMINOLOGY:

- DNC “**Death by Neurological Criteria**” is the new term to replace “Brain Death”, to clearly indicate death using neurological criteria as opposed to cardiopulmonary criteria.
- Death by Neurological Criteria **indicates** permanent loss of the function of the brain as a whole including the brainstem resulting in coma, brainstem areflexia and apnea.

## PHYSICIAN REQUIREMENTS:

- **Adult DNC:** the guidelines didn’t address special qualifications
- **Pediatric DNC:** DNC should be performed by 2 attendings, either pediatric intensivists, neonatologist, pediatric neurologist, neurosurgeon, trauma surgeon or anesthesiologist with critical care training or adult specialist trained in neurology or critical care.
- Clinician involved in DNC should **avoid any direct involvement in organ donation decision** making to avoid conflict of interest

## PREREQUISITES:

### PATIENT SELECTION:

- o DNC evaluation is indicated in patient who is **comatose, apneic** with **absent brain stem reflexes** with **identifiable cause** of brain injury that is known to cause brain death
- o Consent is NOT needed to proceed with DNC evaluation; however clinician should inform the family the plan to perform DNC.

### IMAGING:

- o Clinician should determine that neuroimaging is consistent with the mechanism and severity of brain injury

### TIMING:

- o Clinician must wait sufficient amount of time after brain injury to ensure there no potential for recovery.
- o Wait at least 24h after hypoxic brain injury in patients 24 months and older
- o Wait at least 48h for infants less than 24 months
- o Wait sufficient amount of time after surgical/medical interventions to treat increased ICP

### VITAL SIGNS:

- o Temperature: Maintain body temperature  $\geq 36^{\circ}\text{C}$  for at least 24h before proceeding with DNC evaluation.
- o Blood Pressure:
  - Adults: SBP > 100mmHg and MAP  $\geq 75$ mmHg
  - Children: SBP and MAP  $\geq 5^{\text{th}}$  percentile for age
  - ECMO patients: same above SBP & MAP values for VV ECMO, use only MAP for VA ECMO
  - Chronic low BP: for patients with a baseline BP that varies from the normal range, target SBP and MAP close to their chronic baseline.

## METABOLIC DERANGEMENTS:

- **Toxicology:** Negative toxicology screen if indicated
- **Alcohol:** level <80mg/dL if indicated
- **CNS depressant** medications: ensure that blood levels are therapeutic or subtherapeutic, if levels are not available:
  - Wait at least 5 half-lives, and longer if there is renal/hepatic dysfunction
  - For pentobarbital, level must be <5 microgram/ml
- Exclude effect of **paralytic agents**, use train of 4 if suspected.
- If **metabolic derangements** are unable to be corrected, but exam and apnea are consistent with DNC, you must use an additional *ancillary test*.

Metabolic Derangements that may Confound Neurological Examination			
<b>Sodium</b>	<130 or > 160 mmol/L	<b>Potassium</b>	<3 or >6 mmol/L
<b>Calcium</b>	<7 or >11 mg/dL	<b>Magnesium</b>	<1.5 or >4 mg/dL
<b>BUN</b>	>75 mg/dL	<b>Ammonia</b>	>75 µmol/L
<b>Glucose</b>	<70 or >300 mg/dL	<b>PH</b>	<7.3 or >7.5
<b>Total T4</b>	<3 or >30 mg/dL	<b>Free T4</b>	≤ 0.4 or >5 ng/dL

## NEUROLOGIC EXAMINATION:

- In adults, at least 1 neurological examination must be performed for DNC, a second clinician may perform a separate examination in adults
- In Children, at least 2 separate neurological examinations must be performed with at least 12h in-between.
- If a component of the examination can't be assessed, you must use *ancillary test*.
- Component of Neurologic Examination:
  - **Mental status:** Comatose, unresponsive to auditory, visual or tactile stimulation
  - **Motor response:** No motor response other than spinally mediated reflexes with noxious stimuli
    - If it is unclear whether observed limb movements are spinally mediated reflexes, *you should use an additional ancillary test.*
  - **Pupillary reflex:** No response to light bilaterally
  - **Oculocephalic reflex:** absent
    - IF can't be performed due to spine injury, OVR test (caloric test) must be performed bilaterally
  - **Corneal reflex:** absent bilaterally
  - **Cough and gag reflexes:** absent
  - **Sucking and rooting reflex in infants < 6 month:** absent

## APNEA TEST:

**NUMBER OF TESTS:** at least 1 in adults and 2 in children

### PREPARATION BEFORE THE TEST:

- Risk of cardiopulmonary decompensation during the test must be acceptable
- **Baseline PaCO<sub>2</sub> and PH:** must be at normal levels (PaCO<sub>2</sub> 35-45, PH 7.35-7.45).
  - If patient is a chronic hypercarbic, PaCO<sub>2</sub> should be at patient's chronic baseline if known, if chronic baseline is not known, clinician should perform *ancillary test*
- **Preoxygenation:** use 100% oxygen for at least 10 minutes to achieve PaO<sub>2</sub> > 200mmHg
- **Arterial line:** needed to allow for multiple ABG measurement and reliable BP monitoring.
- **ABG:** obtain ABG after preoxygenation to determine baseline PaO<sub>2</sub> and PaCO<sub>2</sub>

### PERFORM THE APNEA TEST:

- Ensure adequate oxygenation by either:
  - Disconnect the ventilator from ETT, and deliver 100% oxygen at a 4-6L/m rate through:
    - Catheter in the ETT/tracheostomy just above the level of carina
    - Flow-inflating resuscitation bag with a PEEP valve
  - Stop mechanical ventilation and deliver 100% through CPAP mode on the ventilator
- ABG: Obtain an ABG every 2 minutes
- Duration: 10 minutes, however if ABG parameters were not reached, you may continue longer.

### ABORTION:

- **Abort the test if:**
  - SBP < 100 or MAP < 75 mmHg in adults or < 5<sup>th</sup> percentile for age in children despite pressors.
  - SaO<sub>2</sub> < 85%
  - Cardiac arrhythmia with hemodynamic instability
- If you decide to abort, obtain ABG before placing patient back on the ventilator

### POSITIVE TEST (PATIENT IS APNEIC) IF:

- **No respiration occurs and**
- **PH < 7.3 and**
- **PaCO<sub>2</sub>:**
  - **Non chronic retainers:** PaCO<sub>2</sub> ≥ 60 and ≥ 20 mmHg above the test baseline.
  - **Chronic CO<sub>2</sub> retainers with known PaCO<sub>2</sub> baseline :** PaCO<sub>2</sub> ≥ 60 and ≥ 20 mmHg above the patient's chronic baseline.
  - **Chronic CO<sub>2</sub> retainers with unknown PaCO<sub>2</sub> baseline :** PaCO<sub>2</sub> ≥ 60 and ≥ 20 mmHg above the test baseline. In addition, *ancillary test* must be done

**NEGATIVE TEST (PATIENT IS ABLE TO BREATHE):** if patient was able to take a breath, DNC should be aborted.

### ABORTED TEST:

- If test was aborted for hypoxemia, the test may be repeated using an alternative apneic oxygenation (CPAP or resuscitation bag) or perform *ancillary test*.
- If test was aborted for hypotension, the test may be repeated after augmenting blood pressure or perform *ancillary test*.
- If test was aborted for cardiac arrhythmia, the test may be repeated when it can be safely performed or perform *ancillary test*.

### APNEA TEST IN ECMO PATIENTS:

- Use SBP and MAP for VV ECMO, and MAP only for VA ECMO
- Pre-oxygenate by using 100% oxygen on the ventilator and also on the membrane lung
- CO<sub>2</sub>: To achieve adequate increase in PaCO<sub>2</sub>, either titrate exogenous CO<sub>2</sub> in ECMO circuit or adjust sweep gas flow rate to 0.2-1 L/min
- ABG sampling:
  - VV ECMO: from distal arterial line
  - VA ECMO: From both distal arterial line and ECMO circuit post-oxygenator
  - Patients cannulated through Rt carotid or axillary a: from distal arterial sample on left upper or either lower extremity.
  - Patients cannulated through femoral line: from right upper extremity
- Site of obtaining ABG is critical in VA ECMO patients with cardiac contractility (gas tension in peripheral arteries may not represent cerebral circulation)

### ANCILLARY TESTING:

#### INDICATIONS:

- If neurological exam or apnea test can't be performed or interpreted adequately
  - Component of the neurological exam can't be performed (ex; facial trauma, orbit trauma)
  - Unclear if motor response is a spinal reflex or not
  - Metabolic derangement can't be corrected
  - Apnea test can't be completed due to hypotension, hypoxia or arrhythmia
  - Chronic CO<sub>2</sub> retainers with unknown baseline PaCO<sub>2</sub>

#### TYPES:

- **4-vessel catheter angiography:** Flow arrest at the point of entry of vessels in to the dura
- **Radionuclide Perfusion Scintigraphy:** Hollow-skull sign
- **Transcranial doppler:** Oscillating flow or Systolic spikes in large arteries, only in adults, not validated for children

#### DON'T USE:

- EEG, Evoked potentials: AEP, SEP
- CTA or MRA

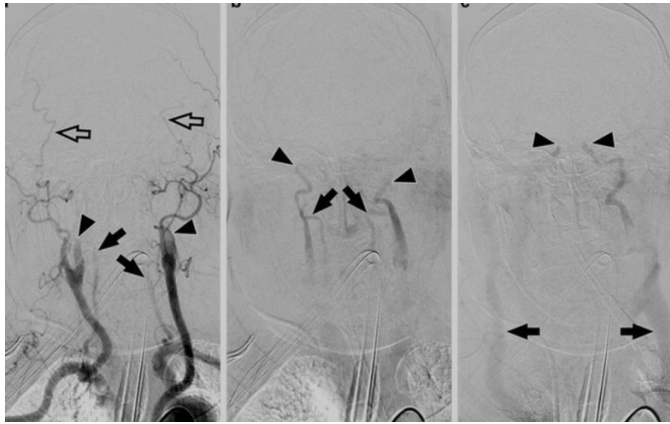
#### TIME OF DEATH:

- No ancillary test: time of the **last ABG results reported during apnea test**
- Ancillary test was done: time ancillary test results were **reported in the chart** (radiology, TCD or angiography report time)

### SPECIAL SITUATIONS:

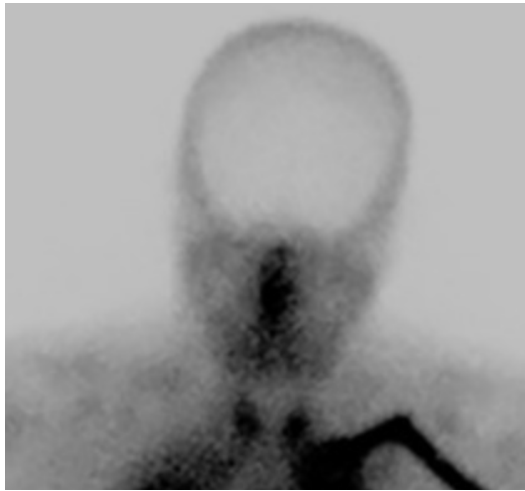
- PREGNANCY:
  - Is **not a contraindication** to proceed with DNC evaluation if clinically indicated
- POSTERIOR FOSSA INJURY:
  - Ensure that posterior fossa process has led to catastrophic **supratentorial injury**, demonstrated on imaging before proceeding with DNC evaluation, even if patient is comatose with brainstem areflexia.

DNC ANCILLARY TESTS IMAGES:

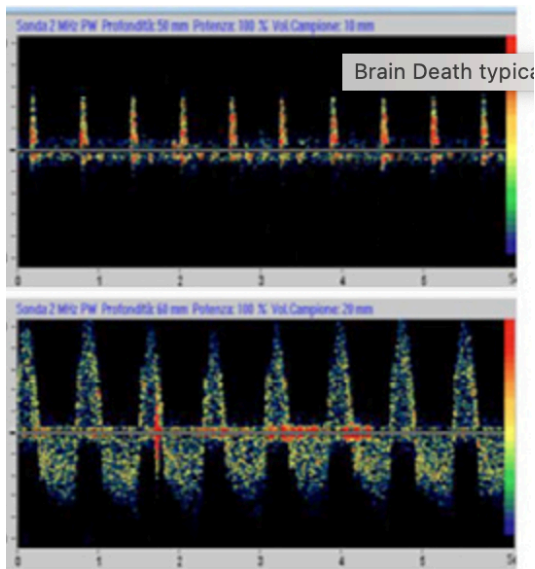


RadiologyKey.com

Cerebral Angiography: No intracranial filling



Scintigraphy/SPECT: Hollow Skull sign



Conti. U. a, 2009 et al

TCD:

- Systolic peaks without diastolic flow
- Oscillating flow
- Systolic spike

# DEATH BY NEUROLOGICAL CRITERIA

DNC Evaluation in non-Co2 retainers (COPD) and non-ECMO Adults																									
<b>Patient</b>	<b>Comatose – Apneic - Brainstem areflexia – Identifiable cause</b> of brain Injury Consent is not needed; however, family should be informed																								
<b>Timing</b>	Wait sufficient amount of time to ensure no potential recovery At least >24h after hypoxic brain injury At least >48h for infants < 24 months old																								
<b>Vital Signs</b>	Temp $\geq 36^{\circ}\text{C}$ for at least 24h SBP >100 & MAP >75 in adults, >5th percentile in kids VA ECMO patients use MAP, special attention regarding ABG sampling site																								
<b>Metabolic</b>	Toxicology negative, alcohol level <80mg/dl if indicated CNS medications are not suprathreshold, wait 5 t-half if level not available. Paralytic agent effect is excluded (use train of 4) if indicated <table border="1" data-bbox="474 829 1321 1087"> <thead> <tr> <th colspan="4">Metabolic Derangements that may Confound Neurological Examination</th> </tr> </thead> <tbody> <tr> <td><b>Sodium</b></td> <td>&lt;130 or &gt; 160 mmol/L</td> <td><b>Potassium</b></td> <td>&lt;3 or &gt;6 mmol/L</td> </tr> <tr> <td><b>Calcium</b></td> <td>&lt;7 or &gt;11 mg/dL</td> <td><b>Magnesium</b></td> <td>&lt;1.5 or &gt;4 mg/dL</td> </tr> <tr> <td><b>BUN</b></td> <td>&gt;75 mg/dL</td> <td><b>Ammonia</b></td> <td>&gt;75 <math>\mu\text{mol/L}</math></td> </tr> <tr> <td><b>Glucose</b></td> <td>&lt;70 or &gt;300 mg/dL</td> <td><b>PH</b></td> <td>&lt;7.3 or &gt;7.5</td> </tr> <tr> <td><b>Total T4</b></td> <td>&lt;3 or &gt;30 mg/dL</td> <td><b>Free T4</b></td> <td><math>\leq 0.4</math> or &gt;5 ng/dL</td> </tr> </tbody> </table>	Metabolic Derangements that may Confound Neurological Examination				<b>Sodium</b>	<130 or > 160 mmol/L	<b>Potassium</b>	<3 or >6 mmol/L	<b>Calcium</b>	<7 or >11 mg/dL	<b>Magnesium</b>	<1.5 or >4 mg/dL	<b>BUN</b>	>75 mg/dL	<b>Ammonia</b>	>75 $\mu\text{mol/L}$	<b>Glucose</b>	<70 or >300 mg/dL	<b>PH</b>	<7.3 or >7.5	<b>Total T4</b>	<3 or >30 mg/dL	<b>Free T4</b>	$\leq 0.4$ or >5 ng/dL
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<b>Examination</b>	1 exam for adults, 2 exams for kids 12h apart Ensure: patient is comatose, no response to stimuli, no motor response other than spinal reflexes, no light, COR, corneal, cough or gag reflexes Caloric test if COR can't be performed (ex, neck injury)																								
<b>Apnea Test</b>	Place an arterial line, obtain baseline ABG, ensure normal PH and PaCO <sub>2</sub> Preoxygenate for 10 minutes, repeat ABG to confirm PaO <sub>2</sub> >200 Get ABG every 2 minutes until Ph <7.3 & PaCO <sub>2</sub> $\geq 60$ and $\geq 20$ mmHg above baseline  <b>Positive:</b> ABG markers achieved and no breath > pronounced dead <b>Negative:</b> patient was able to breath > abort <b>Abort if</b> SaO <sub>2</sub> < 85%, SBP <100 or MAP <75																								
<b>Ancillary Tests</b>	<b>Use:</b> Catheter angiography (flow arrest), Radionuclide scan (hollow skull sign) or TCD (Oscillating flow or systolic spines in large arteries) <b>Don't use:</b> EEG, SSEP, AEP, CTA or MRA <b>Indications:</b> <ul style="list-style-type: none"> <li>o Component of the neurological exam can't be performed (ex; facial trauma)</li> <li>o Unclear if motor response is a spinal reflex or not</li> <li>o Metabolic derangement can't be corrected</li> <li>o Apnea test can't be completed due to hypotension, hypoxia or arrhythmia</li> <li>o Chronic CO<sub>2</sub> retainers with unknown baseline PaCO<sub>2</sub></li> </ul>																								
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