

Brain Death Evaluation in Children With Suspected or Confirmed Coronavirus Disease 2019

OBJECTIVES: To discuss the challenges of conducting a death by neurologic criteria or brain death evaluation in the coronavirus disease 2019 era and provide guidance to mitigate viral transmission risk and maintain patient safety during testing.

DESIGN: Not applicable.

SETTING: Not applicable.

PATIENTS: Children with suspected or confirmed coronavirus disease 2019 who suffer catastrophic brain injury due to one of numerous neurologic complications or from an unrelated process and require evaluation for death by neurologic criteria.

INTERVENTIONS: Not applicable.

MEASUREMENTS AND MAIN RESULTS: There is a risk to healthcare providers from aerosol generation during the neurologic examination and apnea test for determination of death by neurologic criteria. In this technical note, we provide guidance to mitigate transmission risk and maintain patient safety during each step of the death by neurologic criteria evaluation. Clinicians should put on appropriate personal protective equipment before performing the death by neurologic criteria evaluation. Risk of aerosol generation and viral transmission during the apnea test can be mitigated by using continuous positive airway pressure delivered via the ventilator as a means of apneic oxygenation. Physicians should assess the risk of transporting coronavirus disease 2019 patients to the nuclear medicine suite to perform a radionuclide cerebral blood flow study, as disconnections to and from the ventilator for transport and inadvertent ventilator disconnections during transport can increase transmission risk.

CONCLUSIONS: When conducting the neurologic examination and apnea test required for death by neurologic criteria determination in patients with suspected or confirmed coronavirus disease 2019, appropriate modifications are needed to mitigate the risk of viral transmission and ensure patient safety.

KEY WORDS: apnea test; brain death; coronavirus disease 2019; death by neurologic criteria

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Since declaration of the coronavirus disease 2019 (COVID-19) pandemic (1), some medical organizations have modified their guidance on procedures that increase the risk of aerosolization of the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), for example, cardiopulmonary resuscitation and anesthesia (2, 3). The 2011 guidelines for the determination

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of brain death (or death by neurologic criteria [DNC]) in infants and children published by the American Academy of Pediatrics, the Society of Critical Care Medicine, and the Child Neurology Society do not address the risks of disease transmission (4). However, recent guidance has been published in adults (5). In this technical note, we highlight considerations to minimize the risk of SARS-CoV-2 transmission to health-care providers while evaluating children for DNC.

In children, the risk of death from COVID-19 is low (6–9), but it is possible that they may suffer catastrophic illness while coinfecting with SARS-CoV-2 or have a complication of COVID-19 that could lead to catastrophic, irreversible brain injury and death. In this context, clinicians should carefully consider the components of the DNC evaluation that carry added risk of SARS-CoV-2 transmission. For example, the performance of the apnea test is an aerosol-generating procedure when patients are disconnected from mechanical ventilation. Eliciting a gag or cough reflex has the potential to release viral particles into the air. Disconnecting the patient from the ventilator for transport to the nuclear medicine suite to perform a radionuclide cerebral blood flow study can increase the risk of virus exposure for hospital staff, patients, and families. Finally, communication with the family often requires multiple people to be in close proximity, thereby increasing transmission risk.

In this technical note, we provide guidance for performing each step of the DNC evaluation in infants and children with suspected or confirmed COVID-19. Institutions should consider updating their policies and procedures accordingly.

PREREQUISITES

If an evaluation for DNC is anticipated and the patient's COVID-19 status is unknown, providers should arrange COVID-19 testing before initiating the evaluation. The assessment of prerequisites is no different from that in patients without COVID-19.

NEUROLOGIC EXAMINATION

Before clinicians perform the DNC neurologic examination, they should put on appropriate personal protective equipment, because the examination could be aerosol-generating. The DNC neurologic examination is no different from that in patients without COVID-19.

The two components of the examination that may pose additional risk to the examiner are assessing the cough and gag reflexes. The gag reflex is assessed by stimulation of the posterior pharyngeal wall bilaterally. The cough reflex is evaluated by deep tracheal suctioning, typically through the endotracheal tube (ETT). For patients with COVID-19, use inline suction without disconnecting the ventilator and ensure the ETT cuff is inflated to minimize the risk of aerosolization. Either of these reflexes, when intact, can stimulate a cough that is aerosol generating; however, it is unknown whether aerosolization also occurs from the posterior or nasopharynx when the patient is connected to a closed ventilator circuit.

APNEA TEST

The apnea test carries the greatest risk of SARS-CoV-2 transmission to healthcare providers and family members. Protocols for performing the apnea test in children have been published, and the fundamental principles are the same in patients with COVID-19 (4, 10).

To avoid hypoxemia during the apnea test, apneic oxygenation is usually provided using FiO_2 1.0 via tracheal insufflation or T-piece (11). In pediatrics, it is common and often preferred to use continuous positive airway pressure (CPAP) via a flow inflating resuscitation bag (e.g., Mapleson circuit), which can provide an FiO_2 of 1.0 and maintain a positive end-expiratory pressure to prevent atelectasis and a reduction in functional residual capacity (10, 12). Each of these methods requires disconnection of the patient from the ventilator and risk spreading aerosolized virus. Conducting the apnea test using CPAP delivered via the ventilator is a reasonable alternative to reduce the risk of viral transmission (**Table 1**).

Additional risk to healthcare providers during the apnea test can occur if the patient requires hand-ventilation using a resuscitation bag via the ETT for severe hypoxemia or hemodynamic instability. These risks can be mitigated by using more selective criteria for which patients undergo the apnea test; one recent study reported less than 1% failure in performing the apnea test when patients were first determined by a pediatric intensivist to be physiologically stable for testing (10). Patients in whom the apnea test was deferred had a higher oxygenation index and ventilator requirements

TABLE 1.
Modifications to the Apnea Test for Patients With Coronavirus Disease 2019

- 1) Ensure all healthcare providers have appropriate personal protective equipment for performance of a potentially aerosol-generating procedure and that antiviral filters are appropriately placed in line with the ventilator and resuscitation bag
- 2) Preoxygenate patient with FiO_2 of 1.0 via the ventilator for a minimum of 10 min
- 3) Adjust ventilator settings before beginning the apnea test
 - Disable default backup apnea ventilation
 - Disable apnea alarm or lengthen to maximum allowable limit and assign provider to manually silence alarm
 - Remove all condensation from the inspiratory and expiratory limbs of ventilator circuit
 - Position the ventilator circuit away from the patient's body to allow for close examination of the chest and abdomen
 - Adjust the trigger sensitivity to a level that avoids autotriggering but is sensitive enough to detect a true spontaneous breathing effort
- 4) Begin the apnea test by changing the ventilator mode from volume/pressure-control to continuous positive airway pressure with FiO_2 of 1.0 and the same positive end-expiratory pressure the patient required prior to the apnea test
- 5) If no respiratory effort is observed and the measured PaCO_2 is ≥ 60 mm Hg and at least 20 mm Hg above the starting level, the apnea test is complete and consistent with DNC
- 6) If oxygen saturations $\leq 85\%$, hemodynamic instability, or $\text{PaCO}_2 \geq 60$ mm Hg cannot be achieved
 - Initiate volume-/pressure-controlled ventilation with appropriate treatment to restore normal oxygen saturation, PaCO_2 , and hemodynamic parameters
 - Consider manual ventilation with a resuscitation bag if the patient becomes severely hypoxemic or hemodynamically unstable
 - If a resuscitation bag is required, consider briefly clamping the endotracheal tube for the transition from the ventilator to the resuscitation bag to maintain functional residual capacity and limit the risk of viral transmission
 - The DNC evaluation may be repeated after sufficient time to allow for improvement of cardiopulmonary status, or an ancillary study may be pursued

DNC = death by neurologic criteria.

compared with patients who had the apnea test performed. If the patient is deemed to be at high risk for decompensation during the apnea test such that it is deferred, an ancillary test is needed (see below).

Transcutaneous carbon dioxide (CO_2) monitoring (tcP_{CO_2}) can be used to follow the rise in partial pressure of CO_2 and guide the timing of arterial blood gas sampling to minimize the apnea duration and potential risk of cardiopulmonary instability (13). Additionally, a modified apnea test has been proposed for patients at high risk of severe hypoxemia or hemodynamic instability, in which minute ventilation is reduced by at least

50% and serial blood gas measurements are made until the arterial partial pressure of CO_2 reaches the appropriate threshold. At that time, the ventilator is changed to the CPAP mode and the patient is observed for 60 seconds. If no spontaneous respirations are observed, the patient meets criteria for DNC (14).

Finally, if it is necessary to disconnect the patient from the ventilator for manual ventilation, providers could consider briefly clamping the ETT during the transition from the ventilator to a resuscitation bag in order to reduce the risk for aerosol transmission. Personal protective equipment should minimize the risk to the provider.

ANCILLARY TESTING

Ancillary testing with a radionucleotide cerebral blood flow study involves transfer to the nuclear medicine suite. Physicians should assess the risk of transporting COVID-19 patients, as disconnections to and from the ventilator for transport and inadvertent ventilator disconnections during transport can increase viral transmission risk. Connections should be assessed and secured before transport. Portable single-photon-emission computed tomographic (SPECT) scanners can be used at the bedside if available.

COMMUNICATION

Effective communication with families of children with acute, catastrophic brain injury is essential, but can be complicated by restrictions related to COVID-19. Many institutions have limited the number of people present at the patient's bedside in order to decrease the risk of viral spread; hence, parents may not have additional support at the bedside. Furthermore, some hospital staff such as social workers and clergy may not be readily accessible. Despite these challenges, physicians should explain to the family, in person, the extent of the child's brain injury, the concept of brain death, and the intent to perform an evaluation for the determination of DNC using appropriate personal protective equipment and social distancing measures (15).

CONCLUSIONS

Additional considerations are warranted for conducting the neurologic assessments required for the determination of DNC in patients with suspected or confirmed COVID-19 in order to mitigate the risk of viral transmission to healthcare providers and ensure patient safety. With appropriate modification to the assessment, particularly the apnea test, adherence to published guidelines and institutional protocols is feasible.

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