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The Modified Apnea Test during Brain Death Determination: an Alternative in Hypoxic Patients

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Abstract

Introduction—Conventional apnea testing in patients with severe hypoxemia or hemodynamic instability with removal from ventilator support is unsafe. We describe an alternative approach to apnea testing, which may be used in hypoxic patients unable to undergo conventional apnea testing.

Methods—Case Report. A 42-year-old man suffered a severe traumatic brain injury resulting in diffuse cerebral edema and subarachnoid hemorrhage with herniation. His presentation was complicated by hypoxic respiratory failure from pulmonary contusions and hemorrhagic shock. On hospital day 2, the patient lost brainstem reflexes. Brain death testing with conventional apnea testing was attempted but aborted due to hypoxia.

Results—A modified apnea test was applied, which had been approved by appropriate hospital committees including critical care operations, ethics, and the brain death protocol council. Minute ventilation was gradually decreased by 50% to attain a PaCO₂ level 20 mmHg above baseline. The ventilation mode was then switched from volume control to continuous positive airway pressure while observing the patient for signs of respiration for a duration of 60 seconds.

Conclusion—The modified apnea test does not require circuit disconnection and can be successfully applied to determine brain death without compromising safety in high-risk patients suffering from severe hypoxia.

Keywords

brain death; apnea testing; neurocritical care

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INTRODUCTION

Apnea testing is an essential component of brain death determination in comatose patients. The apnea test serves to examine whether there is loss or preservation of medullary function through the delivery of a hypercarbic respiratory stimulus to the patient. The subsequent hypercarbia results in cerebral spinal fluid (CSF) acidosis, which stimulates the respiratory reflex in the medulla. Before initiating apnea testing, all patients must meet pre-requisite baseline characteristics including a body temperature $>36^{\circ}\text{C}$, a systolic blood pressure >90 mmHg, the absence of hypoxia and acidosis, and a euvoletic state¹. Declaration of apnea in brain death can, nonetheless, be harmful to patients due to the possibility of adverse events such as hypotension, hypoxia, acidosis, arrhythmias, asystole, and pneumothorax using conventional methods². Severely compromised patients who have underlying injuries that render them difficult to stabilize from a respiratory and hemodynamic standpoint are at particularly high risk. Therefore, apnea testing is commonly omitted in these patients because of the fear of further adding to hemodynamic and respiratory compromise, possibly resulting in cardiac arrest. Cerebral angiography may be attempted, but is also frequently impossible in this patient population due to the respiratory and cardiovascular safety concerns during transportation to the angiography suite.

We describe a successfully established modified apnea test protocol that can be conducted safely in high-risk patients with severe respiratory and hemodynamic compromise who may not tolerate removal from the ventilator, or travel to angiography.

METHODS

Case Description

A 42 year-old man was involved in a high-speed motor vehicle collision. Upon arrival to the trauma bay in the emergency room, he developed profound hypotension (51/32 mmHg) due to hemorrhagic shock from a splenic laceration and renal artery dissection, and hypoxia with an oxygen saturation of 86%. After resuscitation, his neurological examination showed a Glasgow Coma Scale (GCS) score of 3T and his pupils were fixed and dilated at 6mm. Brisk corneal reflexes bilaterally and a weak gag and cough reflex were observed. Head CT revealed diffuse cerebral edema with effacement of the basilar cisterns (Marshall CT grade III)³, pneumocephalus, a right subdural hematoma with a descending transtentorial herniation, traumatic subarachnoid hemorrhage, and an occipital bone fracture (Figure). Chest CT revealed a small right basilar pneumothorax, bilateral pulmonary contusions and pleural effusions, and rib fractures. ICP monitoring was not pursued after the Neurosurgery attending and the treating Neurointensivists agreed that aggressive neurosurgical care was futile. Over the next eight hours in the ICU, hemodynamic instability, metabolic acidosis, and acute renal failure ensued despite resuscitation. The patient's neurological condition worsened despite osmotherapy with mannitol, and by the next morning he had lost all brainstem reflexes. Brain death testing was initiated.

The patient did not receive any sedation during the course of hospitalization. At the time of initial brain death examination, the patient's core temperature was 38.5°C and his blood pressure was 101/66 mmHg while receiving dopamine and norepinephrine. His lactic

acidosis had improved. On neurological examination he had no cerebral motor response to painful stimulation. His pupils remained dilated and non-reactive. Corneal reflexes were absent. Given the normal alignment of the cervical vertebrae, with only a C7-transverse process fracture, and no evidence of spinal canal compromise on cervical CT, he was cleared of cervical spine precautions by the trauma team to allow oculocephalic reflex testing. No lateral or vertical eye movements were produced with passive head turn. Gag reflex testing with stimulation of the posterior pharynx was absent. There was no cough response to deep tracheal suctioning. Prior to oculovestibular testing, both the right and left tympanic membranes were found to be intact on otoscopic examination; irrigation of the ears with ice water subsequently failed to produce eye movements. Per our institutional protocol, a second brain death examination was performed again six hours later with no evidence of brain function.

Following conclusion of the second brain death examination, conventional apnea testing was initiated at the bedside. The patient was pre-oxygenated with 100% O₂ for 10 minutes; his baseline arterial blood gas (ABG) was pH: 7.25/PaCO₂: 40 mmHg/PaO₂: 178 mmHg with a SaO₂ 99%. The patient was subsequently disconnected from the mechanical ventilator, and 100% O₂ was delivered via a catheter inserted into the endotracheal tube to the level of the carina. After approximately 8 minutes of observation for signs of respiration, the patient's SaO₂ fell from mid 90% to 85%. The apnea test was aborted and he was placed back on the ventilator due to hypoxemia. An ABG obtained just prior to re-initiation of mechanical ventilation read pH: 7.23/PaCO₂: 58 mmHg/PaO₂: 53 mmHg, confirming that the apnea test had been aborted too early, just shy of achieving the necessary 20 mmHg increase in PaCO₂. Consequently, modified apnea testing was initiated per our approved brain death protocol. At our institution, this modified apnea test has been approved by multiple committees, including the brain death protocol, ethics, and critical care operations committees. The patient was pre-oxygenated again with 100% O₂ for 10 minutes and a baseline ABG showed a pH: 7.28/PaCO₂: 53 mmHg/PaO₂: 190 mmHg with SaO₂ 99%. Minute ventilation was reduced by approximately 50%. Periodic ABGs were drawn to monitor when the PaCO₂ level had reached > 73 mmHg (baseline: 53 mmHg). After thirty minutes of hypoventilation, the ABG showed a PaCO₂ of 99 mmHg. No hemodynamic changes were noted. The ventilator mode was switched from volume control to continuous positive airway pressure (CPAP), and the patient was observed for signs of respiration for 60 seconds. No breaths were seen. The ABG taken immediately after the 60 seconds of observation revealed a pH: 7.06/PaCO₂: 99 mmHg/PaO₂: 128 mmHg. The patient was officially declared brain dead.

DISCUSSION

Apnea testing has long been an integral component in the determination of brain death. Establishing appropriate criteria and techniques to accurately identify apnea⁴ in this context has proven difficult, as patients often have significant comorbidities that place them at risk of decompensating during conventional testing. The modified apnea test protocol described herein is a means to safely assess for apnea in patients that are hypoxic, hemodynamically unstable despite interventions, or known to have metabolic or biochemical disturbances. This technique is predicated on the same baseline criteria as other methods⁵, including a normal core body temperature, pre-oxygenation with 100% O₂ for 10 minutes, and a

baseline ABG. Following establishment of these criteria, the patient is hypoventilated while still connected to the ventilator by reducing minute ventilation (MV) at least 50% compared to stabilized baseline ventilator settings. The rationale behind decreasing MV by ~ 50% lies in the fact that brain dead patients are commonly not just hypoxic, but also hemodynamically unstable. Rapid changes in MV may add to further hemodynamic instability. By means of hypoventilation, the PaCO₂ increases steadily, and periodic arterial blood gases will detect a PaCO₂ level 20mmHg than baseline. The time elapsed to reach this point will vary on an individual basis depending on the patient's metabolic rate and the degree of hypoventilation. Upon reaching the target PaCO₂ level, the ventilator mode is switched from volume control to CPAP to ensure airway maintenance by continued PEEP application and maximizing the likelihood of adequate alveolar oxygenation. The patient is then observed for signs of respiration for a duration of 60 seconds. If no respiratory effort is seen, the patient is designated as apneic.

At our institution, use of the modified apnea test has been successfully established for patients who cannot tolerate ventilator removal due to hypoxia or an unstable blood pressure, as acidosis can exacerbate hypotension thereby placing patients at risk. In contrast to conventional apnea testing methods, which typically require patient observation of respiratory effort for a period of eight or more minutes, this protocol only requires 60 seconds of observation⁶. Previous literature demonstrates that apnea is declared when the carbon dioxide reaches target levels and the patient fails to demonstrate respiratory efforts. Accurate apnea testing does not therefore require a specific amount of time-elapsed, and can be completed in as little as one minute⁷. Arterial CO₂ levels and the resulting decrease in CSF pH are the most important indicators of respiratory stimulation, and once sufficient partial tension levels have been achieved, prior literature suggests that only 30–60 seconds are needed to confirm apnea⁸. The slower increase in PaCO₂ compared to conventional apnea testing does not result in CSF pH equilibrium. A swine study demonstrated that CSF pH is reduced after 15 minutes of hypoventilation and stays stable for at least 60 minutes, indicating that equilibration does not occur in that time period⁹. Based on our experience, the target rise of PaCO₂ is achieved within these 60 minutes.

This modified apnea test is not new as the method was first described over twenty years ago^{10,11}. However, to our knowledge, the protocol has yet to be widely adopted in the United States in the patient who is at risk for hypoxemia or hemodynamic instability.

Use of a pre-apnea test recruitment maneuver to prevent alveolar collapse during disconnection from the ventilator circuit has recently been described to maintain adequate oxygenation in hypoxic patients with lung pathology¹². The risk of severe adverse events such as barotrauma and arrhythmias following this technique may be low,¹³ however, there may be severe consequences if they occur. In addition, other adverse events such as transient hypotension and desaturation are common after an alveolar recruitment maneuver¹³. The modified apnea test is therefore appealing in the assessment of patients with ARDS, as the risks are much smaller due to maintenance of CPAP/PEEP.

CONCLUSION

The modified apnea test can serve as a means to safely assess for apnea in complex patients in need of brain death determination, such as those with significant hypoxia or hypotension minimally responsive to hemodynamic therapy. This test requires neither specific equipment nor an elaborate set-up, and thus can be performed in all health-care settings.

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Figure.

Non-contrast head CT reveals diffuse brain edema with descending transtentorial herniation (black arrow), traumatic subarachnoid hemorrhage (arrowhead), fracture of the right occipital squama and body of the sphenoid, and associated pneumocephalus (white arrow).