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ORIGINAL RESEARCH

Medicolegal Complications of Apnoea Testing for Determination of Brain Death

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Abstract Recently, there have been a number of lawsuits in the United States in which families objected to performance of apnoea testing for determination of brain death. The courts reached conflicting determinations in these cases. We discuss the medicolegal complications associated with apnoea testing that are highlighted by these cases and our position that the decision to perform apnoea testing should be made by clinicians, not families, judges, or juries.

Keywords Brain death · Apnoea testing · Consent

Introduction

Although a small number of critics believe brain death is a legal fiction, it is widely recognized in the medicolegal community to be consistent with legal death throughout much of the world (Sprung et al. 2014; Shemie et al. 2014; Burkle, Sharp, and Wijdicks 2014; Bernat 2013; President's Commission 1981). Accordingly, a survey of 1,283 members of critical care professional societies from thirty-two countries demonstrated that 93 per cent of respondents believed that all therapies sustaining organ function should be discontinued after brain death determination unless organ donation is planned (Sprung et al. 2014).

Throughout the United States, brain death equates to legal death (Burkle, Schipper, and Wijdicks 2011). Medical society guidelines on determination of brain death for both adult and paediatric patients require that a patient be comatose, have complete absence of all brainstem reflexes, and be unable to breathe spontaneously (Wijdicks et al. 2010; Nakagawa et al. 2012). Assessment of the ability to breathe spontaneously (the apnoea test) evaluates the functionality of the medullary chemoreceptors to stimulate respiration in response to a rise of carbon dioxide and fall in pH (Datar et al. 2014). The apnoea test is the last portion of the clinical examination performed for determination of brain death (American Academy of Pediatrics 1987), but it is perhaps the most important component. In fact, when examining the topic of brain death, the President's Council on Bioethics noted that it is philosophically and ethically conceptually sound because it represents a state in which a person with irreversible loss of consciousness is no longer able to perform their fundamental vital work (breathe), so therefore they are dead (President's Council on Bioethics 2008).

Recently, there have been four major lawsuits in the United States on the conduct of apnoea testing during brain death determination (*Re Mirranda Grace Lawson* [2016]; *Re Allen Callaway* [2016]; *Alex Pierce v Loma Linda University Medical Center* [2016]; *Brett and Yvonne Shively v Wesley Medical Center and Lindall*

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Smith [2006]). Herein, we examine these cases and the medicolegal complications associated with apnoea testing. We conclude that because brain death is legal death throughout the United States, as with all other medical determinations, the decision to perform apnoea testing should be the responsibility of clinicians and should not be adjudicated in a courtroom.

The Medical History of Apnoea Testing

Criteria for determination of brain death were first described in the United States by an ad hoc committee at Harvard in 1968. To perform an apnoea test, the committee noted that a patient must have a normal carbon dioxide level and breathe room air for at least ten minutes before the test. According to their description, the ventilator was turned off for three minutes, during which the patient was monitored for spontaneous respirations, but no further details were provided (Harvard Medical School 1968). As a result, a 1977 review of 503 comatose patients being evaluated for brain death at eight centres across the United States found that verification of apnoea was "scientifically imprecise, but at the bedside was readily recognized" (*An Appraisal of the Criteria of Cerebral Death* 1977, 984). Similarly, a 1986 survey of neurologists in Colorado and California found that the methodology for apnoea testing varied and 12 per cent of respondents didn't even perform apnoea testing during determination of brain death (Earnest, Beresford, and McIntyre 1986).

In 1995, the American Academy of Neurology (AAN) published comprehensive, evidence-based guidelines on determination of brain death in adults based on a review of the pertinent literature on Medline between 1976 and 1994 and current textbooks of neurology, medicine, intensive care, pulmonology, and anaesthesiology (Wijdicks 1995). The 1995 guidelines noted that the carbon dioxide level at which the medullary chemoreceptors are maximally stimulated is unknown but concluded based on prior research that a Pa_{CO2} value of 60 mm Hg is an appropriate target for assessment of brain death. At the time of publication of the 1995 guidelines, studies on the method of testing for apnoea were limited and no technique was favoured. The 1995 guidelines indicated that the following prerequisites needed to be met before the apnoea test was performed: 1) temperature greater than 36.5°C; 2) systolic blood pressure ≥ 90 mm Hg; 3) euvolemia (preference for hypervolemia in the hours preceding the test); 4) eucapnia (option of arterial $P_{CO2} \geq 40$ mm Hg); and 5) normoxemia (option of arterial $P_{O2} \geq 200$ mm Hg). In order to conduct the test, the examiner was advised to: 1) disconnect the ventilator; 2) deliver 100 per cent oxygen at a rate of 6 L/min (option to place a nasal cannula at the level of the carina); 3) monitor for abdominal or chest excursions that produce adequate tidal volumes (option to use a spirometer); and 4) reconnect the ventilator if respirations are seen, the patient becomes unstable (systolic blood pressure < 90 mm Hg, marked desaturation, cardiac arrhythmia), or after eight minutes passed. The test is positive if no respirations are seen and the Pa_{CO2} is ≥ 60 mm Hg or increased by 20 mm Hg from baseline. If no respirations are seen, but the Pa_{CO2} does not increase adequately, the test needs to be repeated for ten minutes if the patient is stable. If no respirations are seen, but the patient is unstable and the Pa_{CO2} does not increase adequately, an ancillary test is required (Wijdicks 1995).

The AAN guidelines were updated in 2010 based on a review of the literature from 1996 to 2009. The authors found that use of apnoeic oxygenation diffusion is safe, but there was insufficient evidence to determine the comparative safety of different techniques (Wijdicks et al. 2010). The procedures for performing the apnoea test described in the 1995 guidelines were reiterated with the following minor modifications: 1) systolic blood pressure before starting the procedure is required to be ≥ 100 mm Hg (rather than ≥ 90 mm Hg); 2) preprocedural eucapnia is defined as 35–45 mm Hg (rather than merely noting that there is an option for arterial $P_{CO2} \geq 40$ mm Hg); 3) preoxygenation is advised for at least ten minutes with 100 per cent oxygen to obtain a $Pa_{O2} > 200$ mm Hg (rather than noting that preoxygenation is necessary, but not providing a duration of time or goal); and 4) guidance is now provided that if oxygen saturation becomes <85 per cent for thirty seconds, the examiner should abort the procedure, but consider retrying with a T-piece, CPAP 10cm H_2O, and 100 per cent oxygen at 12 L/min (whereas previously the oxygen saturation at which to abort the test was merely described as "marked" and no advice was provided about how to perform the procedure safely under these circumstances) (Wijdicks et al. 2010; Wijdicks 1995). These criteria were endorsed by the Neurocritical Care Society, the Child Neurology Society, the Radiological Society of North America, and the American College of Radiology (Wijdicks et al. 2010).

Guidelines for determination of brain death in paediatric patients were published in 1987 and updated in 2011 by the Society of Critical Care Medicine, the American Academy of Pediatrics, and the Child Neurology Society (Nakagawa et al. 2012; American Academy of Pediatrics 1987). The 1987 guidelines merely state that apnoea testing should be performed using "standard guidelines" after completion of the remainder of the clinical evaluation for brain death (American Academy of Pediatrics 1987). The 2011 guidelines provide much more detail and are grossly similar to the adult guidelines in regard to apnoea testing but differ in two notable ways: 1) two apnoea tests are required (instead of one); and 2) the test is positive if there are no respirations during the test and Pa_{CO2} is ≥ 60 mm Hg *and* increased by 20 mm Hg from baseline (versus Pa_{CO2} is ≥ 60 mm Hg *or* increased by 20 mm Hg from baseline) (Nakagawa et al. 2012; Wijdicks et al. 2010).

The Legal History of the Apnoea Test

State laws on determination of death are based on the Uniform Determination of Death Act (UDDA) which was written by the President's Council for Bioethics in 1981. The Council (a committee composed of philosophers, ethicists, religious officials, lawyers, and physicians) was commissioned to evaluate the use of neurologic criteria to determine death. Although the medical profession generally accepted brain death after the idea was introduced in 1968, this concept represented a departure from long-accepted social standards for the definition of death (Harvard Medical School 1968; President's Commission 1981). As a result, it warranted scrutiny by people outside the biomedical community to ensure this new concept of death reflected the rights and values of American society. After an extensive evaluation of the definition of death, the Council wrote the UDDA. They decided that the process of defining death should be handled on a state level and recommended that individual states create statutes on determination of death modelled off of the UDDA (President's Commission 1981).

The UDDA states that,

> An individual who has sustained either 1) irreversible cessation of circulatory and respiratory functions, or 2) irreversible cessation of all functions of the entire brain, including the brain stem, is dead. A determination of death must be made in accordance with acceptable medical standards. (President's Commission 1981, 2).

Although the complete language of the UDDA is included in the definition of death in only 71 per cent of states, and there are subtle variations in the wording of the definitions in the remaining states, death by neurologic criteria is considered to be legal death in every state (Lewis, Cahn-Fuller, and Caplan 2017).

The authors of the UDDA chose not to include medical criteria for determination of brain death in the UDDA, as they felt "it [was] not necessary—indeed, it would be a mistake—to enshrine any particular medical criteria, or any requirements for procedure or review, as part of a statute" and that it was the responsibility of the medical community to continue to develop tests and criteria for determination of death by neurologic criteria (President's Commission 1981). Thus, the details of apnoea testing are not included in the UDDA or the definition of death in any state (President's Commission 1981; Lewis, Cahn-Fuller, and Caplan 2017).

Lawsuits

Between 2006 and 2016, there were four lawsuits in four different states that addressed conduct of apnoea testing during brain death determination (*Re Mirranda Grace Lawson* [2016] CL16-2358; *Re Allen Callaway* [2016] DG-16-08; *Alex Pierce v Loma Linda University Medical Center* [2016] No. DS1608931; *Brett and Yvonne Shively v Wesley Medical Center* [2006], Court of Appeals of the State of Kansas). The outcome of each of these cases was different (see Table 1).

In 2006, Brett Shively, Jr., a two-year-old, was hospitalized at Wesley Medical Center in Kansas after drowning—or near drowning. The hospital believed that he was brain dead, but his parents objected to performance of apnoea testing. The case was heard by the district court who ruled that because his parents did not consent to performance of the test, the hospital should continue to treat him as though he were not brain dead. He was subsequently discharged home on organ support. The case was then escalated to the Court of Appeals based on the premise that even though the subject was moot for Shively, it was an issue of statewide importance, but they dismissed the case. Thus, there is precedent in Kansas that consent is required for apnoea

Table 1 Key Points in lawsuits about apnoea testing

Patient/Age	State	Year	Key Points
Brett, Jr., two-years-old (In *Brett and Yvonne Shively v Wesley Medical Center* [2006], Court of Appeals of the State of Kansas)	Kansas	2006	- Brett was admitted to the hospital after drowning. - His parents objected to apnoea testing for determination of brain death. - The District Court ruled that the hospital could not perform the test and needed to continue to treat him as though he were not brain dead. - Brett was discharged home on organ support. - The case was escalated to the Court of Appeals, but they determined that because a finding would not affect Brett, the issue was moot, so they dismissed the case.
Allen Callaway, six-years-old (In *Re Allen Callaway* [2016] DG-16-08)	Montana	2016	- Allen was admitted to the hospital after drowning. - Allen's mother consented to the hospital performing procedures to determine the condition of his brain. - During an apnoea test, his Pa_{CO2} increased from 39 mm Hg to 100 mm Hg and he did not breathe. - Allen's stepfather felt the apnoea test caused pain, stress, and physical harm. - Allen's mother refused to allow the hospital to perform a second apnoea test and filed a lawsuit, stating that she has the right to make medical decisions on her child's behalf. - The District Court ruled that the hospital could not perform the test because Montana law does not mandate that clinicians perform a brain death evaluation and performance of a medical procedure on a child requires parental consent.
Mirranda Grace Lawson, two-years-old (In *Re Mirranda Grace Lawson* [2016] CL16-2358; Richer 2016)	Virginia	2016	- Mirranda choked on popcorn and went into cardiopulmonary arrest. - She was found to be comatose with absent brainstem reflexes. - Apnoea testing was planned, but Mirranda's family refused and filed a lawsuit, citing their Christian beliefs and concern that the test would be harmful. - Virginia Circuit Court ruled the test could be performed, but the family appealed the decision. - Mirranda went into cardiopulmonary arrest and was declared dead by cardiopulmonary criteria. - The appeal was withdrawn.
Alex Pierce, thirteen-years-old (In *Alex Pierce v. Loma Linda University Medical Center* [2016]; Claverie 2016)	California	2016	- Alex was admitted to the hospital after drowning. - Apnoea testing was discussed, but Alex's mother objected and filed a lawsuit, citing concern that it could be harmful and that based on her Christian beliefs, she felt he could recover. - A temporary restraining order was issued, and the test was not performed. - Alex was relocated to another facility where organ support was discontinued. - No legal ruling was made.

testing (*Brett* and *Yvonne Shively v Wesley Medical Center* [2006]).

In May 2016, Mirranda Grace Lawson, a two-year-old, was brought to the Virginia Commonwealth Health System (VCUHS) after choking on a popcorn kernel and going into cardiopulmonary arrest. She suffered profound anoxic brain injury and was found to be comatose with no brainstem reflexes, so an apnoea test

was planned as part of a brain death evaluation. Lawson's parents filed a lawsuit with the Virginia Circuit Court objecting to performance of an apnoea test, stating that: 1) according to their Christian beliefs, their daughter could not be declared dead until her heart stopped beating; 2) as her parents, only they, not the hospital, could make healthcare decisions for her; and 3) an apnoea test was not in her best interest because it could cause harm. The Circuit Court ruled that VCUHS could perform the test, but the Lawsons appealed this decision. However, the appeal was withdrawn in December 2016 due to Lawson's subsequent cardiopulmonary arrest (*Re Mirranda Grace Lawson* 2016; "Supreme Court of Virginia Apellate Case Management System," 2016; Richer 2016).

In June 2016, Alex Pierce, a thirteen-year-old boy, was admitted to Loma Linda University Medical Center in California after drowning. His course was complicated by seizures and a brain death evaluation was discussed. Pierce's mother opposed the performance of apnoea testing due to concern that elevated arterial carbon dioxide levels could be harmful to his brain, noting that she was, "a Christian and believe[d] in the healing power of God … [and did] not want him pulled off life support." A temporary restraining order was issued to prevent the hospital from performing apnoea testing, but Pierce was ultimately relocated to another hospital where organ support was discontinued, so there was no legal ruling made. As a result, should this issue come up in a future case in California, it is unclear how it will be handled (*Alex Pierce v Loma Linda University Medical Center* [2016]; Claverie 2016).

In July 2016, Allen Callaway, a six-year-old, was brought to St. Vincent's Healthcare (SVH) in Montana after drowning—or near drowning. St Vincent's Healthcare sought consent from Callaway's mother to perform procedures, including an apnoea test, to determine the condition of his brain. She consented to these procedures (although, of note, she reported afterwards that she was not aware these procedures could lead to a determination of brain death). During the first apnoea test, the Pa_{CO2} increased from 39 mm Hg to 100 mm Hg, and Callaway did not breathe. His stepfather was present during the test and voiced concern that the test caused pain, stress, and physical harm. When performance of a second apnoea test was discussed, Callaway's mother refused, and filed a lawsuit stating that she had the fundamental right to make medical decisions on her child's behalf. The District Court found that: 1) Montana law does not mandate that clinicians perform a brain death evaluation, and it is not up to a hospital or its personnel to decide whether or not medical procedures should be performed; 2) performance of a medical procedure on a child requires parental consent based on the rights to personal autonomy, privacy, and protection; and 3) a court cannot infringe on a parent's fundamental rights to make child-rearing decisions even if a clinician or judge believes "a 'better' decision could be made," unless there is a compelling state interest in the case (*Re Allen Callaway* [2016]).

Medical Considerations When Performing Apnoea Testing

The Callaway, Lawson, Pierce and Shively cases address concerns that apnoea testing is associated with risk of harm. While it is important to recognize that there are risks associated with apnoea testing, as with all patient safety issues, complications can be avoided with proper training and adherence to guidelines. Because there is the potential for complications during apnoea testing, it should not be conducted until the rest of the brain death evaluation is complete and it is clear that the patient is comatose and has no brainstem reflexes (Solek-Pastuszka et al. 2015).

Adherence to Prerequisites for Apnoea Testing

Apnoea test guidelines acknowledge that intentional induction of hypercarbia and respiratory acidosis can lead to cardiac arrhythmias (usually premature ventricular contractions or ventricular tachycardia), hypotension, or hypoxemia (particularly in patients with severe pulmonary disease, acute respiratory distress syndrome, or neurogenic pulmonary oedema) (Wijdicks 1995; Mathur and Ashwal 2015). However, compliance with prerequisites for apnoea testing (particularly the need for appropriate preoxygenation) decreases the risk of these complications (Wijdicks 1995; Datar et al. 2014). In a retrospective review of ninety-three adult patients at a hospital in China, complications developed in 21 per cent of apnoea tests, the majority of which were attributed to inadequate baseline blood pressure and preoxygenation (Wu et al. 2008). A similar study in the United States evaluated the rate of complications during sixty-three apnoea tests and found that although

6 per cent of patients became hypoxic and 17 per cent became hypotensive, no patients developed an arrhythmia or had a cardiac arrest during the test, and only 2 per cent of tests needed to be aborted (Datar et al. 2014).

A single-centre series found that in 7 per cent of patients, the prerequisites could not be achieved due to hemodynamic instability or poor oxygenation at baseline (Wijdicks et al. 2008). To avoid risks of complications, if the prerequisites are not met, instead of performing an apnoea test, an ancillary test such as an electroencephalogram, nuclear study, or cerebral angiogram should be performed to confirm the clinical determination of brain death (Nakagawa et al. 2012; Wijdicks et al. 2010).

Concerns About the Effects of Acidosis and Hypercarbia

Some clinicians worry that the intentional production of acidosis and hypercarbia during apnoea testing can depress brain function and cause a secondary neurologic insult to patients with potential for recovery (Rady and Verheijde 2015; Tibballs 2010).

Although apnoea testing inherently results in development of acidosis, a study looking at left-ventricular function during apnoea testing found that the fractional area changes of the heart, a surrogate for ejection fraction, increased during the test, indicating that the acidosis (pH 7.09 ± 0.08) was systemically well-tolerated (Orliaguet et al. 1994).

Carbon dioxide is a potent vasodilator and high levels can lead to impaired autoregulation (Nusbaum et al. 2016). Experimental models have demonstrated that an increase in Pa_{CO2} by 1 mm Hg results in a 5.8 ± 0.9 per cent increase in grey matter cerebral blood flow (Noth et al. 2008). However, a study looking at the effects of increasing Pa_{CO2} in piglets demonstrated that although an increase in Pa_{CO2} from 38 ± 4 to 96 ± 12 mm Hg over a three hour period was associated with a significant increase in arterial blood pressure and cerebral perfusion pressure ($p<0.0001$), it was not associated with a significant increase in intracranial pressure; the intracranial pressure was 13 ± 2 mm Hg initially and was 10 ± 5 mm Hg after three hours (Nusbaum et al. 2016). Thus, concerns about the effects of transient hypercarbia on a patient with severe brain injury undergoing a brain death evaluation remain theoretical (Roth et al. 2015, 2016).

But even if this data was discounted and intracranial pressure increased above the normal range of 10–20 mm Hg during apnoea testing, would this be harmful? Intracranial hypertension leads to both intracranial and systemic changes, including cerebral ischemia and hypoxia, resulting in neuronal death; inflammation, oedema, and necrosis of the heart, lung, kidney, and liver; and hormonal changes (decreased catecholamines, thyroxine (T4), triiodothyronine (T3), adrenocorticotropic hormone, cortisol, and antidiuretic hormone) (Sebening et al. 1995; Heuer et al. 2012; Yang et al. 2005; Bracco et al. 1997). As a result, the Neurocritical Care Society recommends that intracranial pressure be monitored in patients who are at risk of elevated intracranial pressure (Le Roux et al. 2014). Surgical and medical interventions should be performed as needed to try to prevent and treat intracranial hypertension (Rasmussen 2005; Le Roux et al. 2014). However, elevated intracranial pressure can sometimes be refractory, which can lead to catastrophic brain injury or death (Le Roux et al. 2014; Czosnyka et al. 2016). An observational study found that the mean intracranial pressure prior to apnoea testing was 86.6 ± 22.9 mm Hg and the range was 56–152 mm Hg, which is markedly elevated (Roth et al. 2015). Thus, patients who are undergoing apnoea testing have already suffered substantial injuries, so the question of whether an apnoea test can induce further brain damage is inconsequential. Accordingly, when the prerequisites for brain death are met and a patient is found to be comatose with absent brainstem reflexes, that patient will be found to be brain dead over 90 per cent of the time (Ma et al. 2006; Nakagawa et al. 2012; Wijdicks et al. 2010).

Methods to Minimize Medical Complications Associated With Apnoea Testing

Of course, in order to minimize the risk of complications and ensure accuracy, apnoea testing must be performed properly. A 1995 review of ninety-three brain death determinations found that 22 per cent had an imprecise apnoea test and 25 per cent did not even have an apnoea test (Mejia and Pollack 1995). A review of paediatric brain death determinations between 2000 and 2004 in southern California found that apnoea testing was only performed on 40 per cent of patients, and of those who had apnoea tests, there was an inadequate rise in Pa_{CO2} in 50 per cent of patients (Mathur et al. 2008). Similarly,

a single institution retrospective study on brain death determination between 2011 and 2015 found that apnoea testing was only completed in 40 per cent of patients (Pandey et al. 2017). A 2015 review of 508 adult brain death protocols from institutions in the United States found wide variations between local apnoea testing guidelines compared with the AAN guidelines. Notably, only 79 per cent indicated preoxygenation was necessary, 57 per cent recommended provision of oxygen during the test, and 64 per cent provided conditions under which the apnoea test should be aborted (Greer et al. 2016). The 2010 AAN guidelines are evidence-based, approved by numerous medical societies, and have been referred to as the standard for brain death determination both in the United States and around the world (Ding et al. 2015; Wijdicks et al. 2010; Greer et al. 2016). Despite this, it is clear that these guidelines are not consistently followed nationally or internationally (Greer et al. 2016; Wahlster et al. 2015). Perhaps, this may in part be explained by the fact that clinicians involved with brain death determination are not always well-versed on the guidelines. On a test evaluating the knowledge of a diverse group of specialists responsible for brain death determination, respondents scored only 52 per cent on questions regarding apnoea testing (MacDougall et al. 2014).

There are risks or apnoea testing, but they can be minimized through adherence to guidelines (Nakagawa et al. 2012; Wijdicks et al. 2010), so it is imperative that institutional protocols reflect societal guidelines and clinicians be frequently educated and re-educated about brain death determination procedures including apnoea testing. We believe that governmental regulatory guidelines and certification and credentialing procedures would be helpful to ensure determinations are performed accurately and with minimal risk to patients (Greer et al. 2016).

Legal Considerations Associated With Apnoea Testing

In addition to the Callaway, Lawson, Pierce, and Shively lawsuits, there have been a number of other prominent lawsuits associated with determination of death by neurologic criteria (*Israel Stinson v Children's Hospital Los Angeles* [2016] BS164387; *Re A (A Child)* [2015] EWHC 443 (Fam); *Re Guardianship of Hailu* [2015] 361 P.3d 5; *McMath v California* [2015] No. 3:15-06042 N.D. Cal.; *Re Allen Callaway* [2016]; *Re Mirranda Grace Lawson* [2016]; *Brett and Yvonne Shively v Wesley Medical Center and Lindall Smith* [2006]; *Alex Pierce v Loma Linda University Medical Center* [2016]). Public familiarity with the definition and implications of brain death is poor. Surveys have demonstrated that the public does not know the difference between brain death (a state in which there is irreversible loss of function of the entire brain and brainstem which is legally equivalent to cardiopulmonary death), coma (a temporary condition in which brain function is grossly impaired, causing loss of consciousness, which may worsen leading to brain death, transition to a minimally conscious or vegetative state, or progress towards recovery), and a persistent vegetative state (a state of unresponsive wakefulness lasting greater than thirty days in which a patient may have eye-opening, retention of brainstem reflexes, and the ability to breathe without assistance) (Shah, Kasper, and Miller 2015; Siminoff, Burant, and Youngner 2004; Posner et al. 2007). These topics are infrequently discussed with the public outside of the unfortunate circumstance in which a person's family member suffers a severe brain injury, so public understanding of brain death is largely based on media, television, and movies, all of which grossly misrepresent the detailed process of brain death determination and often insinuate that patients are declared brain dead specifically for the purpose of organ donation (Lewis, Weaver, and Caplan 2017; Lewis et al. 2016).

Allen Callaway, Mirranda Grace Lawson, Alex Pierce, and Brett Shively, Jr. were all paediatric patients, which made their brain injuries particularly devastating for their families. Additionally, while there are many potential aetiologies for paediatric brain death that are unpreventable (strokes, metabolic disorders, infections, tumours, etc.), all of these patients developed brain injuries due to accidents (choking and drowning). Burkle and Benson (2012) noted that families like the Callaway, Lawson, Pierce, and Shively families insist on continued treatment in the setting of futility due to grief, guilt, religious or cultural beliefs, faith in future medical advances to change a patient's prognosis, or concern that a physician's prognosis is influenced by financial incentive or patient race or socioeconomic status. In fact, racial and ethnic minorities more commonly request continued treatment in the setting of futility.

Having addressed the medical considerations associated with the fear that apnoea testing could be harmful, we turn now to the legal considerations of these cases.

Laws and Principles Relevant to Apnoea Testing

Brain death is accepted as legal death throughout the United States, but state laws on determination of death vary somewhat (Lewis, Cahn-Fuller, and Caplan 2017). For example, four states have caveats in their determination of death laws or guidelines that include mention of provision of accommodation for families who object to determination of death by neurologic criteria on religious or moral grounds (some devout believers in the Christian, Orthodox Jewish, Japanese Shinto, Buddhist, and Muslim communities believe that death does not occur until the heart stops beating) (Lewis, Varelas, and Greer 2016; Burck et al. 2006). In California and New York, hospitals are instructed to make reasonable efforts to accommodate religious or moral objections to determination of death by neurologic criteria (*AB 2565 Assembly Bill* 2008; New York State Department of Health and New York State Task Force on Life and the Law 2011). In Illinois, hospitals must take religious beliefs into account when determining time of death (*Illinois Compiled Statutes 210 ILCS 85 Hospital Licensing Act*. [2008] section 6.24). The law is most stringent in New Jersey, where death by neurologic criteria cannot be declared in violation of a patient's religious beliefs (New Jersey Ad Hoc Committee on Declaration of Death by Neurologic Criteria 2014). These caveats are based on the rights to religious freedom (First Amendment) and privacy (Fourteenth Amendment) contained in the U.S. Constitution, and are the end-of-life corollaries to *Roe v Wade* (Burt 2002). Despite these directives on accommodation during determination of death by neurologic criteria, performance of apnoea testing is not specifically addressed in state laws or guidelines (Lewis, Cahn-Fuller, and Caplan 2017).

The Need to Perform a Brain Death Evaluation

As the Montana District Court noted, the Determination of Death Act in Montana, and in every other state, does not mandate that a physician conduct a brain death evaluation (*Montana Code Annotated §50-22-101*, 1983; Burkle, Schipper, and Wijdicks 2011; Lewis, Cahn-Fuller, and Caplan 2017). In rare circumstances, a physician may elect to not perform a brain death evaluation due to their personal religious beliefs (Lewis, Varelas, and Greer 2016; Burck et al. 2006). When this occurs, the physician can transition the patient's care to another clinician. More commonly, however, families object to determination of death by neurologic criteria due to religious beliefs, doubt about the prognosis and belief that a patient will recover, or desire to continue to collect a patient's government benefits (Lewis et al. 2016; Lewis et al. 2017). Nearly 50 per cent of adult neurologists have encountered families who objected to brain death determination or discontinuation of organ support after brain death determination (Lewis et al. 2016). This number is even higher for clinicians who care for paediatric patients with severe neurologic injuries (over 60 per cent) (Lewis et al. 2017).

However, without performing a brain death evaluation (a complete clinical exam and apnoea testing or, if apnoea testing is not feasible, a complete clinical exam and an ancillary test), a clinician has no way of knowing whether a patient is alive or dead. Whereas cardiopulmonary death is acute and dramatic, brain death can be gradual, and while bodies appear pale and motionless after cardiopulmonary death, brain dead corpses in fact have the appearance of live, comatose patients (President's Commission 1981). Thus, a distinction between the dying and the brain dead can only be made through medical procedures for determination of brain death, including apnoea testing (Wijdicks et al. 2010; President's Commission 1981). Hospitals are facilities for the living to receive necessary medical care, not to maintain the dead. Knowledge of whether a patient is alive or dead affects triage of physician and hospital time and resources (intensive care unit bed, medications, ventilator) and has an impact on allocation of healthcare dollars, so hospitals should have the fundamental right to evaluate a patient to determine if they are alive or dead (Lewis et al. 2016; Burck et al. 2006). It costs nearly U.S.$10,000 a day to provide organ support for a single patient in an intensive care unit, and hospitals and physicians have an ethical duty not to squander healthcare dollars, particularly because insurance companies may reject payments if determination of brain death is delayed (Liao and Ito 2010; Spike and Greenlaw 1995; Flamm, Smith, and Mayer 2014; *Re Mirranda Grace Lawson* [2016]).

Notably, only a small percentage of hospitals have protocols that address management of patients who are presumed to be dead, or are dead, but whose families object to brain death testing or discontinuation or organ support after determination of brain death (Lewis, Varelas, and Greer 2016). In these circumstances, a

physician can 1) seek assistance from their hospital administration, ethics committee, legal counsel, risk management, or pastoral care; 2) defer to the family's requests and continue care until death can be declared by cardiopulmonary criteria; 3) transfer care to another practitioner or institution; or 4) perform the evaluation and discontinue organ support if the patient is brain dead against the family's wishes (Lewis, Varelas, and Greer 2016). These situations are tense and uncomfortable for physicians, who, amongst other concerns, worry they will result in litigation or unfavourable media attention (Lewis et al. 2016; Lewis et al. 2017; Smith and Flamm 2011; Flamm, Smith, and Mayer 2014; Burt 2002; Burck et al. 2006; Spike and Greenlaw 1995).

Should Consent Be Obtained Before Apnoea Testing Is Performed?

The principle of informed consent evolved based on lawsuits that followed adversarial relationships between physicians and patients. It focuses on valuing patient autonomy and avoiding paternalism. Informed consent is regularly obtained for clinical procedures for ethical, legal, and administrative purposes (del Carmen and Joffe 2005; Hall, Prochazka, and Fink 2012). But should families be given the option to choose whether physicians can perform an apnoea test to differentiate life from death?

Although Callaway's clinicians sought consent from his family before performing an apnoea test, this is not routinely done (*Re Allen Callaway* [2016]; *Re Mirranda Grace Lawson* [2016]; Lewis et al. 2016; Lewis et al. 2017). In a survey of adult neurologists in the United States, 78 per cent of respondents disagreed that physicians should obtain consent from a patient's family before performing a brain death evaluation (Lewis et al. 2016). Similarly, in a survey of paediatric neurologists and intensivists in the United States, 72 per cent believed that it is not necessary to obtain consent before performing a brain death evaluation (Lewis et al. 2017).

Physicians who believe that consent should be required prior to performance of an apnoea test argue that 1) informed consent is required for all procedures, and apnoea testing should not be treated as an exception; 2) consent should be required because there are risks associated with the procedure and that the rise in Pa_{CO2} could harm a patient; and 3) the procedure has no possibility of benefiting the patient, so the risks of an apnoea test clearly outweigh the benefits (Truog and Tasker 2017). Notably, critics also argue that 1) the importance of the apnoea test in the concept of brain death is philosophically unsound, and that "lack of apnoea may not indicate ongoing integration [of the organism] while apnoea can coexist with ongoing integration," and "apnoea is not sufficient to prove death, and much 'vital work' continues with apnoea during brain death" (Joffe, Anton, and Duff 2010); and 2) the reliability of apnoea testing is suspect as there have been reports of spontaneous breathing in patients with Pa_{CO2} as high as 112 mm Hg (Tibballs 2010).

Brain death is a medical diagnosis like any other, so it should be made when it exists, and yet the distinction between life and death is far more profound than the determination that any other medical condition, such as cirrhosis or endocarditis, is present or absent. As a result, while patients or families can choose to avoid a liver biopsy or a transoesophageal echocardiogram, they should not be given the option to choose whether or not an evaluation for determination of death should be performed. As discussed above, apnoea testing could cause arrhythmias, hypoxia, or hypotension, but these risks are low if the prerequisites and techniques for apnoea testing described in societal guidelines are followed (Nakagawa et al. 2012; Wijdicks et al. 2010). With regards to the risks of intentional production of acidosis and hypercarbia, the extent of brain damage in patients who are comatose and have no brainstem reflexes and the likelihood that these patients are, in fact, brain dead, make these risks purely theoretical (Orliaguet et al. 1994; Nusbaum et al. 2016; Roth et al. 2015, 2016; Ma et al. 2006). Given that brain death is established as legal death throughout the country, conceptual arguments that brain death is not real death should be considered obsolete and should not impact our practice (Lewis, Cahn-Fuller, and Caplan 2017). Lastly, and most importantly, the legal obligations when considering a determination of brain death should be the same as those when making a determination of death by cardiopulmonary criteria (Lewis and Greer 2017b). Thus, clinicians, not families, judges, or juries, should be responsible for determining when it is appropriate to perform apnoea testing.

Interestingly, in reaction to the controversy evoked by the three cases objecting to apnoea testing in 2016, Nevada became the first state to change the language of their UDDA to indicate that because

brain death determination is a clinical diagnosis, consent is not required (In *Re Mirranda Grace Lawson* [2016]; In *Re Allen Callaway* [2016]; *An Act Relating to the Determination of Death, 2017 Nevada Acts Ch. 315 (A.B. 424), Effective Oct 1, 2017*; Lewis, Cahn-Fuller, and Caplan 2017; Alex Pierce v. Loma Linda University Medical Center 2016). In order to minimize future legal complications associated with apnoea testing, the legal and medical communities in other states should encourage lawmakers to follow Nevada's lead and specify in their definition of death that consent is not required for determination of brain death (*An Act Relating to the Determination of Death, 2017 Nevada Acts Ch. 315 (A.B. 424), Effective Oct 1, 2017*; Lewis and Greer 2017a, 2017b).

While it would be overly optimistic to expect that this simple change would completely eliminate future lawsuits about determination of brain death, it would certainly help to decrease the number to lawsuits related to apnoea testing. However, even if every state updated their determination of death definition in this manner, some families will inevitably continue to believe death does not occur until the heart stops or will doubt the prognosis a physician provides and believe a patient could recover. As a result, we expect that some families would still turn to the legal system to prevent determination of death by neurologic criteria, citing religious freedom or privacy as reasons to prevent apnoea testing from being performed (Lewis et al. 2016; Lewis et al. 2017; Burt 2002). Further public education about brain death may be helpful in this regard (Lewis et al. 2016; Lewis et al. 2017).

Conclusions

The Callaway, Lawson, Pierce, and Shively cases highlight the medicolegal complications associated with apnoea testing. Since its description by an ad hoc committee at Harvard in 1968, apnoea testing has evolved (Harvard Medical School 1968; Wijdicks 1995; Wijdicks et al. 2010; Nakagawa et al. 2012; American Academy of Pediatrics 1987). To minimize the risk of medical complications during apnoea testing, physicians who perform this procedure should be credentialed and certified to do so after being educated on recommended guidelines including prerequisites for testing, the testing procedure, and complications that can occur during apnoea testing (Nakagawa et al. 2012; Wijdicks et al. 2010). Hospital protocols should be updated to ensure they conform with societal guidelines (Nakagawa et al. 2012; Wijdicks et al. 2010; Greer et al. 2016). Although apnoea testing has risks, adherence to guidelines minimizes these risks and ensures accurate determinations are made (Datar et al. 2014; Nakagawa et al. 2012; Wijdicks et al. 2010). Additionally, physicians should be educated about the appropriate way to discuss brain death with families (Lewis et al. 2017).

Discussions about death, particularly death of a child and sudden death, can be extremely emotional and must be handled delicately. Families should be seen as extensions of patients and treated compassionately and respectfully (Burt 2002; Burck et al. 2006). It is usually prudent to include paramedical personnel such as social work, palliative care, and chaplaincy in discussions about brain death (Lewis et al. 2016; Lewis et al. 2017). It is important for families to be educated and re-educated about brain death and given time to accept and understand the gravity and finality of a situation in which a brain death determination is being discussed (Lewis et al. 2017). Until there is uniform legal guidance about the need for consent prior to apnoea testing, if families object to performance of apnoea testing, it is necessary to escalate management of the controversy to one's hospital ethics committee, administration, and legal department in an attempt to negotiate management internally and prevent a family from feeling the need to pursue the issue in the legal system, which can be both time-consuming and expensive (Lewis, et al. 2016).

Should consent be required to perform an apnoea test? The findings of the Shively and Callaway cases threaten physician authority to declare brain death (Lewis and Pope 2017). However, because the Callaway, Lawson, Pierce, and Shively cases had conflicting decisions, it is unclear how similar future cases in other states will be handled (Claverie 2016). The UDDA authors noted that judges should not be relied upon to define or modify standards for determining death and recommended that the procedure for determination of death be the same throughout the country (President's Commission 1981). Decision-making about performance of apnoea testing should not be adjudicated in a courtroom and it should not be left up to families. Rather, the decision to perform apnoea testing should be the responsibility of clinicians.

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