

A Survey of Brain Death Certification – An Impetus for Standardisation and Improvement

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Abstract

Introduction: Despite well-established guidelines, multiple recent studies have demonstrated variability in the conduct of brain death certification. This is undesirable given the gravity of the diagnosis. We sought therefore to survey local clinicians involved in brain death certification to identify specific areas of variability, if any, and to elicit information on how the testing process can be improved. **Materials and Methods:** An anonymous questionnaire was sent to all clinicians on the brain death certification roster in a tertiary neurosciences referral centre. This survey covered clinician demographics, evaluation of current and proposed resources to assist clinicians in certification, knowledge of the legislation governing brain death and organ procurement, technical performance of the brain death tests, and their views on the appropriate limits of physiological and biochemical preconditions for brain death testing. **Results:** We found significant variability in the conduct of brain death testing, especially in performing the caloric and apnoea tests. Of the existing resources to assist clinicians, written aide-memoires were the most popular. Respondents felt that bedside availability of a more detailed written description of the brainstem tests, and a formal accreditation course would be useful. There was wide variation in the limits of serum sodium and glucose, and the minimum core temperature and systolic blood pressures that respondents felt would preclude testing but we were able to identify thresholds at which the majority would be happy to proceed. We addressed the issues identified in our study by improving our written hospital brain death protocol, and designing an instructional course for clinicians involved in brain death certification. **Conclusions:** Our findings confirm that variability in the performance of brain death testing is indeed a universal phenomenon. Formal training appears desirable, but more importantly, clear and detailed protocols for testing should be made available at the bedside to assist clinicians. These protocols should be tailored to provide step-by-step instructions so as to avoid the inconsistencies in testing identified by this and other similar studies.

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Introduction

Brain death is legally recognised in most developed countries. Certification is usually a prelude to either the withdrawal of cardiorespiratory life support or organ procurement and donation. It is therefore a diagnosis of great significance, and there should be rigorous standards in place to govern the process of brain death testing and certification.¹⁻⁴ Despite this, many recent studies have demonstrated a general lack of knowledge on brain death definitions and concepts amongst physicians certifying brain death,⁵⁻⁷ inconsistencies in institutional brain death certification protocols and documentation,⁸⁻¹¹ and

inconsistencies in the performance of brain death testing.^{12,13}

We sought to determine if the same variability in brain death testing existed in our institution and whether the preconditions to brain death testing were consistently applied. We also sought to establish if resources and support provided to clinicians during brain death testing were adequate and to identify areas for improvement. To this end, we conducted a questionnaire survey to (1) determine the attitudes and knowledge of local clinicians with regard to brain death certification; (2) identify areas in which the technical performance of brain death tests was likely to deviate from published guidelines; and (3) elicit

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user opinions on ways to make the testing process more consistent and robust.

Materials and Methods

In Singapore, the definition and certification of cardiac and brain death are legislated under an Interpretation Act¹⁴ passed by Parliament in 1998. Brain death is defined as brainstem death with complete loss of brainstem function, determined through performing 7 bedside brainstem tests, similar to those recommended in the United Kingdom Code of Practice.^{2,3} This Act was amended in January 2004 to include the use of supplementary tests (cerebral angiography or radionuclide cerebral perfusion scanning) for confirmation of brain death in situations when the preconditions to bedside brain death testing cannot be fully met, or if contraindications to performance of one or more of the 7 brainstem tests exist. Two fully registered medical practitioners are required for certification of brain death, at least one of whom must not have been involved in the care of the patient. Where organ procurement and donation are contemplated, both certifying medical practitioners must not be involved in the care of either the potential donor or organ recipients. Medical practitioners certifying brain death must also possess postgraduate qualifications in one of the following specialties: anaesthesiology, internal medicine, surgery or paediatrics.

The study was carried out in Tan Tock Seng Hospital (TTSH), a tertiary neuroscience referral centre in Singapore with a 12-bed Neuroscience Intensive Care Unit (ICU). The hospital has a brain death certification roster with 2 certifying clinicians rostered daily from departments with specialists in Surgery (except Neurosurgery), Internal Medicine, Neurology, and Anaesthesiology. When patients in the hospital are diagnosed to be brain dead by the attending doctors in the ICU, clinicians from the brain death certification roster are called upon to provide independent confirmation of brain death and, where applicable and suitable, proceed to organ procurement under the provisions of the Human Organ Transplant Act (HOTA).

Following institutional review board approval, we mailed an anonymous questionnaire in October 2004 to all clinicians listed on the hospital brain death certification roster for September and October 2004, and to all specialists in the Department of Anaesthesiology. The questionnaire covered 5 main areas: clinician demographics and experience in performing brain death certification, evaluation of existing and proposed resources to assist physicians in brain death certification, their knowledge of the salient details of the legislation governing brain death certification and organ donation in Singapore, technical performance of the brainstem tests, and their views on appropriate limits of physiological and biochemical parameters required as

preconditions for brain death testing. In order to preserve responder anonymity, survey returns were not tracked, and no attempts were made to contact recipients to request completion of the questionnaire. Responders were allowed to complete the questionnaire on their own and were not prevented from referring to personal notes, manuals or textbooks before or during the completion of this questionnaire.

Statistical analyses were conducted using SPSS software version 13.0 (SPSS Inc, Chicago, IL). Descriptive statistics were calculated for all variables as appropriate. The Pearson chi-square test or Fisher's exact test was used for comparisons between pre-specified subgroups. A *P* value of <0.05 represented statistical significance.

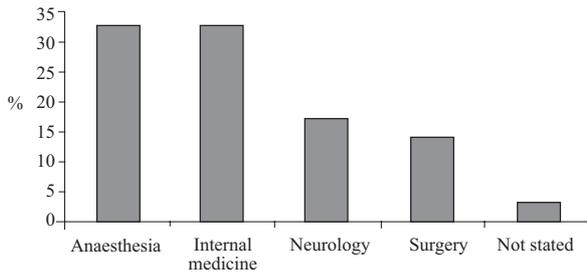
Results

A total of 111 clinicians were polled with 36 responding with fully or partially completed questionnaires, giving a response rate of 32.4%. The distribution of respondents by specialty, seniority, and experience in brain death testing are shown in Figure 1. We did not perform subgroup analysis on our results as was initially intended due to the small respondent numbers obtained.

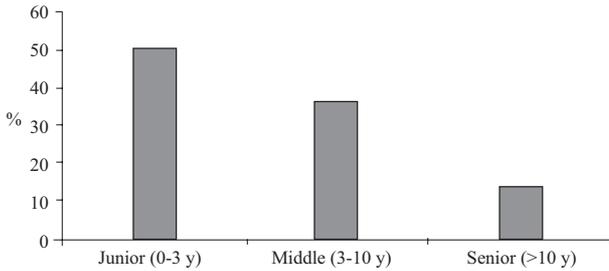
On questions pertaining to the clinicians' knowledge of the legislation governing brain death certification and organ procurement laws in Singapore, 31 respondents (86%) had one or more wrong answers. Responses to questions on the technical performance of brain death tests are summarised in Table 1. One-third of respondents reported a lack of confidence in their ability to perform brain death testing correctly without either referring to on-site resources or assistance from doctors in the ICU. Only 7 respondents (19%) were very confident of their ability to perform the brain death tests correctly.

In conducting the brainstem tests, 23 respondents (64%) said they would apply a painful stimulus to an area on the face, while the rest would do so on the hands, feet or an area on the torso. Twenty respondents (56%) would look for the response to painful stimuli on the face. Only 16 respondents (44%) said they would both apply a pain stimulus and assess for the response on the face, while 9 (25%) said they did neither. Twenty-one respondents (58%) said they were confident of being able to distinguish a spinal from a brainstem reflex during brainstem testing. Six respondents (18%) would test for the gag reflex by manipulating the tracheal tube, rather than stimulating the posterior pharynx with a spatula (13 respondents or 38%) or stimulating the trachea with a suction cannula (15 respondents or 44%). For conduct of the caloric test, only 1 respondent (3%) correctly identified all the steps for performance of this test, which are: using 50 mL of ice-cold water to irrigate the ear canal over at least 1 minute with a 5-minute interval between testing each side. If the testing interval was

Distribution of respondents by specialty



Distribution of respondents by seniority



Distribution of respondents by experience in brain death testing

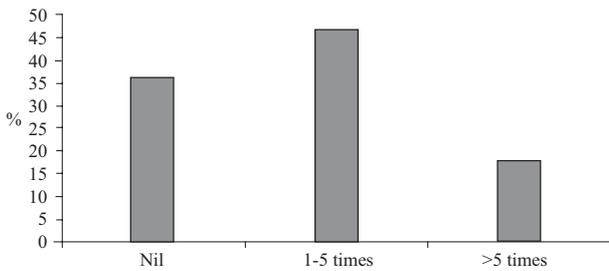


Fig. 1. Distribution of respondents by specialty; seniority (junior = 0-3 years post-specialty qualification, middle = 3-10 years, senior = more than 10 years), and experience (measured as number of brain death tests performed over the preceding 3 years).

disregarded, there were 4 (11%) correct responses. If only water temperature and volume were considered, there were 13 (36%) correct responses. Thirty-two respondents (91%) said they would not perform the caloric test in the presence of a perforated tympanic membrane, although the national guidelines clearly state that this is not a contraindication.¹⁵

For the conduct of the apnoea test, only 5 respondents (14%) were able to describe the test correctly with all the following parameter limits: supplying supplemental oxygen at a flow rate of 6 to 8 L/min, observing for apnoea for a period of 4 to 9 minutes, and targeting PaCO₂ at 50 to 60 mm Hg as an adequate stimulus. This number increased to 18 (50%) if the testing parameters were relaxed to include oxygen at any flow rate ≥ 6 L/min, an apnoeic interval of 4 to 9 minutes, and a target PaCO₂ of 50 to 65 mm Hg.

The respondents' opinions on what constituted appropriate biochemical and physiological limits as preconditions for brain death testing are summarised in Table 2. Twenty-two respondents (63%) felt that it was

Table 1. Responses to Questions on the Technical Performance of Selected Brain Death Tests

	% (n)
Assessment of motor response to a painful stimulus	
<i>Site of application of painful stimulus</i>	
Face	64 (23)
Hands	39 (14)
Feet	11 (4)
Torso	36 (13)
<i>Type of painful stimulus</i>	
Pressure	92 (33)
Pinprick	8 (3)
<i>Site assessed for motor response</i>	
Limb to which pain is applied	47 (17)
Face	56 (20)
Other body parts (unspecified)	14 (5)
Assessment of the vestibulo-ocular reflex by caloric testing	
<i>Temperature of water</i>	
Ice-cold	97 (35)
37°C	3 (1)
<i>Volume of water injected per ear (mL)</i>	
10	22 (8)
20	39 (14)
30	3 (1)
50	36 (13)
<i>Approximate speed of injection</i>	
Rapid <30 sec	61 (22)
Moderate ~1 min	39 (14)
<i>Interval between testing each side (min)</i>	
0	11 (4)
1	14 (5)
2	22 (8)
3	14 (5)
5	31 (11)
Assessment of the gag reflex	
Tactile stimulation of the posterior pharynx or uvula	38 (13)
Insertion of a suction catheter into the tracheal tube	44 (15)
Manipulation of the tracheal tube	18 (6)
Apnoea testing	
<i>Oxygen flow rate (L/min)</i>	
2	11 (4)
4	6 (2)
6	17 (6)
8	3 (1)
10	33 (12)
15	25 (9)
<i>Conduit for oxygen delivery</i>	
Suction catheter	61 (22)
Ventilator circuit	33 (12)

Table 1. Contd.

	% (n)	
<i>Apnoeic interval (min)</i>		
	1-3	11 (4)
	4-6	47 (17)
	7-9	11 (4)
	10-12	22 (8)
	>12	6 (2)
<i>Minimum target PaCO₂ as an endpoint for testing (mm Hg)</i>		
	45	3 (1)
	50	25 (9)
	55	19 (7)
	60	39 (14)
	65	11 (4)

unacceptable to use reversal agents such as flumazenil and naloxone to reverse the effects of opioids or sedatives so as to allow brain death testing. Only 11 (31%) would routinely assay for plasma levels of sedative drugs and 6 (17%) would routinely test thyroid function before brain death testing. Thirty respondents (83%) said it was unacceptable to rapidly correct hypernatraemia solely to allow brain death testing.

Of existing resources to assist clinicians in the conduct of brain death testing, the most popular (in descending order) among respondents were (1) a written protocol kept on file in each of the ICUs; (2) a copy of the critical care handbook written and published by doctors of the institution (which contains a description of the process); (3) consultation with the ICU specialist on duty, departmental colleagues or the on-duty neurologist (in that order). Of proposed new measures to further assist clinicians performing brain death testing, the most popular was a step-by-step guide to the brainstem tests provided in the ICUs (50% of votes), followed by attending a formal short course with accreditation on how to perform brain death testing (36%), and regular didactic lectures conducted by intensivists or neurologists (14%) on brain death testing.

Discussion

We surveyed clinicians from a hospital brain death certification roster and found significant variability in their knowledge of the technical aspects of brain death testing. Certain characteristics of our survey population may have contributed to these results. We had a large proportion of relatively inexperienced and junior clinicians, as well as clinicians without a strong background in the neurosciences in our study. The low response rate was also disappointing but not entirely unexpected, and may reflect reluctance amongst clinicians to reveal their ignorance regarding this subject or disinterest and apathy amongst clinicians on the

Table 2. Respondents' Opinions on the Appropriate Biochemical and Physiological Limits Required as Preconditions for Brain Death Testing

	% (n)	Cumulative %
<i>Maximum plasma sodium</i>		
145	17 (6)	17
150	34 (12)	51
155	17 (6)	68
160	17 (6)	86
165	3 (1)	89
No limit	11 (4)	100
<i>Minimum plasma sodium</i>		
135	20 (7)	20
130	46 (16)	66
125	14 (5)	80
120	14 (5)	94
No limit	6 (2)	100
<i>Maximum glucose</i>		
8	12 (4)	12
10-12	15 (5)	27
15	20 (7)	47
20	15 (5)	62
25	9 (3)	71
No limit	29 (10)	100
<i>Minimum core temperature (°C)</i>		
>36.5	21 (7)	7
36	30 (10)	51
35	27 (9)	79
34	15 (5)	94
33	3 (1)	97
32	3 (1)	100
<i>Minimum systolic blood pressure (mm Hg)</i>		
100	34 (12)	34
90	43 (15)	77
80	23 (8)	100

The limits highlighted in bold indicate the value at which most of the respondents would be comfortable with proceeding to brain death testing.

topic of brain death certification. This study, conducted in a single institution coupled with the low response rate of 32.4%, may limit the validity of these results as representative of the knowledge and practice of doctors in the institution or the wider pool of doctors in Singapore. Notwithstanding these limitations, we believe this study provides valuable information that can help improve compliance with published guidelines on brain death testing among clinicians in Singapore.

The majority of respondents in this study were relatively

inexperienced and junior doctors and may be reflective of the need to maintain a large enough pool of doctors performing brain death certification to fill the certification roster all year round. It has been suggested that only neurological experts should be involved in the diagnosis of brain death.¹⁶ In our study, the majority of physicians reported that they had performed only 5 or fewer brain death certifications in the preceding 3 years. Evidence from studies done elsewhere does not support the view that experience and expert knowledge improve compliance with published guidelines. A 1986 survey of American neurologists on their conduct of the apnoea test found that only 88% actually tested for apnoea.¹² Of these, 74% used an apnoeic interval of 3 minutes or less, and 61% did not even administer any supplemental oxygen during testing. Bell et al¹³ surveyed members of the Neuroanaesthesia Society of Great Britain and Ireland, 70% of whom carried out brain death testing more than 5 times a year and found variability in testing for gag, caloric and apnoea similar to those seen in our study. Wijdicks¹⁷ acknowledged that “the determination of brain death is difficult” and noted that there has been no evidence to suggest that a second assessment by a different physician reduces errors in testing.

Of the 7 brainstem tests, the caloric and apnoea tests seem most prone to error and variation in practice. It appears that the speed of water injection during caloric testing is an especially contentious area. Both the American Academy of Neurology guidelines^{18,19} and the United Kingdom Code of Practice³ call for an injection of 50 mL over 1 minute. This slow rate is difficult to achieve in practice. During caloric testing, the main aim is to apply ice-cold water for a sufficiently long duration (arbitrarily set at 1 minute) to ensure that adequate cooling of the semicircular canals occurs. The actual volume of water used is of secondary importance as long as sufficient cooling of the tympanic membrane occurs. We suggest that “infusing” an unspecified volume of ice-cold saline into the external ear canal from a suspended IV infusion bag for 1 minute may be a better way of carrying out this test. Physicians should also appreciate the need to continue observation for at least 1 minute after injection (in case of a delayed response), and to allow at least 5 minutes to elapse before testing the other side (in case of overriding effects from the previously irrigated ear).¹⁷

The reluctance of physicians to perform the caloric test in the presence of tympanic membrane perforation should also be addressed. The presence of a hole in the tympanic membrane is not a contraindication to performing the caloric test in that ear. The only exception being situations where the likelihood of brain death is low and the conduct of the caloric test may lead to the damage of middle ear structures and introduce infection.

Establishing absence of hypercarbic respiratory drive is normally the last and final step of brain death certification.²⁰ However, the apnoea test is complicated to perform and carries significant risks of complications, especially if performed without adequate precautions.¹⁷ At best, an incorrectly performed test may result in premature termination of the test before reaching the required PaCO₂ target; at worst, significant irreversible ischaemic damage to organs may result. Physicians must be aware, not only of the minimum PaCO₂ that must be achieved, but also the steps that must be taken to prepare the patient, with the monitoring required and what to do in the event of haemodynamic instability during conduct of the test. We believe that this is best addressed by providing a detailed written protocol, as well as conducting physician training on the proper conduct of this test.

Physiological and biochemical limits as preconditions to brain death testing are another area of variation in practice. As a first step to certification of brain death there must be irrefutable evidence of structural damage to the brain that can plausibly lead to brain death, e.g., CT scan evidence of a large intracerebral clot with mass effect and midline shift. This is followed by checking through the medication history, and reviewing the haemodynamic parameters and laboratory results to rule out known neurological and metabolic co-morbidities that can confound the neurologic findings, e.g., hypotension, hypoxaemia, hypothermia and hypoglycaemia.²¹ Beyond these well-published exclusionary conditions (which are equally applicable to the brainstem or whole brain death criteria), most guidelines and legislations do not state specific limits and deliberately allow room for clinical judgment, acknowledging the lack of evidence to support recommending rigid physiological and biochemical limits. However, this failure to set limits may contribute to uncertainty and confusion amongst relatively inexperienced physicians during brain death testing. Our survey has identified threshold values of physiological limits that were acceptable to a majority of our surveyed physicians, and these agree closely with those reported by Bell et al,¹³ suggesting that they may be generalised. While it would be inappropriate to insist upon these limits as standards, they could be incorporated into local protocols to provide guidance to more inexperienced physicians who may need reassurance that their practice is consistent with those of colleagues. These limits may also minimise the application of inappropriately lax limits, which can compromise test validity.

The similarity of our results to those of Bell et al¹³ suggests that the difficulties encountered in brain death testing at the bedside are universal. Nevertheless, like previous commentators,²² we must emphasise that these findings are not an indictment of the failure of current brain

death certification procedures. In our institution, there exists multiple layers of safeguards in the certification of brain death, starting first with a clinical diagnosis of brain death by the attending intensivist and neurosurgeon (or other specialists, depending on the clinical department into which the patient was admitted) in the ICU, followed by independent verification of brain death by 2 clinicians on the brain death certification roster. In addition, the answers from respondents in our survey may not reflect actual practice at the bedside, but rather the answers based on knowledge retained by physicians, which at the time of brain death testing is usually augmented by referring to written guidelines and protocols in the ICU. Any inaccuracies in knowledge and practices found in this study may have therefore been greatly exaggerated. What our study does indicate is that brain death testing is a complex and uncommonly performed procedure, and hence argues strongly for providing comprehensive on-site guides for clinicians at the bedside.

Based on our findings, we have since revised several aspects of our hospital protocol on brain death certification to improve the quality and outcome of the certification process: (1) provide a bedside guide which describes the conduct of the brainstem tests in greater detail and (2) highlighting important areas of potential confusion or uncertainty in the guide with explanatory notes added. This guide is attached as an appendix to this paper. We have also embarked, in collaboration with the Singapore Ministry of Health, to conduct an instructional course on Brain Death Testing and Certification for clinicians. These changes are in keeping with concerns echoed by Wijdicks,²⁰ who emphasised the importance of “standardisation of policy, appropriate education of staff, introduction of checklists in intensive care units, and brain death examination by designated experienced physicians who have documented proficiency in brain death examination”.

Conclusion

Brain death testing is a complex and infrequently performed procedure, which is prone to variability in performance, despite the existence of rigorous and specific guidelines. Training is obviously essential, but may not be sufficient in itself. To insist that only senior physicians or neuroscience specialists perform brain death testing is not always practical, and may not guarantee compliance with published guidelines. Instead, national agencies with oversight responsibilities for brain death certification and organ procurement, in collaboration with individual institutions, should ensure that clear, detailed, and regularly updated protocols exist at the bedside to assist clinicians. Surveys similar to ours may be useful in highlighting areas of shortfall in these protocols that can then be addressed and improved upon.

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Appendix

TTSH Brain Death Testing Guide

We understand that you do not perform brain death certification on a regular basis and may not recall the details of each test offhand. We have therefore compiled these concise guidelines to the 7 tests you will need to perform. On the reverse side are additional explanatory notes on each test that you may refer to should you require additional information.

First, ensure that these pre-conditions have been met before performing the 7 brainstem tests:

- a) Have an identifiable, irreversible structural cause for brain death present (CT or MRI evidence)
- b) Exclude other reversible causes of CNS depression
 - i) Drugs (narcotics, barbiturates, benzodiazepines, tricyclic antidepressants, phenothiazines, lithium, ethanol)
 - ii) Hypotension (SBP <90 mm Hg); Hypoxia (PaO₂ <60 mm Hg)
 - iii) Hypothermia (>35°C); endocrine causes (e.g. hypothyroidism)
 - iv) Severe electrolyte and/or acid base disorders; hypoglycaemia
- c) Ensure absence or reversal of neuromuscular blockade

1. Absent pain response

- Apply firm pressure with thumb over the supraorbital notch and observe for response in face or extremities.
 - Apply sternal rub or pressure to the nail beds of all 4 extremities.
- ⇒ **There should be no limb movements or facial grimaces elicited**

2. Absent pupillary response to light stimulation

- Check that no anti-cholinergic drugs or eyedrops have been administered recently.
 - Shine a bright light into each eye and observe for a pupillary light response
- ⇒ **There should be no constrictive pupillary response in both eyes.**

3. Absent corneal reflex

- Elevate the eyelid and touch the cornea with a wisp of cotton wool.
 - If no response is elicited, repeat test by applying firm pressure with a moistened cotton bud, taking care to avoid traumatising the cornea.
- ⇒ **There should be no muscle contractions elicited around the eyes (from the orbicularis oculi).**

4. Absent oculo-cephalic reflex (Doll's eye reflex)

- This test is contra-indicated if the cervical spine has not been cleared.
 - Stand at the head end and grasp the sides of patient's head firmly with both hands and hold the eyelids open with both thumbs. Turn the head quickly 90 degrees to the left and to the right and observe for movements of the eyes
- ⇒ **The eye should not move with head turning but remain fixed in the midline, turning with the head.**

5. Absent gag and cough reflex

- Using one spatula to depress the tongue, apply firm pressure to the posterior pharyngeal wall with a second wooden spatula.
 - Insert a suction catheter all the way down the endotracheal tube to stimulate the trachea
- ⇒ **There should be no gagging or coughing elicited.**

6. Absent oculo-vestibular reflex (caloric test)

- Inspect both external ear canals with an otoscope to ensure intact tympanic membranes and rule out obstruction with blood or other debris. Perforation of the TM is not a contraindication to caloric testing.
 - Elevate the head of bed to 30°. Have an assistant elevate both eyelids. Using a black suction catheter and 50 mL syringe, inject 50 mL of ice-cold water slowly (over 15 to 30s) into the ear. Look for tonic deviation of the pupil towards the ear being irrigated. Observe for at least 1 minute.
 - Wait 5 minutes and repeat test on the other ear.
- ⇒ **There should be no eye movements noted.**

7. Apnoea test

- Pre-oxygenate the patient with 100% oxygen for 10 to 20 minutes before commencing the test.
 - Check an arterial blood gas (ABG) to determine the baseline PaCO₂ (should be around 35 to 40 mm Hg).
 - Monitor ECG, BP, and SpO₂ and ensure that systolic BP >90 mm Hg and SpO₂ >90% throughout the test. If SBP <90 mm Hg or SpO₂ <90% or severe arrhythmias develop, take an ABG and reconnect to ventilator.
 - Insufflate oxygen at 6L/min via white or green suction catheter after disconnecting from the ventilator. Take care to avoid passing the catheter too far in (endobronchial position).
 - Disconnect from the ventilator and observe for respiratory efforts from the patient. Observe for 5 to 8 minutes and check an ABG before reconnecting the patient to the ventilator.
- ⇒ **There should be no respiratory movements seen at a PaCO₂ > 50 mm Hg or a rise of >20 mm Hg over the baseline.**
- If the target PaCO₂ has not been reached, repeat the test (after pre-oxygenation and restoration of normocapnia) and lengthen the apnoeic interval to 10 minutes.
 - If any of the 7 brainstem tests cannot be completed and those completed are consistent with brain death, supplementary tests (cerebral angiogram or radionuclide scan) may be performed to confirm brain death.

TTSH Brain Death Testing Guide

Explanatory notes on brain death testing

Pain response

- Pain should be applied to a number of sites, including supraorbital nerve, sternum and fingers.¹ It is important to apply pain to and look for responses in the cranial nerve distribution.
- Spontaneous movements of the limbs from spinal mechanisms ("spinal reflexes") can occasionally occur, especially in younger patients. These often occur during apnoea testing, in response to hypoxia, respiratory acidosis, or hypotension, rather than during application of painful stimuli. These reflexes include rapid flexion in arms, raising of all limbs off the bed, grasping movements, spontaneous jerking of one leg, walking-like movements, and movements of the arms up to the point of reaching the ETT.²

Pupillary response

- It is not necessary for pupils to be fully dilated; however they should not be constricted.¹ In brain dead patients, they are usually moderately dilated (4 to 6 mm).²

- Round, oval or irregularly shaped pupils are compatible with brain death.²
- Pre-existing anatomic abnormalities of the iris or effects of previous surgery should be excluded.²

Oculo-cephalic (Doll's eye) reflex

- Testing is done only when no fracture or instability of the cervical spine is present.²
- The normal response is eye deviation to the side opposite to that of head turning.

Gag and cough reflex

- Both reflexes must be tested. The gag reflex may be difficult to interpret in orally intubated patients.²
- Tugging on the ETT or tracheostomy tube is not an adequate stimulus for testing the cough reflex.

Oculo-vestibular reflex (caloric test)

- The purpose of otoscopy is to look for obstruction of the ear canal by clotted blood or earwax, and presence of acute injury or disease in the middle ear, which may render the test unreliable. Gentle attempts to irrigate or clear the canal of debris may be attempted; referral to an ENT specialist may be required.
- In chronic perforations of the tympanic membrane, cold air has been suggested as an alternative stimulus to water.³
- Base of skull fractures resulting in blood, CSF or brain tissue in the external auditory canal is a contraindication to the test.³ Supplementary testing is indicated in this case.
- Elevation of the head to 30° ensures that the lateral semi-circular canals are vertical, maximising the response.³
- Local guidelines suggest that the eyes be observed for up to 3 minutes after injection;¹ AAN and other guidelines recommend 1 minute and waiting at least 5 minutes before testing the other side.^{2,3}

Apnoea testing

- AAN guidelines² suggest the following pre-requisites to minimise the risk of deterioration in vital signs (hypoxia, hypotension, arrhythmias) during testing. These are a) core temperature $\geq 36.5^\circ$; b) systolic BP ≥ 90 mm Hg; c) euvolaemia or positive balance in previous 6 hours; d) normocapnia or PaCO₂ ≥ 40 mm Hg; e) normoxaemia or PaO₂ ≥ 200 mm Hg.
- Insufflation of oxygenation and preoxygenation help to prevent hypoxaemia during the apnoeic period. Preoxygenation with

100% O₂ for 10 to 30 minutes has been suggested.³ Using flow rates in excess of 6 L/min during the test may result in partial clearance of CO₂ and hence invalidate the test.³

- The catheter should be secured at the appropriate depth to avoid endobronchial placement. It should also be narrow enough to allow expiratory flow around it, or else air trapping may occur leading to hypotension and pneumothorax.
- Respiration is defined as abdominal or chest excursions that produce adequate tidal volumes.²
- Respiratory-like movements can occur (agonal breathing patterns), characterised by shoulder elevation and adduction, back arching, and intercostals expansion without generating significant tidal lung volumes. Spinal reflexes may also be seen. These movements are compatible with the presence of brain death.²
- There is no firm evidence on the upper limit of PaCO₂ required for maximal stimulation of the respiratory centre. Local and UK guidelines target a PaCO₂ of >50 mm Hg.^{1,4} Most other guidelines adopt a higher threshold of 60 mm Hg.^{2,3} Others have suggested using an increase of ≥ 20 mm Hg over baseline PaCO₂² or an arterial pH of <7.30 .³
- Local guidelines¹ recommend an apnoeic interval of 5 minutes. PaCO₂ rises by 2.5 mm Hg/minute on average. AAN guidelines² recommend an apnoeic interval of 8 to 10 minutes.
- If the test has to be aborted prematurely because of cardiovascular instability or desaturation, and the PaCO₂ has not reached the target level, this is an indeterminate result, and supplementary testing is indicated to confirm the diagnosis of brain death.

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