Original Investigation

Variability of Brain Death Policies in the United States

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IMPORTANCE Brain death is the irreversible cessation of function of the entire brain, and it is a medically and legally accepted mechanism of death in the United States and worldwide. Significant variability may exist in individual institutional policies regarding the determination of brain death. It is imperative that brain death be diagnosed accurately in every patient. The American Academy of Neurology (AAN) issued new guidelines in 2010 on the determination of brain death.

OBJECTIVE To evaluate if institutions have adopted the new AAN guidelines on the determination of brain death, leading to policy changes.

DESIGN, SETTING, AND PARTICIPANTS Fifty-two organ procurement organizations provided US hospital policies pertaining to the criteria for determining brain death. Organizations were instructed to procure protocols specific to brain death (ie, not cardiac death or organ donation procedures). Data analysis was conducted from June 26, 2012, to July 1, 2015.

MAIN OUTCOMES AND MEASURES Policies were evaluated for summary statistics across the following 5 categories of data: who is qualified to perform the determination of brain death, what are the necessary prerequisites for testing, details of the clinical examination, details of apnea testing, and details of ancillary testing. We compared these data with the standards in the 2010 AAN update on practice parameters for brain death.

RESULTS A total of 508 unique hospital policies were obtained, representing the majority of hospitals in the United States that would be eligible and equipped to evaluate brain death in a patient. Of these, 492 provided adequate data for analysis. Although improvement with AAN practice parameters was readily apparent, there remained significant variability across all 5 categories of data, such as excluding the absence of hypotension (276 of 491 policies [56.2%]) and hypothermia (181 of 228 policies [79.4%]), specifying all aspects of the clinical examination and apnea testing, and specifying appropriate ancillary tests and how they were to be performed. Of the 492 policies, 163 (33.1%) required specific expertise in neurology or neurosurgery for the health care professional who determines brain death, and 212 (43.1%) stipulated that an attending physician determine brain death; 150 policies did not mention who could perform such determination.

CONCLUSIONS AND RELEVANCE Hospital policies in the United States for the determination of brain death are still widely variable and not fully congruent with contemporary practice parameters. Hospitals should be encouraged to implement the 2010 AAN guidelines to ensure 100% accurate and appropriate determination of brain death.

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The Uniform Determination of Death Act established a legal determination of brain death as "irreversible cessation of all functions of the entire brain, including the brain stem."[1] However, the Uniform Determination of Death Act included a statement that would allow differences of interpretation over time: "A determination of death is made with acceptable medical standards." In 1995, the Quality Standards Subcommittee of the American Academy of Neurology (AAN) published practice parameters for determining brain death in adults.[2] In 2006-2008, a study was performed to determine how closely leading US neuroscience institutions were adhering to these parameters and found that there were wide variations in terms of prerequisites, methods of testing (including apnea testing), and the use and performance of ancillary testing.[3]

Subsequently, in 2010, updated practice parameters were put forth through the AAN,[4] with the aims of performing an evidence-based review of the literature since 1995 regarding the validity of determination of brain death and providing clear, step-by-step instructions, including a detailed checklist, for accurate and consistent determination of brain death, specifically, prerequisites, clinical testing, ancillary testing, and documentation. The main premise was that the 2010 AAN practice parameters (AANPP) would be widely adopted, be easy to use, and ensure that determination of brain death is performed accurately 100% of the time.

The objective of the current study was to assess how widely these updated practice parameters have been incorporated into hospital policies in the United States. We have chosen to assess not just the leading neuroscience institutions but all institutions in the United States in which determination of brain death may take place. Our hypothesis was that hospitals had taken steps in the years following the AANPP to update their guidelines.

Methods

Similar to the study in 2008,[3] we sought to obtain protocols on brain death directly from hospitals. For this study, we specifically asked only for policies regarding adult patients. Given the large number of hospitals with intensive care capabilities (>600 estimated)—a requirement for the determination of brain death given the need for ventilatory support—we enlisted the help of the Association of Organ Procurement Organizations to encourage regional organ donation organizations to obtain protocols on determination of brain death from the hospitals they served. The initial appeal was from staff members of the Association of Organ Procurement Organizations, followed by direct communication from one of us (D.M.G.) encouraging participation. Institutions were provided assurance that there would be no information published that could identify them and that the purpose of the study was to provide summary statistics across all participating institutions. Informed consent and institutional review board approval were not required; the study involved no human participants and the guidelines were not considered private property.

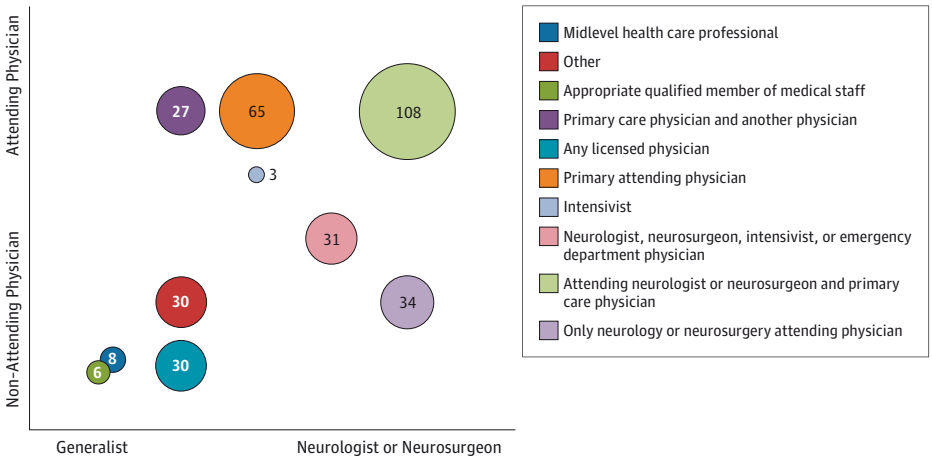
We again used 5 categories of data: determination performance (ie, who was qualified to determine brain death), prerequisites for testing, details of the clinical examination, details of apnea testing, and details of ancillary testing. Using this framework, we created summary statistics for variability or commonality with the 2010 AANPP and between institutions for data that were not specified in the 2010 AANPP. The data were analyzed by all of us from June 26, 2012, to July 1, 2015.

Results

Fifty-two of 508 organ procurement organizations provided policies for hospitals in the regions they served. We obtained 508 unique hospital or health system policies (often, several hospitals would use a common policy adopted by a health system; thus, the total number of hospitals represented is higher than 508). Of the 508 policies, 492 provided adequate data for analysis. There was broad representation from hospitals in all 50 states.

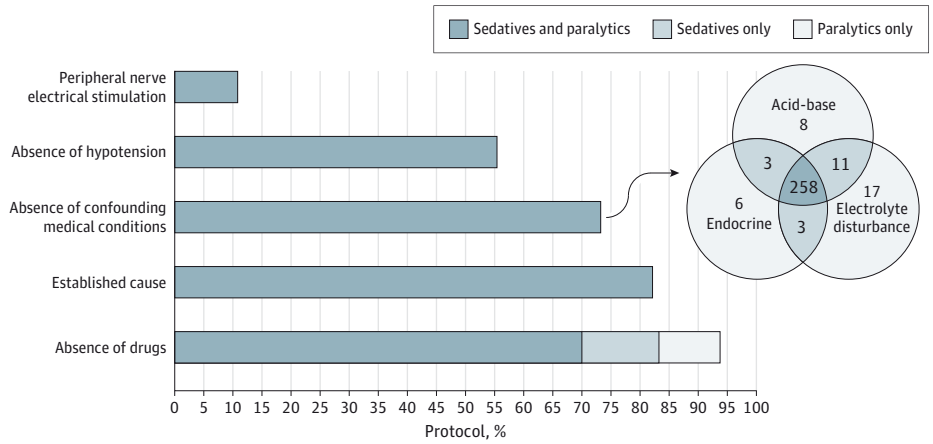
Regarding who could perform the determination of brain death (**Figure 1**), 33.1% of policies (163 of 492) required spe-

Figure 1. Type of Health Care Professional Performing Brain Death Determination



Types and qualifications of health care professionals performing determination of brain death, with larger circles representing more of that type of health care professionals.

Figure 2. Prerequisites for Clinical Testing



The prerequisites prior to performing determination of clinical brain death are shown here, with their relative percentages as found in the policies.

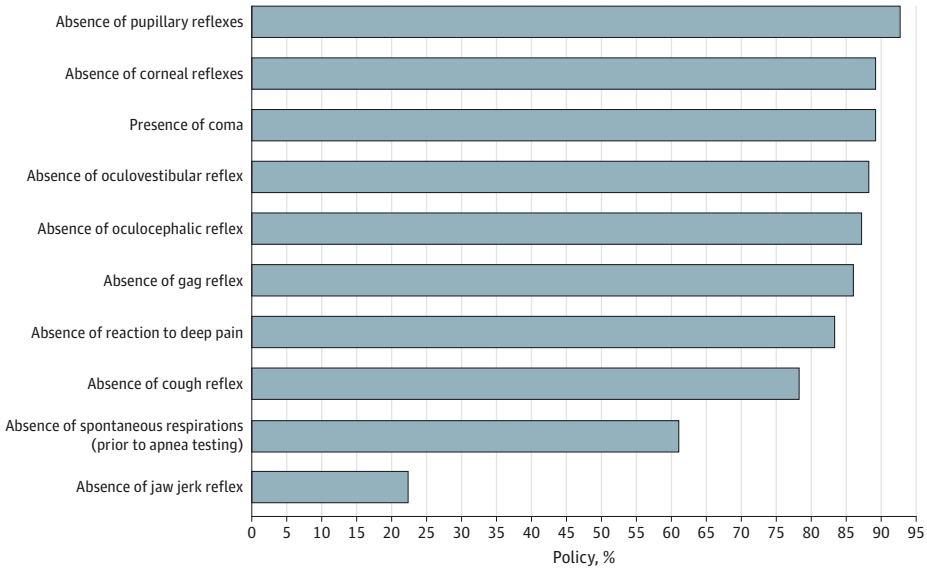
cific expertise in neurology or neurosurgery. There was no mention of who could perform the determination in 150 policies. Two hundred twelve of 492 policies (43.1%) stipulated that an attending physician determine brain death; 8 policies allowed advanced practice health care professionals to make the determination. The AANPP state that all physicians are legally allowed to determine brain death in most of the 50 states, although some states require specific expertise. Most hospitals (324 of 492 [65.9%]) required 2 separate examinations to determine brain death, and 103 (20.9%) required more than 2 examinations (up to 5); 64 policies (13.0%) required only 1 examination (eFigure in the Supplement). The AANPP state that 1 examination is sufficient, although they did recognize that some states require 2 examinations. More than half the policies require that the 2 examinations, when required, be performed by different physicians. For policies that required more than 1 examination, 54.1% (266 of 492) specified a waiting period between examinations; 27 (10.2%) required less than 6 hours, 189 (71.1%) required at least 6 hours, 7 (2.6%) required at least 12 hours, and 3 (1.1%) required at least 24 hours. A specific waiting period for cardiac arrest was stipulated in 7.1% of policies (35 of 491); that waiting period was most commonly set at 24 hours or more (29 of 35 policies [82.9%]). Stratification by age was present in 28.9% of policies (142 of 492), and 1 to 6 different age groups were specified within policies. Two hundred one of 492 policies (40.9%) required notification of the local organ procurement organization when testing for brain death was being considered.

Regarding prerequisites for clinical testing (**Figure 2**), 459 of 491 protocols (93.5%) stipulated prerequisites before clinical testing. Of these protocols, 82.9% (408 of 492) required that the cause of brain dysfunction be established, and 94.3% (463 of 491) required the absence of effect of specific medications, including sedatives alone (65 of 463 [14.0%]), paralytics alone (56 of 463 [12.1%]), or both (342 of 463 [73.9%]). Specific drug levels (eg, for barbiturates) were mentioned in 123 of 491 protocols (25.1%) and absence of paralytic effect measured by peripheral nerve electrical stimulation in 55 of 491 protocols (11.2%). Absence of hypotension was required by more than half (276 of 491 [56.2%]) of the protocols, and 79.4% (181 of 228) required the patient's temperature to be at least 36°C. Absence of confounding medical conditions was required by most policies (363 of 491 [73.9%]), and, of these protocols, the full combination of severe electrolyte, acid-base, and endocrine disorders was specified in 71.1% (258 of 363).

Regarding the clinical examination (**Figure 3**), the vast majority of policies specifically required apnea testing (478 of 491 [97.4%]), but 29 (5.9%) mandated that ancillary testing be performed in all patients. Of 491 policies, 441 (89.8%) stipulated the presence of coma, 414 (84.3%) the absence of reaction to deep pain (217 of 490 [44.3%] specified painful stimulation on the cranium), 456 (92.9%) the absence of pupillary responses (141 [28.7%] specified pupil size), 440 (89.6%) the absence of corneal reflexes, 433 (88.2%) the absence of the oculocephalic ("doll's eye") reflex, 438 (89.2%) the absence of the oculovestibular ("cold caloric") reflex, 111 (22.6%) the absence of a jaw jerk reflex, 428 (87.2%) the absence of a gag reflex, 388 (79.0%) the absence of a cough reflex, and 305 (62.1%) the absence of spontaneous respirations while still receiving mechanical ventilation.

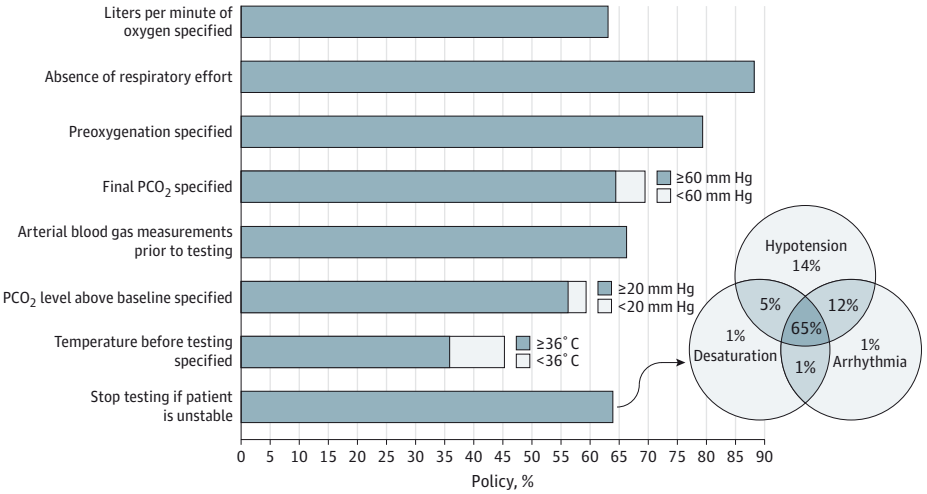
Specific to apnea testing (**Figure 4**), 326 of 491 policies (66.4%) specifically required arterial blood gas measurements before initiation of testing for apnea, and 290 (59.1%) delineated the appropriate baseline P_{CO_2} level. Preoxygenation was specified in 388 of 491 policies (79.0%). Most policies (281 of 491 [57.2%]) recommended maintaining oxygenation by a cannula placed within the endotracheal tube (but only 3 suggested deflating the cuff); 67 of 491 (13.6%) allowed continuation of mechanical ventilation with only flow by oxygenation and no delivery of mechanical breaths. The specific number of liters per minute of oxygen supplied during the apnea test was overtly stated in 310 of 491 policies (63.1%). Of these policies, 172 (55.5%) specified 4 to 6 L/min, 78 policies (25.2%) stipulated a higher flow rate than 6 L/min, and 16 (5.2%) stipulated a flow rate lower than 4 L/min. Four hundred ten of 491 policies (83.5%) specified a final P_{CO_2} level; of these, 379 (92.4%) required that it be 60 mm Hg or higher (to convert to kilopascals, multiply by 0.133). Most policies (288 of 491

Figure 3. Specifics of Clinical Examination Requirements



The details of the clinical examination as stipulated in the policies are represented here.

Figure 4. Specifics of Apnea Testing Requirements

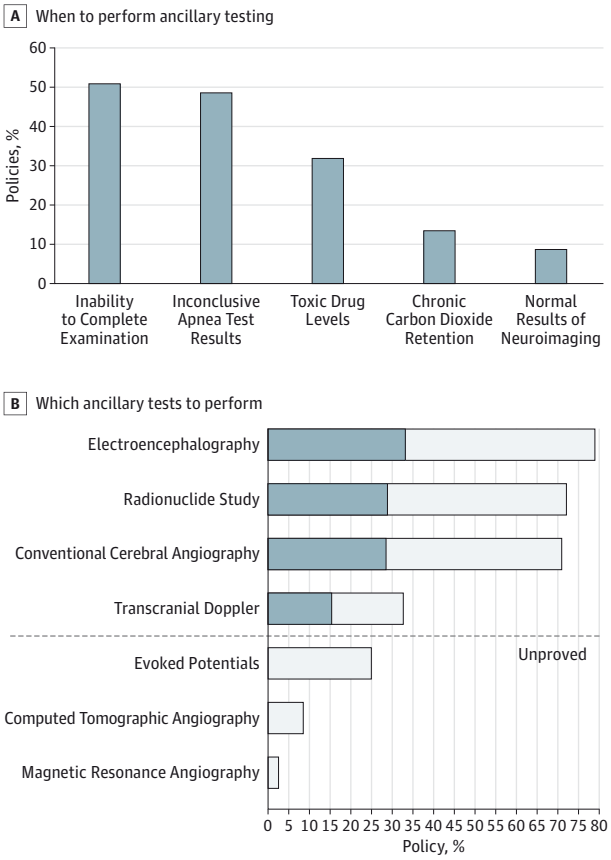


Specific criteria for determination of brain death pertaining to the apnea test are shown here.

[58.7%]) expressly allowed for an increase of the P_{CO_2} level above an elevated baseline level for patients who were known to retain the carbon dioxide level; this increase was at least 20 mm Hg in 275 of 288 policies (95.5%). Four hundred thirty-two of 491 policies (88.0%) specified the absence of respiratory effort during the apnea test, and 312 (63.5%) instructed that the apnea test should be stopped if the patient was unstable (200 of these policies [64.1%] specified that hypotension, arrhythmia, and desaturation must all be present to stop the apnea test). Some policies (60 of 491 [12.2%]) provided a mechanism to repeat the test if results were indeterminate but the patient was stable.

Ancillary testing was mandatory in 32 of 491 policies (6.5%) (**Figure 5**). Specific situations in which ancillary testing should be considered were stipulated in 315 of 491 policies (64.2%); these scenarios included the inability to complete the examination (251 of 491 policies [51.1%]), toxic drug levels (157 of 491 [32.0%]), inconclusive results on apnea testing (238 of 491 [48.5%]), normal results on neuroimaging (43 of 491 [8.8%]), and chronic carbon dioxide retention level (67 of 491 [13.6%]). Electroencephalography was listed as an ancillary test in 387 of 491 policies (78.8%) (with details of the performance given in 164 [33.4%]), transcranial Doppler ultrasonography in 162 of 491 policies (33.0%) (with details of the performance in 76 [15.5%]), conventional cerebral angiography in 350 of 491 policies (71.3%) (with specifics in 141 [28.7%]), and a radionuclide cerebral blood flow study in 355 of 491 policies (72.3%) (with specifics in 143 [29.1%]). Evoked potentials, a test that has gone out of favor for determination of brain death, was still mentioned in 128 of 491 policies (26.1%). Ancillary tests not en-

Figure 5. Specifics of Ancillary Testing



A, When to perform ancillary testing. B, Which ancillary tests to perform. Specifics mentioned are shaded in the darker shade.

dorsed by the AANPP included computed tomographic angiography in 44 of 491 policies (9.0%) and magnetic resonance angiography in 14 (2.9%).

Discussion

The revision of the AANPP in 2010 strived to make the determination of brain death simple and straightforward, with clear guidance about how to approach difficult situations and when to pursue ancillary testing. It was anticipated that the updated practice parameters would also be acceptable in hospitals worldwide, with the understanding that there are clear practice differences in different countries and regions.[5-7]

We made several observations in this study. First, although it is more common that attending physicians—mostly those with neuroscience expertise—determine brain death, many policies still allow for more junior physicians to make the determination. Arguably, the more inexperienced the physician, the more prone to error he or she may be. Second, there remains significant variability in the number of examinations required to determine brain death as well as the waiting periods between examinations when multiple examinations are required. Prolonged waiting periods have been shown to have a negative effect on organ donation.[8] Third, the level of compliance with the 2010 practice parameters remains deficient, particularly for ensuring the absence of confounding conditions, some lower brainstem function testing, and some specifics of apnea testing, including P_{CO_2} goals. Last, the specifics of approved ancillary testing are often missing, and unapproved and/or nonvalidated ancillary tests are sometimes included.

As the AANPP update was released in 2010, we delayed starting the current study until 2012 and continued collecting policies through 2014 with the hope of allowing physicians and hospitals adequate time to update their policies. The 2010 update was meticulously planned, was created to be overtly conservative (ie, erring toward not determining brain death unless strict criteria are met), and did not receive significant criticism. We believe these factors are evidenced by the fact that most of the details specified in the new parameters have been widely incorporated into US policies on determining brain death. However, the adoption of the AANPP has not been uniform or ubiquitous, for which there may be several reasons.

First, the fact that there have been no legitimate "false-positive" determinations of brain death according to the 1995 practice parameters (ie, a determination that a patient experienced brain death without confounding who then regained even minimal brain function) may paradoxically make physicians and hospital administrators feel reassured that their policies are working fine as they are and that no changes are needed. We believe this choice would be an error in judgment because there are several important changes in the 2010 AANPP that prevent misdiagnosis (eg, specifics about ruling out drug intoxication and raising the minimum temperature to 36°C). Although the lowest acceptable temperature is difficult to determine, 36°C is conservative and attainable for the vast majority of patients and definitively eliminates concern for a potential confounding effect of hypothermia on brain function.

Second, changes require not only time but also the desire and drive to change. Physicians and administrators are busy, and without an external body (eg, a government or state accreditation organization) holding them responsible, they may be slow to incorporate the necessary changes to be compliant with the new practice parameters. Without proponents of the AANPP on the local level to push for changes to policy, revision becomes deprioritized or not done at all.

Third, physicians should be encouraged to work with their information technology groups to incorporate checklists, detailed protocols, and order sets into electronic medical record systems to make the determination of brain death more streamlined and straightforward.

We do not believe that the 2010 AANPP update inherently creates any challenges to widespread adoption. On the contrary, we believe it provides a simple and methodical process that can easily be incorporated into any hospital in which the determination of brain death takes place. With more uniformity and specificity in policies should come more consistency and accuracy with determinations of brain death in practice, although one could argue that there may be differences between having an updated policy and having accurate docu-

mentation of brain death declaration for individual patients.[9] Future studies should concentrate on improving policies as well as practice and documentation.

Our study has several limitations. First, despite very aggressive efforts, we were unable to procure every policy in every hospital in the United States. We estimate that there are likely between 600 and 650 hospitals with intensive care unit capabilities, and the 508 policies we obtained represent approximately 80% to 85% of US policies; it is unlikely that the remaining policies would influence our results very much. Second, what happens in practice at local hospitals was not evaluated in this study; physicians may be more or less thorough than what is stipulated in their policies. Third, it is possible that some of the hospitals whose policies we obtained early in the study did change their protocols later to be more compliant with the 2010 AANPP. Fourth, it is possible that some of the policies evaluated herein were not just for individual hospitals but also for health systems, and thus we could have underrepresented how widespread the included policies actually were. We do not think that this underrepresentation would significantly affect the findings. Finally, although we worked with organ procurement organizations to help assemble the policies at the local level, these organizations played no role in the extraction of the data, the analysis, or the interpretation or presentation of the results.

Conclusions

Ongoing gaps remain between written hospital policies for the determination of brain death since the 2010 AANPP update. However, it is encouraging that, even if some hospitals have not updated their policies, no legitimate reports of patients regaining any brain function after being declared brain dead according to the 1995 AAN guidelines have surfaced. The determination of brain death should be accurate 100% of the time, and we have taken steps to ensure that policies can be written in a manner to ensure such accuracy and consistency. We strongly encourage physicians, hospital administrators, and accrediting bodies to bring their policies into full concordance with the 2010 AANPP. Regular audits of practice might further ensure diagnostic accuracy. Acknowledgment of the AAN guidelines by US hospital practice committees would help set a standard that could be a model for other countries.

ARTICLE INFORMATION

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Study concept and design: Greer, Varelas, Henderson.
Acquisition, analysis, or interpretation of data: Greer, Wang, Robinson, Varelas, Wijdicks.
Drafting of the manuscript: Greer, Wang, Varelas, Henderson, Wijdicks.
Critical revision of the manuscript for important intellectual content: Greer, Wang, Robinson, Wijdicks.
Statistical analysis: Greer, Wang.
Administrative, technical, or material support: Greer, Wang, Robinson.
Study supervision: Greer, Varelas, Wijdicks.

Conflict of Interest Disclosures: None reported.

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