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Comparison of 1 vs 2 Brain Death Examinations on Time to Death Pronouncement and Organ Donation: A 12-year Single Center Experience

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- Dr. P. Varelas was an uncompensated member and subsequently Chair of the Advisory Board of Gift of Life of MI. He has received grants for Brain Death Simulation from the Gift of Life Foundation
- Dr. M. Rehman was an uncompensated member and subsequently Chair of the Advisory Board of Gift of Life of MI. He has received grants for Brain Death Simulation from the Gift of Life Foundation
- Dr. C. Mehta reports no disclosures relevant to the manuscript
- Lisa Louchart was a Gift of Life of MI employee for the initial years of the study and subsequently became a Henry Ford Hospital employee

- Dr. L. Schultz reports no disclosures relevant to the manuscript
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- Dr. M. Kananeh reports no disclosures relevant to the manuscript
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Abstract

Objective: To fill the evidence gap on the value of a single (SBD) or dual brain death (DBD) exam by providing data on irreversibility of brain function, organ donation consent and transplantation

Methods: 12-year tertiary hospital and organ procurement organization data on brain death (BD) were combined and outcomes, including consent rate for organ donation and organs recovered and transplanted after SBD and DBD were compared after multiple adjustments for co-variates

Results: two-hundred sixty-six patients were declared BD, 122 after SBD and 144 after DBD. Time from event to BD declaration was longer by an average of 20.9 hours after DBD (p=0.003). Seventy-five (73%) families of patients with SBD and 86 (72%) with DBD consented for organ donation (p=0.79). The number of BD exams was not a predictor for consent. No patient regained brain function during the periods following BD. Patients with SBD were more likely to have at least one lung transplanted (p = 0.033). The number of organs transplanted was associated with the number of exams [beta coefficient, (95% CI) -0.5 (-0.97 to -0.02), p=0.044], along with age (for 5 year increase, -0.36 (-0.43 to -0.29), p<0.001) and PaO_2 level (for 10 mmHg increase, 0.026 (0.008 to 0.044), p=0.005) and decreased as the elapsed time to BD declaration increased (p=0.019).

Conclusions: A single neurologic examination to determine brain death is sufficient in patients with non-anoxic catastrophic brain injuries. A second examination is without additional yield in this group and its delay reduces the number of organs transplanted.

Introduction

One of the major changes in the current American Academy of Neurology Practice Parameter (AANPP) for BD determination [1] compared to the previous one [2], is the adoption of a single BD exam requirement. According to the AANPP, this approach is sufficient to pronounce BD in most of the States in the US.

The data, however, upon which this change was based were non-existent at the time of the AANPP publication. The concern of a SBD exam pronouncing patients BD "too soon" and with the risk of regaining brain function later, was mitigated by a small case-series of patients pronounced BD after a SBD exam without any re-emergence of brain function [3] and by a large New York State study which failed to find any return of brain function between the mandatory dual BD exams [4]. Both studies, published after the AANPP publication, were not followed by subsequent evidence to support this new paradigm. Moreover, the SBD exam was never adopted in the pediatric population [5] or in other countries [6-8], leading to an increased variability in BD evaluation.

In this current study, we aimed to answer 3 questions regarding SBD exam declaration. First, is SBD exam sufficient and did any patient regain brain function after the declaration? Second, was the consent rate for organ donation after SBD exam affected by this approach and delay in declaration? Third, was there any difference in the number of organs recovered or transplanted from the donor patients based on the number of declarations?

Methods

Standard protocol approvals, registrations, and patient consents

We performed an observational prospective review of all patients entered in the database over a 12-year period (1/2006-12/2017). An approval from an ethical standards committee and Institutional Review Board to conduct this study was received (*Henry Ford Health System IRB No 13832*).

Patient population

A prospective database that incorporated data from Gift of Life (GOL; the Organ Procurement Organization (OPO) for the State of Michigan) and Henry Ford Hospital (a large tertiary, level I Trauma center in Detroit) of patients who met criteria for BD was created in 2006, concurrent with the implementation of the hospital's new BD Policy. The reason this database was created by one of the authors, who served as Chair of the Henry Ford Hospital Organ Transplant Committee (PNV), was to prospectively collect data on all future patients who would be declared BD and assess any untoward effects on irreversibility and consent rate that the policy changes might evoke. All adult patients who were declared BD were identified from 3 sources: neurointensivist involved in the declaration, OPO or ICU team notification of the authors and monthly Organ Transplant Committee review of all OPO notifications for BD in the hospital. After identifying the patients who were declared BD, their information (*vide infra*) was entered in the secure database.

Brain Death Determination Protocol

Brain death is determined at Henry Ford Hospital based on a BD policy. Before 2006, the prior BD Policy was allowing only DBD (options # 2 and 3, *vide infra*). The new hospital policy antedated the current AANPP (published in 2010 [1]) because it was developed and implemented in 2006. Therefore, although our study enrolled patients with SBD exam before the AANPP established it as an acceptable alternative to the older DBD exam and continued thereafter, our primary goal was not to compare these two periods, before and after the AANPP publication. The three options for BD declaration at Henry Ford Hospital have been recently published [9]. According to the new, 2006 BD policy, BD is declared after either 1) a SBD exam followed by an apnea test (performed as per the AANPP [1, 2]) and a mandatory ancillary ("confirmatory") blood flow test in patients with catastrophic brain injuries (large hemorrhages or ischemic strokes or severe head trauma with clear signs of brain herniation), 2) two separate clinical BD exams (DBD) by two different attending physicians separated by at least 6 hours followed by apnea test after the 2nd exam (with optional ancillary test) or 3) two separate clinical BD exams (DBD) by two different attending physicians separated by at least 24 hours followed by apnea test after the 2nd exam (with optional ancillary test) in patients with anoxic brain injury. The decision to choose one of the three evaluation options was based on etiology, neuroimaging findings and the attending physician's preference [9]. This conservative approach of not fully adopting the SBD exam according to the AANPP (after it was published) for every patient evaluated for BD at Henry Ford Hospital was not based on local State regulations, but rather on concerns of reversibility (especially after hypoxic-ischemic injury) and unknown effects on consent rates and was similar to low adoption rates by other US hospitals [10].

Organ Donation Approach Process

The process for approaching families for Organ Donation followed at Henry Ford Hospital has also been recently published [9]. Pre-approach (any donation remark to the family before BD declaration) was not allowed. The OPO was notified within 1 hour if a ventilated patient reached Glasgow Coma Scale score of ≤ 5. After a patient was declared brain-dead, the news were conveyed to the family in a separate family meeting room by the declaring team. Families were presented information about the admission status, the treatments offered, the images that revealed the injury and the BD declaration process and all their inquiries were addressed; subsequently and independently, the OPO representative was introducing the concept of organ or tissue donation and was asking for consent. If donation was rejected, the patient was terminally extubated.

Data Review

Data entered into the registry included demographics, diagnosis (stratified into primary neurological etiology [hemorrhages, ischemic strokes or severe head trauma] and other [anoxic-ischemic injury or toxometabolic acute brain injury]), ICU of admission, number of BD determinations (one or two), service involved in the declaration, type of ancillary test, requirement for pressors or inotropes at the time of BD, presence of Diabetes Insipidus (DI) and its treatment, time between hospital admission or event that led to BD and 1st or 2nd BD exam, labs (basic metabolic panel and arterial blood gases) and vital signs closest to the time of death. GOL-provided data included registry status of the patient, whether consent was obtained, time from consent to arrival to the operating room (OR) for organ retrieval and the number of organs procured, discarded or transplanted (focusing on kidneys, lungs, heart and liver, because the number of pancreas and intestine transplanted was either very small or null). The diagnosis of DI

was made with polyuria (>300 ml of urine in 2 consecutive hours), diluted urine (urine specific gravity < 1.005) and increasing serum sodium [9].

Statistical analysis

Socio-demographic, medical and organ donation information, as well as year of death (including stratification based on the AANPP publication year, before and after 2010) were compared to assess *differences* between patients with SBD and DBD. For the binary and categorical variables, chi-square tests were used. For the continuous and ordinal variables, two-sample t-tests or Wilcoxon tests were used. For donors, ANOVA with Tukey's test for multiple comparisons was employed to assess the relationship between the time from catastrophic event to BD declaration or OR and the number of organs recovered and transplanted. Time between event and BD declaration was divided into four periods: 0-24 hours, 25-48 hours, 49-96 hours and >96 hours. Additionally, multivariate logistic and linear regression analyses were performed to assess the relationships of the number of BD exams with outcome variables of interest, while adjusting for potential confounding variables. These potential confounding variables included in these regression models had to have significant associations with both the number of BD exams and the outcome of interest. A p-value < 0.05 was considered statistically significant. SAS version 9.4 was used for analysis.

Data Availability

The study data are available and will be shared at the request of other investigators for purposes of replicating results.

Results

Two-hundred seventy-one patients were declared BD between 2006 and 2017 at Henry Ford Hospital, with 266 patients included in the analysis after excluding 5 patients with missing data. One hundred forty (53%) were male, 146 (55%) were African Americans, 87 (33%) Caucasians and 16 (6%) belonged to a different group. The mean age was 48.7 ±16.8 years (range 16 to 85). Twenty-five patients (9.4%) were registered donors at the time of BD, with this percentage increasing over the years, from 0% in 2006 to 28% in 2017 ($p < 0.001$).

One hundred and twenty-two (46%) patients underwent a SBD exam and 144 (54%) DBD exams [Table 1 and Data available from Dryad (Supplementary Table e-1]. Initial diagnosis, primary neurological cause, admission ICU, incidence of DI and ancillary testing differed between patients with SBD and DBD exams. More patients with primary neurological injury (ischemic stroke, ICH, SAH) were admitted to the NICU and were declared after a SBD exam, as compared to more patients with cardiac arrest, who were admitted to the other ICUs and were declared after DBD exams. There was also a decline in the rate of DBD exams over the years ($p = 0.003$) in the subgroup of patients with primary neurological injury, as more physicians were espousing the SBD exam for catastrophic brain injuries [Data available from Dryad (Supplementary Figure e-1]. There was also a trend for more neurointensivists to perform a SBD or at least one of the two DBD exams over the years [Data available from Dryad (Supplementary Figure e-2)]. Apnea test was not completed or aborted in 10-16% of patients due to instability and all these patients were declared brain dead after an ancillary test. Patients with SBD exam had higher rate of ancillary tests (as expected, since per policy every SBD exam had to be followed by an ancillary test), were on average older than patients with DBD exams and had

higher mean values for sodium, peak sodium, PaO_2 and systolic BP, while having lower mean values for potassium, creatinine, BUN and heart rate when compared to patients with DBD exams (Table 2). As expected, the time between the event that led to BD and the final BD exam was longer for patients with DBD exams compared to those with SBD exams by an average of 20.9 hours. For patients with DBD exams, the mean time between exams was 22.2 ±10.7. No patient with SBD or DBD exam regained any brain function nor had cardiac arrest before organ retrieval in the OR. No patient, who was not a donor and was extubated, exhibited any breathing or other returning brain function and all developed cardiac arrest within few minutes post-extubation.

One hundred sixty-one (72.5%) families consented for organ donation amongst the 222 families who were approached by GOL. There was no difference in the consent rate for organ donation between those with SBD or DBD exams [75 (46.6%) and 86 (53.4%) patients, respectively, p = 0.9], even after adjusting for year of the exam and excluding patients in the registry. There was neither any difference in consent rate based on the time-period from injury to BD declaration after adjustment for race, apnea test completion and number of exams. A significantly longer interval lapsed between the onset of the catastrophic event and the time the patient entered the OR for organ retrieval in patients with DBD compared to patients with SBD exam (by an average of 20.3 hours). This was mainly due to the delay that occurred between the two exams in this group and less to the delay after consent was obtained (i.e the time between consent and OR), although there was also a trend for longer delays to reach the OR after consent was obtained in DBD patients (by an average of 6.2 hours, p = 0.08, Table 2).

In patients with DBD exams there was an increase in the dose or number of pressors or inotropes between the 1st and the 2nd exam in 17.7%, a decrease in 55.4% and in 26.6% there was no

change. More patients were off pressors or inotropes during the 2nd exam (75%) than the first (22%), and for those who were on these medications, the average dose of individual drugs (neosynephrine, norepinephrine, dopamine, vasopressin and epinephrine) at the time of the first and the second exam did not differ ($p > 0.05$).

The number of organs recovered or transplanted did not differ between the SBD and DBD exam groups in the univariate analysis (Table 1). However, the number of clinical exams was independently associated with the number of organs transplanted [beta coefficient, (95% CI) -0.5 (-0.97 to -0.02), $p = 0.044$], along with age (for 5 year increase, -0.36 (-0.43 to -0.29), $p < 0.001$) and PaO_2 level (for 10 mmHg increase, 0.026 (0.008 to 0.044), $p = 0.005$) in the multiple regression model, while time from event to BD declaration ($p = 0.067$) and BUN ($p = 0.099$) were no longer significant after adjusting for the other variables. Since the NICU service (neurointensivists) performed a significant proportion of SBD exams [Data available from Dryad (Supplementary Table e-1)], we also developed models assessing their independent impact on organ transplantation. Such an association was not found ($p = 0.687$), although the other variables remained significant predictors. Patients with SBD were also more likely to have at least one lung transplanted, but there was no difference for the other organs (Table 3). This association was no longer significant in the multivariable logistic regression after adjusting for age, PaO_2, BUN and time from event to BD declaration (OR=1.86, 0.73, 4.71, $p = 0.193$). However, the average number of organs transplanted decreased with increasing elapsed hours between the catastrophic event that caused brain death and BD declaration [$p = 0.019$, Figure 1 and Data available from Dryad (Supplementary Figure e-3)], with the comparison of 0-24 hours vs > 96 hours being significant. There was also a decreasing trend for the average number of recovered organs over the elapsed hours ($p = 0.058$, Figure 1).

Discussion

After preconditions are met (following the AANPP stipulations), physicians should examine a patient for brain death when there is no breathing effort nor presence of several brainstem reflexes involving all three structures of the brainstem. A lingering question has been whether one comprehensive study is sufficient. This question continues to surface despite no evidence of change in neurologic examination since the practice became more standardized and worldwide. Change in examination challenges the fundamental tenet that, once all brainstem reflexes and breathing drive are lost, recovery is out of the question. Performing one BD exam offers many advantages: it shortens the time that a patient may wait to be declared BD and potentially decreases the incidence of multi-organ dysfunction in these critically ill patients, thereby increasing the number and quality of organs procured per donor. In practical terms, it also means that a search for a timely available and skilled physician is not needed. On the other hand, the disadvantage with SBD exam is the theoretical concern that some of these patients might have regained some neurological function by the time of a second exam. Some disadvantage may be the shortened grieving period for families that accompanies a SBD exam, and the suggestion that "rushing" might potentially affect the consent rates. Our prior data showed that the time of declaration of BD was shortened by on the average 14.4 hours which decreased the cost by an estimated $1,200/ patient and the consent rate and the organs recovered and transplanted were similar between those with SBD and DBD exams [3]. The current study over a much longer time span of 12 years and with more than double the sample size confirms this concern of longer delays, but did not analyze cost savings. Although the average additional time to perform the 2nd

exam was 21 hours, no patient regained brain function (i.e. return of brainstem reflexes or new breathing effort after a completed apnea test). Moreover, none developed a cardiac arrest while awaiting a second examination and until organ retrieval. In a large study from the New York Organ Donor Network, which reported a similar interval between the 1st and 2nd BD exams (19.2 hours), no patient regained any brain function, similarly to ours, but 8% of BD patients developed cardiac arrest between the two exams [4]. The fact that none of our BD patients had this complication (despite having similar percentage of patients with anoxia-ischemia as the etiology of BD, 23% vs 29%), points to the higher variability of practices amongst the over 100 hospitals' bedside practices in the study from New York compared to our single-center study. We can assume that support of the brain dead donor has improved with full transfer of care to organ donation agency. This may have included more judicious use of vasopressin and often rapid initiation of thyroid hormone replacement.

Although the 2010 AANPP does not require a mandatory ancillary test after a SBD exam and specifies that these tests can be performed when part of the neurological exam is unreliable or when the apnea test cannot be performed [1], our hospital chose to continue using an ancillary blood flow test after the AANPP publication for few reasons, namely because 1) performing a SBD exam was a shift from the old paradigm of having more than one exams performed in sequence and separated by an observation period 2) the AANPP SBD recommendation was based on non-existent data of irreversibility, dictating an additional safety net of data 3) the AANPP language lacked specificity regarding the time between injury onset and BD exam ("one exam should be sufficient if a certain period of time has passed since the onset of the brain insult to exclude the possibility of recovery [in practice, usually several hours]"), introducing a potential risk of inadequate time antedating the SBD exam and 4) because many other Guidelines

or National Policies in other countries still require two BD exams either separated by a certain observation period (in children [5]) or performed consecutively (United Kingdom [8] or Australia-New Zealand [6]) or concurrently (Canada [7]). All these reasons funneled down to the same basic concern that a SBD exam might have not been sufficient enough to prove irreversibility and exclude false positive BD declarations and that the ancillary tests might provide an additional safety net. Our study, the largest ever BD series from a single center and spanning over more than a decade, provides evidence that no patient after a SBD exam recovered any brain function and also questions the need for a mandatory ancillary test.

Another important finding in our study, refuting the concern of shorter grieving period affecting the consent rate, is the absence of any difference in consent rate based on the number of exams, even after adjustment for the period of time that elapsed between the event that caused BD and the BD declaration time, race and completion of apnea test. In the study from New York, the authors had reported an inverse correlation between the interval to BD declaration and organ donation consent [4]. Difference in sample size and population, lack of pediatric patients and attitudes towards organ donation may be the reason for our finding compared to New York's, where no SBD exam was allowed since two BD exams separated by at least 6 hours was mandatory before 2011 (currently a SBD exam is recommended in New York State too [11]). Although in the univariate analysis we did not find a difference in the total organs recovered or transplanted based on the number of exams, the average number of organs per donor recovered or transplanted were higher after SBD exam (Table 1) and also the percentages per organ were higher in three out of four organs transplanted after SBD exams compared to DBD exams (Table 3). There was also a higher number of transplanted lungs after SBD exam, but this did not retain significance after adjustment for covariates. Furthermore, after adjustment there was an

association between fewer organs transplanted and higher number of exams, older age and lower PaO_2. This may be a reflection of the transplant surgeons preferences, but also the function of these organs at the time of the BD examination, with more prolonged periods between the catastrophic event to BD declaration (as occurring after DBD exams) leading to worse function and eventually lower organ recovery and transplantation (Figure 1). As an example, it appears that despite the fact that patients with SBD were significantly older, with higher sodium and a trend for higher chloride levels than those with DBD exams, their kidney function (assessed by surrogate markers such as BUN and creatinine) was better. In addition, SBD exam patients had also higher SBP and lower heart rate at the time of the single exam compared to DBD exam patients (at the 2nd exam time-point) despite a higher incidence of DI in the former (and the hemodynamic instability that is usually associated with). This difference in vital signs between the two groups may be the reflection of a better cardiovascular state during the time of the SBD exam or be due to the decrease in the utilization of pressors or inotropes during the 2nd BD exam in more than half of patients with DBD exams.

Our study has limitations. It represents a single, large, urban hospital experience, reflecting the South-East Michigan patient population. It is however, to our knowledge the largest single-center study ever presented on BD and also the second attempt in the literature to answer the single vs dual BD exam question. Our hospital policy had adopted a 24-hour policy when brain death is caused by anoxic –ischemic injury. The overall incidence of brain death in anoxic brain injury is relatively low, because anoxic injury frequently spares the brainstem. Patients who become brain dead invariably have diffuse brain edema on neuroimaging. Although patients after cardiopulmonary resuscitation may have improving brainstem reflexes with time, there is no evidence that, in this small subgroup with diffuse edema, brainstem reflexes return. In our study,

we allowed sufficient time from the event to the exam for all patients with SBD exam after anoxic injury in order to exclude recovery of brainstem reflexes. In addition, diffuse edema was present and ancillary tests were also performed. However, because only a small number of patients with SBD after anoxic injury was included, this may remain an open question. Therefore, extension of the SBD exam to this anoxic patient population, especially too early after the anoxic event and while neuroimaging does not show diffuse cerebral edema, is not adequately assessed in our study. Another limitation is that our study does not include children. In this patient population, a DBD exam is required [5]. Unlike our previous study, this larger cohort does not include any analysis on the economics of prolonged ICU length of stay with DBD exams. It also lacks data on families' experience with the shortened time-frames with SBD exams. Although this did not translate into a difference in consent rates and as a whole saved more lives through organ transplantation, at the individual family level might have led to reduced satisfaction with the process. Lastly, it lacks data on transplanted organs' function at a later follow up time. It is possible that these organs recovered and functioned differently based on the pre-transplantation delays.

Appendix 1: Authors

Name	Location	Contribution
Panayiotis N. Varelas, MD, PhD, FAAN, FNCS	Albany Medical Center, USA	Designed and conceptualized study, data acquisition, analyzed the data, interpreted data, drafted manuscript
Mohammed Rehman, DO	Henry Ford Hospital, USA	Major role in acquisition of data, revised manuscript for intellectual content
Chandan Mehta, MD	Henry Ford Hospital, USA	Revised manuscript for intellectual content
Lisa Louchart, RN	Henry Ford Hospital, USA	Revised manuscript for intellectual content
Lonni Schultz, PhD	Henry Ford Hospital, USA	Analyzed the data, interpreted data, revised manuscript for intellectual content
Paul Brady, MD	Henry Ford Hospital, USA	Major role in acquisition of data
Mohammed F. Kananeh, MD	Henry Ford Hospital, USA	Major role in acquisition of data, revised manuscript for intellectual content
Eelco F. Wijdicks, MD, PhD	Mayo Clinic, USA	Reviewed the data, interpreted data, revised manuscript for intellectual content

References

1. Wijdicks EF, Varelas PN, Gronseth GS, Greer DM, American Academy of N. Evidence-based guideline update: determining brain death in adults: report of the Quality Standards Subcommittee of the American Academy of Neurology. Neurology 2010;74:1911-1918.

2. Practice parameters for determining brain death in adults (summary statement). The Quality Standards Subcommittee of the American Academy of Neurology. Neurology 1995;45:1012-1014.

3. Varelas PN, Rehman M, Abdelhak T, et al. Single brain death examination is equivalent to dual brain death examinations. Neurocritical care 2011;15:547-553.

4. Lustbader D, O'Hara D, Wijdicks EF, et al. Second brain death examination may negatively affect organ donation. Neurology 2011;76:119-124.

5. Nakagawa TA, Ashwal S, Mathur M, Mysore M, Committee For Determination Of Brain Death In Infants C. Guidelines for the determination of brain death in infants and children: an update of the 1987 task force recommendations-executive summary. Annals of neurology 2012;71:573-585.

6. (ANZICS) AaNZICS. THE ANZICS STATEMENT ON DEATH AND ORGAN DONATION [online]. Available at: https://www.anzics.com.au/wp-content/uploads/2018/08/Brain-Death-Determination-Statement-FINAL.pdf.

7. Shemie SD, Doig C, Dickens B, et al. Severe brain injury to neurological determination of death: Canadian forum recommendations. CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne 2006;174:S1-13.

8. Colleges AoMR. A Code of Practice for the Diagnosis and Confirmation of Death [online]. Available at: https://www.aomrc.org.uk/reports-guidance/ukdec-reports-and-guidance/code-practice-diagnosis-confirmation-death/.

9. Kananeh MF, Brady PD, Mehta CB, et al. Factors that affect consent rate for organ donation after brain death: A 12-year registry. Journal of the neurological sciences 2020;416:117036.

10. Greer DM, Wang HH, Robinson JD, Varelas PN, Henderson GV, Wijdicks EF. Variability of Brain Death Policies in the United States. JAMA neurology 2016;73:213-218.

11. New York State Guidelines for Determining Brain Death [online]. Available at: https://www.health.ny.gov/professionals/hospital_administrator/letters/2011/brain_death_guidelines.pdf.

Figure 1. Title: Number of organs recovered or transplanted based on the elapsed period from event to BD declaration

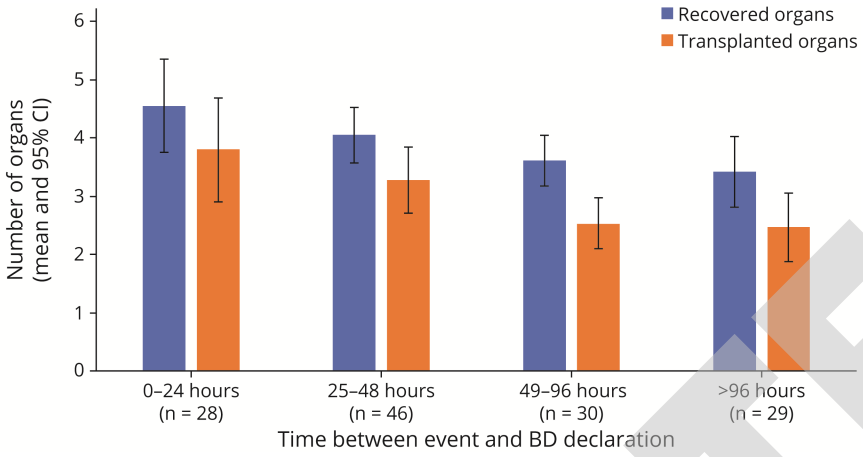

Table 1: Comparing single and dual BD exams (n=266)

Variable	Response	Single (N= 122)	Dual (N= 144)	p-value
Sex	Female	55 (45%)	71 (49%)	0.492
	Male	67 (55%)	73 (51%)	
Race	Caucasian	41 (34%)	46 (32%)	0.861
	African American	64 (52%)	82 (57%)	
	Other	8 (7%)	8 (6%)	
	Not reported	9 (7%)	8 (6%)	
Religion [a]	Christian	43 (68%)	56 (77%)	0.714
	Muslim	3 (5%)	3 (4%)	
	Buddhist	1 (2%)	0 (0%)	
	Other	7 (11%)	6 (8%)	
	None	9 (14%)	8 (11%)	
Diagnostic categories	Stroke/CVA	22 (18%)	9 (6%)	**<0.001**
	ICH/IVH	55 (45%)	20 (14%)	
	SAH	11 (9%)	11 (8%)	
	Cardiac arrest	5 (4%)	71 (49%)	
	Trauma	26 (21%)	21 (15%)	
	Other	3 (2%)	12 (8%)	
Diabetes insipidus	Yes	87 (71%)	85 (59%)	**0.037**
	No	35 (29%)	59 (41%)	
Apnea test completed	Yes	108 (90%)	120 (84%)	0.148
	No	12 (10%)	23 (16%)	
Confirmatory test	Yes	121 (99%)	67 (47%)	**<0.001**
	No	1 (1%)	77 (53%)	

Consent among those approached [b]	Yes	75 (73%)	86 (72%)	0.799
	No	27 (27%)	34 (28%)	
Number of organs recovered [c]	1	4 (6%)	8 (11%)	0.101
	2	4 (6%)	9 (12%)	
	3	25 (36%)	28 (37%)	
	4	14 (20%)	11 (14%)	
	5	7 (10%)	5 (7%)	
	6	3 (4%)	9 (12%)	
	7	11 (16%)	5 (7%)	
	8	1 (1%)	1 (1%)	
	Mean ± SD	4.1 ± 1.8	3.6 ± 1.7	
Number of organs transplanted [c]	0	5 (7%)	6 (8%)	0.113
	1	9 (13%)	12 (17%)	
	2	10 (14%)	17 (24%)	
	3	19 (27%)	18 (25%)	
	4	9 (13%)	8 (11%)	
	5	4 (6%)	3 (4%)	
	6	8 (12%)	4 (5%)	
	7	5 (7%)	4 (6%)	
	Mean ± SD	3.3 ± 2.0	2.8 ± 1.8	

[a] Data on religious beliefs was only available for 136 patients. No patients listed Judaism as religion, [b] Data on 222 patients whose families have been approached for donation, [c] data on 161 donors

ICH = intracerebral hemorrhage, IVH = intraventricular hemorrhage, SAH = subarachnoid hemorrhage, BD = brain death

Table 2: Comparing single and dual BD exams (n=266)

Variable	Single (N= 122)	Dual (N= 144)	p-value
Age (Mean ± SD years)	51.1 ± 16.3	46.8 ± 17.1	**0.037**
Sodium (Mean ± SD mmol/L) at time of death	151.8 ± 7.5	149.0 ± 8.9	**0.007**
Peak sodium (Mean ± SD mmol/L)	156.9 ± 10.5	153.1 ± 10.0	**0.002**
Potassium (Mean ± SD mmol/L) at time of death	3.9 ± 0.6	4.1 ± 0.6	**0.003**
Bicarbonate (Mean ± SD mmol/L) at time of death	23.7 ± 3.6	23.3 ± 4.5	0.409
Chloride (Mean ± SD mmol/L) at time of death	122.0 ± 9.6	119.4 ± 13.3	0.064
Creatinine (Mean ± SD mg/dL) at time of death	1.7 ± 2.2	2.4 ± 2.4	**0.010**
BUN (Mean ± SD mg/dL) at time of death	16.7 ± 14.4	26.4 ± 23.0	**<.001**
pH (Mean ± SD) at time of death	7.2 ± 0.1	7.1 ± 0.8	0.149
PaCO2 (Mean ± SD mmHg) at time of death	72.0 ± 16.0	72.0 ± 15.4	0.992
PaO2 (Mean ± SD mmHg) at time of death	235.8 ± 132.4	181.0 ± 123.8	**<.001**
Heart rate (Mean ± SD beats/min) at time of death	89.3 ± 23.6	96.3 ± 21.0	**0.011**
SBP (Mean ± SD mmHg) at time of death	125.3 ± 30.1	117.4 ± 26.4	**0.023**
Time event to 1st exam (Mean ± SD, hours)	53.6 ± 52.4	55.9 ± 55.1	0.735
Time event to BD declaration (Mean ± SD, hours)	54.7 ± 52.7	75.6 ± 57.1	**0.003**
Time event to OR (Mean ± SD, hours) [a]	92.1 ± 58.0	112.4 ± 54.9	**0.044**
Time consent to OR (Mean ± SD, hours) [a]	13.2 ± 1.6	19.4 ± 2.2	0.085

[a] Based on 75 patients with SBD and 87 patients with DBD exams who consented for donation

BUN = blood urea nitrogen, SBP = systolic blood pressure, OR = operating room

Table 3: Organs transplanted based on the number of exams (n = 161 donors)

Variable	Response	Single (N= 75)	Dual (N= 86)	p-value
Kidney transplant (at least one)	Yes	53 (71%)	56 (65%)	0.452
	No	22 (29%)	30 (35%)	
Lung transplant (at least one)	Yes	24 (32%)	15 (17%)	**0.031**
	No	51 (68%)	71 (83%)	
Heart transplant	Yes	20 (27%)	23 (27%)	0.991
	No	55 (73%)	63 (73%)	
Liver transplant	Yes	58 (77%)	57 (66%)	0.121
	No	17 (23%)	29 (34%)	