

Changing Trends in Brain Death at an Inner-City Hospital: A 12-Year Experience

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Abstract

Introduction: Over the past decade, patient characteristics and donation patterns in organ donation occurring after neurological determination of brain death have evolved due to clinical, demographic, and societal changes. This study aimed to evaluate trends in donor characteristics, brain death etiology, and donation specifics over a decade in an inner-city hospital.

Methods: This is a retrospective observational analysis of adult patients diagnosed with brain death between January 2013 and June 2025, divided into two periods (Periods I and II).

Results: Lung disease was more frequent in Period II (41.4% vs. 26.0%; $p = 0.025$). Overall urine toxicology positivity increased significantly (49% vs. 25.3%; $p = 0.003$), with a specific increase in cocaine detection (26.9% vs. 10.8%; $p = 0.010$). The organ donor rate increased from 4.55 to 8.07 donors per year ($p = 0.018$), while the proportion of brain-dead patients who became organ donors did not differ significantly between periods (34% vs. 32%).

Conclusions: This analysis demonstrated an increased annual rate of organ donation after brain death in the post-2020 period, while the proportion of brain-dead patients who became organ donors did not differ significantly between periods. A higher prevalence of positive toxicology screens, particularly for cocaine and cannabinoids, was also observed. Over the past decade, there appears to have been a shift in demographic characteristics and patterns of drug use.

Categories: Neurology, Transplantation, Internal Medicine

Keywords: brain death, covid-19, critical care, epidemio-toxicology, organ donation

Introduction

Organ donation following brain death remains a cornerstone of transplant medicine [1]. Evolving demographic, clinical, and societal factors have reshaped the patterns associated with brain death diagnosis and subsequent organ donation. Brain death accounts for approximately 2% of in-hospital deaths in the United States, corresponding to an estimated 15,000-20,000 cases annually. The annual number of brain death diagnoses increased from approximately 12,500 in 2012 to more than 15,000 by 2016 [2]. Historically, cerebrovascular events and traumatic brain injury were the predominant causes of brain death; more recent analyses show that fatal drug overdoses have become an increasingly important contributor to deceased organ donation [3,4]. Characterizing the epidemiological and clinical profiles of brain-dead patients is particularly important in inner-city hospitals, which serve socioeconomically and racially diverse populations and experience distinct burdens of trauma, overdose, and chronic disease [5]. However, understanding of organ donation following brain death in this population remains limited.

The COVID-19 pandemic posed unique challenges and led to lasting changes in cultural and socioeconomic norms. Although an increased prevalence of lung disease after COVID-19 has been reported [6], its prevalence specifically among brain-dead patients remains unclear. Patterns of substance use appear to have shifted in the post-COVID-19 era, likely reflecting multifactorial influences; however, the underlying drivers of these changes remain poorly understood. Such shifts may have particular implications for vulnerable urban hospital populations.

Although national registry data show that the number of donors after brain death has increased after a dip during the pandemic, data specific to inner-city populations remain limited [7]. National aggregates may obscure hospital-level variations, particularly within high-acuity, high-risk urban centers. Accordingly, we conducted this epidemiological study to provide an important longitudinal view of how brain death and organ donation patterns evolved over the last decade, including a global pandemic, in an inner-city hospital. The primary outcome of the study was the change in the proportion of all in-hospital deaths that were attributable to brain death, compared between Period I and Period II. Secondary outcomes included the annualized number of organ donors, the proportion of brain-dead patients who proceeded to organ donation, and changes in demographic, clinical, and toxicology characteristics between the two study

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periods.

Materials And Methods

Study design and setting

This was a retrospective, observational, single-center cohort study. Our institution serves the South and Central Bronx in New York City. The study included all adult patients diagnosed with brain death from January 1, 2013, to June 30, 2025. The analysis compared two prespecified timeframes: Period I (January 2013–March 2020) and Period II (June 2020–June 2025). A gap between the two study periods resulted from interruptions in standardized data collection during the COVID-19 pandemic.

The hospital includes a 36-bed adult intensive care unit providing medical, cardiac, and surgical critical care. Determination of brain death at our institution is performed by credentialed physicians and follows the New York State Guidelines [8]. A comprehensive neurological examination followed by an apnea test is the preferred diagnostic approach. Under some circumstances, the brain death clinical examination and apnea test could not be completed, such as in patients with injuries to the head and neck that precluded evaluation of cranial nerve reflexes or when apnea testing cannot be completed safely because of the patient's underlying medical condition. Some examples of those underlying clinical conditions include severe acid-base imbalance, severe hypoxia requiring high supplemental oxygen, and cardiac arrhythmias, among others. In those cases, a radionuclide flow scan is performed. As per hospital protocol, all eligible cases are referred to the local organ procurement agency.

Definition

Lung disease was defined as a documented history of chronic pulmonary disease, including chronic obstructive pulmonary disease, asthma, interstitial lung disease, bronchiectasis, pulmonary fibrosis, or other chronic structural or obstructive lung disorders. Acute pulmonary conditions arising during the index hospitalization, such as pneumonia, aspiration, acute respiratory distress syndrome, or pulmonary edema, were not classified as pre-existing lung disease.

Organ donation was defined as the successful procurement of at least one solid organ from a patient declared brain dead for the purpose of transplantation. Patients who were evaluated or consented for donation but did not undergo organ procurement were not classified as organ donors.

Inclusion and exclusion criteria

We included all adult patients (≥ 18 years) with a confirmed diagnosis of brain death documented according to institutional protocol between January 2013 and June 2025. Patients younger than 18 years of age and those with inconclusive brain death determination were excluded. Tissue-only donors were also excluded from the study analysis.

Data sources

Demographic and clinical data were obtained from retrospective chart review of the hospital's electronic health record covering the study period. Organ donation outcomes were obtained from the hospital's organ procurement registry. Toxicology testing was performed as part of routine clinical care and was not mandated systematically by the study protocol.

Statistical analysis

We compared two prespecified periods: Period I (January 2013–March 2020) and Period II (June 2020–June 2025). Continuous variables (age) are reported as mean $\pm$ SD and compared with Welch's *t*-test (two-sided). Binary comparisons used Pearson's χ^2 test with Yates' continuity correction; when any expected cell count was < 5 , we used Fisher's exact test. For these binary outcomes, we report effect sizes as odds ratios (ORs) with 95% CIs, calculated for Period II vs. Period I. Overall comparisons for multilevel categorical variables used Pearson's χ^2 test; organ donation rate across periods was analyzed as events over time using a Poisson rate framework: donor rates (per year) were compared via incidence rate ratio (IRR) with log-normal 95% CI, and two-sided *p*-values were obtained from the conditional binomial test under the null of equal rates given total exposure.

Missing data handling

Accurate data on total hospital mortality for 2013 were unavailable; therefore, hospital mortality and brain death case data for 2013 were obtained from the local organ procurement organization.

Predefined entries indicating unavailable assessments were treated as missing and excluded from denominators for percentage calculations; no imputation was performed. Continuous outcomes used complete-case analysis. The period-level organ donor analysis used exact calendar exposure (in years) for each period.

All tests were two-sided, with α = 0.05. Analyses were conducted in Python (pandas, SciPy; Python Software Foundation, Fredericksburg, VA, USA).

The final study size included all participants who met the inclusion criteria and had data available.

Results

We analyzed two cohorts: Period I (January 2013-March 2020) and Period II (June 2020-June 2025). A total of 224 adults declared brain-dead during the study period were included, comprising 96 patients in Period I and 128 in Period II.

The demographic characteristics of patients in the two study periods are compared in Table 1. Age was comparable between the periods (mean ± standard deviation (SD); p = 0.343), as was the gender distribution (p = 0.535). A modest but statistically significant difference in racial distribution was observed (p = 0.043). However, no individual racial category had a large standardized residual (|z| ≥ 2) contributing disproportionately to this difference. The proportion of nursing home residents did not differ significantly between the two periods (p = 0.331).

Variable	Period I (n = 96)	Period II (n = 128)	p-value
Age, mean ± SD	54.9 ± 15.6	56.9 ± 13.9	0.343
Gender			0.535
Female	41 (42.7%)	60 (46.9%)	
Male	55 (57.3%)	68 (53.1%)	
Race			0.043
African American	34 (35.4%)	36 (28.1%)	
Caucasian	0 (0.0%)	5 (3.9%)	
Hispanic	22 (22.9%)	19 (14.8%)	
Other	40 (41.7%)	68 (53.1%)	
Nursing home facility residents	14 (14.6%)	12 (9.4%)	0.331

TABLE 1: Demographic characteristics of the patients

A comparison of comorbid conditions and prior cardiac arrest between the two study periods is presented in Table 2. Lung disease was significantly more prevalent in Period II than in Period I (RR = 1.59, 95% CI: 1.07-2.36; OR = 2.01, 95% CI: 1.13-3.57; p = 0.025). Other comorbidities, including diabetes, coronary heart disease/heart failure, cancer, and HIV, as well as the incidence of prior cardiac arrest, did not differ significantly between the two periods.

Variable	Period I (n = 96)	Period II (n = 128)	p-value	OR (95% CI)
Diabetes	33 (34.4%)	53 (41.4%)	0.351	1.35 (0.78-2.34)
CAD/heart failure	32 (33.3%)	44 (34.4%)	0.984	1.05 (0.60-1.83)
Malignancy	13 (13.5%)	9 (7.0%)	0.163	0.48 (0.20-1.18)
Lung disease	25 (26.0%)	53 (41.4%)	0.025	2.01 (1.13-3.57)
IV drug use	8 (8.3%)	17 (13.3%)	0.342	1.68 (0.69-4.08)
History of cardiac arrest	28 (29.2%)	34 (26.6%)	0.779	0.88 (0.49-1.58)

TABLE 2: Comorbidities and history of cardiac arrest

Evaluation of illicit substance use was based on urine and serum toxicology testing, with comparisons

between the two study periods presented in Table 3. Among patients with available toxicology results, 21 of 83 (25.3%) in Period I and 53 of 108 (49.0%) in Period II had positive toxicology screens. Several toxicology findings were significantly more frequent in Period II, including cocaine positivity (RR = 2.48, 95% CI: 1.24-4.94; OR = 3.02, 95% CI: 1.34-6.80; $p = 0.010$), cannabinoid positivity (RR = 2.11, 95% CI: 0.99-4.51; OR = 2.40, 95% CI: 1.01-5.70; $p = 0.048$), and positivity in the “other substances” category (RR = 2.74, 95% CI: 1.06-7.08; OR = 3.09, 95% CI: 1.10-8.69; $p = 0.046$). Overall urine toxicology positivity was also significantly higher in Period II (RR = 1.89, 95% CI: 1.23-2.91; OR = 2.52, 95% CI: 1.39-4.59; $p = 0.003$). No statistically significant differences were observed for the other analytes, including opiates, amphetamines, and methadone. Testing for synthetic opioids was not available during the study period.

Variable	Period I (n = 96)	Period II (n = 128)	p-value	OR (95% CI)
Positive toxicology	21/83 (25.3%)	53/108 (49%)	0.003	2.52 (1.39-4.59)
Cocaine	9/83 (10.8%)	29/108 (26.9%)	0.010	3.02 (1.34-6.80)
Cannabinoids	8/83 (9.6%)	22/108 (20.4%)	0.048	2.40 (1.01-5.70)
Opiates	10/83 (12.0%)	15/108 (13.9%)	0.875	1.18 (0.50-2.77)
Amphetamines	0/83 (0.0%)	3/108 (2.8%)	0.259	5.54 (0.28-108.76)
Methadone	5/83 (6.0%)	8/108 (7.4%)	0.931	1.25 (0.39-3.96)
Other	5/83 (6.0%)	18/108 (16.7%)	0.046	3.09 (1.10-8.69)
Alcohol intoxication	3/83 (3.6%)	0/108 (0.0%)	0.077	0.10 (0.01-2.04)

TABLE 3: Substance use patterns

The diagnostic methods used to determine brain death and the etiologies of brain death are presented in Table 4. Radionuclide cerebral blood flow scanning was the most frequently used diagnostic test in both study periods. The overall distribution of diagnostic tests did not differ significantly between Period I and Period II ($p = 0.152$). Similarly, no significant difference was observed in the distribution of brain death etiologies between the two periods ($p = 0.262$). The use of targeted temperature management was also comparable between the periods ($p = 1.000$). Standardized residuals for these multicategory comparisons did not identify any individual category with a large deviation from the expected distribution ($|z| \geq 2$).

Variable	Period I (n = 96)	Period II (n = 128)	p-value
Diagnostic test			0.152
Apnea test	24 (25.0%)	22 (17.2%)	
Radionuclide flow scan	72 (75.0%)	106 (82.8%)	
Cause of brain death			0.262
Cardiac arrest	27 (28.1%)	40 (31.2%)	
Drug overdose	14 (14.6%)	28 (21.9%)	
Neurological event	44 (45.8%)	43 (33.6%)	
Other	11 (11.5%)	17 (13.3%)	
Targeted temperature management use	7 (7.3%)	10 (7.8%)	1

TABLE 4: Diagnostic test, etiology of brain death, and targeted temperature management use

A comparison of organ donation patterns between the two study periods is presented in Table 5. We evaluated the number of patients declared brain-dead and the total number of hospital deaths in each period. Accurate hospital mortality data for 2013 were unavailable; therefore, hospital mortality and brain death case data for that year were obtained from the local organ procurement organization. The proportion of total hospital deaths involving patients who met the criteria for brain death increased from 2.8% in Period

I to 3.8% in Period II, representing a statistically significant difference (p = 0.022). During Period II, 41 donors were identified over approximately 5.07 years, compared with 33 donors over approximately 7.25 years during Period I. Accordingly, the annual donor rate was significantly higher in Period II (IRR = 1.77, 95% CI: 1.12-2.80; p = 0.018). Although more patients were declared brain-dead during Period II, the proportion of brain-dead patients who became organ donors remained comparable between the periods, at 34% in Period I and 32% in Period II.

Variable	Period I	Period II	p-value
Total mortality hospital-wide	3,428	3,343	
Number of patients declared brain-dead	96	128	
Brain-dead patients/total hospital mortality	96/3,428 (2.8%)	128/3,343 (3.8%)	0.022
Donors, n (%)	33 (34%)	41 (32%)	
Exposure time, years	7.25	5.08	
Donor rate per year	4.55	8.07	
Incidence rate ratio (IRR)	1.77 (1.12-2.80)		0.018

TABLE 5: Organ donation trends

Discussion

We present a longitudinal review of brain death cases at our institution over a 12-year period. We observed a modest but statistically significant difference in racial distribution between the two study periods (p = 0.043), although no individual racial category showed a large standardized residual. This shift may reflect changes in the population served by our institution or broader temporal changes in the population of patients experiencing brain death. The mean age of patients declared brain-dead was approximately 56 years, and males accounted for approximately 53%-57% of cases across the two periods. These demographic characteristics are consistent with those reported in previous studies of adult brain death populations [9]. Compared with Period I, Period II had numerically higher proportions of brain death cases attributed to drug overdose and cardiac arrest; however, the overall distribution of brain death etiologies did not differ significantly between the periods. These observations are consistent with broader trends described in the 2023 Organ Procurement and Transplantation Network annual report [7].

One notable finding was the significantly higher prevalence of chronic lung disease among patients declared brain-dead in Period II. Approximately 41% of patients in Period II had an underlying lung disease, compared with 26% in Period I (p = 0.025). To our knowledge, this association has not been extensively described in previous studies of patients declared brain-dead. One possible explanation is that patients with underlying pulmonary conditions, such as chronic obstructive pulmonary disease (COPD) or fibrotic lung disease, may have reduced physiological reserve during critical illness and may be more vulnerable to severe acute neurological insults. However, given the observational nature of our study, this finding does not establish a causal relationship and should be interpreted cautiously. Population-based studies examining the effects of the COVID-19 pandemic on patients with COPD have reported relatively low rates of COPD exacerbations during the pandemic, followed by an increase in total outpatient visits for COPD in the post-pandemic period [10-12]. In addition, Mannan et al. reported increased mortality among patients with COPD in the post-pandemic period after adjusting for COVID-19-associated deaths [12]. Although these findings provide broader context for changes in the health status of patients with chronic pulmonary disease, their relationship to the increased prevalence of lung disease in our brain death cohort remains uncertain.

Another important finding was the marked increase in positive toxicology screens among patients declared brain-dead in Period II. Nearly half of the patients with available toxicology results in Period II had positive screens (49.0%), compared with 25.3% in Period I (p = 0.003). Cocaine positivity increased from 10.8% in Period I to 26.9% in Period II (p = 0.010). Cannabinoid positivity also increased from 9.6% to 20.4%, with borderline statistical significance (p = 0.048). Similarly, positivity in the category of other substances increased from 6.0% to 16.7% (p = 0.046). These findings may reflect temporal changes in substance exposure, testing practices, or the clinical characteristics of patients in the two cohorts. Nevertheless, the relatively small numbers of events and the potential for ascertainment bias related to the availability and indications for toxicology testing warrant cautious interpretation.

National databases have documented a substantial increase in fatal drug overdoses over the past decade, with the trend worsening during the COVID-19 pandemic [13-15]. Because some patients who experience fatal overdoses develop severe hypoxic-ischemic brain injury, overdose-related deaths may contribute to the

pool of potential organ donors when organ function and other eligibility criteria are met. Durand et al. reported that overdose-related deaths accounted for an increasing proportion of deceased organ donors in the United States, rising from 1.1% in 2000 to 13.4% in 2017 [16]. Although this trend provides a plausible context for our findings, our study did not establish that the increase in positive toxicology screens contributed directly to the observed increase in organ donation. Recent reports have also described declines in opioid-related deaths during 2024 and 2025 [17,18], suggesting that overdose trends may be changing. Such changes may reflect a combination of factors, including substance-use patterns, public health interventions, access to treatment, and emergency response. The extent to which these broader trends relate to the findings at our institution remains to be determined.

We observed a greater annualized number of brain-death cases in Period II than in Period I, with 128 cases over approximately 5.1 years compared with 96 cases over approximately 7.3 years, respectively. The estimated proportion of total hospital deaths involving patients who met the criteria for brain death increased from 2.8% in Period I to 3.8% in Period II ($p = 0.022$). These proportions are broadly comparable with the national estimate of approximately 2% reported in the literature [19]. Our findings suggest that the increase in brain death cases observed nationally over the past decade may also have continued at our institution into the 2020s. However, interpretation of this trend requires consideration of changes in case ascertainment and the availability of ancillary testing. In our institution, radionuclide cerebral blood-flow studies were commonly used in brain death determination, and the requirement for surrogate consent to perform these studies may have influenced the number of patients who underwent ancillary testing. We hypothesize that changes in patient characteristics, including the observed increase in positive toxicology screens and the prevalence of chronic lung disease, may partly explain the higher number of brain death cases in Period II. However, the study design does not allow us to determine the contribution of these factors independently.

Organ donation also increased in absolute and annualized terms during Period II. We identified 41 donors over approximately 5.07 years in Period II, compared with 33 donors over approximately 7.25 years in Period I, corresponding to annual donor rates of 8.07 and 4.55, respectively. This increase was statistically significant (IRR = 1.77, 95% CI: 1.12–2.80; $p = 0.018$). National data indicate that the United States achieved record-high deceased organ donation in 2020 despite a brief decline in April of that year [20]. An important finding in our cohort, however, was that the proportion of patients declared brain-dead who subsequently became organ donors remained relatively stable between the two periods (34.4% in Period I vs. 32.0% in Period II). This suggests that the higher annual number of donors was primarily associated with the greater number of brain death cases rather than an improvement in donor conversion following brain death determination. Although overdose-related deaths may contribute to the pool of potential donors, our data cannot establish whether changes in overdose-related brain injury accounted for the observed increase in donation.

The proportion of brain-dead patients who proceeded to organ donation at our institution was slightly lower than the approximately 40% reported in some national estimates [21,22]. Potential explanations include differences in patient characteristics and case mix, medical suitability for donation, and local cultural or consent-related factors. Older patients and those with substantial comorbidities may not meet organ-specific eligibility criteria, while family decisions and local donation practices may also influence whether donation proceeds. These factors warrant further investigation before differences in donor conversion rates can be attributed to any single cause.

Finally, diagnostic practices for brain death determination remained broadly consistent between the two study periods. The overall distribution of diagnostic tests did not differ significantly, and radionuclide cerebral blood-flow scanning remained the predominant ancillary test, accounting for approximately 80% of cases. This consistency suggests that institutional diagnostic practices were maintained throughout the study period. The frequent use of ancillary testing may reflect institutional protocols and the clinical complexity of brain death determination, particularly when components of the neurological examination or apnea testing could not be completed or reliably interpreted. Current guidance emphasizes standardized criteria for determining death by neurological criteria, including the appropriate use of ancillary testing when indicated [19]. A study from Germany reported that high COVID-19 intensive care unit burdens were associated with fewer brain death determinations and missed donor identifications early in the pandemic [23]. In contrast, our institution recorded more brain death cases during Period II while maintaining broadly consistent diagnostic practices. These findings suggest continuity in local brain death determination and organ donation processes during a period that included the COVID-19 pandemic, although they do not establish that the pandemic had no effect on these processes.

This study has several limitations. First, its single-center, retrospective design limits generalizability. In addition, the absence of data for April and May 2020 may have introduced selection bias and limited the completeness of comparisons across the study periods. Second, the available data did not permit further classification of the “neurological events” category used to describe the etiology of brain death. This category may have encompassed heterogeneous conditions, including traumatic brain injury, intracerebral hemorrhage, and ischemic stroke. A more detailed classification could have revealed differences that were not apparent in the present analysis. Third, although toxicology results provide information about substance exposure, they do not establish that a detected substance caused the brain injury leading to death by

neurological criteria. Positive screens may reflect incidental or prior substance use rather than the primary cause of brain injury, and toxicology testing was not available for all patients. Furthermore, the absence of testing for synthetic opioids limited our ability to assess exposure to these substances and may have resulted in underrecognition. Changes in toxicology screening indications, testing frequency, or analytical methods over time may also have introduced ascertainment bias and influenced the observed differences between periods. Finally, differences in baseline characteristics and comorbidities between the cohorts may have influenced the observed outcomes. These limitations underscore the need for cautious interpretation and highlight the importance of larger, multicenter studies with consistent data collection and toxicology testing protocols to validate the trends observed in our cohort.

Conclusions

This study characterized the epidemiological and clinical profiles of patients declared brain-dead at our institution over a 12-year period. Although demographic characteristics were generally comparable between the two study periods, racial distribution differed modestly, and notable changes were observed in comorbidities and substance exposure. Positive toxicology findings were more prevalent in the second period, consistent with broader trends in substance-related harm during and after the COVID-19 pandemic. The annual rate of organ donation also increased significantly in the second period, whereas the proportion of brain-dead patients who proceeded to organ donation remained relatively stable. These findings suggest that the increase in annual organ donation was primarily associated with the greater number of brain-death cases rather than an improvement in donor conversion.

Our findings highlight the importance of maintaining robust systems for brain death determination and organ donation, including during periods of substantial healthcare disruption. They also underscore the evolving clinical and epidemiological characteristics of patients managed by critical care and transplant teams. Continued surveillance of brain death trends, together with public health interventions addressing preventable causes of fatal brain injury, is warranted. Further multicenter studies are needed to determine whether these trends are generalizable and to clarify the factors underlying changes in brain death cases and organ donation.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Institutional Review Board of BronxCare Hospital Center issued approval 12142304. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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