ORGAN PROCUREMENT AND TRANSPLANTATION NETWORK

OPTN Deceased Donor Potential Study (DDPS)
Task 6
DHHS Contract 234-2005-37011C/0023

6.1. UNOS, as the OPTN Contractor, has been charged by HRSA to conduct a research study that revisits the existing understanding of deceased donor potential in the United States. Under the contract's existing research task, the OPTN is to contribute new knowledge that will minimize barriers to transplantation and enhance transplant outcomes. The Deceased Donor Potential Study (DDPS) is expected to further this goal and task requirement. Specifically, the DDPS will aim to generate more current scientific evidence that is based on rigorous epidemiologic and demographic analyses of deceased donor system for the purpose of determining the potential number of organ donors, and to determine the potential trend in that number over time. The results of this study will include implications for short-term and intermediate needs for determining national plans. It is essential to determine a true measure of deceased donor potential across the network in order to better estimate and monitor such potential, to assess and develop tailored strategies to improve the deceased donation process, and to measure performance of the National Organ Transplant System

The Contractor shall provide a plan and implementation schedule to increase the efficiency and productivity of the DDPS in pursuant to Task 6 of Contract No. 234-2005-370011c as modified by contract modification number 19.

Contents

List of Figures in the OPTN Deceased Donor Potential Study Report

List of Tables in the OPTN Deceased Donor Potential Study Report

Acknowledgement

This work was supported in part by Health Resources and Services Administration contract 234-2005-370111C. The content is the responsibility of the authors alone and does not necessarily reflect the views or policies of the Department of Health and Human Services, nor does mention of trade names, commercial products, or organizations imply endorsement by the U.S. Government.

SUMMARY

Impetus for Study: HRSA Commissions the OPTN to Conduct a Study

On July 28, 2010, the Health Resources and Services Administration (HRSA) of the Department of Health and Human Services requested a proposal to modify the United Network for Organ Sharing's (UNOS) existing Organ Procurement and Transplantation Network (OPTN) Contract # HHSH 234-2005-37011C to conduct a commissioned study—the **OPTN Deceased Donor Potential Study (DDPS)**. This project would be conducted under its existing contract, Task 6: Conduct Research Studies. The Purpose of Task 6 is to contribute new knowledge that will minimize barriers to transplantation and enhance transplant outcomes.

HRSA's impetus for the study is perhaps best characterized in the opening paragraph of the proposed Statement of Work, which states:

> Since the initiation of the OPTN contract in 2005, annual estimates of the potential number of deceased donors in the United States have been decreasing, reflecting shifts in demographics, changes in the health of the population, improvements in transportation safety, and changes in hospital and critical care practice, etc. The only studies that have been conducted on donor potential are dated. The OPTN and HRSA Division of Transplantation are in need of a rigorous epidemiologic and demographic study of national, regional, and local deceased donor potential to plan for program activity now and in the immediate future. Understanding donor potential across the country is the key to developing appropriate strategies to improve deceased organ procurement and measure performance on the National organ transplantation system.

Study Elements and Project Aims

Research Question. What is the true larger potential for deceased organ donation in the United States?

Project Aims.

- To accurately characterize the current size and composition of the potential donor pool in the United States.
- To accurately characterize the predicted size and composition of the potential donor pool in the United States in the next five (5) to ten (10) years.
- To provide an empirical foundation for developing national goals for deceased organ donation within the context of true donor potential.
- To inform strategic planning processes to identify and implement methods to increased deceased organ donation.

Data. The data sources included nationally representative data sets and relevant sources of data from within health care and transplantation communities.

Methods. The study methods included

- Population-based inquiry
- Demographic methods
- Epidemiological approaches
- Trend analysis

Mechanisms for Research Input and Guidance. The project team consulted with a stakeholder committee that provided subject matter expertise and knowledge, shared insights from the field, provided guidance, and reviewed the study processes.
The DDPS Stakeholder Committee consisted of 52 members, including HRSA and OPTN leadership. The Stakeholder Committee comprised a number of subcommittees that were organized by specialty area and provided advice to the project team. Two of the subcommittees were most directly involved in developing the methods used for estimating donor potential:

The Caregiver Informant Group (CIG) Subcommittee consisted of transplant clinicians (surgeons and physicians) and other clinicians with expertise in critical care, emergency medicine, palliative care, and transplant nursing.

The Organ Procurement Organization (OPO) Subcommittee consisted of organ procurement organization leaders and procurement professionals.

Key Study Findings

Current size and Composition of the Potential Deceased Donor Pool in the U.S.

Estimates of the Number of Potential Deceased Organ Donors

The OPO and CIG subcommittees performed separate analyses which both found that as many as 35,000 to 40,000 deceased organ donors may be available each year to help meet the needs of end-stage organ failure patients. Currently, organs for transplantation are recovered from about 8,000 deceased donors per year, potentially only one-fifth of the true potential. These findings suggest that significant donation potential exists that is not currently being realized.

However, the gap between donor potential and current numbers may not be as large as suggested by this analysis. Firstly, OPOs are already aware of and pursue many more cases than the 8,000 actual donors recovered per year. For example, in 2010 an additional 2,500 eligible[1]

[1] Based on OPTN Policy 1.2, an eligible death is defined any death or imminent death (ventilated and non-ventilated) reported by a hospital that is evaluated and meets organ donor eligibility requirements; who is aged 70 years or younger; meets meeting death by neurological criteria; and has not been diagnosed with exclusionary

deaths that did not result in donation and an additional 7,800 deaths classified as "imminent" – having characteristics consistent with eligible donors but without a declaration of brain death – were reported by OPOs to the OPTN. These additional cases would increase the number of cases identified by the OPOs to over 18,300. Furthermore, additional information about the estimated 35,000-40,000 potential donors – such as lab values, serologies, and whether brain death was actually declared, which were not available in the national data sources – may have precluded donation in some cases, reducing this estimate to some degree.

This study found that the difference between potential and actual donors is greatest among older individuals, in particular those age 50 to 75, who accounted for approximately two-thirds of the gap. In fact, the estimated donation realization rates (EDRR)[2] varied substantially by age group for the analyses conducted by both subcommittees. While approximately one-half of potential donors age 18-34 became actual donors, the EDRR was much smaller among decedents age 50-75, with only about one-tenth of donation potential currently being realized. These findings suggest that the greatest opportunity to increase organ donation may exist among older potential donors. Although there were differences in the detailed findings of the OPO and CIG analyses, the general pattern exhibited by the donation realization rates with respect to age was consistent between the two analyses.

Predicted size of the potential donor pool over the next five to ten years

Five- to Ten-Year Projections of the Number of Potential Deceased Organ Donors

The CIG and OPO subcommittees used different data sources, each with its own strengths and weaknesses, and methods for forecasting donation potential over the next decade. Forecasts from both subcommittees suggested that, in the absence of significant population demographic changes, the number of potential deceased organ donors is not anticipated to change substantially over the coming ten-year period. Specifically, the forecasts predict an approximately 5% increase in the potential number of deceased organ donors between 2010 and 2020.

Applying this 5% growth rate to the 10-year period from 2010 to 2020, study findings estimated that as many as 37,000 to 42,000 deceased organ donors may be available in 2020.

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medical conditions. This definition does not include all potential donors, but was developed for reporting purposes in the context of DSA performance assessment.

[2] For this study, the estimated donation realization rate (EDRR) is defined as the number of actual donors as a percentage of the estimated number of potential donors.

INTRODUCTION

This report presents the findings of the OPTN Deceased Donor Potential Study (DDPS) that was conducted in response a request from HRSA that was framed as follows:

> *Since the initiation of the OPTN contract in 2005, annual estimates of the potential number of deceased donors in the United States have been decreasing reflecting shifts in demographics, changes in the health of the population, improvements in transportation safety, and changes in hospital and critical care practice, etc. The only studies that have been conducted on donor potential are dated. The OPTN and HRSA Division of Transplantation are in need of a rigorous epidemiologic and demographic study of national, regional, and local deceased donor potential to plan for program activity now and in the immediate future. Understanding donor potential across the country is key to developing appropriate strategies to improve deceased organ procurement and measure performance on the National organ transplantation system.*

Study Elements and Project Aims

Elements of the study included the research question, specific aims, study objectives, data, methods, and mechanisms for providing input into the research process. These are described briefly as follows:

- Research Question. The project must answer the fundamental question, "What is the potential for deceased organ donation in the United States?"
- Specific Aims. The project's specific aims were
    - To accurately characterize the current size and composition of the potential donor pool in the United States.
    - To accurately characterize the predicted size and composition of the potential donor pool in the United States in the next five (5) to ten (10) years.
    - To provide an empirical foundation for developing national goals for deceased organ donation within the context of true donor potential.
    - To inform strategic planning processes to identify and implement methods to increased deceased organ donation.
- Data. The data sources were to reflect the anticipated methods to be used, and included national databases (transplant, health statistics, and census) and relevant sources of data from primary sources within health care and transplantation.
- Methods. The study methods included:
    - Population-based inquiry
    - Demographic methods
    - Epidemiological approaches
    - Trend analysis

- Mechanisms for Research Input and Guidance. The last requested element included the desire for an advisory committee to provide subject matter expertise and experiential knowledge, share insights from the field, provide guidance, and review of study processes.

Stakeholder Committee's Contributions to Study Approach: Formulation, Composition, and Processes

The DDPS Stakeholder Committee consisted of 52 members, including HRSA and OPTN leadership. The committee was large by design. Redundancy was built into the committee roster in key functional roles and subject-matter expertise. The Stakeholder Committee was comprised of several smaller subcommittees by functional or specialty area. The two subcommittees most directly involved in developing methods used for estimating donor potential were the following:

Caregiver Informant Group (CIG) Subcommittee—consisted of transplant clinicians (surgeons and physicians), and other clinicians with expertise in critical care, emergency medicine, palliative care, and transplant nursing.

OPO Subcommittee — consisted of organ procurement organization leaders and procurement professionals.

Background and Significance of Problem

<u>A Persistent Demand for Organs</u>

Despite the successes of this area of modern medicine, the need for transplantable organs continues to increase. In particular, the total number of deceased donors has not kept pace with the increased demand for deceased donor organs. The transplant waiting list continues to grow, expanding to well over 115,000 candidates (with nearly 74,000 active candidates) (1), with longer waiting times and reported deaths on the waiting list for many patients, as seen in the OPTN/SRTR 2010 Annual Report (2). Persons awaiting a kidney constitute the largest portion of those in need of an organ; the kidney waiting list experienced a 53% increase in the number of active patients, from 34,120 in 1998 to 52,503 in 2009 (2).

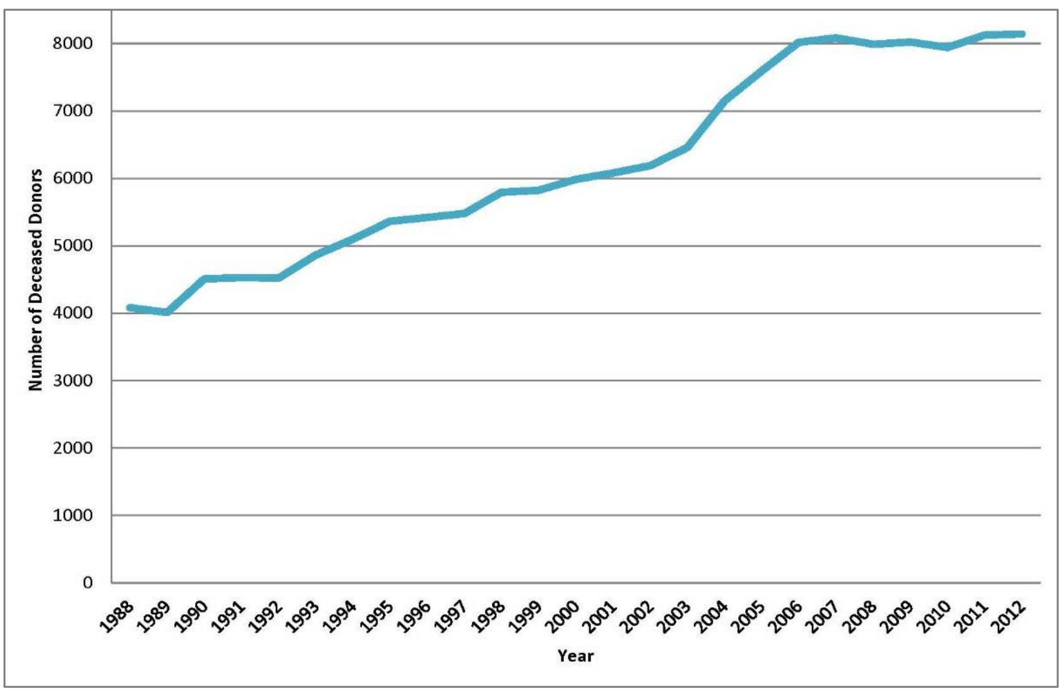
While commonly accepted by professionals in the field, the present reality has led to many assumptions about how the system is currently operating and what, if any, interventions should be taken to address this persistent disparity. Given that the number of reported deaths in a year through national vital statistics is significantly larger than the size of the waiting list, a true ascertainment of what can be expected for deceased donor potential is critical for national strategic and programmatic transplant initiatives at the federal level.

Framing the Question

With more than 2 million deaths occurring annually in the US, the question arises, "What are the reasons for such a significant drop-off from all deaths to donors?" In other words, why is there such a drastic narrowing of the pool that occurs between the total number of deaths (over 2 million) and the number actual organ donors (about 8,000)? Notwithstanding the numbers of individuals who would be determined as meeting criteria for organ donation, the total number of deceased organ donors in any given year has been very small relative to the total number of deaths.

Figure 1 reflects the trend in deceased donation over a twenty year period, and suggests this number has steadily grown for over a decade until around 2002 (3). With the introduction of the U.S. Organ Donation Breakthrough Collaborative, Shafer et al. estimate that between October 2003 and September 2006, the number of organs donors increased by 22.5%, a 4-fold increase in the percentage increase over the prior period (4). In recent years, the number of donors has been relatively stable at around 8,000 per year. That less than 0.5% of the total deaths result in organ donation raises the essential question of whether the full potential for donation in the United States is being realized.

Figure 1: Deceased Donors Recovered in the United States, 1988-2012



Deceased Organ Donor Trends and Characteristics

OPTN data indicate that the total number of deceased organ donors was relatively stable between 2006 and 2012. There were 8,016 deceased organ donors in 2006 and 8,143 in2012. Donation after brain death (DBD) accounted for more than 94% of the total number of donors from 1995 to 2004. Beginning in 2005, when donation after circulatory death (DCD) donors accounted for 7.4% of all organ donors, the percentage of DCD donors has increased annually by 1%. In 2012, DCD donors accounted for13.6% of the total number of deceased organ donors.

During the 13-year period from 2000 to 2012, cerebrovascular disease/stroke and head trauma were the two most prevalent causes of death of deceased donors. Cerebrovascular disease or stroke accounted for 43.3% of all deceased organ donors in 2000 and 34.8% of all deceased donors in 2012. Head trauma accounted for 41.9% of all deceased organ donors in 2000 and 32.3% of all deceased donors in 2012.

Intracranial hemorrhage/stroke and blunt force trauma were the two most prevalent mechanisms of death. Hemorrhage or stroke accounted for 46.8% of all deceased organ donors in 2000; in 2012, they accounted for 35.8%. Blunt force trauma accounted for 29.4% of all deceased organ donors in 2000 and 21.9% of all deceased organ donors in 2012. In recent years, natural causes was the most prevalent circumstance of death. It was the circumstance of death for 21.6% of all deceased organ donors in 2000 and 45.0% of all donors in 2012.

Deceased Donor Potential: A Literature Review of Selected Evidence

A review of selected evidence on estimates of deceased organ donor potential revealed a range of methods and resulting estimates of donation potential. Potential donor estimates have been reported in a number of ways. Most have provided some estimate of “evaluable”[3] deaths, together with a subset estimate of “eligible” deaths, and finally some estimation of deceased donor potential. Experts in the field continue to debate definitions and metrics that could be standardized and used over time to reflect both total donor potential and progress made toward reaching that potential. The field continues to evolve in pursuit of appropriate measures and greater precision for quantifying both national and region-specific deceased donor potential. Several recent studies are cited in **Table 1** below.

Using a multi-hospital, medical record review of 1997-1999 data, Sheehy et al. (2003) found that the number of potential donors was more than twice that of actual donors. Actual donors from participating hospitals ranged from 2,399 to 2,763, while the number of potential donors

[3] Evaluable deaths is a term used to describe and evaluate deceased donation in a plausible pool of donors (that is, a population of decedents in which the prospect of donation is at least theoretically feasible). The term is also viewed as the identified in-hospital deaths in which there were no medical contraindications. After applying defined criteria used to stratify the deaths, the deaths that fulfilled all criteria were labeled as "evaluable deaths" as described in Ojo (1999).

ranged from 5,462 to 6,843. In 2012, Sheehy et al. used NCHS, SRTR and U.S. Census Bureau data to find that of over 2 million in-hospital deaths in the U.S., 42,339 (4.8%) were evaluable deaths.

Table 1. Summary of Select Evidence for Potential and Actual Donors

Author, Year **Key Attributes of Study and Data**	**Potential Donors**	**Actual Donors**
Sheehy et al., 2003 (5) **Data** Secondary data analyses using chart/medical record review **Timeframe of Data** 1997–1999 **Geographic Coverage of Data** US (varied distribution within US with lowest participation of OPOs in the southeast) **Relevant Objective** To determine size and composition of the brain-dead organ donor pool and examine ways to increase donation rates.	**Potential donors from participating hospitals, n** 1997: 6,843 1998: 6,219 1999: 5,462 **Estimates of national pool of potential organ donors** *Applying sample conversion rate* 1997: 13,565 1998: 13,728 1999: 13,317 *Extrapolating sample study results* 1997: 10,845 1998: 10,465 1999: 10,754	**Actual donors from participating hospitals, n** 1997: 2,763 1998: 2,628 1999: 2,399 **Actual national pool of donors, n** 1997: 5,479 1998: 5,793 1999: 5,824

Author, Year Key Attributes of Study and Data	Potential Donors	Actual Donors
Michael et al., 2009 (6) **Data** Secondary data analyses using OPO-specific data **Timeframe of Data** 2005–2008 **Geographic Coverage of Data** Hospitals served by OPO regions (Virginia, North Carolina, West Virginia) **Relevant Objective** To identify factors associated with successful organ retrieval among patients referred for potential organ donation.	**Referrals to OPO for possible donation, n** Total: 6,731 Referrals from ED: 717 Referrals from inpatient: 6,014 **Referred donors with organs retrieved, n (%)** 466 (6.9) **Referrals with consent eventually denied, %** Referrals from ED: 33.5 Referrals from inpatient: 42.7	**Referred donors found medically suitable by OPO, n (%)** 787 (11.7) Results of those found medically suitable: Organs retrieved: 466 (59.2) Consent denied: 321 (40.8) **Proportion of medically suitable donors with organs recovered, by referral source, %** ED: 15.48 Inpatient: 5.90 Odds ratio: 2.92 (2.32, 3.67) **Reasons for nonretrieval, by referral source** Medically acceptable, but consent denied, % ED: 7.81 Inpatient: 4.41 Medically unacceptable (infection, malignancy, or some other medical contraindication), % ED: 61.79 Inpatient: 80.16 Proportion of medically suitable donors who eventually did not meet clinical criteria for brain death and patient survived, % ED: 14.92 Inpatient: 9.53

Author, Year Key Attributes of Study and Data	Potential Donors	Actual Donors
Sheehy et al., 2012 (7) **Data** Secondary data analyses using: NCHS Vital Statistics Mortality Data (Multiple Cause of Death files); OPTN Eligible death data; U.S. Census Bureau data (County-level) **Timeframe of Data** 2007; 2001 and 2005 added for comparison across 3 time periods **Geographic Coverage of Data** US (national) **Relevant Objective** To investigate whether mortality data can help explain the variation in underlying supply of organs for transplantation across US OPO service areas.	**Potential pool of evaluable deaths, n** ▪ 2,428,343 deaths in the U.S. (with 873,589 occurring in hospitals) o Eliminate deaths over 70 years of age o Eliminate medically unsuitable deaths (ICD-10 Codes) like those causes that prevent organ donation (e.g., metastatic cancer) o Select deaths from cerebrovascular accident (CVA) and trauma (i.e., causes that are most often associated with brain death) ▪ **42,339 evaluable deaths (4.8% of 2007 in-hospital deaths)** **Range of in-hospitals deaths per million population across donation service areas (2007)** ▪ Deaths ≤ 70 years from CVA and trauma o High—229 o Third quartile—175 o Median—146 o First quartile—120 o Low—91 *Mean: 144 ▪ Eligible deaths per million population ranged from 15.6 to 59.3, with a national mean of 34.8. ▪ Correlation of deaths per million population (PMP) from trauma and CVAs with reported eligible deaths PMP by OPO resulted in an r-square of 0.79.	NR

* Data regarding deceased donors only were abstracted.

ED: emergency department, ICD-10: International Classification of Diseases, 10th Revision, NCHS: National Center for Health Statistics, NR: not reported, SRTR: Scientific Registry of Transplant Recipients.

Overview of Analytic Approaches

Reported here are two components of the study:

I. Estimation of the number of potential deceased organ donors, using different data sets, assumptions, and methods to obtain estimates of this number.

To estimate the number of potential donors, two different "filtering" approaches were applied to national death data sets. These filters incorporated clinical criteria, such as the absence of metastatic cancer and other factors that preclude donation, to narrow down the approximately 2.4 million annual deaths in the U.S. to those that ostensibly had the potential to donate transplant quality organs.

II. Development of donor potential projections over a five- to ten-year period.

Regression modeling was used to produce two different forecasts of the number of potential donors available annually through the year 2020. This approach used recent trends in the estimated number potential donors from the aforementioned filters to extrapolate future growth in this potential.

An additional approach was used that involved analysis of trends in the number and causes of death, as well as the changing distribution of deaths by age, to provide a complementary method for forecasting donation potential. This methodology and the resulting projections are provided in **Appendix A**.

I. Estimating the Number of Potential Deceased Organ Donors

Data Sources

OPTN Data

Description. Data are reported to the Organ Procurement and Transplantation Network (OPTN) on every deceased donor recovered in the United States since October 1, 1987. A donor is one from whom at least one organ was recovered for transplant. Data are submitted to the OPTN by the Organ Procurement Organization (OPO) that recovered the donor. Demographics, laboratory values, serology results, medications used during data management, social history and lifestyle factors, medical history, and organ-specific test results are reported on all deceased donors. These data are submitted electronically and must pass a series of data validation edits.

OPOs must also report person-level information to the OPTN on all deaths meeting imminent or eligible death criteria, which include exclusions for age, infections, malignancies and other conditions. These criteria are defined in OPTN policy 1.2 (http://optn.transplant.hrsa.gov/ContentDocuments/OPTN_Policies.pdf#nameddest=Policy_01).

Data Limitations. The imminent and eligible death definitions were developed to provide a standard population on which OPO performance could be assessed. These definitions are not intended to be inclusive of all potential donors and are not intended to be used to rule out potential organ donors. For example, the imminent and eligible death definitions do not include decedents over 70 years old and patients declared dead based on circulatory criteria. These populations, as well as others excluded from the imminent and eligible death definitions, may have donation potential. Therefore, the OPTN database cannot be used in isolation for estimating the current number of potential donors or for projecting the number of potential donors. But imminent and eligible deaths reported to the OPTN are useful in accounting for some of the gaps between the estimated number of potential donors and the number of actual donors.

CDC's NCHS National Mortality Data

Description. United States Multiple Cause Mortality File contains records on all deaths in the United States reported between 2000 and 2010 (US DHHS, CDC, NCHS 2000-2010). These data were obtained from the Centers for Disease Control and Prevention's National Center for Health Statistics (NCHS). These mortality data are reported on death certificates, which are completed by funeral directors, attending physicians, medical examiners, and coroners. The original records are filed in state registration offices, and statistical information is compiled in a national database through the Vital Statistics Cooperative Program of the Centers for Disease Control and Prevention's National Center for Health Statistics (Kochanek KD, Xu J, Murphy SL et al. 2012). More than 99% of deaths occurring in the United States are believed to be registered (National Center for Health Statistics). Causes of death for the specified 11-year period were processed using the International Classification of Diseases, Tenth Revision (ICD-10) (8).

Each death certificate contains a primary cause of death and up to 20 additional causes. The causes of death obtained from the certificate are translated into record axis codes to assign the most meaningful codes and to resolve contradictions and imprecision on the death certificate. The record axis codes best describe the overall medical certification portion of the death certificate. The record axis codes are the basis for NCHS multiple cause tabulations (8).

Data Limitations. To be able to produce the most accurate estimate of the number of potential donors, a data source would need to include complete information on multiple causes of death, all procedures performed, the hospitalization status at death, and all co-morbidities for every death in the US. Such a source does not exist. The NCHS data do not have all of these items, but this source does possess sufficient detail to develop useful estimates of donation potential. Examples of limitations of the NCHS data in developing these estimates are described below.

The types of medical procedures performed on each patient prior to death are not available through the NCHS data. The CIG's assumption that decedents must have been mechanically ventilated during the hospital stay to have potential for donation was also assumed to apply for the NCHS-related analyses. However, it was not possible to identify ventilation use directly from the NCHS data, due to lack of procedure information.

Another limitation of the NCHS dataset is that the only clinical information available is related to cause of death. Other co-morbidities, if not related to the death, are not available from this source. As a result, there may be deaths in the analysis that are considered to have donation potential but should have been excluded from consideration if complete clinical information had been available. Thus, any estimates based solely on NCHS data may overestimate the true number of potential deceased organ donors. It is not possible to quantify the degree to which donor potential is overestimated strictly from the NCHS data.

Researchers from the NCHS noted an unusually large increase in the number of deaths assigned to ICD-10 code R99 (Other ill-defined and unspecified causes of mortality) for New Jersey, Ohio and West Virginia in 2009 (Kochanek KD, Xu J, Murphy SL, et al. 2012). (The number of deaths for these 3 states with this ICD-10 code increased from 988 deaths in 2008 to 4843 deaths in 2009). As unknown cause of death may result in this population not being considered to have donation potential, the estimates of donor potential in 2009 may be affected. This may also affect the projections of donor potential between 2011 and 2020.

For an accurate comparison of the distribution of causes of death of potential donors vs. actual donors, it was necessary to map the ICD-10 causes to the donor causes of death reported by OPOs into the OPTN system. Since there is not a direct mapping of these codes, there may be some inaccuracies introduced by this process. Therefore, strong conclusions based on comparisons of cause of death between the two sources may not be warranted.

AHRQ's HCUP Data – NIS

For Caregiver Informant Group (CIG) analyses, clinical and administrative data from the Agency for Healthcare Research and Quality (AHRQ), called the Nationwide Inpatient Sample (NIS), were used.

AHRQ set up the Healthcare Cost and Utilization Project (HCUP) for collecting and sharing multistate, administrative, population-based data on insured and uninsured patients in a uniform format (9).

The Nationwide Inpatient Sample (NIS) is a unique and powerful database of hospital inpatient stays. Researchers and policymakers use these data to identify, track, and analyze national trends in health care utilization, access, charges, quality, and outcomes. Key features include:

- The NIS is the largest, all-payer, inpatient care database in the United States. It contains data from nearly 8 million hospital stays each year.
- The 2010 NIS contains all discharge data from 1,051 hospitals located in 45 States, approximating a 20-percent stratified sample of U.S. community hospitals.
- The sampling frame for the 2010 NIS lists hospitals that comprised about 95 percent of all hospital discharges in the United States.
- NIS data are available from 1988 to 2010, allowing analysis of trends over time. The number of states in the NIS has grown from 8 in the first year to 45.

- The NIS is the only national hospital database containing charge information on all patients, regardless of payer, including persons covered by Medicare, Medicaid, private insurance, and the uninsured.

- The NIS's large sample size allows analyses of rare conditions, such as congenital anomalies; uncommon treatments, such as organ transplantation; and special patient populations, such as the uninsured.

- For most states, the NIS includes hospital identifiers that permit linkages to the American Hospital Association (AHA) Annual Survey Database (Health Forum, LLC © 2010) and county identifiers that permit linkages to the Area Resource File.

The NIS contains clinical and resource use information included in a typical discharge abstract, with safeguards to protect the privacy of individual patients, physicians, and hospitals (as required by data sources). The NIS can be weighted to produce national estimates. Beginning with the 2002 NIS, severity adjustment data elements including APR-DRGs, APS-DRGs, Disease Staging, and AHRQ Comorbidity Indicators, became available. Beginning with the 2005 NIS, Diagnosis and Procedure Groups Files containing data elements from AHRQ software tools designed to ease the use of the ICD-9-CM diagnostic and procedure information were made available. Beginning with the 2007 NIS, data elements describing hospital characteristics and provision of outpatient services were made available in the Hospital Weights file.

The NIS survey is conducted annually and is one of five data sets distributed by the HCUP.

The analysis of the NIS included only records of patients who died in the hospital.

Data Limitations (NIS).

- The clinical information in NIS is limited to ICD-9-CM diagnosis and procedure codes and basic demographic information (age, gender, ethnicity). Clinical information from laboratory reports, including measures of organ function or serologies, is not included.

- Analyses based on the NIS are dependent on the accuracy of reporting diagnosis and procedure codes. Practices for reporting these codes vary by state and may change over time.

- Reporting of E-codes (accidents) varies greatly by state (per AHRQ's "Introduction to the HCUP Nationwide Inpatient Sample (NIS), 2010").

- The NIS does not contain revenue codes or other billing codes to identify patients that died and ultimately gave the gift of life through organ donation.

Additional analyses were performed based on the Nationwide Emergency Department Sample (NEDS), also obtained from AHRQ. While deaths in the emergency department have less potential for donation than inpatient deaths, this is a potential source of future organ donation potential that is important to examine. The results of these analyses were not included in the estimates of donor potential or forecasts and are only briefly mentioned in the main body of the report. However, a description of NEDS, its limitations, and the results are included in **Appendix B**.

Methods and Assumptions

OPO Subcommittee Related Research Methods and Assumptions

The OPO Subcommittee had five major goals:

1. To describe and investigate potential organ donor screening and evaluation practices among U.S. OPOs;
2. To develop a methodology for determining organ donor potential;
3. To test, validate and apply that methodology to estimate organ donation potential;
4. To develop a methodology for forecasting organ donor potential; and
5. To apply that methodology for forecasting the number of potential organ donors.

The methods for the first three items are addressed in this section; the methods for projecting organ donation potential are described in a subsequent section.

Survey methods

To assess potential organ donor screening and evaluation processes among OPOs, a survey (**Appendix C**) was developed based on input from the OPO Subcommittee. The survey was designed to elicit opinions of OPO personnel regarding relative and absolute exclusionary criteria in the OPO's decision process for identifying potential deceased organ donors. A pilot version of the survey was tested by 7 OPOs between July 2011 and September 2011; their feedback was used to refine the survey for clarity, clinical significance and applicability to OPO practice. The final survey was distributed electronically by the Association of Organ Procurement Organizations (AOPO) in November 2011 to its 58 member OPOs. The OPOs were requested to have either their operations director or director of procurement respond to the survey.

Questions in the first section of the survey were designed to capture the age limits, clinical and behavioral/social history characteristics of a potential donor the OPO would be willing to recover under any circumstances. The clinical factors included in the survey were based primarily on the eligible death definition in OPTN policy 1.2 (http://optn.transplant.hrsa.gov/ContentDocuments/OPTN_Policies.pdf#nameddest=Policy_01), accessed September 25, 2012). The behavioral/social history factors were based substantially on the Public Health Service guidelines for preventing transmission of HIV in organ and tissue transplantation (26). The clinical and behavioral factors in the survey are shown in **Table 2.** The survey allowed different responses for donation after death declared by neurologic criteria (DBD) and for donation after death declared by circulatory criteria (DCD).

Table 2. Clinical and Behavioral Factors Included in Survey

Category	Questions	
Demographics	Maximum age Minimum age and/or minimum weight	
Clinical factors	Positive Serological or Viral Culture Findings for HIV Suspected or Diagnosed Active Tuberculosis Human Immunodeficiency Virus Infection with specified conditions Creutzfeldt-Jacob Disease Hepatitis B Surface Antigen Positive Rabies Any Retro Virus Infections	Malignant neoplasms Primary CNS tumors Melanoma Hodgkin's Disease, Multiple Myeloma, Leukemia Aplastic Anemia Agranulocytosis Fungal Meningitis Viral Meningitis Viral Encephalitis Gangrene of Bowel HCV Positive
Behavioral/ social factors	Men who have had sex with another man in the preceding 5 years. Persons who report nonmedical intravenous, intramuscular, or subcutaneous injection of drugs within the preceding 5 years. Persons with hemophilia or related clotting disorders who have received human-derived clotting factor concentrates. Men or women who have engaged in sex in exchange for drugs or money in the preceding 5 years. Persons who have had sex in the preceding 12 months with any person described in items above or with a person known or suspected to have HIV. Persons who have been exposed in the preceding 12 months to known or suspected HIV-infected blood through percutaneous inoculation or through contact with an open wound, non-intact skin, or mucous membrane. Inmates of correctional systems or jail, or released from a correctional system or jail in the past 12 months?	

The questions in the first section of the survey were closed-ended responses. The respondents were requested to consider the characteristics individually, rather than in combination, for each donor type (DBD and DCD). In the second section of the survey, open-ended questions were asked for both donor types to capture feedback on three separate issues: individual factors that would be absolute contraindications to donation (other than those already listed in **Table 2**); combinations of factors that would be an absolute contraindication to donation; and any other comments.

The OPO survey instrument and detailed results can be found in **Appendix C**.

Method for estimating donor potential from national death data

Though it was hypothesized that donor acceptability criteria would differ substantially for DCD versus DBD donors, the survey results did not support that hypothesis. Though for some clinical characteristics respondents tended to be less restrictive for DBDs compared to DCDs, the subcommittee did not believe that the filtering method used for estimating donor potential needed to have different inclusionary and exclusionary criteria depending on donor type.

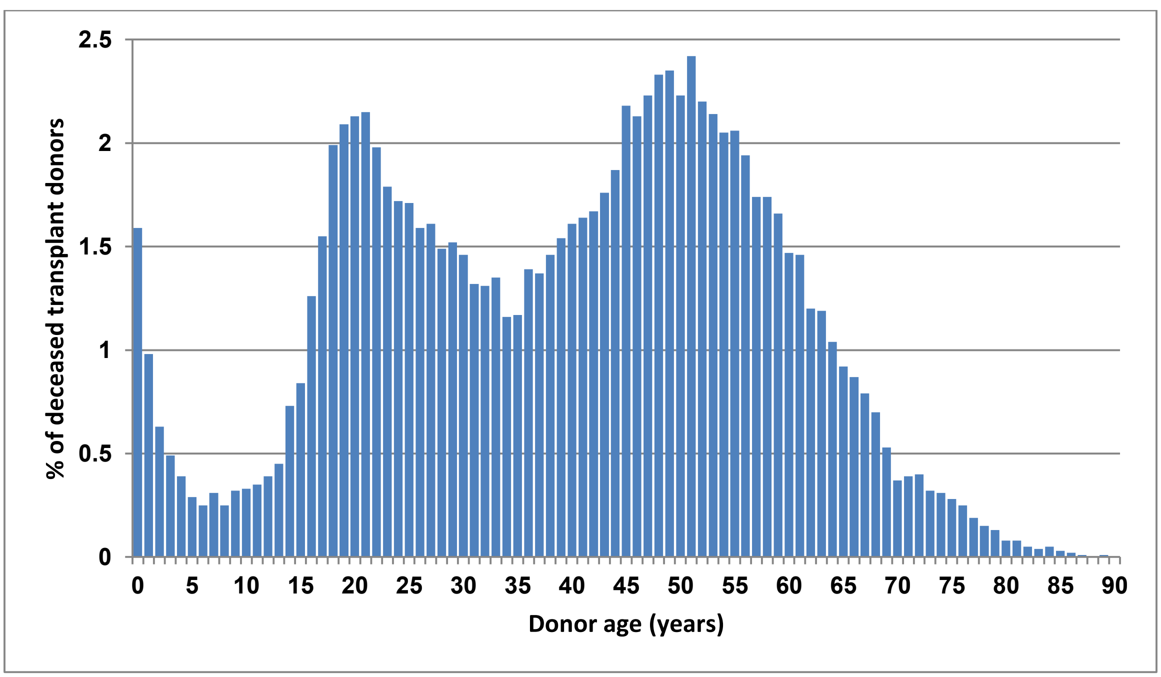
Multiple stakeholder groups reviewed the criteria identified in the OPO survey. Based on the survey results and input from other OPO stakeholders, a final set of criteria was developed for identifying deaths in the NCHS multiple cause mortality data where organ donor potential was likely to exist. These criteria reflect both inclusionary and exclusionary characteristics. When developing the final set of criteria, the scope of the criteria was limited to variables available in the NCHS data, with one notable exception: ventilation use. Ventilation use was not available in the NCHS data but is an important consideration for development of estimates of donor potential. Because other criteria were identified in the OPO survey but were not available in the NCHS data, the donor potential estimates based on the filtering process are likely to be overestimates.

The filtering criteria were applied to the NCHS data in multiple steps, with each stage being a subset of the previous stages. The result in stage 5 is the final estimate of donor potential.

<u>Stage 0:</u> All deaths in the US (NCHS data)

<u>Stage 1</u>: Limit deaths based on age at death

Figure 2: Age distribution for deceased transplant donors recovered between 2008 and 2012



Based on OPTN data:

- The 99th percentile of donor age for transplant donors recovered in 2012 was 75 years;
- The maximum donor age for transplant donors recovered in 2012 was 85 years;
- The maximum donor age for transplant donors recovered between 2008 and 2012 was 90 years.

Because the donors in the top 1 percentile may represent an unusual population that is difficult to characterize, 75 years was selected as the maximum age limit for the potential donor filtering process. All estimates of donor potential in the OPO Subcommittee sections of this report are based on an age cut-off of 75 years. The other values were used to assess the sensitivity of the potential donor estimate to changes in age limits. To avoid any confusion, results based on age limits of 85 years and 90 years are referred to as filtered deaths rather than potential donors.

Stage 2: Limit deaths to those occurring in-hospital.

Stage 3: Limit deaths to those without an ICD-10 exclusionary cause of death code.

The exclusionary codes are causes of death that are absolute contra-indications to donation, including tuberculosis, viral meningitis, rabies, malignant neoplasms, and amyloidosis (see **Appendix D** for a complete list of the exclusionary codes). The death was excluded if any of the multiple causes of death, reflected in record axis codes, appeared in the list of exclusionary codes.

Stage 4: Limit deaths to those with at least one ICD-10 inclusionary cause of death code.

The inclusionary codes are those causes of death where there is likely to be some potential for donation, including intracerebral hemorrhage, head injury, and anoxia. (See **Appendix E** for a complete list of inclusionary codes). The death was included if any of the multiple causes of death, reflected in record axis codes, appeared in the list of inclusionary codes.

Stage 5: Limit deaths to those in which mechanical ventilation was administered prior to death. This was done indirectly, by applying ventilated probabilities based on NIS data to Stage 4 deaths.

The CIG determined that decedents must be mechanically ventilated during the hospital stay to have potential for donation, and the OPO subcommittee adopted this assumption for its analysis. However, it was not possible to identify ventilation use directly from the NCHS data, due to lack of information regarding procedures performed. An indirect approach was taken to incorporate the ventilation rate in estimated donor potential. The development of the ventilation rates is described in more detail on page 31 in the CIG section of the report.

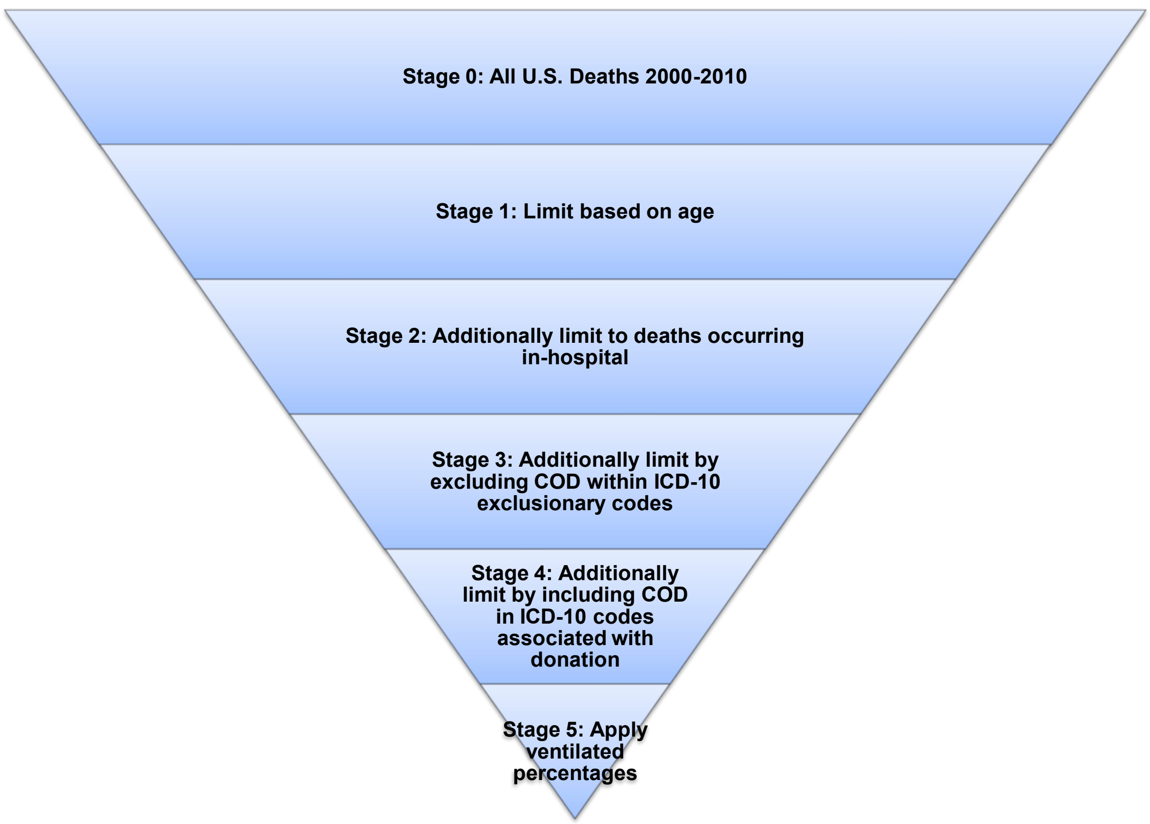
Ventilation use rates, based on the NIS data, were stratified by year of death, age group, and cause of death or diagnosis for inpatient deaths.

These percentages were applied to the population of NCHS deaths, after filtering for the inclusion and exclusion criteria developed by the OPO Subcommittee. Although this was an indirect approach at adjusting for differential rates of ventilation use, applying rates after stratifying by age, cause of death, and year was a significant refinement over assuming all decedents had the same chance of having been on a ventilator.

An example of how the ventilation rates would be applied to obtain Stage 5 estimates:

Diagnosis/cause of death	Age group	Ventilation rates (2010)	Inpatient filtered deaths through Stage 4 (hypothetical #s)	Stage 5. Estimated number of potential donors = ventilation rate*inpatient filtered deaths (rounded)
Acute cerebrovascular disease	**<1**	83.9%	200	168
	1-5	75.3%	50	38
	6-10	79.8%	25	20

Figure 3: Multiple Cause Mortality File Filtering For Donor Potential Flow



NOTES:

- Stage 1: Though donor potential was limited to a maximum age of 75 years, tabulations were also produced for filtered deaths using a maximum age of 85 years and 90 years (see **Appendix F** for the Results section).
- Stage 2: Though the OPO Subcommittee's definition of donor potential was limited to inpatient deaths, outpatient/emergency department filtered deaths were also tabulated

(see **Appendix B** for these results.). These deaths were considered to have a substantially reduced potential for donation.

- Stage 3: Exclusionary ICD-10 codes are shown in the **Appendix D.**
- Stage 4: Inclusionary ICD-10 codes are shown in the **Appendix E**.
- Stage 5: Ventilated percentage for inpatient deaths were stratified by age, cause of death and year of death. For outpatient deaths, the percentages were stratified only by age. Ventilation rates are shown in the **Appendix G**.

__Caregiver Information Group Research Methods and Assumptions__

Subcommittee Approach and Design

The DDPS Caregiver Informant Group (CIG) subcommittee performed two tasks. First, the group established two key principles that would guide the approach used for identifying potential donors. Second, the group built upon these principles to provide more specific guidance on clinical criteria to use as “filters” for identifying potential deceased organ donors among deaths occurring in the United States, similar in spirit to the OPO subcommittee’s filter analysis.

Specification of Clinical Conditions Used to Identify Potential Deceased Donors in National Data

CIG Subcommittee members expressed concern that the clinical conditions used to define “eligible deaths” in the U.S. (per OPTN Policy 1.2) were inappropriate for assessing donor potential and therefore considered alternative definitions for identifying potential deceased organ donors.

Thus, the group established two key principles they believed should be considered to identify potential deceased organ donors:

- **Principle 1:** Potential deceased organ donors should not have conditions that would preclude organ function in the event of transplant.

- **Principle 2:** Potential deceased organ donors should not have conditions that would be thought unacceptable to potential recipients due to risk of adverse health events (e.g., spread of infectious disease or cancer).

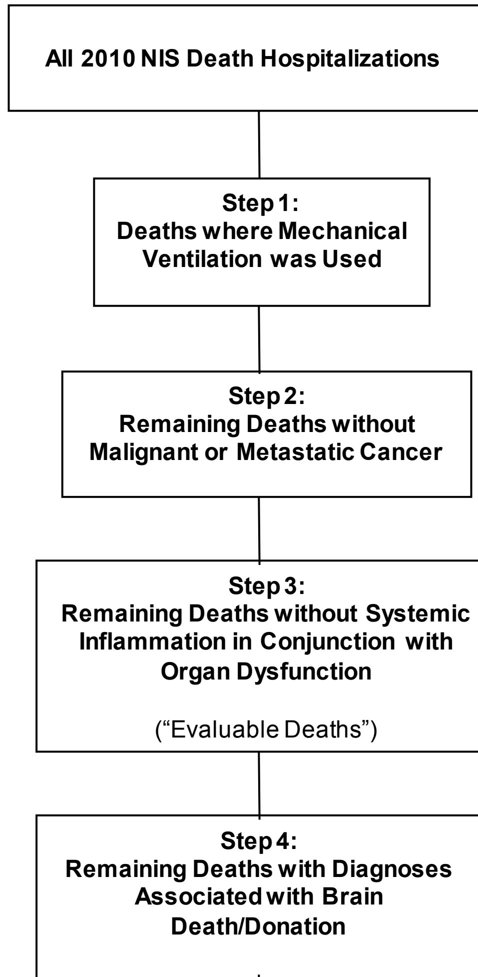
They also agreed that it would be important to compare how using these principles to identify potential donors would differ from the use of current OPTN “eligible death” definition (Policy 1.2) in estimating the number of potential donors.

Developing a Potential Donor Filter

This flowchart, or “potential donor filter,” reflects a graphical illustration for identifying potential organ donors in administrative data among community hospital (either inpatient or emergency room) deaths. The following major concepts identified by CIG Subcommittee members were incorporated into the donor potential filter:

- Use of mechanical ventilation as a necessary condition for a hospital death to be considered a potential donor
- Key medical contraindications to donation that must be absent:
    - Metastatic cancer (as well as certain other malignant cancers)
    - Multi-system organ failure
- Neurological determination of death (brain death): deaths in which brain death was declared are more likely to result in donation, though there is also donor potential among non-heart-beating (DCD) deaths
- Hospital length of stay (LOS): organ donation is more likely to occur after a short stay.
- Burden of illness: deaths with a relatively low burden of comorbid illness are more likely to be candidates for donation.

Figure 4: CIG's Potential Donor Filter and Sensitivity Matrix (Flow Diagram)



Sensitivity Matrix

Step 5: Remaining Deaths with Age<=90		Length of Stay		
		<=3	<=14	Any
Age	Severity of Illness Score			
0-75	<=18	Cell 1	Cell 2	Cell 3
	Any	Cell 4	Cell 5	Cell 6
0-85	<=18	Cell 7	Cell 8	Cell 9
	Any	Cell 10	Cell 11	Cell 12
0-90	<=18	Cell 13	Cell 14	Cell 15
	Any	Cell 16	Cell 17	Cell 18

Figure 4 is a graphical illustration of the CIG's potential donor filter. The filter has five steps, plus a sensitivity matrix for estimating donor potential with varying assumptions for the maximum age, length of stay (LOS), and severity of illness.

Step 1 of the filter removed deaths that did not have a reported procedure code corresponding to the use of respiratory intubation or mechanical ventilation. Death hospitalizations in the NIS were considered to have had mechanical ventilation administered if clinical classification software (CCS) procedure code 216 "respiratory intubation and mechanical ventilation" was present among any of the (up to 15) procedure codes listed for each patient discharge record. CCS procedure code 216 includes the following ICD-9-CM codes:

9390: CONT POS AIRWAY PRESSURE (Begin 1988)
9392: OTH MECH RESP ASSIST (Begin 1988 End 1991)
9601: INSERT NASOPHARYN AIRWAY
9602: INSERT OROPHARYN AIRWAY
9603: INSERT ESOPH OBTU AIRWAY
9604: INSERT ENDOTRACHEAL TUBE
9605: RESP TRACT INTUBAT NEC
9670: CONT MECH VENT-UNSPC DUR (Begin 1991)
9671: CONT MECH VENT < 96 HRS (Begin 1991)
9672: CONT MECH VENT 96+ HRS (Begin 1991)

Step 2 removed deaths having one or more diagnosis codes with metastatic or malignant cancer. Any patient discharge record with an ICD-9-CM code associated with metastatic cancer was considered to have an exclusionary cancer. Malignant tumors, melanoma, and lymphomas were also considered exclusionary. However, non-melanomous skin cancers such as basal cell carcinoma, were not considered exclusionary. Cancers isolated in the brain were also not considered exclusionary. ICD-9 "v-codes" (which can indicate history of cancer, family history of cancer, or screening for cancer) were also not considered exclusionary. The full list of ICD-9-CM codes used to identify "cancer rule-outs" is found in Table H-1 in **Appendix H.**

In **Step 3**, remaining deaths were filtered to exclude those with multi-system organ failure (MSOF). Patients with severe sepsis or systemic inflammation accompanied by organ dysfunction were considered to have MSOF. These conditions were identified by the presence of either of the following two ICD-9-CM codes:

99592: SYS INFLAM / INFECTI W ORGAN DYSFUNCTI (Begin 2002)
99594: SYS INFLAM / NON-INFECT W ORGAN DYSFUN (Begin 2002)

Like Step 1, **Step 4** can be thought of as an *inclusion* criterion, as opposed to a rule-out or exclusionary step. In order to pass through this step of the filter, death records must have one or more diagnoses identified by the CIG as being associated with brain death and/or organ donation in general. Deaths with any one of the following CCS codes among the (up to 25) diagnoses included in each discharge record were considered to having been potential for being declared brain dead. These codes were based on a study by Cuende, et al (10).

35: Cancer of brain and nervous system
47: Other and unspecified benign neoplasm
109: Acute cerebrovascular disease
228: Skull and face fractures
233: Intracranial injury

The CIG also identified the following subset of CCS E-codes, which reflect “external causes of injury and poisoning,” that were considered to be associated with an increased likelihood of organ donation and were thus incorporated in the Step 4 inclusion criteria.

2603: E Codes: Fall
2607: E Codes: Motor vehicle traffic (MVT)
2620: E Codes: Unspecified
2615: E Codes: Suffocation
2618: E Codes: Other specified and classifiable
2605: E Codes: Firearm
2611: E Codes: Natural/environment
2619: E Codes: Other specified; NEC
2614: E Codes: Struck by; against
2604: E Codes: Fire/burn
2602: E Codes: Drowning/submersion
2610: E Codes: Transport; not MVT
2601: E Codes: Cut/pierce
2608: E Codes: Pedal cyclist; not MVT
2609: E Codes: Pedestrian; not MVT
2612: E Codes: Overexertion
2606: E Codes: Machinery

E-Codes 2613 (Poisoning), 2616 (Adverse Effects of Medical Care), 2617 (Adverse Effects of Medical Drugs), and 2621 (Place of Occurrence) were not considered inclusionary criteria.

Data elements that could reliably distinguish brain death (BD) versus donation after circulatory death (DCD) potential were not available. Codes selected by the CIG for this Step 4 inclusion criterion were those considered to have a high likelihood of leading to brain death or neurological devastation consistent with organ donation potential.

In **Step 5**, remaining deaths over age 90 were excluded. Those death records still remaining after all five steps are displayed in the appropriate cell(s) of the sensitivity matrix, depending on decedent age, length of stay, and severity of illness.

Each “cell” of the matrix can be thought of as a different scenario based on a specific set of assumptions with respect to maximum age, length of stay, and severity of illness. These sensitivity analysis results are intended to provide insight into the impact of making different assumptions regarding these three parameters.

Decedents in "cell 1" of the sensitivity matrix are those meeting the *most conservative* set of assumptions: age≤75, LOS≤3 days, and severity of illness score≤18. Those in "cell 2" had age≤75, LOS≤14 days, and severity of illness score≤18. The remaining cells are identified by number in **Figure 4**.

"Cell 18" is equal to the result of filter Step 5, and represents *the least conservative scenario*, including deaths up to age 90, with no maximum length of stay, and no maximum severity of illness score.

Rationale for Age Cutoffs Applied in Sensitivity Matrix

An analysis of OPTN data from 2008-2012 revealed that viable organs thought to be of benefit to patients have rarely come from donors of very advanced age (**Figure 1**). Still, occasionally successful organ donation has come from donors in their 70's, 80's, or on rare occasions, even in their 90's. Such organs will not be ideal for expected longevity, but may still provide a quality of life and survival benefit for older patients, for example those on dialysis waiting for a kidney. The liver is the organ most often used for transplantation from donors of advanced age.

Though donation from among the oldest decedents is possible, it is still rare. This conclusion is informed by existing OPTN data. And while current recovery and transplant practice may not routinely make use of older donors, the cutoff decision had two goals: a) include feedback from the CIG members, who did not feel confident defining a specific, maximum age cutoff as a filtering criteria; b) while avoiding the possibility of overestimating donor potential by assuming the viability for donation of all older decedents. Consequently, this analysis of donation potential incorporated the three age cutoffs described on page 25 as part of the sensitivity matrix.

Rationale for Length of Stay Cutoffs Applied in Sensitivity Matrix

The CIG Subcommittee indicated that hospital stays of three or fewer days were most likely to lead to donation. Though shorter hospital stays were thought to be generally associated with higher likelihood of donation, the stakeholders indicated it is not implausible for viable donor organs to be recovered after stays of up to 14 days. Consequently, the sensitivity matrix incorporated the following three LOS scenarios: 0-3 days, 0-14 days, and any number of days.

An analysis of OPTN data showed that among donors with an organ recovered for the purpose of transplantation from 2008-2012, the median length of stay was three days, consistent with the "ideal" threshold identified by the CIG stakeholders. While many donors had length of stay far longer than three days, few had stays longer than two weeks. In fact, 14 days represented the 97th percentile length of stay among actual donors, a finding consistent with the stakeholders' recommendation of 14 days as an approximate upper limit for organ donation potential.

Rationale for Severity of Illness Cutoffs Applied in Sensitivity Matrix

The severity of illness for each decedent in the NIS was estimated by adapting a comorbidity score per van Walraven, et al (11). The list of ICD-9-CM codes mapped to each comorbidity, per Elixhauser (12), is shown in Table H-2 in **Appendix H**. If a decedent had any of the 29 Elixhauser medical conditions among either the *primary or secondary* diagnoses, the corresponding comorbidity score "points" were assigned to that death record. For example, decedents with a diagnosis of congestive heart failure were assigned 7 points (**Table 3**).

Table 3. Point Assignments for Adapted Severity of Illness Score

Elixhauser condition	Severity of Illness Points (van Walraven)
AIDS	0
ALCOHOL: Alcohol abuse	0
ANEMDEF: Deficiency anemias	-2
ARTH: Rheumatoid arthritis/collagen vascular disease	0
BLDLOSS: Blood loss anemia	-2
CHF: Congestive heart failure	7
CHRNLUNG: Chronic pulmonary disease	3
COAG: Coagulopathy	3
DEPRESS: Depression	-3
DM: Diabetes mellitus	0
DMCX: Diabetes mellitus, complicated	0
DRUG: Drug abuse	-7
HTN_C: Hypertension, complicated	0
HYPOTHY: Hypothyroidism	0
LIVER: Liver disease	11
LYMPH: Lymphoma	9
LYTES: Fluid and electrolyte disorders	5
METS: Metastatic cancer	12
NEURO: Other neurological disorders	6
OBESE: Obesity	-4
PARA: Paralysis	7
PERIVASC: Peripheral vascular disorders	2
PSYCH: Psychoses	0
PULMCIRC: Pulmonary circulation disorders	4
RENLFAIL: Renal failure	5
TUMOR: Solid tumor without metastasis	4
ULCER: Peptic ulcer disease excluding bleeding	0
VALVE: Valvular disease	-1
WGHTLOSS: Weight loss	6

The severity of illness score was calculated as the sum of the points across all diagnoses present for each death record. Higher scores are associated with greater severity of illness, or "burden of disease." Though this score was developed to predict mortality, the CIG considered it reasonable to assume that a severity of illness measure highly correlated with the chances of dying was also highly (but inversely) correlated with the likelihood of donation for those who had already died.

Conditions assigned negative points per **Table 3** were associated with lower mortality risk than the baseline patient chosen by van Walraven, et al, in their analysis. The fact that some of the points are positive and others negative is not important for this analysis. For example, a value of 25 could be added to each patient's total score to make all scores positive; this would not have changed the rank-ordering of patients, who would still be ordered according to severity of illness or disease burden after sorting by total score. The rank-ordering is paramount, not the particular scale chosen for assigning points.

Figure 5 shows a histogram of the severity of illness scores among deaths that passed through Steps 1-4 of the filter. The mode, or most frequent value, was zero; in fact, over 20% of filtered decedents had a severity score of zero. Most of the patients with a score of zero had none of the 29 Elixhauser morbidities, though some may have had conditions assigned negative points that offset conditions assigned positive points. In total, 25% of filtered decedents had severity scores of zero or less.

The median severity score was 6.0 and the mean 7.5. Only 25% of scores exceeded 12, and the 90th percentile score was 18, the 95th 21, and the 99th 28.

Figure 5: Distribution of Adapted van Walraven Severity of Illness Scores Among NIS Decedents in 2010 that Passed through DDPS Filter (Steps 1-4)

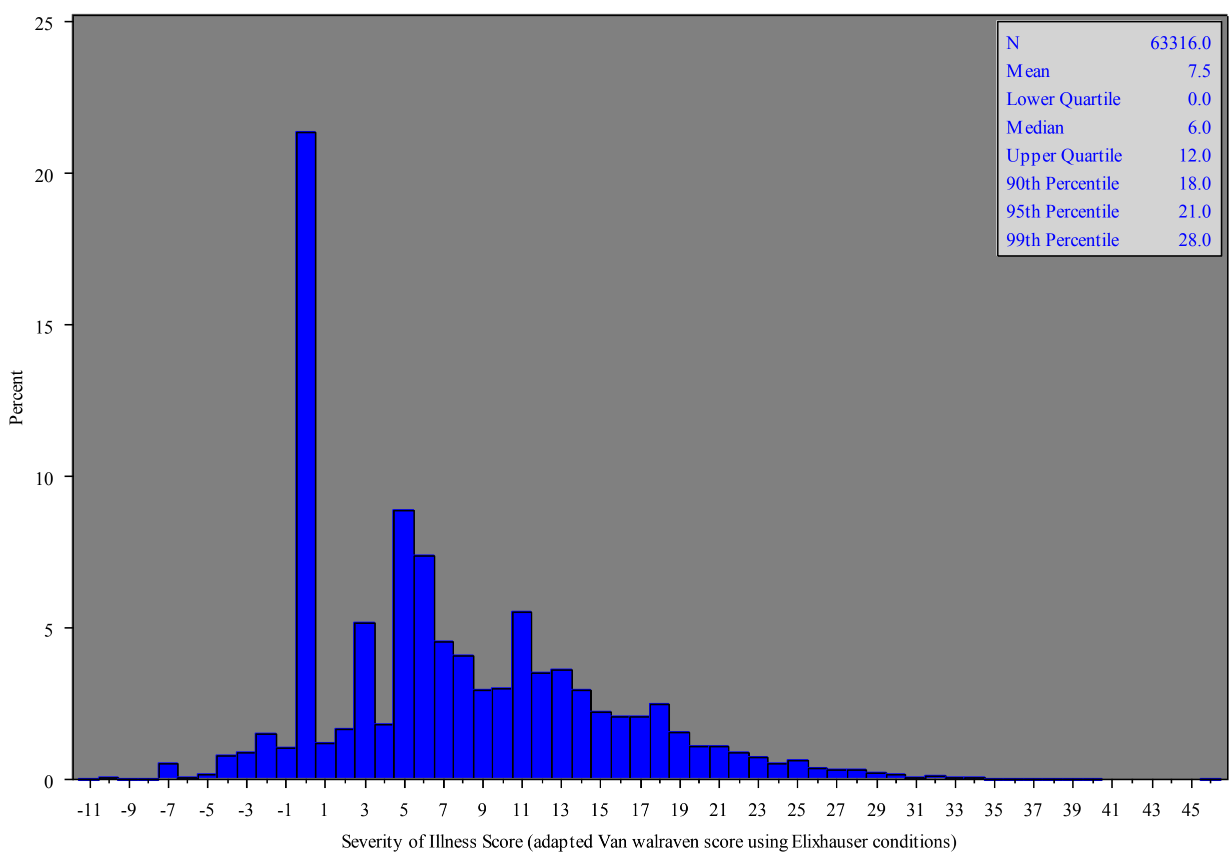


Table 4 examines the prevalence of six severe, organ-specific chronic illnesses that may affect organ donation, by severity score groups. Clearly, decedents with a score of zero or less had a low burden of illness prior to death, with only 0.1% having had congestive heart failure, 1.9% chronic lung disease, 0% liver disease, 0.3% pulmonary circulation disorders, and 0.3% renal failure. Nearly 14% had diabetes, however.

As the severity score increased, the prevalence of each of these six conditions increased. For patients with scores between 13 and 18 (>75th to 90th percentiles), about 25% to 35% had congestive heart failure, chronic lung disease, diabetes, and/or renal failure. Less than 10% had either liver disease or pulmonary circulation disorders. By contrast, patients with scores between 19 and 28 (>90th to 99th percentiles) had much higher rates of congestive heart failure (58.3%), renal failure (41.3%), liver disease (20.5%), and pulmonary circulation disorders (16.9%).

Table 4. Presence of Organ-Specific, Elixhauser Morbidity Conditions by Adapted van Walraven Severity of Illness Scores Among 2010 NIS Decedents that Passed through DDPS Filter (Steps 1-5)

	Congestive Heart Failure	Chronic Lung Disease	Diabetes	Liver Disease	Pulmonary Circulation Disorders	Renal Failure
Severity of Illness Score						
<=0 (0-25%)	0.1%	1.9%	13.6%	0.0%	0.3%	0.3%
1-6 (25-50%)	3.0%	13.5%	18.0%	0.3%	2.4%	7.4%
7-12 (50-75%)	19.8%	19.3%	22.4%	2.2%	5.2%	16.8%
13-18 (75-90%)	35.8%	26.2%	24.2%	6.9%	8.6%	25.6%
19-28 (90-99%)	58.3%	36.3%	24.3%	20.5%	16.9%	41.3%
29+ (99-100%)	78.3%	50.3%	32.1%	45.7%	37.7%	56.0%
All	16.0%	15.8%	19.4%	3.6%	4.8%	13.5%

Table 5 shows that only 2.2% of patients with severity score of zero or less had one of the following 4 conditions – congestive heart failure, chronic lung disease, renal failure, or liver disease – and only 0.1% had two of these conditions. About 1/3 of patients with scores of 13-18 had none of these conditions, while 40.2% had one, 22% had two, and 3.6% had three. None had all four conditions. By comparison, only 8.6% of patients with scores of 19-28 had none of the four conditions, while over 50% had two or more, and a small percentage had all four conditions.

Based on these results, the 90th percentile severity of illness score (a value of 18) was chosen to exclude potential donors based on burden of disease in the sensitivity analysis. It is conceivable that some decedents with scores greater than 18 could donate usable organs; however, estimating donor potential without including burden of disease would be contrary to the guidance provided by CIG stakeholders and also likely overestimate donor potential.

Table 5.
Number of Severe Elixhauser Morbidity Conditions
(Congestive Heart Failure, Chronic Lung Disease, Renal Failure, Liver Disease)
by Adapted van Walraven Severity of Illness Scores
Among 2010 NIS Decedents that Passed through DDPS Filter (Steps 1-5)

	How Many of the Four Conditions? (%)				
	0	1	2	3	4
Severity of Illness Score (percentile)					
<=0 (0-25%)	97.7	2.2	0.1	0.0	0.0
1-6 (25-50%)	76.7	22.2	1.0	0.0	0.0
7-12 (50-75%)	51.3	39.4	8.9	0.5	0.0
13-18 (75-90%)	34.2	40.2	22.0	3.6	0.0
19-28 (90-99%)	8.6	39.0	39.9	12.4	0.1
29+ (99-100%)	0.0	15.4	45.2	32.7	6.7
All	63.9	25.1	9.1	1.9	0.1

Rationale for Selecting "Cell 2" for Estimating Donor Potential

Though CIG stakeholders did not specify a maximum age for donation potential, "cell 2" (age≤75, LOS≤14 days, severity score≤18) contains two criteria closely associated with CIG stakeholder recommendations. This scenario incorporates the length of stay criterion specified by subcommittee, as well as burden of illness, another major concept identified as an essential factor for accurate estimation of donor potential. As previously indicated, the donor age category generated discrepant views among subcommittee members and resulted in no specific maximum age recommendation. The DDPS research team agreed to focus on "cell 2" assumptions for describing the composition of potential donors as well as projecting future donor potential for two reasons: a) the age thresholds were empirically derived from the OPTN data; in the absence of a clear decision from the stakeholders on this point, a data-driven alternative was used; and b) selecting this age cutoff would permit equivalent comparisons to the work of the OPO Subcommittee. The latter would aid in triangulating the findings and inform the outcome of interest—estimating deceased donation potential.

Estimating Donor Potential "Realization Rates"

Using OPTN data, the number of *actual* donors with an organ utilized for transplantation in 2010 was tabulated, and divided by the *estimated* potential number of donors ("cell 2") to derive an estimated potential donor "realization rate." This calculation was performed overall and by age group. An implicit assumption in these rate calculations is that actual donors are among the pool of estimated potential donors.

Describing the Composition of Potential Donors

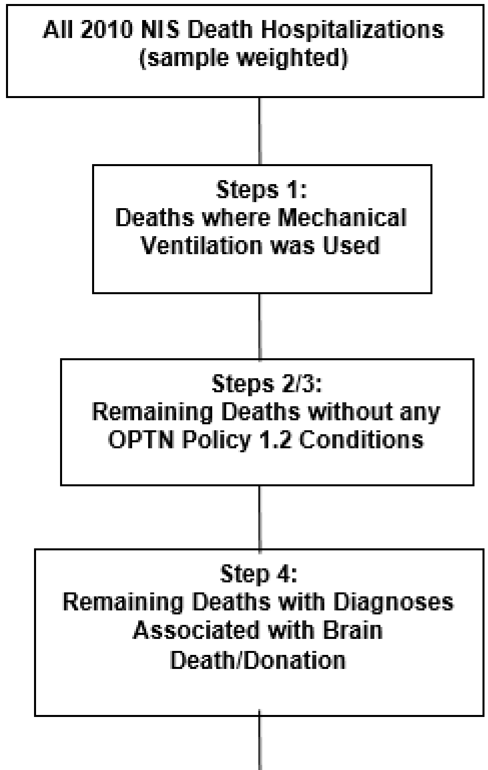
The distribution of age, length of stay, severity of illness score, number of diagnoses, gender, and race of decedents who passed through the filter and had age≤75, LOS≤14 days, and severity score≤18 (“cell 2”) was analyzed. The prevalence of each of the Elixhauser comorbidities[4] (e.g., obesity) was also calculated for these potential donors. Potential donors were also examined for prevalence of each of the 250+ CCS diagnosis groups, overall, and by age group.

Alternate Potential Donor Filter based on OPTN “Eligibility” Definition

Though the types of malignancy and infectious disease listed as exclusionary criteria in the OPTN’s “eligible death” definition (Policy 1.2) are not intended to preclude the possibility of pursuing donation in such cases, anecdotal evidence suggests this definition has been misinterpreted by some to reflect absolute bounds on organ donation. Consequently, the CIG expressed interest in examining an alternate potential donor filter based on the Policy 1.2 conditions instead of Step 2 (metastatic/malignant cancer) and Step 3 (MSOF) of the filter defined by CIG stakeholders (**Figure 16**). The alternate filter flow diagram is presented in **Figure 6.**

[4] . Researchers customarily use Elixhauser conditions to identify *co*-morbidities in administrative and clinical data. However, this analysis applied the Elixhauser comorbidities to decedents considered to have the condition if the corresponding ICD-9-CM codes were reported for any of the diagnoses, *including the primary diagnosis*.

Figure 6: *Alternate* Potential Donor Filter (OPTN Policy 1.2) and Sensitivity Matrix



Sensitivity Matrix

Step 5: Remaining Deaths with Age<=90		Length of Stay		
		<=3	<=14	Any
Age	Severity of Illness Score			
0-75	<=18	Cell 1	Cell 2	Cell 3
	Any	Cell 4	Cell 5	Cell 6
0-85	<=18	Cell 7	Cell 8	Cell 9
	Any	Cell 10	Cell 11	Cell 12
0-90	<=18	Cell 13	Cell 14	Cell 15
	Any	Cell 16	Cell 17	Cell 18

Sample Weighting in NIS

The NIS is a stratified, clustered sample of approximately 20% of all inpatient stays in the U.S., among community-based hospitals. The counts and percentages were weighted using the sample weights provided in the NIS. Sample weights were generally close to 5.0 for most discharge records, though they varied from 3.7057866 to 18.6849096 in the 2010 NIS. Potential donor estimates are shown rounded to the nearest integer. The unweighted count of NIS deaths in 2010 was 148,162; the weighted deaths totaled 740,748.11.

Similarities and Differences between OPO and CIG Subcommittee Analyses

Data Sources

The CIG Subcommittee's primary data source was the Nationwide Inpatient Sample (NIS); the OPO Subcommittee analyzed data from the Multiple Cause Mortality Data, which is distributed by the NCHS. There were some inherent differences in these two datasets that could affect the results of the analyses and, therefore, the conclusions.

- Underlying population:
  - The NCHS includes all deaths in the US
  - The NIS includes all hospital discharges for a 20% sample of community hospitals in the US.

  The NIS dataset contains more clinical and administrative detail on a smaller sample of patients than the NCHS dataset. The NIS data allows for more precise and direct filtering in estimation of donor potential.

- Data elements:
  - The NCHS contains multiple causes of death
  - The NIS contains multiple diagnoses and procedure codes.

  Although related, causes of death and diagnoses reflect different concepts. If a diagnosis was related to a co-morbid condition that did not lead to death, it would be available in the NIS dataset but not in the NCHS dataset.

  The procedure codes in the NIS dataset allow for direct determination of whether the patient was on mechanical ventilation at some time during the patient's hospital visit. Therefore, direct filtering for the use of mechanical ventilation was possible in the NIS since the use of the ventilation was known for each death record. Direct filtering was not possible for the NCHS dataset. So "indirect," or probabilistic, filtering was performed on the NCHS data by applying estimated rates of mechanical ventilation (from the NIS dataset) to the filtered deaths in order to estimate the number of deaths that passed through other steps of the filter *and* had ventilation usage.

- Coding:
  - Causes of death in the NCHS dataset were coded using ICD-10
  - Diagnoses in the NIS dataset were coded using ICD-9-CM

  So, even if cause of death and diagnosis were directly comparable, which they are not, the coding schemes differ between the two sources. Though rough mapping between the two sets is possible, an exact match does not exist for many codes.

Approach

Besides differences in the data sources, the OPO Subcommittee and the CIG approached the research question from different perspectives.

- The OPO Subcommittee's goal was to identify potential organ donor screening and evaluation practices among the OPOS that would allow for an expansion of the five diagnoses described above. Thus, there would be a broader net for the inclusion criteria in the donor potential filter applied to the NCHS dataset.
- The potential donor filter developed by the CIG incorporated the five diagnoses (brain cancer; benign neoplasms; acute cerebrovascular disease; skull/face fractures; intracranial injury) per Cuende (10) that were found to predict a high percentage of brain death cases in several Spanish hospitals. The CIG also identified a subset of "E-codes," which are diagnoses associated with accidents (e.g., falls, auto accidents), that were considered to be associated with an increased likelihood of organ donation.

  Although the diagnoses used to implement the approaches taken by the two Subcommittees were originally identified in the context of brain death, they also identify potential controlled DCD donors.

Methods

The approaches developed by both groups were conceptually similar in that filters were specified to narrow the number of inpatient deaths down to the estimated number of potential donors.

- The OPO Subcommittee approach included direct application of some filters to the NCHS dataset and indirect application of the mechanical ventilation filter. The OPO Subcommittee filters are:
  - Limit on age
  - Inpatient
  - Cause of death exclusions
  - Cause of death inclusions (brain death, accident codes)
  - Mechanical ventilation (indirect filter)
- The CIG approach included direct application of the filters to deaths in the NIS dataset. The data source contained only inpatient records, so implicitly it is strictly a filter for inpatient donor potential. The CIG filters are:
  - Inpatient (implicit)
  - Mechanical ventilation
  - Diagnosis exclusions
  - Diagnosis inclusions (diagnoses associated with brain death, or "E-codes")
  - Limit on age
  - Limit on severity of illness score
  - Limit on length of hospital stay

Though there was considerable overlap in the concepts used in the filtering process, there were some important differences in the details of these filters. The diagnosis/cause of death exclusionary and inclusionary criteria were similar, though not identical. This is partially a reflection of the different philosophical approaches of the two groups, but also reflects differences in the data sources (e.g., diagnosis vs. cause of death, ICD-9-CM vs. ICD-10). Due to the level of detail in the NIS data, ventilation use could be filtered directly, whereas an indirect filter was used for the NCHS data.

Additional detail comparing and contrasting the OPO and CIG approaches

Though the OPO and CIG groups developed their potential donor filters largely independently, there were two notable exceptions to the independent working of the two subcommittees. First, the two subcommittees agreed that a decedent's being on mechanical ventilation at some point during the decedent's hospital visit was an essential criterion for being a potential deceased organ donor. As a consequence, the mechanical ventilation case rates that were calculated using NIS data and used by the CIG subcommittee were also used by the OPO subcommittee. The two subcommittees based their work on the same mechanical ventilation data because the NCHS data used by the OPO subcommittee did not have ICD procedure codes that identified which individuals who died from a particular cause had been on a ventilator. Because the use of mechanical ventilation played a critical step in the logic followed by the two subcommittees, use of the same ventilation data by both subcommittees may have increased the likelihood that their estimates would agree to some extent. Moreover, use of the same empirically-derived age thresholds by the two subcommittees may have increased the likelihood that their estimates would agree. The same age thresholds were applied to the datasets used by the two subcommittees in order to create a consistent point of reference when the results of the two approaches were compared.

Organ-Specific Donor Potential Estimates

Since some deaths identified by the CIG's filter as potential donors had diagnoses that would preclude donation of particular organs, organ-specific potential donor estimates were produced. The methods are included in **Appendix I**.

Characteristics of Potential Donors Compared with Evaluable Deaths

Evaluable deaths represent a broader pool of decedents meeting bare minimum thresholds – not having metastatic cancer or multi-system organ failure, and having been administered ventilation-from which the smaller pool of potential donors derived. Potential donors tended to be younger, more often male, and less often white than the broader pool of evaluable deaths. Further comparisons between potential donors and evaluable deaths can be found in **Appendix J**.

Estimates of Donation Potential from Emergency Department Visits

Organ donations from patients who died in the emergency department and were not admitted for a hospital stay represent an unproven, but potentially significant future source of transplant-quality organs. The data and methods used, additional details of the results, and limitations are explained in **Appendix B**.

II. Projections of Deceased Donor Potential over a 5 – 10 Year Period

Data Sources

CDC's NCHS National Mortality Data

The United States Multiple Cause Mortality File for all deaths in the United States reported between 2000 and 2010 were used for the analysis of forecasting future donor potential. A detailed description of these data appeared earlier in the report, in the section on Estimating the Number of Potential Deceased Organ Donors.

AHRQ's HCUP Data – NIS

The Nationwide Inpatient Sample (NIS)

Ten years of NIS datasets (2001- 2010) were evaluated for use in the analysis of donor potential trends and for projecting future donor potential.

Data Limitations (NIS). Attempting to apply the CIG stakeholder-derived filter to all ten years of data revealed the ICD-9-CM codes used to identify severe sepsis/multi-system organ failure – 99592 (SYS INFLAM / INFECTI W ORGAN DYSFUNCTION) and 99594 (SYS INFLAM / NON-INFECT W ORGAN DYSFUN) – were not in existence throughout this entire time period.

After discussions with a medical coding specialist at the Centers for Disease Control (CDC) (14) it was determined the two codes were introduced in October 2002 to allow for the coding of "severe sepsis" as a distinct condition from other codes reflecting septicemia. Since these two new codes represented the introduction of "new concepts," there were no codes prior to 2002 that reflected these two conditions. The CIG had identified both codes as being necessary and appropriate for identifying cases of multi-system organ failure (MSOF).

Further analysis of ten years of NIS data revealed that although these two codes were introduced in late 2002, it took several years before the codes were fully adopted, as shown by the dramatic increase from 2002 to 2003 (and in the next 2 years) in the use of these codes among discharge/death records. From 2005 through 2010, however, only incremental rises in the use of these codes was seen. This gradual trend mirrored the gradual rise in septicemia prevalence seen throughout the period, 2001-2010. Due to the absence of consistently used MSOF codes prior to 2005, it was decided to limit the potential donor trending analysis to 2005-2010.

Applying the filter across ten years' worth of NIS data also revealed a steep and steady increase in the reported use of mechanical ventilation or respiratory intubation (CCS procedure code 216). This code was reported among the (up to) 15 procedure codes for 34.8% of NIS death records in 2001; however, by 2010, 49.5% of NIS deaths had the use of ventilation reported. Since the trend between 2001 and 2010 was gradual – i.e., no sudden spikes or drops – there was no obvious concern about ICD-9 coding or mapping changes for mechanical ventilation during this period.

However, this rapid rise in the reported use of CCS procedure code 216 raised the question whether the reporting increase was because of a real change in clinical practice (ventilation being administered to more individuals who eventually die in the hospital) or rather merely attributable to a change in reporting practices.

In discussing this concern with both a CDC medical coding specialist (14) and also a clinician and health services researcher at AHRQ (15) from AHRQ, it was thought that while “reimbursement issues” may have fueled some of the increase in reported rates of mechanical ventilation, it is more likely the trend reflects a real change in clinical practice. Consequently, the use of mechanical ventilation was applied as the first step of the donor potential filter, as originally planned, using 2005-2010 NIS.

Changes were made during these six years in the ICD-9-CM codes used to identify various forms of cancer; the CDC has documented all ICD-9-CM coding changes in the following conversion table: http://www.cdc.gov/nchs/data/icd9/ICD9CM_FY13_CNVTBL.pdf. However, it turns out the types of cancers identified by the CIG as rule-out conditions already included both the old and newly remapped codes. The rate of malignant or metastatic cancer among NIS deaths using the codes identified by the CIG was remarkably stable from 2001 through 2010, varying within a very narrow range of 22.0% to 23.2%. Hence, recoding to account for changes in the coding of malignant or metastatic cancer was not required.

Methods and Assumptions

OPO Subcommittee Related Research Methods and Assumptions

Methods

A robust regression model using M estimation (16) was developed for projecting donor potential beyond the existing NCHS data. Robust regression was used because it provides more stable results in the presence of outliers, such as the estimate for 2009 as noted previously. The M estimation method is based on an iteratively reweighted least squares model, where the weights are a function of the residuals. Outliers receive less weight in the parameter estimation, resulting in less influence of a possibly inaccurate value on the projections.

The linear model using robust regression was fit to the annual donor potential estimates for 2000 through 2010. The parameter estimates resulting from this model were then used to project point estimates and confidence intervals for the estimated number of potential donors each year between 2011 and 2020.

Assumptions

The accuracy of the predicted values is predicated on the accuracy of the input values, the donor potential estimates between 2000 and 2010. If any of the assumptions used to develop the estimates is inaccurate or incomplete, this would also affect the projections. Due to the limited availability of clinical information in the NCHS dataset, it was not possible to filter deaths based on comorbidities. Therefore, it is anticipated that the true underlying donor potential was overestimated. If the overestimate was similar each year, then the projections will be similarly affected. However, if the overestimate is greater in recent years, this could result in a steeper slope for the projections with the more distant years being affected to a greater extent. Conversely, if the overestimate is greater in the earlier years, this could result in a slope that is too shallow, and projections might be too conservative, particularly in the more distant years.

The confidence intervals can only reflect the variability in the input values; the model cannot account for error in the method for estimating donor potential. Therefore, the confidence intervals reflect only that there is variation from year-to-year in the donor potential estimates between 2000 and 2010. The appropriateness of the confidence intervals is also predicated on the accuracy of the donor potential estimates.

CIG-Related Research Methods and Assumptions

Methods, Assumptions, and Procedures for Potential Donor Trending and Forecasting Analysis (CIG)

The CIG's potential donor filter was applied to six years (2005-2010) of NIS data.

Graphical trends in estimated potential donors over time appeared about linear, suggesting the use of simple linear regression. The potential donor estimates were modeled as a linear function of year plus residual variation. Regression estimation was done using SAS's REG procedure.

Projections for 2011 through 2020 were made by extrapolating the estimated regression lines. 95% confidence and prediction intervals for the predicted number of potential donors were obtained from SAS's PROC REG. Confidence intervals express the uncertainty inherent in the mean predicted value due to residual yearly variation after adjusting for the time trend. Prediction intervals express both the uncertainty inherent in the mean predicted value, as well as additional uncertainty needed to capture, with 95% confidence, prediction of donor potential for a particular year. As with all regression models, the intervals become wider the further the predictions are from the center of the observed data.

An additional approach was used to complement the two regression-based approaches for projecting donation potential through the year 2020. Details of this method can be found in **Appendix A**.

RESULTS

I. Deceased Donor Potential: Estimating Current Donor Potential

Results from the Organ Recovery and Caregiver Perspectives

Overview. The OPO subcommittee's filter produced an estimate of 37,258 potential donors available in 2010, while the CIG filter resulted in an estimate of 38,292 potential donors. Both of these estimates were about 5 times greater than the number of donors actually recovered and used for transplantation in 2010 (7,535). Although there were some differences by age group, particularly for pediatrics, the general pattern was consistent between the two analyses.

Current donor potential estimation: OPO Subcommittee Estimates

The filtering described in **Figure 2** was applied to the NCHS data yielding donor potential estimates for each year between 2000 and 2010. Based on the rationale provided in the methods section, the estimates for donor potential were based on inpatient deaths in patients 75 years and younger. These results are shown in **Table 6**.

Two additional sets of tabulations are shown in the appendices: inpatient deaths that met all of the filtering criteria other than age (**Appendix F**); and in-hospital outpatient and emergency department deaths that met the ICD-10 exclusions and inclusions (**Appendix B**). Both sets of tabulations were produced using the ventilation rates. These tables are provided for reference but are not reflective of donor potential for the OPO Subcommittee analysis.

Table 6. Estimated deceased donor potential for inpatient deaths 0 to 75 years

Number of deaths

Year	Stage 0: All deaths	Stage 1: ≤ 75 years	Stage 2: Inpatient	Stage 3: ICD-10 exclusions	Stage 4: ICD-10 inclusions	Stage 5: Vent rates applied
2000	2,407,193	1,110,016	480,358	225,217	59,715	35,679
2001	2,419,960	1,111,535	474,530	225,645	58,035	34,794
2002	2,446,796	1,116,957	470,370	225,460	57,500	35,767
2003	2,452,154	1,118,729	464,442	223,973	55,797	36,316
2004	2,401,400	1,099,222	445,697	218,054	54,213	36,242
2005	2,452,506	1,116,026	444,593	217,785	53,335	36,463
2006	2,430,725	1,112,287	439,251	215,724	52,509	36,485
2007	2,428,343	1,111,602	436,609	214,416	52,947	37,208
2008	2,476,811	1,127,284	433,559	211,712	50,442	36,231
2009	2,441,219	1,126,882	412,918	204,802	47,686	35,615
2010	2,472,542	1,130,036	416,246	205,478	49,087	37,258

Percentage of all deaths

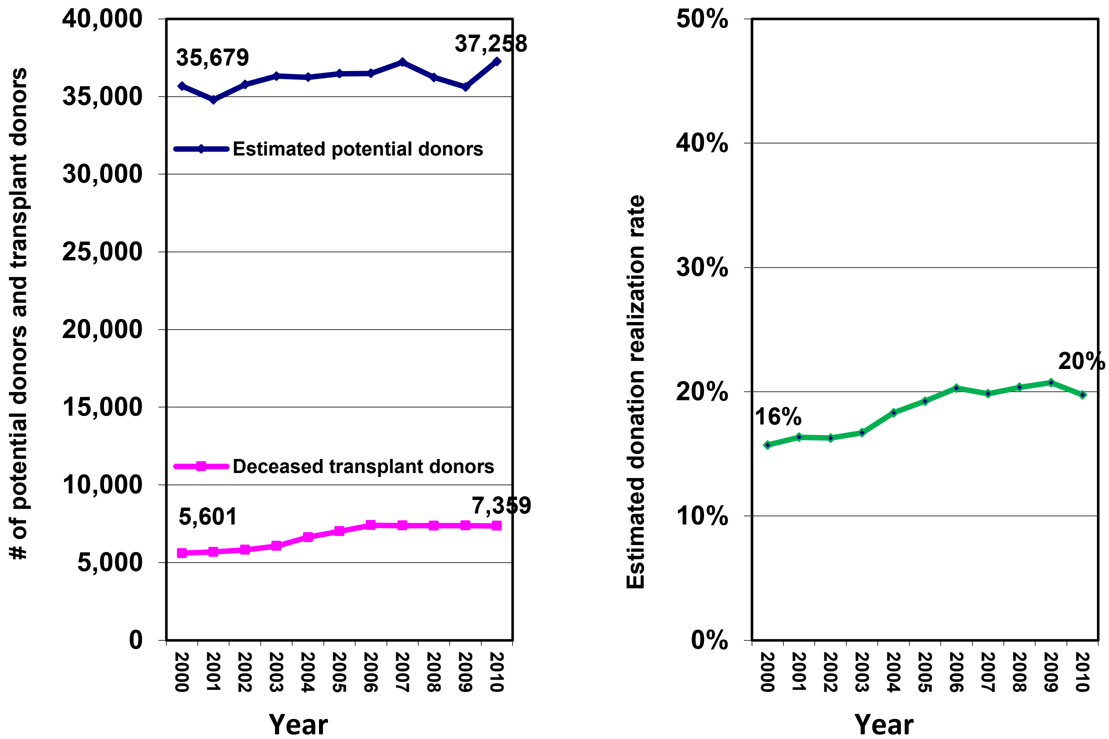
Year	Stage 0: All deaths	Stage 1: ≤ 75 years	Stage 2: Inpatient	Stage 3: ICD-10 exclusions	Stage 4: ICD-10 inclusions	Stage 5: Vent rates applied
2000	100	46.1	20	9.4	2.5	1.5
2001	100	45.9	19.6	9.3	2.4	1.4
2002	100	45.6	19.2	9.2	2.4	1.5
2003	100	45.6	18.9	9.1	2.3	1.5
2004	100	45.8	18.6	9.1	2.3	1.5
2005	100	45.5	18.1	8.9	2.2	1.5
2006	100	45.8	18.1	8.9	2.2	1.5
2007	100	45.8	18	8.8	2.2	1.5
2008	100	45.5	17.5	8.5	2	1.5
2009	100	46.2	16.9	8.4	2	1.5
2010	100	45.7	16.8	8.3	2	1.5

Percentage of all deaths ≤ 75 years

Year	Stage 0: All deaths	Stage 1: ≤ 75 years	Stage 2: Inpatient	Stage 3: ICD-10 exclusions	Stage 4: ICD-10 inclusions	Stage 5: Vent rates applied
2000	-	100	43.3	20.3	5.4	3.2
2001	-	100	42.7	20.3	5.2	3.1
2002	-	100	42.1	20.2	5.1	3.2
2003	-	100	41.5	20	5	3.2
2004	-	100	40.5	19.8	4.9	3.3
2005	-	100	39.8	19.5	4.8	3.3
2006	-	100	39.5	19.4	4.7	3.3
2007	-	100	39.3	19.3	4.8	3.3
2008	-	100	38.5	18.8	4.5	3.2
2009	-	100	36.6	18.2	4.2	3.2
2010	-	100	36.8	18.2	4.3	3.3

- Based on NCHS data, the estimates of donor potential between 2000 and 2010 had a fairly narrow range: from a minimum of 34,794 (in 2001) to a maximum of 37,258 (in 2010).
- If annualized, there was an increase of approximately 150 potential donors each year.
- The estimates of donor potential consistently represented 1.4-1.5% of all deaths during each year.

Figure 7: Time trends in deceased transplant donors and estimated potential donors



NOTE: Since donor potential was limited to 75 years or younger, transplant donors in this analysis were limited to the same age range for appropriate comparison.

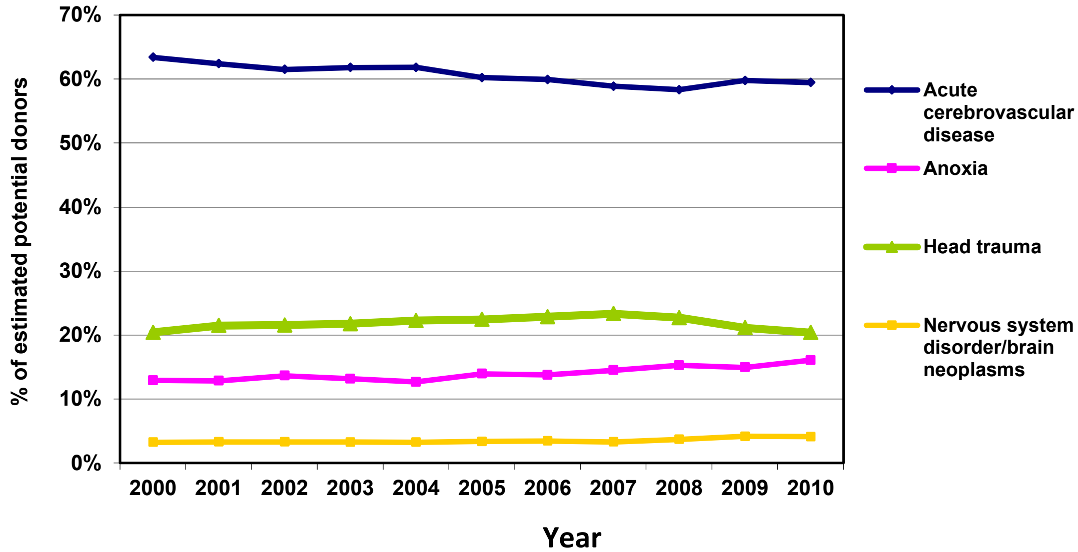
Estimated donation realization rate (EDRR) = # transplant donors/# estimated potential donors, reflecting the percentage of potential donors who become transplant donors.

- There was a much faster growth rate during this time period for transplant donors (31% increase) than for estimated potential donors (4% increase).
- Transplant donors represented between 16% and 21% of estimated potential donors, with a slow but steady increasing trend.

Composition of the estimated potential donor population

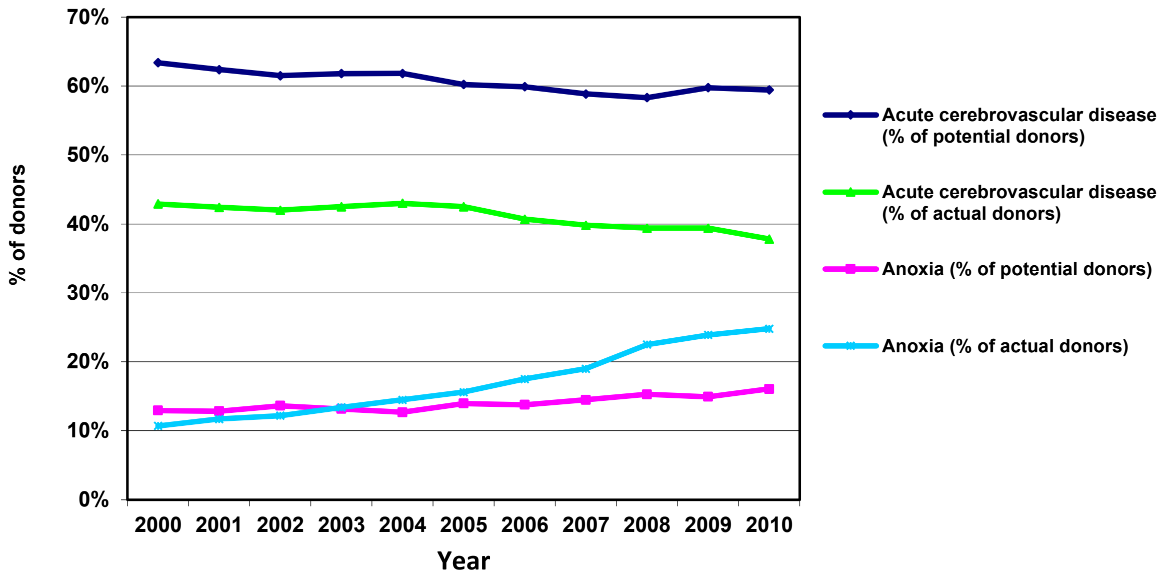
Cause of death

Figure 8: Cause of Death Distribution for Estimated Potential Donors



- There was a slight decrease in the percentage of deaths due to cerebrovascular causes in the estimated donor population, with a corresponding slight increase in the percentage of deaths due to anoxia.
- A similar phenomenon has occurred in transplant donors, though the changes are more pronounced for actual transplant donors than for potential donors.

Figure 9: Comparison of Cause of Death Distribution for Estimated Potential Donors and Actual Transplant Donors

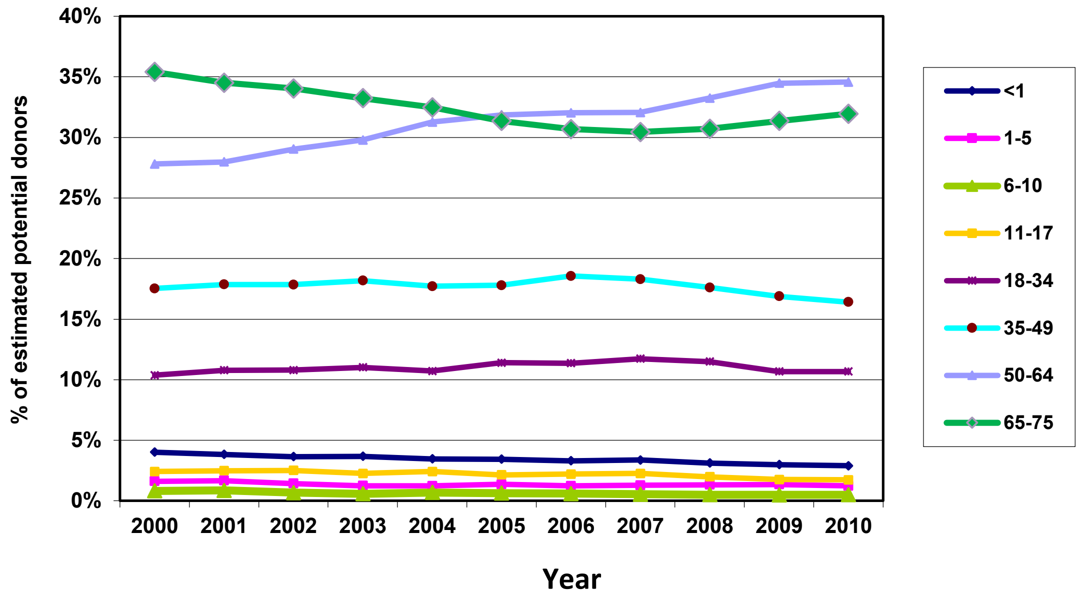


NOTE: Since donor potential was limited to 75 years or younger, transplant donors in this analysis were limited to the same age range for appropriate comparison.

- While deaths due to anoxia represented similar percentages of potential donors and transplant donors between 2000 and 2005, the percentages have diverged with transplant donors much more likely to have died of anoxia in recent years.
- While the percentage of deaths due to cerebrovascular disease is the most common cause of death for both potential donors and transplant donors, the percentages differ considerably. This may be partially a function of challenges in mapping ICD-10 codes for NCHS data to the donor causes of death in the OPTN system.

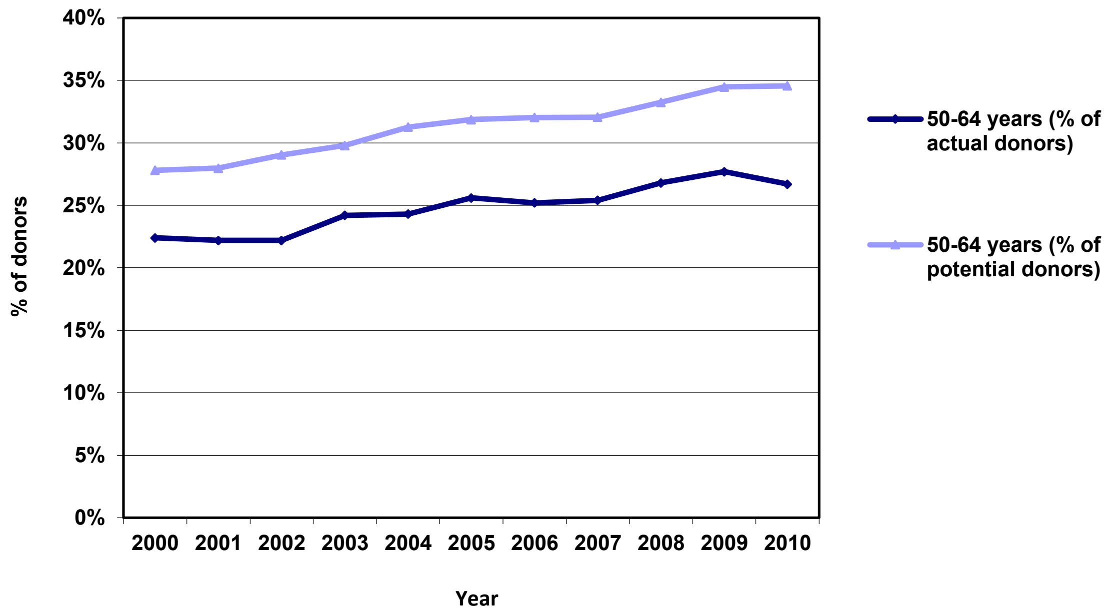
Age

Figure 10: Age Distribution for Estimated Potential Donors



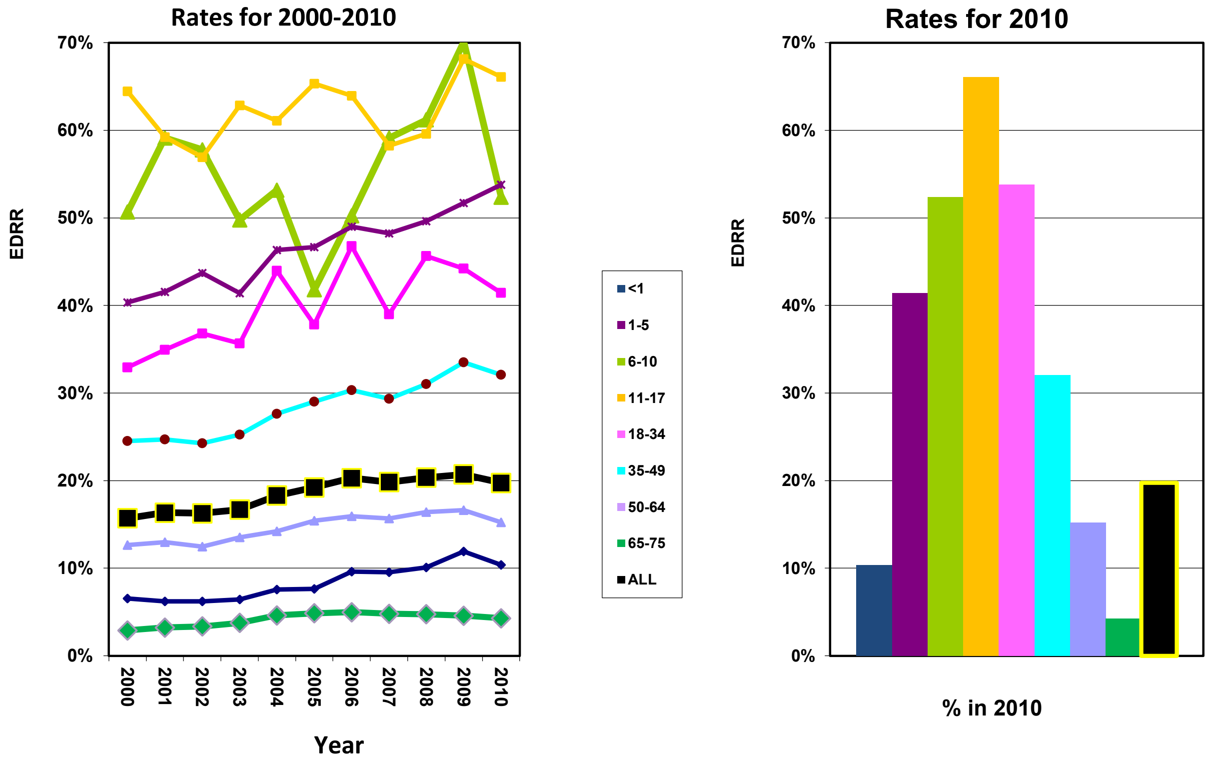
- The most notable changes seen in the age distribution of estimated potential donors were for the 50-64 and 65-75 age groups.
    - There was a marked increase in the percentage who were 50-64 years (28% in 2000 up to 35% in 2010) with a corresponding decrease for the 65-75 age group through 2007 (35% in 2000 down to 30% in 2007).
    - After 2007, there was a reversal of this trend for the 65-75 age group, though not returning to the level of 2000.
- Between 2007 and 2010, there was a small decrease in the percentage of 35-49 year olds (19% in 2006 down to 16% in 2010).
- The other age groups were represented with fairly similar percentages throughout the study period.

Figure 11: Comparison of Age Distribution for Estimated Potential Donors and Actual Transplant Donors



- The age group of 50-64 years is one of the most common for both transplant donors and potential donors.
- This age group represents a fairly similar percentage of both transplant donors and potential donors.
- Except for a slight downturn in 2010 for actual transplant donors, the patterns of change for transplant donors and potential donors are quite similar.

Figure 12: Transplant Donors as a Percentage of Potential Donors by Age



NOTE: Since donor potential was limited to 75 years or younger, transplant donors in this analysis were limited to the same age range for appropriate comparison.

- The two most common age groups of transplant donors (18-34 and 35-49) saw substantial and relatively consistent increases in EDRRs across the study period.
  - The EDRR for 18-34 year old potential donors increased from 40% to 54%.
  - The EDRR for 35-49 year old potential donors increased from 25% to 32%.
- Some of the youngest potential donors had the highest EDRRs. Because the number of potential donors and transplant donors in these age groups are relatively low, there is less certainty about these rates. In 2010:
  - It was estimated that over 65% of 11-17 year old potential donors became transplant donors.
  - About half of the 6-10 year old potential donors became transplant donors.
- The EDRR for potential donors less than 1 year of age is relatively low (<10% in most years), midway between that for 50-64 year olds and 65-75 year olds. This may be the result of two separate issues:
  - Infants may have comorbid conditions that would preclude donation but which may not be reflected in the ICD-10 codes, thus falsely inflating the number of potential donors.
  - Due to size issues, organs from donors less than 1 year old are predominately transplanted into recipients who are also quite young. There may be infant

potential donors identified by an OPO but where there are no suitable recipients. This situation is less likely to occur in other age groups.

- The EDRR for the 65-75 year old potential donors was quite low, less than 5% every year.
    - Based on the OPO survey, fewer comorbidities are needed in this age group to be ruled as an absolute contraindication to donation. It is likely that some of the comorbid conditions in this population leading to rule-out were not reflected in the donor potential filters. Since fewer comorbid conditions were needed for rule-out in this age group than in younger age groups, it is possible the estimated realization rates are affected more in the older population.
    - Willingness of transplant centers to transplant organs from older donors may affect the number of transplant donors.
    - Even if the estimates of donor potential are not precise, it is still anticipated that the EDRR are substantially lower for the oldest age group compared to the younger potential donors.

Discussion of current donor potential estimation

Using the donor potential definition specified for the OPO Subcommittee analysis, the estimates of donor potential ranged from approximately 35,000 to 37,000 between 2000 and 2010, with the estimate in 2010 of 37,258. These estimates are predicated on reasonably accurate determination of donor potential. If the filtering process used to estimate donor potential is inaccurate, or if the ventilation rates are not appropriate, then the resulting estimates may not reflect the true underlying population of potential donors. Some of the characteristics identified in the OPO survey as being absolute contraindications to donation, either alone or in combination, were reported in the NCHS data only if they were causal factors of death. So the estimates of donor potential are likely to be moderately inflated.

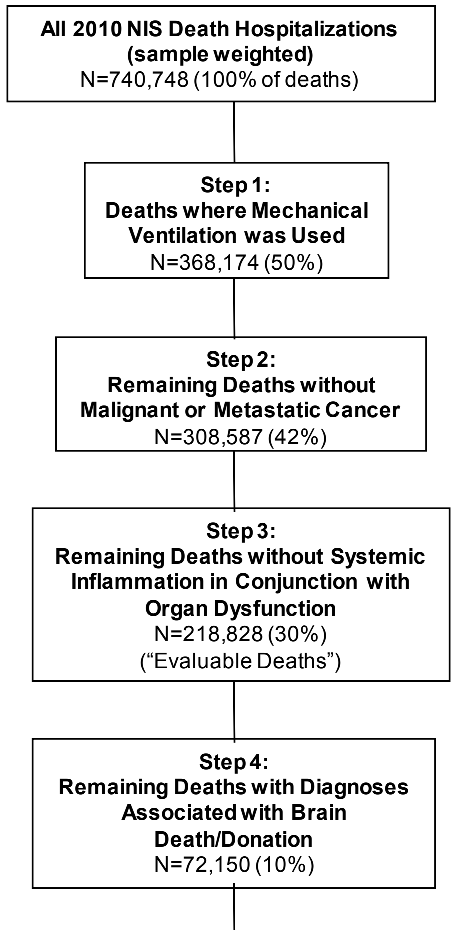
In 2010, the number of transplant donors was approximately 20% that of the donor potential estimate. Even if the estimates of donor potential are somewhat inflated, there is still a large unrealized potential. This is particularly evident in the extreme age groups, where the estimated realization rate was 10% or lower in 2010 for <1 year olds, as well as for 65 years and older.

Estimating the Number of Potential Donors: CIG Results

Donor Potential from Inpatient Hospital Deaths

Figure 13 shows the results of applying the CIG's potential deceased donor filter to the 740,748 in-patient deaths recorded in the 2010 NIS.

Figure 13: Filter for Potential Deceased Donors Applied to 2010 NIS



Step 5: Remaining Deaths with Age<=90 N=69,332 (9%)		**Length of Stay**		
		<=3	**<=14**	**Any**
Age	**Severity of Illness Score**			
0-75	**<=18**	24,638	38,292	42,436
	Any	25,474	40,835	46,030
0-85	**<=18**	32,846	51,979	57,816
	Any	33,991	55,604	62,928
0-90	**<=18**	35,981	57,222	63,590
	Any	37,301	61,360	69,332

The CIG stakeholders advised that, for duration of hospital stay, cases in which length of stay was no more than three days could be considered “ideal” for identifying donation potential. Coupling this assumption with an age 75 cutoff and severity of illness score cutoff of 18 (90^{th} percentile) yielded a much more conservative estimate of 24,638 potential in-patient donors (“cell 1”). The CIG also pointed out that though hospital stays of three or fewer days are more likely to result in donation under current practice, donation potential still exists for lengths of stay as great as two weeks. An analysis of OPTN data revealed the median length of stay for actual donors with organ(s) recovered and transplanted in 2008-2012 was three days. Many actual donors had hospital stays well beyond three days, including 3% with LOS exceeding 14 days (97^{th} percentile).

The estimate of donation potential that is most closely aligned with CIG stakeholder guidance was derived by increasing the length of stay cutoff from 3 to 14 days. This set of assumptions – age≤75, LOS≤14, and severity score≤18 (90^{th} percentile) – resulted in an in-patient, potential donor estimate of 38,292 (“cell 2”) in 2010.

The sensitivity matrix within Step 5 of the potential donor filter (**Figure 13**) illustrates the effect different maximum age, length of stay, and severity of illness cutoffs had on the estimated donation potential.

Estimated Potential Donors vs. Actual Transplant Donors

The scenario most closely aligned with CIG-stakeholder guidance (“cell 2”) resulted in an estimate of 38,292 potential donors for 2010. In reality, only 7,359 donors under age 75 were recovered in 2010 and had at least one organ transplanted. Hence, this potential donor estimate reflects an approximately 5-fold increase compared to donors actually recovered with organs used for transplantation under current practice. The estimated organ donor “realization rate” – the actual number of donors utilized as a percentage of the estimated number of potential donors available – was 19.7% (**Table 7**).

However, estimated realization rates approached or exceeded 50% for several decedent age groups: 6-10, 11-15, and 18-34. Estimated realization rates were much lower, though, among decedents age 50+. Of the estimated difference in potential versus actual donors of 30,757, over 22,000 (73%) were potential donors age 50 or older. This suggests that one of the greatest opportunities for expanding deceased organ donation may be realized from decedents over age 50.

Table 7. Estimated Potential Donors, Actual Donors (age ≤75), and Realization Rates by Age

Age	Estimated Potential Donors ("cell 2")	Actual Donors w/ Organ(s) Transplanted (per OPTN)	Estimated "Realization Rates" (Actual/ Potential Donors)
<1	504	112	22.2%
1-5	634	191	30.1%
6-10	201	100	49.8%
11-15	808	427	52.8%
18-34	5,052	2,140	42.4%
35-49	6,268	1,961	31.3%
50-64	13,274	1,965	14.8%
65-75	11,552	463	4.0%
All	38,292	7,359	19.2%

Composition of potential donors (inpatient)

The average decedent that passed through Steps 1-5 of the filter and had age≤75, LOS≤14, and severity score≤18 ("cell 2") was 52 years old (**Table 8**). Twenty-five percent were age 42 or less, and 10% were age 22 or less. The ages ranged from 0 to 75.

The average length of stay for filtered, "cell 2" deaths was 3.5 days, with 25% having stayed at most one day in the hospital prior to death. Only 10% had hospital stays greater than 9 days. The lengths of stay ranged from 0 to 14 days. (**Table 8**)

Table 8.
Descriptions of Potential Donors (NIS 2010)
Age<=75, LOS<=14, Severity Score<=18 ('Cell 2')

	Min	P10	P25	Mean	P75	P90	Max
Decedent Age	0.0	22.0	42.0	52.0	67.0	72.0	75.0
Length of Stay	0.0	0.0	1.0	3.5	5.0	9.0	14.0
Severity of Illness Score	-11.0	0.0	0.0	5.4	9.0	14.0	18.0
Number of Diagnoses	1.0	5.0	7.0	10.9	14.0	18.0	31.0

P10=10th percentile; P20=20th percentile; P75=75th percentile; P90=90th percentile

Table 9 reveals that only 38.7% of the "cell 2" deaths were females, and more than half was white. Just over 17% were black and 28.0% were of another race.

Table 9.
Gender and Race of Potential Donors (NIS 2010)
Age<=75, LOS<=14, Severity Score<=18 ('Cell 2')

Characteristic	% of potential donors
Female	38.7%
Black	17.2%
White	54.8%
Other Race	28.0%

Table 8 shows the mean number of recorded diagnoses was 10.9 among "cell 2" deaths, and the mean severity of illness score was 5.4 with a range of -11 to 18. Nearly one third of "cell 2" deaths had a severity score of 0 or less, while 13.4% had a score between 13 and 18. (**Table 10**)

Table 10.
Severity of Illness Score Distribution of Potential Donors (NIS 2010)
Age<=75, LOS<=14, Severity Score<=18 ('Cell 2')

Decedent Type	Percent of Deaths, by Adapted van Walraven Score						All
	<=0	1-6	7-12	13-18	19-28	29+	
Cell 2 Deaths	32.9	30.4	23.3	13.4	0.0	0.0	100.0

The prevalence of the 29 Elixhauser comorbidities[5] for each of the potential donors ("cell 2") is shown in **Table 11**. Prevalence is shown overall, and by severity of illness score group. For example, 34% had a fluid and electrolyte disorder, 17.9% had diabetes mellitus, and 11.6% had chronic pulmonary disease. In addition, 9.2% had renal failure, 7.4% congestive heart failure, 2.6% pulmonary circulation disorders, and 2.4% liver disease. Less than 0.5% had AIDS, a condition that explicitly precludes donation under current U.S. law. As expected, the prevalence of most conditions was significantly higher for decedents with higher severity of illness scores, which are derived from these Elixhauser comorbidities.

Table 11.
(Sample-Weighted) Prevalence of Each Elixhauser Condition
Among ANY of the (up to) 25 Diagnosis Codes for each Discharge
For the 2010 NIS Filtered Deaths with
Age<=75, LOS<=14, and Severity<=90th Percentile ('Cell 2')
(Elixhauser conditions adapted to incorporate primary as well as secondary diagnoses.)

Elixhauser Condition	% of Deaths with Condition, Overall	% of Deaths with Elixhauser Condition, By Adapted van Walraven Score			
		<=0 (0-25%)	1-6 (25-50%)	7-12 (50-75%)	13-18 (75-90%)
LYTES: Fluid and electrolyte disorders	34.0	3.2	39.4	57.0	57.1
NEURO: Other neurological disorders	24.2	1.8	27.5	33.7	55.0
DM: Diabetes mellitus	17.9	12.3	17.5	22.0	25.5
CHRNLUNG: Chronic pulmonary disease	11.6	2.0	12.1	18.0	22.7
COAG: Coagulopathy	11.5	0.9	13.3	18.8	20.8
PARA: Paralysis	11.4	0.3	2.6	20.8	42.5
ANEMDEF: Deficiency anemias	9.6	4.2	10.6	12.5	15.5

[5] Indicated as either the primary diagnosis or a secondary diagnosis

Elixhauser Condition	% of Deaths with Condition, Overall	% of Deaths with Elixhauser Condition, By Adapted van Walraven Score			
		<=0 (0-25%)	1-6 (25-50%)	7-12 (50-75%)	13-18 (75-90%)
RENLFAIL: Renal failure	9.2	0.4	7.0	16.1	24.2
ALCOHOL: Alcohol abuse	8.7	8.4	9.1	8.1	9.8
CHF: Congestive heart failure	7.4	0.1	2.0	14.0	26.3
OBESE: Obesity	6.7	5.6	7.9	7.1	6.2
DEPRESS: Depression	5.8	5.9	6.5	5.0	5.0
PERIVASC: Peripheral vascular disorders	5.3	0.7	5.1	8.4	11.5
DRUG: Drug abuse	5.0	8.8	4.2	2.5	1.9
HYPOTHY: Hypothyroidism	4.7	3.4	4.8	5.8	6.2
WGHTLOSS: Weight loss	4.1	0.0	2.5	6.4	13.8
VALVE: Valvular disease	3.2	2.3	2.4	3.9	5.8
PSYCH: Psychoses	2.6	1.7	2.2	3.9	3.6
PULMCIRC: Pulmonary circulation disorders	2.6	0.4	1.9	3.9	6.9
LIVER: Liver disease	2.4	0.0	0.4	3.3	10.9
DMCX: Diabetes mellitus, complicated	2.4	0.7	1.5	4.3	5.0
ARTH: Rheumatoid arthritis/collagen vascular disease	1.4	0.6	1.3	2.2	2.1
TUMOR: Solid tumor without metastasis	1.2	0.0	0.9	2.2	3.0
BLDLOSS: Blood loss anemia	0.6	0.3	0.8	0.8	0.5
AIDS	0.4	0.4	0.4	0.5	0.5
ULCER: Peptic ulcer disease excluding bleeding	0.0	0.0	0.0	0.0	0.0
HTN_C: Hypertension, complicated	0.0	0.0	0.0	0.0	0.0
LYMPH: Lymphoma	0.0	0.0	0.0	0.0	0.0
METS: Metastatic cancer	0.0	0.0	0.0	0.0	0.0

Table 12 was developed to further examine the potential donors by showing the proportion of these decedents having each of the most prevalent clinical classification software (CCS) conditions. (Prevalence for the full list of conditions is provided in **Appendix K, Table K-2)**.

Table 12 also shows the proportion of deaths by age group having each clinical condition. For many conditions, the prevalence varied dramatically depending on decedent age.

For comparison, **Table K-3** in **Appendix K** is provided, showing the prevalence of CCS conditions for evaluable deaths.

Table 12. (abbreviated – full table in Appendix K)
(Sample-Weighted) Prevalence of Each Clinical Classifications Software (CCS) Condition Among ANY of the (up to) 25 Diagnosis Codes for each Discharge
For the 2010 NIS Filtered Deaths with Age<=75, LOS<=14, and Severity<=90th percentile ('Cell 2')

CCS Condition	% of Deaths with CCS Condition	% of Deaths with CCS Condition, By Age							
		<1	1-5	6-10	11-17	18-34	35-49	50-64	65-75
131: Respiratory failure; insufficiency; arrest (adult)	65.5	41.7	65.8	63.5	57.0	55.3	64.0	68.6	68.9
109: Acute cerebrovascular disease	52.7	22.8	9.6	22.2	8.8	17.7	50.3	64.3	63.2
95: Other nervous system disorders	45.6	35.4	61.8	67.4	63.7	52.4	49.3	44.4	39.9
98: Essential hypertension	37.2	7.2	2.4	7.9	4.4	8.3	30.6	44.9	50.6
55: Fluid and electrolyte disorders	34.0	38.9	35.8	26.2	22.8	34.3	34.1	35.9	32.2
233: Intracranial injury	29.6	47.6	48.3	49.4	70.4	62.2	32.3	21.1	18.6
257: Other aftercare	29.3	7.2	8.0	7.1	6.9	10.3	21.2	33.4	41.5
85: Coma; stupor; and brain damage	26.0	31.9	43.9	28.4	21.0	19.6	27.3	28.6	24.1
106: Cardiac dysrhythmias	23.6	17.1	16.2	7.5	15.2	17.1	18.0	22.2	32.8
244: Other injuries and conditions due to external causes	20.4	47.9	66.3	41.2	36.6	34.3	19.9	15.2	15.4
49: Diabetes mellitus without complication	20.3	6.8	4.1	2.7	2.4	6.5	14.8	23.0	29.1
663: Screening and history of mental health and substance abuse codes	19.3	0.0	0.0	0.0	0.6	8.9	22.3	24.8	19.5
117: Other circulatory disease	18.8	15.5	16.4	25.1	26.5	16.3	17.2	19.0	20.1
259: Residual codes; unclassified	18.6	12.4	12.2	5.4	4.3	9.8	17.8	20.5	22.5
107: Cardiac arrest and ventricular fibrillation	17.9	29.1	36.4	20.8	22.2	20.9	20.2	16.6	14.9
53: Disorders of lipid metabolism	16.9	1.1	0.0	0.0	0.0	0.9	8.0	18.0	30.6
234: Crushing injury or internal injury	15.2	10.7	24.3	39.1	40.8	41.4	18.8	8.8	6.5
101: Coronary atherosclerosis and other heart disease	15.0	0.0	0.0	0.0	0.0	0.6	5.3	15.8	28.5
157: Acute and unspecified renal failure	14.8	9.2	5.5	0.0	5.4	8.5	12.8	17.4	17.4
58: Other nutritional; endocrine; and metabolic disorders	12.6	3.1	5.6	5.4	5.8	7.3	12.3	14.4	14.6

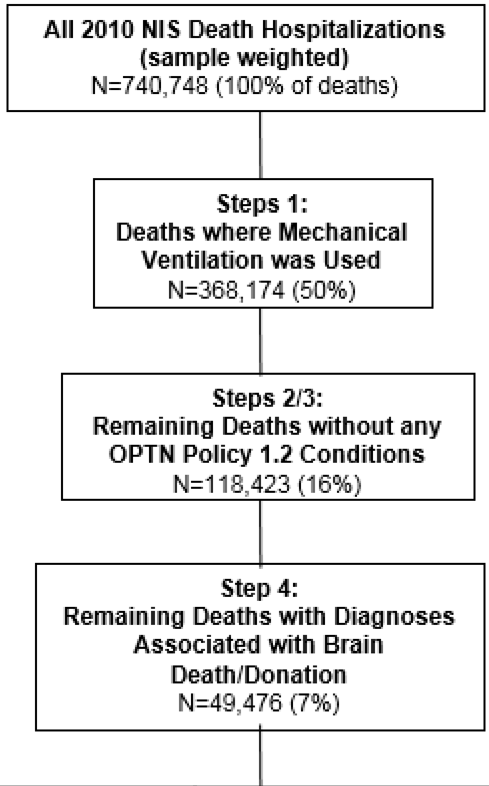
CCS Condition	% of Deaths with CCS Condition	% of Deaths with CCS Condition, By Age							
		<1	1-5	6-10	11-17	18-34	35-49	50-64	65-75
2607: E Codes: Motor vehicle traffic (MVT)	12.3	6.0	14.9	28.9	36.1	32.4	14.6	8.1	5.4
81: Other hereditary and degenerative nervous system conditions	12.2	4.1	5.6	10.1	5.1	5.5	12.3	16.1	11.8
99: Hypertension with complications and secondary hypertension	12.2	1.0	2.5	0.0	3.2	2.9	11.1	14.8	15.7
2603: E Codes: Fall	12.0	6.1	3.2	7.4	2.0	5.1	8.7	12.0	18.3
231: Other fractures	12.0	12.1	10.8	18.4	18.0	20.8	15.9	9.3	8.6
62: Coagulation and hemorrhagic disorders	11.9	28.2	24.3	17.9	23.3	17.9	11.8	10.4	8.8
59: Deficiency and other anemia	10.8	19.6	8.3	2.7	6.9	6.1	9.3	11.2	13.4
83: Epilepsy; convulsions	10.7	16.5	18.8	17.5	9.0	8.5	12.7	11.6	8.9
82: Paralysis	10.2	1.0	2.4	5.1	0.7	3.6	8.5	11.9	13.5
129: Aspiration pneumonitis; food/vomitus	9.9	5.1	4.1	12.5	7.0	6.0	8.3	10.7	12.1
2620: E Codes: Unspecified	9.1	23.3	19.0	5.1	15.5	15.6	9.8	6.8	6.8
158: Chronic renal failure	8.9	0.0	0.8	0.0	0.0	2.0	7.2	10.9	12.3

As shown in **Tables 11 and 12**, some of the 'cell 2' deaths had chronic renal failure and/or acute and unspecified renal failure. This, along with the presence of liver disease, congestive heart failure, and chronic lung diseases among these decedents, motivated the development of organ-specific potential donor estimates that are provided in **Appendix I**.

Alternate Filter for Potential Donors, using OPTN Policy 1.2 Conditions

For comparison with estimates derived from the CIG-stakeholder filter, an alternate filter using OPTN Policy 1.2 conditions was developed. Instead of excluding decedents from consideration as potential donors if they had metastatic cancer or multi-system organ failure, a decedent was filtered in Steps 2 & 3 if any OPTN Policy 1.2 condition (tuberculosis, septicemia, mycoses, HIV, hepatitis, etc.) was present among the (up to) 25 diagnoses. The results of this alternate filter are shown in **Figure 14**.

Figure 14: *Alternate* Filter for Potential Deceased Donors Applied to 2010 NIS



Step 5: Remaining Deaths with Age<=90 N=47,598 (6%)		Length of Stay		
		<=3	<=14	Any
Age	Severity of Illness Score			
0-75	<=18	20,702	29,279	30,552
	Any	21,212	30,534	32,082
0-85	<=18	27,244	39,115	40,919
	Any	27,995	41,000	43,241
0-90	<=18	29,719	42,942	44,906
	Any	30,595	45,138	47,598

In comparison with the CIG-stakeholder filter that resulted in 218,828 (30%) in-hospital deaths remaining after filtering for mechanical ventilation, cancer, and MSOF (**Figure 13**), replacing Steps 2 & 3 with exclusion criteria based on OPTN Policy 1.2 left only 118,423 (16%) decedents for Steps 4 and 5 of the filter. Applying the alternate filter along with age≤75, LOS≤14, and severity score≤18 cutoffs resulted in 29,279 estimated ("cell 2") potential donors, 9,013 fewer than the 38,292 identified by the CIG-stakeholder filter.

Table 13 quantifies the degree to which the less restrictive CIG stakeholder-defined filter increased the estimated number of potential donors.

Table 13. Estimated number of potential donors from inpatient deaths using OPTN 1.2 conditions versus CIG stakeholder-derived filter

	Filter Applied			
	Alternate (OPTN Policy 1.2*)	**CIG Stakeholder ****	**Increase**	**Relative Change**
Estimated potential donors (age≤75, LOS≤14, severity ≤18)	29,279	38,292	9,013	+31%

***** Diagnoses identified by OPTN policy 1.2 used as rule-out criteria in Step 2 of the filter.
****** Metastatic or malignant cancer and multisystem organ failure used as rule-out criteria in Step 2 & 3 of filter.

<u>Comparison of Estimates from OPO and CIG Subcommittees Filters</u>

Despite the different data sources used – the NCHS with multiple causes of death and the NIS with diagnosis codes – and the different filtering assumptions applied, the number of deaths passing through the filters were very similar (**Table 14)**.

Table 14. Comparison of Estimated Potential Donors from OPO vs. CIG Analyses

Subcommittee	Data source	Filtered Deaths (Inpatient)
OPO	**2010 NCHS**	37,258
CIG	**2010 NIS**	38,292
	Difference	1,034 (2.8%)

The OPO Subcommittee's filter yielded an estimate of 37,258 potential donors in 2010. By comparison, applying the CIG-recommended length of stay threshold (14 days) and a burden of illness cutoff (score≤18) resulted in a CIG estimate of 38,292 potential donors in 2010 – ***a difference of less than 3%*** (1,034 potential donors). (**Table 14**)

Both the OPO and CIG subcommittees' inpatient donor potential estimates were approximately 5 times greater than the number of (age 75 or less) donors actually recovered and utilized for transplantation in 2010 (7,359). The estimated realization rates – the number of actual donors as a percentage of estimated potential donors – varied substantially by age group for both analyses. Estimated realization rates were much lower than average among decedents age 50+, suggesting opportunity for possibly expanding organ donation among older potential donors. Though some differences were present between OPO and CIG analyses, in particular for pediatric groups which had much smaller sample sizes, the general pattern of realization rates with respect to age was consistent between the two analyses (**Table 15**).

Table 15. Comparison of Estimated Donor Potential "Realization Rates"

Age	Estimated Donation Realization Rates (EDRR) (actual/potential donors)						
		OPO (2010 NCHS)			CIG (2010 NIS)		
	Actual number of transplant donors	Estimated number of potential donors	"Gap" (Estimated – Actual)	EDRR	Estimated number of potential donors	"Gap" (Estimated – Actual)	EDRR
<1	112	1,080	968	10.4%	504	392	22.2%
1-5	191	461	270	41.4%	634	443	30.1%
6-10	100	191	91	52.4%	201	101	49.8%
11-15	427	646	219	66.1%	808	381	52.8%
18-34	2,140	3,978	1,838	53.8%	5,052	2,912	42.4%
35-49	1,961	6,115	4,154	32.1%	6,268	4,307	31.3%
50-64	1,965	12,881	10,916	15.3%	13,274	11,309	14.8%
65-75	463	10,788	10,325	4.3%	11,552	11,089	4.0%
All	*7,359*	*37,258*	*29,899*	*19.8%*	*38,292*	*30,933*	*19.2%*

Discussion

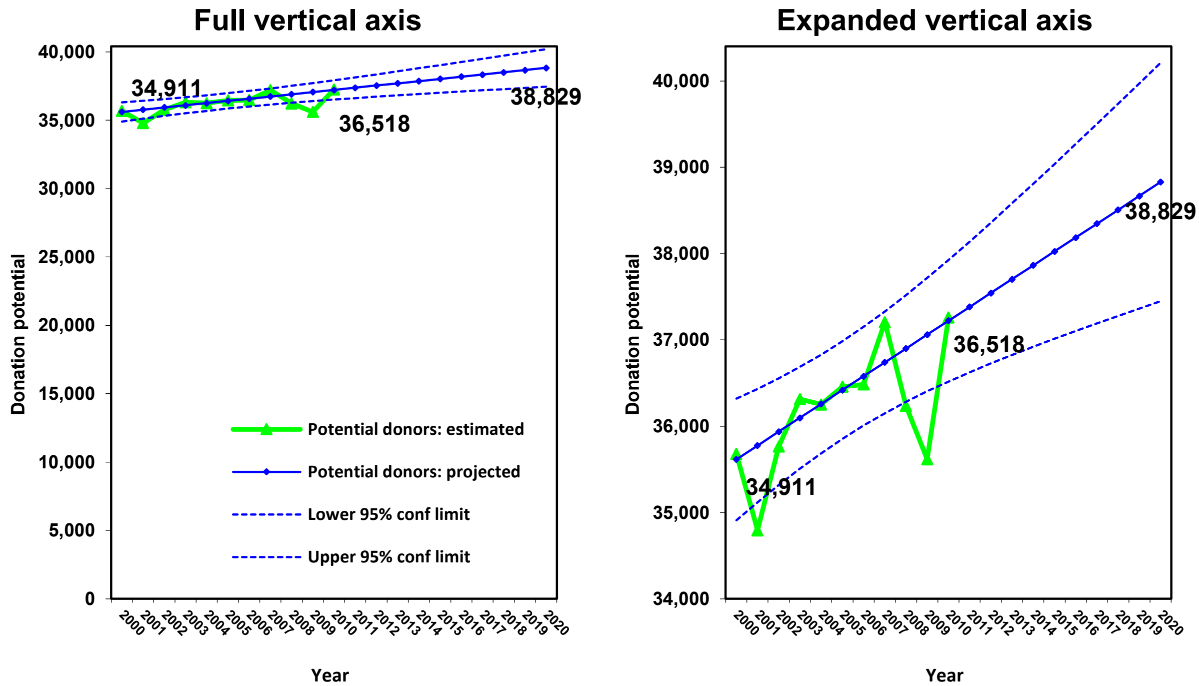
By using two largely independent approaches to develop each filter, and two very different data sources, the research team's efforts to triangulate produced estimates that closely converged. This convergence increases confidence that the estimates are reasonable. Of course, both sets of estimates still possess the aforementioned limitations inherent in their respective data sources, so one cannot conclude that merely because the estimates closely agree necessarily makes them accurate. However, to reiterate from a research perspective, such agreement from independent data sources and approaches certainly increases the level of confidence with these findings.

While these estimates suggest that approximately half of potential donors aged 18-34 are currently being realized as organ donors, realization rates are dramatically lower among donors age 50 and above. While realization rates are also quite low among infant donors (age<1 year), in absolute terms very little potential exists in this age group, which may yield organs of inadequate size for most transplant recipients anyway. Of the total estimated gap between potential and actual donors of roughly 30,000, over two-thirds (approximately 22,000) of this unrealized potential exists among decedents age 50 and above. Focusing attention on OPO's and transplant programs' practices and perceptions about the utility of organs from donors in these age groups (50-64 and 65-75) could yield significant gains in organ availability (Table 15).

II. Five to Ten Year U.S. Donor Potential Projections

Projection Results – OPO Subcommittee Analysis

Figure 15: Trends in estimated and projected potential donors

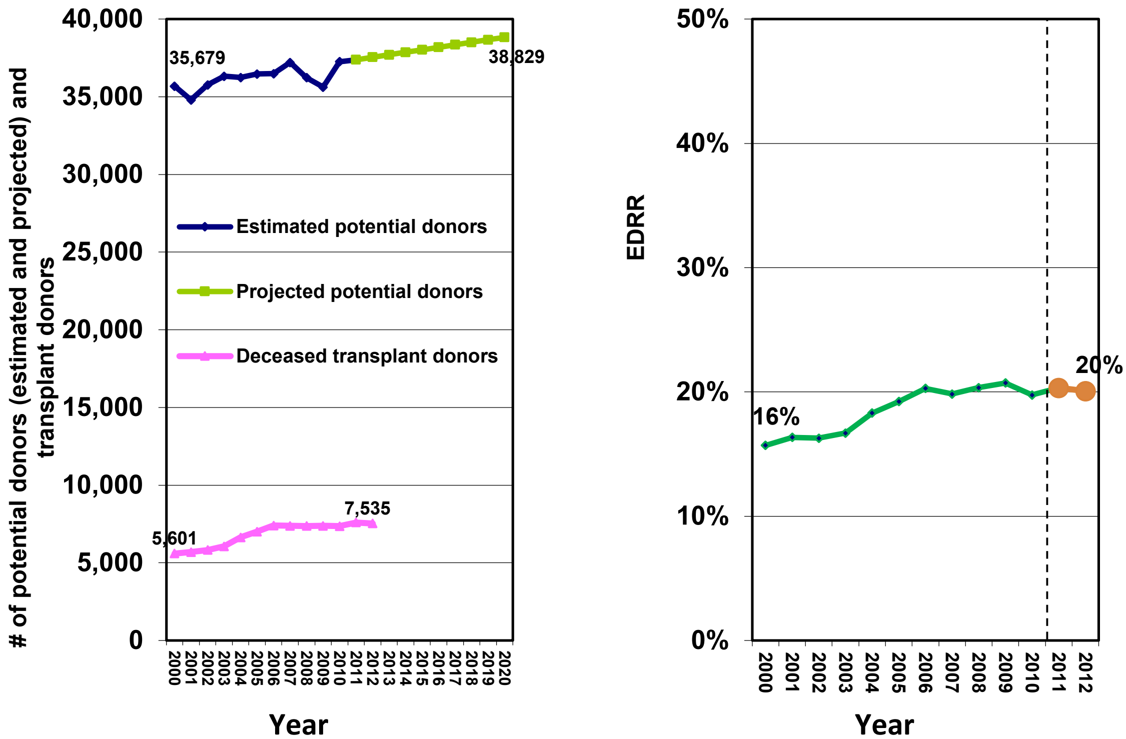


Based on the NCHS dataset for deaths between 2000 and 2010 of inpatients who were 75 years or younger, the donor potential is projected to increase slightly every year from 2011 to 2012. The projected net absolute increase is approximately 200 additional potential donors each year.

Table 16: Estimated and projected potential donors from 2000 through 2020

Year	Donation potential: estimated	Donation potential: projected	95% confidence limits for projected values	
2000	35,679	35,615	34,911	36,319
2001	34,793	35,776	35,119	36,433
2002	35,765	35,937	35,318	36,555
2003	36,314	36,097	35,508	36,686
2004	36,253	36,258	35,687	36,829
2005	36,458	36,419	35,854	36,983
2006	36,484	36,579	36,008	37,150
2007	37,205	36,740	36,151	37,329
2008	36,236	36,901	36,282	37,519
2009	35,617	37,061	36,404	37,718
2010	37,261	37,222	36,518	37,926
2011	-	37,383	36,625	38,140
2012	-	37,543	36,728	38,359
2013	-	37,704	36,826	38,582
2014	-	37,865	36,921	38,808
2015	-	38,025	37,013	39,038
2016	-	38,186	37,103	39,269
2017	-	38,347	37,191	39,502
2018	-	38,507	37,277	39,737
2019	-	38,668	37,363	39,973
2020	-	38,829	37,447	40,210

Figure 16: Time trends in deceased transplant donors, estimated potential donors and projected potential donors



NOTE: Since donor potential was limited to 75 years or younger, transplant donors were limited in this analysis to the same age range for comparison.

Though NCHS data were available only through 2010, OPTN data on the number of transplant donors were available through 2012. So these figures reflect two additional years of transplant donors and EDRR beyond the figures on current donor potential. The estimated realization rates in 2011 and 2012, which were based on projected potential donors, reflect a very similar rate as in 2006 through 2010, which were based on estimated potential donors. Even if the estimated realization rate remains stable through 2020 at approximately 20%, there would still be a small increase in the number of transplant donors because the number of potential donors is projected to increase.

Discussion

The donor potential is projected to increase slightly every year from 2011 to 2020. If the realization rate remains constant, as it has been for the past 6 years, this would translate into approximately 40 additional deceased transplant donors per year. As there is a still a large unrealized potential, an increase in the realization rate from 20% to a higher percentage is possible.

There are even more assumptions underlying the projections of potential donors than with the estimate of potential donors. The issues of most concern regarding the potential donor estimates are the steps in the filtering process and application of ventilation rates. If there were any inaccuracies for these, then the resulting estimates may not reflect the true underlying population of potential donors. Because some of the absolute contraindications (from the OPO survey) could not be precisely identified using variables within the NCHS dataset, the estimates of donor potential are likely to be moderately inflated.

Even if the assumptions underlying the estimates of potential donors hold true, there are additional assumptions underlying the projections of potential donors. The primary assumption is that the general pattern of change seen in 2000 through 2010 will continue in the subsequent 10 years. Because the demographic characteristics and morbidities in the US population are changing, the distribution of age and cause of death in decedents may change, thus affecting whether a decedent has donation potential. For example, as the population ages and rates for some morbidities increase (e.g., diabetes), there may actually be a decreased potential for donation. It is also possible that decedents currently deemed not to have donation potential, may be assessed differently in the future with the availability of new technology for donor management and treatment.

Projection Results – CIG Subcommittee Analysis

The CIG subcommittee filter was applied to six years of NIS data to produce a trend in estimated potential donors from 2005-2010. The results are shown in **Table 17**.

Table 17. Trends in Inpatient and Filtered Deaths (NIS), 2005-2010

CIG Donor Potential Filter Stage	Calendar year					
	2005	2006	2007	2008	2009	2010
Total Inpatient Deaths (N)	818,843	805,182	765,651	811,211	757,841	740,748
Step 1 Deaths (mechanical ventilation)	326,538	339,550	337,869	365,931	362,560	368,174
Step 2 Deaths (metastatic cancer)	277,346	289,751	283,191	306,105	302,829	308,587
Step 3 'Evaluable' Deaths (MSOF)	222,617	228,062	217,596	223,901	213,508	218,828
Step 4 Deaths (brain death/donation)	57,716	63,837	59,562	64,842	63,175	72,150
Step 5 Potential Donors: "Cell 2" (Age<=75, LOS<=14, Score<=18)	31,167	33,918	31,604	32,342	31,760	38,292
Total Inpatient Deaths (%)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Step 1 Deaths (mechanical ventilation)	39.9%	42.2%	44.1%	45.1%	47.8%	49.7%
Step 2 Deaths (metastatic cancer)	33.9%	36.0%	37.0%	37.7%	40.0%	41.7%
Step 3 'Evaluable' Deaths (MSOF)	27.2%	28.3%	28.4%	27.6%	28.2%	29.5%
Step 4 Deaths (brain death/donation)	7.0%	7.9%	7.8%	8.0%	8.3%	9.7%
Step 5 Potential Donors: "Cell 2" (Age<=75, LOS<=14, Score<=18)	5.2%	5.8%	5.7%	5.7%	5.9%	7.0%

The total number of inpatient deaths declined between 2005 and 2010 (**Table 17**). However, the number of Step 1 deaths – those reported to have been administered respiratory intubation or mechanical ventilation – increased during this same time period (**Table 17**), owing to the steady rise in the reported use of ventilation.

Despite the increasing trend in Step 1 deaths, the number of "evaluable deaths" – those with ventilator use and without cancer or MSOF – remained stable during the six-year window. This is attributable, at least in part, to the increased reporting of codes associated with severe sepsis or MSOF.

Though evaluable deaths remained fairly steady from 2005 through 2010, Step 4 deaths – those evaluable deaths having a diagnosis associated with brain death and/or organ donation potential – increased by 25% (57,716 to 72,150) from 2005 to 2010 (**Table 17**). This trend reflects an increase in deaths having diagnoses involving accidents and/or acute cerebrovascular disease.

The number of potential donors increased from 2005 to 2010. Much of the increase occurred from 2009 to 2010.

Table 17 shows the six-year trend in the percentage of filtered deaths at each step relative to the total number of inpatient deaths. Though the total number of deaths decreased, this time period saw an increase in the percentage of in-hospital deaths that passed through the filter and into "cell 2," from 3.8% of deaths in 2005 to 5.2% in 2010.

Projecting Future Inpatient Donor Potential, 2011-2020 (NIS)

Simple linear regression using six years of NIS data was employed to predict the number of potential donors over the subsequent 10 years. The regression estimation resulted in a positive slope parameter, reflecting a projected *increase* in the number of potential donors each year.

An annual increase of 854 was projected for potential donors. The projected annual rate of change was approximately +3%. These projections are illustrated in **Figure 17**.

Owing to the relatively small sample size (6 data points) and substantial year-to-year variability, the estimated slope parameter was not statistically different from zero. It also must be recognized that the projected increasing trends are largely dependent on one time point in particular, namely 2010, which saw a sizable jump in estimated potential donors. Hence, 2010 is a highly influential data point in the regression model; without it, the slope estimate would have been much closer to zero.

Projections of potential donors, including 95% confidence and prediction[6] intervals are displayed in **Figure 17**. Regression output is provided in **Appendix L**.

The potential donor projections and uncertainty intervals are provided in **Table 18**. For 2011, the model predicted 36,169 potential donors, with an uncertainty interval of 27,039 to 45,299. The large year-to-year variability in estimated potential donors, even after adjusting for the time trend, combined with the small sample size, caused these intervals to be wide. As the extrapolation extended further beyond the observed data (i.e., closer to 2020), the confidence and prediction intervals became substantially wider.

The model predicts a 15% increase in the number of potential donors from 2010 (38,292 estimated potential donors) to 2020 (43,854, projected). As illustrated by the uncertainty intervals, this forecast contains substantial inherent uncertainty.

[6] Confidence intervals express uncertainty in the predicted mean value. Prediction intervals express uncertainty in the predicted mean value as well as uncertainty in estimating individual predictions for a given year.

Figure 17: Graphical Display of Potential Donor Projections, 2011-2020 (NIS) with 95% Confidence Intervals and Prediction Intervals

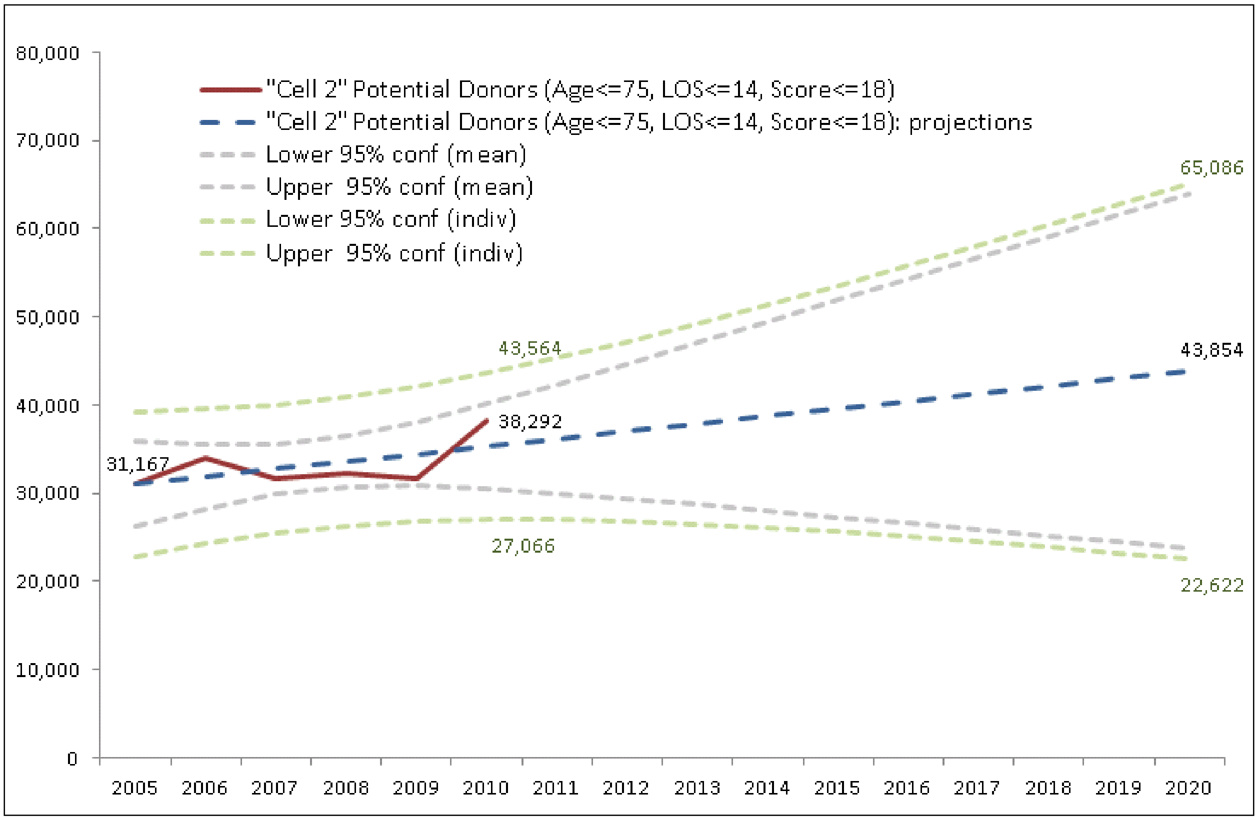


Table 18. Projected Inpatient Deaths that would Pass through Filter, 2011-2020 ("Cell 2": Age≤75, LOS≤14, Severity Score≤18) with 95% Confidence Intervals and Prediction Intervals

YEAR	Projected Potential Donors ("Cell 2")	Lower 95% conf (mean)	Upper 95% conf (mean)	Lower 95% prediction (indiv)	Upper 95% prediction (indiv)
2011	36,169	29,948	42,390	27,039	45,299
2012	37,023	29,335	44,712	26,836	47,210
2013	37,877	28,678	47,077	26,507	49,247
2014	38,731	27,995	49,466	26,086	51,376
2015	39,585	27,298	51,872	25,598	53,572
2016	40,439	26,589	54,288	25,062	55,816
2017	41,293	25,874	56,711	24,488	58,097
2018	42,146	25,153	59,140	23,887	60,406
2019	43,000	24,429	61,572	23,263	62,737
2020	43,854	23,701	64,007	22,622	65,086

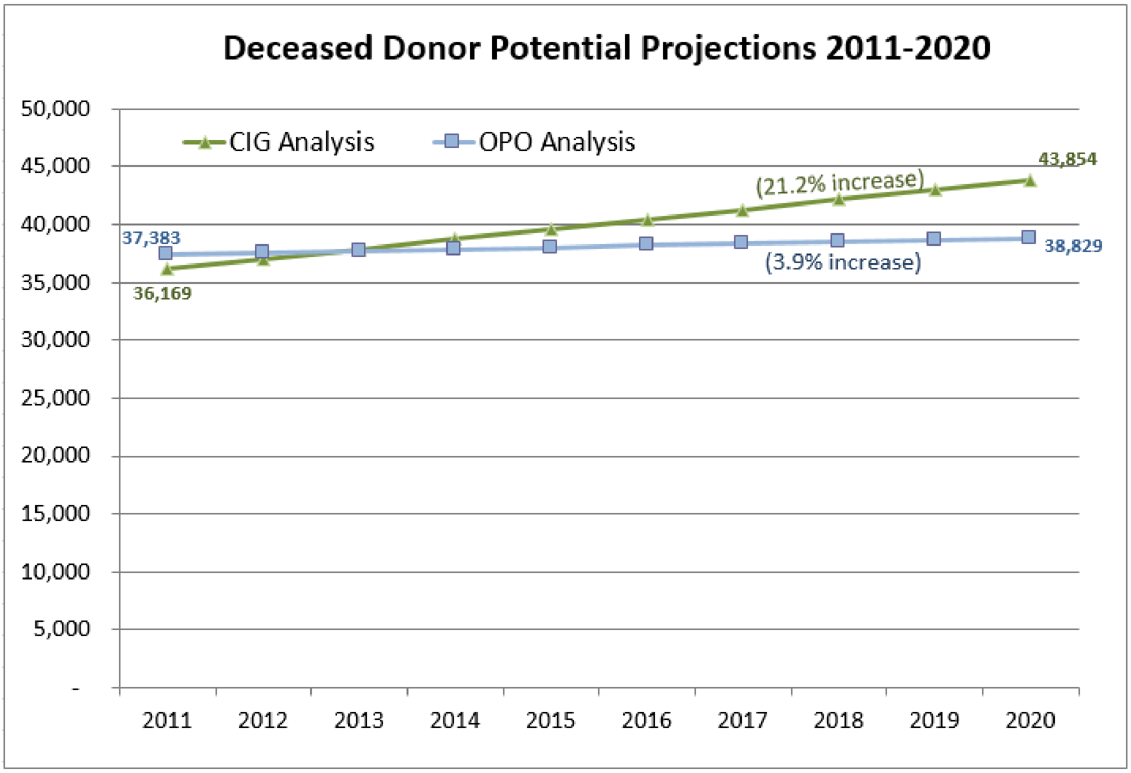
Comparison of Inpatient Donor Potential Projections

The estimated number of potential (inpatient) deceased donors with viable organs available for transplantation was forecast for 2011 through 2020 by extrapolating from linear regression models applied to two sources of data (NCHS, NIS).

These regression-based forecasts indirectly account for trends in factors that contribute to donor potential and which were included in the filtering process. For example, any trends in the causes of death associated with brain death between 2000 and 2010 were inherent in the time series of potential donor estimates derived from historical NCHS datasets, and thus will influence the estimated regression slope for forecasting potential donors. Trends in the burden of illness, for example, among inpatient decedents were intrinsically included in the results of applying the CIG filter to the 2005-2010 NIS datasets, since decedents with extreme severity of illness were excluded from potential donor estimates.

The results of these two regression-based approaches was supported by a system dynamics approach accounting for the impact on donation potential of projected changes in both causes of death and age among inpatient decedents in the U.S. This approach and its results are described in **Appendix A**.

Figure 18: Projections of Deceased Donor Potential (2011-2020)



Description of the Projections

OPO: Robust linear regression was applied to filtered deaths with age≤75 from the 2000-2010 NCHS datasets.

CIG: Simple linear regression was applied to filtered deaths with age≤75, LOS≤14, and severity score≤18 ("cell 2" of sensitivity matrix) from the 2005-2010 NIS datasets.

Summary and Comparison of Projections

As described previously, the relatively steep slope of the CIG's regression-based projections is highly dependent on the estimated number of potential donors in 2010; without this one data point, the projected slope would be much closer to reflecting no growth in potential donors[7]. Even when a robust regression algorithm was used, the CIG's analysis resulted in a projected 10-year increase of over 20%. Further, the prediction intervals around the regression-based NIS projections were very wide. Given this degree of uncertainty with the CIG's estimates, the NIS results are considered less reliable. A relatively shallow projected trend in potential donors – about 5% over 10 years, or 0.5% per year – is more likely than the substantially steeper slope estimate derived from the NIS. This was supported by a complementary, system dynamics-based approach (**Appendix A**) yielded a 10-year increase (5.2%) very similar to that found by the OPO subcommittee's analysis (3.9%).

Applying a projected 5% increase in potential donors over 10 years to the baseline estimates for year 2010 from the OPO (37,258) and CIG (38,292) analyses yielded projections of 39,121 and 40,207 potential donors in year 2020, respectively. A more realistic range estimate that accounts for statistical uncertainty is approximately 37,000 to 42,000. As with all estimates, this estimate (approximately 37,000-42,000) of the number of potential deceased organ donors available in 2020 reflects error associated with a number of sources beyond just statistical (sampling) error (e.g., measurement error, model specification error). However, the fact that two approaches that used different assumptions, data sources, and methodologies reported very similar estimates for the rate of change increases confidence in the finding that the rate of change in potential deceased organ donors is likely to be modest. Furthermore, despite placing less emphasis on the CIG's regression-based projections due to the high degree of statistical uncertainty from substantial year-to-year variability, the approach forecasted 43,854 potential donors in 2020—a prediction not very far from the range estimate of 37,000-42,000.

[7] The estimated slope was statistically no different from zero (p-value = 0.21).

CONCLUSIONS

High-Level Conclusions Based on OPO and CIG Subcommittee Analyses

Based on findings from the OPO and CIG subcommittee analyses, approximately 35,000-40,000 potential deceased organ donors may be available per year from inpatient hospital deaths. This estimate represents a 5-fold increase over the current state of transplantation, in which organs from about 8,000 deceased donors are transplanted each year. The estimates of unrealized potential likely include many imminent and eligible deaths already identified by OPOs, so it is important to recognize that not all of the "gap" between actual and potential donors is currently unrecognized as having donation potential. . Because of limitations in the available data sources, possible factors such as organ-specific laboratory measurements and serologies could contraindicate organ transplantation from a fraction of the estimated 35,000-40,000 donors, lessening this potential donor range estimate to some degree. Still, these two largely independent analyses, for which the results closely converged, strongly suggest that significant donor potential exists that is not currently being realized.

Further, the analyses have revealed that under current practice, unrealized organ donation potential exists across all age groups. About half of the estimated donor potential is currently being realized among decedents less than 35 years of age. However, less than 10% of the estimated potential is being achieved among decedents over age 64, and less than 20% for decedents ages 50-64. These results indicate that potential donors over age 50 may offer the most significant opportunity for substantially expanding the number of transplant donors available each year.

The aforementioned analyses focused on donation potential from deaths occurring in hospitals among patients admitted with inpatient status. OPO and CIG subcommittee analyses of outpatient and emergency department death records (**Appendix B**) found that around 3,000 additional potential donors may be available from this largely untapped source. Due to added uncertainties with emergency department data, however, this estimate cannot be cited with high confidence. Given this increased uncertainty and practical challenges associated with obtaining consent and recovering viable organs for transplantation in an outpatient setting, this estimate of 3,000 potential donors was not added to the overall estimate of 35,000-40,000 potential donors from inpatient deaths. Still, the outpatient and emergency department potential donor analyses highlighted that many deaths in the emergency department are younger individuals involved in accidents or victims of stroke, both causes of death associated with higher likelihood of organ donation viability.

Of course, to achieve an expansion in deceased organ donation, changes in clinical practice are imperative. Key practice areas that should be revisited in light of these findings include, but are not limited to, the accurate recognition of potential organ donors by referring hospitals and OPOs, as well as transplant centers' willingness to accept less-than-ideal organs. Centers' willingness to accept organs that would confer a net benefit to their patients, vis-a-vis remaining on the waitlist, is a key practice area with the potential to increase donor supply. Revision of OPO and transplant program performance metrics and/or the way they are used may be needed to spur changes in practice that would result in the increased use of older donors, where a large fraction of unrealized donor potential resides.

Projecting the Future Number of Potential Donors

Based on results from multiple forecasting methods, the number of potential donors is not anticipated to change substantially over the coming decade. The most likely outcome is an approximately 5% increase in donors between 2010 and 2020, since similarly shallow rates of change (about 0.5% per year) were predicted by two independent approaches.

Under assumptions most closely aligned with stakeholder recommendations (e.g. length of stay ≤ 14 days) and an empirically derived age ≤ 75 cutoff, approximately 35,000 to 40,000 potential donors were estimated to be available in 2010. Applying a 5% growth rate over a decade to this range estimate results in a forecast of approximately 37,000 to 42,000 potential donors in 2020.

As illustrated by confidence and prediction intervals for both the CIG and OPO subcommittee-based regression based forecasts, inherent statistical uncertainty is present in these forecasts, due to residual year-to-year variation. The uncertainty is greater for forecasts further into the future.

Although the forecasted number of potential donors available in 2020 contains uncertainty, the fact that two independent methods resulted in similar estimates increases confidence that the rate of change in potential donors is likely to be modest over the next 10 years. Furthermore, though the findings from the CIG's regression-based approach have been deemphasized due to the high degree of statistical uncertainty, that approach forecasted 43,854 potential donors in 2020, a prediction not very far from the range estimate of 37,000-42,000.

Perspectives and Recommendations Drawn from this Study

The organ transplantation system in the United States is characterized by wide variation in transplant program and OPO characteristics. There is significant variation in size, organizational structure, institutional resources, financial resources, and populations served, which vary by demographics such as urban versus rural, ethnicity, race, and economics. OPOs differ by the number of local transplant programs served, and the number and type of donor hospitals that comprise their referral base. There are significant challenges produced by variations of geography. Transplant programs similarly differ in size and resources and by various patient demographic factors. The organ transplant system is also complicated by layers of regulatory oversight that results from the requirements of multiple organizations including the OPTN, CMS, the Joint Commission on Hospital Accreditation, and third-party payers. This complexity results in significant challenges for OPOs and transplant programs in setting attainable goals and uniform clinical practice patterns. The development of uniform national transplant policy directed to achieving agreed upon system wide goals, while adequately accounting for these wide and largely immutable variations, is a significant and important challenge.

Major conclusions of the work reported here are several. First, it is clear there is significant deceased donor potential that is currently unused. It is important to acknowledge that some of this potential is already recognized by the transplant community under current practice but may not be realized due to factors such as inability to obtain consent, delayed referral from the donor hospital, and risk aversion among both OPOs and transplant programs. Some of the unrealized potential may also be unrecognized under current practice, with organ donation not pursued due to misperceptions of the suitability for donation and concerns about impact of pursuit on performance metrics.

The majority of the untapped deceased donor potential likely resides in the donor population older than fifty years of age, although there is unrealized potential in all age groups. Potential donors in older age groups present challenges to both OPOs and transplant programs because of co-morbid conditions affecting organ quality and likely lower numbers of organs per donor. Making optimal use of organs from these donors will likely require changes in current policy by the OPTN and CMS, as well as changes in clinical practice. Additionally, an important study finding is that based on current policy and practice, there is only minimal projected growth of the potential donor population through 2020. A preliminary analysis of geospatial patterns in actual and potential donors[8] revealed that unrealized donor potential does not appear to be uniformly distributed geographically.

Current performance goals for OPOs arose from the work of the Organ Donation Breakthrough Collaborative. These include aggressive goals for the number of organs transplanted per donor, increasing the percentage of DCD donors, and increasing the donor conversion rate. OPO performance oversight also results from analysis of data by the SRTR resulting in statistically-derived expectations for evaluating both the total number of organs transplanted from each donor, as well as organ–specific transplant counts. OPOs that fall statistically short of expected results are flagged for review by the OPTN Membership and Professional Standards Committee, which is charged by HRSA with program performance oversight. Although the Breakthrough Collaborative initiative resulted in significant increases in organ donor procurement in the early 2000’s, this progress has since stalled and the annual number of organs procured and transplants performed in the United States has stagnated since approximately 2006. It is believed by many stakeholders that the current structure of OPO goals does not reflect the medical characteristics of the current donor population and provides a disincentive to maximizing the number of organs procured. (13)

The performance metrics applied to transplant program evaluation as well as the current third-party payer environment also affect transplant program clinical practice. Though statistical risk adjustment accounts for much of the disparity in demographic and clinical characteristics associated with transplant outcomes, this approach still results in a conservative risk-averse clinical practice, which translates into lower numbers of transplants performed. (21) OPO and transplant center performance are not independent: increased risk aversion among an OPO’s local transplant center(s) may affect the subset of potential donors the OPO chooses to pursue. Policy changes and resulting clinical practice changes go hand in hand to affect both OPO and transplant center performance.

Policy Related Recommendations

1. Set specific, attainable, evidence based, performance goals for national transplant policy to emphasize an increased numbers of transplants.

2. Set evidence based policy goals and metrics for OPOs designed to increase the number of transplantable organs procured by removing disincentives to procurement of less than ideal donors. Current measurement of OPOs based on conversion rates and organs per donor may limit pursuit of donors likely to yield lower organ numbers, despite statistical risk adjustment.

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[8] A preliminary geospatial analysis of donation potential across the U.S. was completed but not included in this report.

(13) Much of the estimated unused donor potential resides in older donor populations where donation is less likely to yield multiple organs.

3. Revise transplant center performance metrics to allow increased use of organs from less than ideal donors. This should be in conjunction with revision of OPO metrics encouraging procurement in this population as well. Broader focus on program structure and resources and the use of pre-transplant metrics may result in transplant programs meeting a goal of increased transplant numbers. Performance goals should move beyond the current overemphasis on patient and graft survival among the subset of patients that receive transplants, to also include performance in meeting the needs of the population of end-stage organ failure patients through by far the most effective treatment modality, transplantation. This may result in increased patient life years following diagnosis with organ failure.

4. Explore strategies to link OPO and transplant center performance assessments.

5. Harmonize regulatory policy to the extent possible, accounting for the specific needs of the OPTN, HRSA, and CMS. Additionally, policy should emphasize mutual accountability among OPOs, transplant programs, and donor hospitals.

6. Devise policy to promote early recognition of potential donors and timely referral from donor hospitals.

7. Adjust OPO and transplant center goals to account for geographic and demographic variation in potential donor populations and in recipient populations.

Practice Related Recommendations

1. Identify OPO best practices, including further exploration of geographic disparities in donor realization rates, and devise strategies to disseminate these to the OPO community and stakeholders.

2. Identify transplant program that have successfully used marginal organs, achieving good outcomes. Identify their best practices and disseminate these to other transplant centers.

3. Develop predictive algorithms that can assess the outcomes of specific OPO practice changes.

4. Develop predictive algorithms that can be used to predict the outcomes of specific transplant program clinical practice changes.

5. Update educational efforts promoting early recognition and donor referral by donor hospitals to reflect current clinical conditions. This may permit the identification of a wider population of potential donors by donor hospitals.

6. Increase the use of DCD donors and evaluate new technology designed to improve organ quality.

Recommendations Related to Future Research

Further Research Aimed at Refining and Improving Potential Donor Estimation

1. Refine filtering assumptions through augmenting or linking national databases.

   Since there is no information in either the NCHS or NIS datasets indicating which decedents actually became organ donors, it is not possible to formally validate the filtering assumptions used to estimate donation potential. Such a confirmation would allow an assessment of whether a significant number of donors having one or more exclusionary criteria (or not having any *inclusionary* criteria) are being recovered and used for transplantation under current practice. If that were the case, such a validation exercise would suggest modifications in the filtering logic that could further refine the donor potential estimate. In other words, if certain types of cases identified through the filtering process as potential donors in reality never actually resulted in donation, refinements to the filter could be made by revisiting key assumptions and revising exclusionary and/or inclusionary factors.

   Augmenting either the NCHS or NIS to include information on whether each death resulted in donating organs for transplantation would allow such a validation exercise. Alternatively, linkage of either of these national datasets to OPTN data would also identify decedents that became donors and help this type of analysis.

   Additionally, opportunities to incorporate more detailed clinical information such as laboratory measures, serology results, and whether death was determined by cardiac or neurological indication, into national databases would also be valuable for more precisely identifying donor potential.

   Finally, more complete collection of data on clinical conditions and use of procedures among emergency room decedents is needed. Although hospital emergency room decedents may represent an untapped source of potential donors, application of the donor potential filter to the NEDS data identified relatively few deaths that could potentially lead to donation. Emergency department data are known to be inaccurate and incomplete, however, limiting confidence in these estimates. Further, most existing practices in organ recovery are set-up for the in-hospital area of clinical practice. Subject matter experts on the OPTN DDPS Stakeholder Committee members expressed a desire to further investigate the clinical practices within emergency departments for opportunities to better clinically integrate this area into the field's practice.

2. The impact of changes in billing and coding practices should be further studied to better understand their impact on the reporting of diagnosis and procedure codes in national administrative databases.

   Coding (reporting of diagnosis and procedure codes) practices are known to change over time, and may be influenced by reimbursement issues and changes to Medicare Diagnostic Related Groups (DRG's). Since these codes are integral to the methods used in this study, changes in the way they are reported could influence the overall estimates and trends in donor potential. The NEDS data in particular is believed to suffer from underreporting of procedure and secondary diagnoses. Understanding the nature and degree of reporting changes over time in both the NIS and NEDS would allow for better understanding of the limitation of the results and possibly enable further refinements.

3. Pursue a better understanding of the surprising increase in ICD-10 "R99" codes reported for three states (New Jersey, Ohio, West Virginia) in 2009.

   Researchers from the NCHS documented an unexpectedly large increase in the number of deaths with ICD-10 code "R99: Other ill-defined and unspecified causes of mortality)" In three states. The increase in R99 codes for these three states resulted in fewer deaths meeting the potential donor filter's inclusionary criteria. This issue affected both the estimated number of potential donors for 2009, as well as the forecasts of potential donors. So a better understanding of whether the increase in "ill-defined and unspecified" causes of death was a real phenomenon or the artifact of a coding or data processing problem is important for more precisely assessing the reliability of estimates produced using NCHS data.

Research Related to Characterizing Organ Donation Potential

1. Further explore gaps in the estimated "donor realization rates" beyond just decedent age.

   The OPO Subcommittee's analysis revealed that more unrealized potential for deceased donation may exist among older (age 50+) potential donors as well as very young donors (<1 year old Preliminary analyses also found large disparities in organ donor realization in different parts of the country, as well as among different ethnic and racial groups. Since these analyses revealed great differences in the current use of potential donors by decedent characteristics, it is likely that analyses of other factors – cause of death, gender, etc. – would reveal disparate utilization gaps as well. Interactions between geography and decedent characteristics may be particularly powerful in identifying areas in which deceased organ donation may have the greatest opportunities to expand.

2. Analyses of whether certain types of hospitals (e.g., large, urban, teaching) have higher proportions of potential donors relative to total inpatient deaths could provide significant insights into opportunities to expand organ donation. Further research is needed to ascertain whether institutional factors that vary between regions and jurisdictions such as diagnostic guidelines, referral procedures and patterns of practice in hospitals and/or among coroners and medical examiners might be affecting the identified pool of medically suitable potential donors.

3. Pursue an increased understanding of *combinations of factors* that substantially lower clinicians' perception of organ utility.

Both OPO and CIG Subcommittee surveys asked clinicians about the acceptability for transplant of organs from various types of donors. Though these surveys asked for responses separately depending on whether the decedent had the potential for brain death donation or donation after circulatory death, the surveys did not incorporate combinations of factors that together might result in some clinicians considering the organs unsuitable for transplantation. In fact, several respondents to the OPO Subcommittee's survey suggested (in free-form, text responses) various combinations of factors that they would consider rule-outs to donation. Both cumulative effects of many factors together and interaction effects may exist. A survey instrument that allows the user to indicate what combinations of factors [for example, elevated age *and* questionable social history *and* U.S. Public Health Service (PHS) high risk status] could help identify such combinations, which could then be incorporated into a more refined potential donor filter.

A more interactive approach, where individuals are presented case studies in a simulated setting designed to mimic the environment in which clinicians receive organ offers, might provide even more insightful information. Profiles of donors with varying characteristics would be shown to the clinician, who would have to decide whether to accept the offer for one or more of his hypothetical waitlisted patients. Donor profiles would be varied systematically such as through the use of conjoint analysis, for example, to identify key factors and interaction effects that lead to the decision to accept or decline organ offers.

Finally, regression analysis of OPTN data could be used to complement the above approaches. OPTN data have been analyzed to determine factors and combinations of factors that influence the likelihood of organs to be discarded, as well as the likelihood of organ offers to be declined by individual transplant centers (23-25). Future refinements could focus on identifying combinations of factors associated with high rates of organ offer refusal or discard but not having significantly adverse effects on graft (delayed graft function, long-term survival) and patient (complications, long-term survival) outcomes.

Opportunities for Action

It is clear from this study and many previous ones that the transplant community is far from achieving the deceased donor potential in the U.S. This can be deduced also from the wide DSA[9] and region-specific variability in various performance measures that quantify donation, recovery, and transplant rates across regions and institutions. (22) Where there is variability, there is opportunity for improvement. A gap between the potential number of donors and the actual number undoubtedly exists in all regions and DSAs. Certainly the gap is larger in some areas than in others.

Opportunities for action lie within direct control of the transplant community and could be pursued as a collaborative effort by a multidisciplinary group of transplant professionals as well as representatives of CMS and HRSA. One such opportunity lies in the refinement of donation-related definitions currently used for quantifying categories of donor potential, particularly what it means to be an "eligible" donor. There is broad agreement, supported by the results of this study, that many more deaths are eligible for organ donation than are included in the current OPTN definition of "eligible death." The total pool of potential donors includes not only individuals declared brain dead, but also those whose conditions are consistent with brain death as well as donors after cardiac death.

In areas of the country where data suggest the gap between potential and actual could be larger than others, death records and referral data could be mined and further analyzed. Data sources could be regional or national for the purpose of quantifying 1) deaths that, under revised donation definitions, could be considered eligible deaths; 2) eligible deaths not referred; and 3) referrals that did not become donors. Data linked to identified for selected areas of the country could be used to identify the types sorts of donors and reasons for non-donation that are specific to each DSA, for the purpose of regional collaboratives and performance improvement initiatives aimed at bridging donor potential gaps in each area.

Another opportunity lies in cross-organizational discussions that have already begun, for the purpose of examining any unintended consequences of various policies, metrics, and systems on organ recovery and use. In various contexts, organizations including the OPTN/UNOS, HRSA, the Alliance, AOPO, CMS, the SRTR, AST, ASTS, and others are meeting and planning how to effectively pursue, together, our the mutual goal of increasing the number of safe, high quality, timely transplants for patients with end stage organ disease. This work needs to continue quickly and conclude with decisions that can be implemented and make a significant difference in the number of effective transplants.

[9] Donation service area (DSA) is the geographic area designated by CMS that is served by one organ procurement organization (OPO), one or more transplant centers, and one or more donor hospitals.

REFERENCES

1. OPTN/UNOS Data as of October 9, 2012; Total number of U.S. waiting list candidates is 115, 940; Total number of active waiting list candidates is 73,954. Available at http://optn.transplant.hrsa.gov/. [Accessed October 9, 2012].
2. Organ Procurement and Transplantation Network (OPTN) and Scientific Registry of Transplant Recipients (SRTR). OPTN / SRTR 2010 Annual Data Report. Rockville, MD: Department of Health and Human Services, Health Resources and Services Administration, Healthcare Systems Bureau, Division of Transplantation; 2011:7.
3. OPTN/UNOS data as of October 12, 2012. Total number of deceased organ donors procured in the network between January 1, 1988 and July 31, 2012 is 151,907. Available at http://optn.transplant.hrsa.gov/. [Accessed October 1, 2012].
4. Shafer TJ, Wagner D, Chessare J, Schall MW, McBride V, Zampiello FA, Perdue J, O'Connor K, Lin MJ, Burdick J. U.S. organ donation breakthrough collaborative increases
5. Sheehy E, Conrad SL, Brigham LE, Luskin R, Weber P, Eakin M, Schkade L, Hunsicker L. Estimating the number of potential organ donors in the United States. *New England Journal of Medicine*. 2003 Aug 14;349(7):667-74.
6. Michael GE, O'Connor RE. The importance of emergency medicine in organ donation: successful donation is more likely when potential donors are referred from the emergency department. *Academic Emergency Medicine.* 2009 Sep;16(9):850-8.
7. Sheehy E, O'Connor KJ, Luskin RS, Howard RJ, Cornell D, Finn J, Mone T, Selck FW, Delmonico FL. Investigating geographic variation in mortality in the context of organ donation. American Journal of Transplantation. 2012; 12(6):1598-1602.
8. World Health Organization. International statistical classification of diseases and related health problems, 10th revision. 2nd edition. Geneva, Switzerland. 2004 Available at: http://wonder.cdc.gov/wonder/sci_data/natal/linked/type_txt/cohort00/Introduction00.pdf
9. Moles E, Andrews RM. *Emergency Department Data Evaluation. May 2005.* HCUP Methods Series Report #2005-2. Rockville, MD: Agency for Healthcare Research and Quality. Published ONLINE June 3, 2005. Available at http://www.hcup-us.ahrq.gov/reports/EmergencyDepartmentDataEvaluation.pdf.
10. Cuende N, Sanchez J, Canon JF, Álvarez J, Romero J, Martinez J, Macias S, Miranda YB. Mortalidad hospitalaria en unidades de críticos y muertes encefálicas según los códigos de la Clasificación Internacional de Enfermedades. *Med Intensiva*. 2004; 28(1):1-10.
11. Van Walraven C, Austin PC, Jennings A, Quan H, Forster AJ. A modification of the Elixhauser Comorbidity measures into a point system for hospital death using administrative data. *Medical Care*. 2009; 47 (6): 626-633.

12. Elixhauser A, Steiner C, Harris DR, Coffey RM (1998). Comorbidity measures for use with administrative data. *Medical Care.* 1998*;* 36(1): 8-27.
13. Schold, J.D., and Goldfarb, D.A. “Significant potential utility for donor yield models: but proceed with caution.” American Journal of Transplantation 11.10 (2011): 2009-2011.
14. Personal conversation with Donna Pickett, 4/29/2013
15. Personal conversation with Claudia Steiner, MD, MPH, 5/2/2013
16. Huber, P.J. (1973), “Robust regression: Asymptotics, conjectures and Monte Carlo, Ann. Stat., 1, 799-821 Center for Disease Control/National Center for Health Statistics, *Health US 2010,* Figure 33, P. 43
17. Centers for Disease Control and Prevention , National Center for Health Statistics. Multiple Cause of Death 1999-2010 on CDC WONDER Online Database, released 2012. Data are from the Multiple Cause of Death Files, 1999-2010, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program. Accessed at http://wonder.cdc.gov/mcd-icd10.html on May 7, 2013.
18. Coronado V, Xu L, Basavaraju SV, McGuire LC, Wald MM, Faul MD, Guzman BR, Hemphill JD. Centers for Disease Control and Prevention. Surveillance for Traumatic Brain Injury--Related Deaths --- United States, 1997—2007. MMWR 2011; 60(No. SS5):1-32.
19. Kochanek KD, Xu J, Murphy SL, et al. Deaths: Final Data for 2009. National vital statistics reports; Vol 60 Number 3. Hyattsville, MD: National Center for Health Statistics. 2012: http://www.cdc.gov/nchs/data/nvsr60/nvsr60_03.pdf
20. National Center for Health Statistics. Technical appendix. Vital statistics of the United States: Mortality. Washington, DC Published annually. Available from http://www.cdc.gov/nchs/products/vsus.htm#appendices
21. Schold, J.D., et al. “The association of center performance evaluations and kidney transplant volume in the United States.” American Journal of Transplantation 13.1 (2013): 67-75.
22. Messersmithm E.E., et al. “Development of donor yield models.” American Journal of Transplantation 11.10 (2011): 2075-2084
23. Sung RS, Christensen LL, Leichtman AB, et al. Determinants of discard of expanded criteria donor kidneys: impact of biopsy and machine perfusion. American Journal of Transplant 2008;8:783-92
24. Massie AB, Desai NM, Montgomery RA, Singer AL, Segev DL. Improving distribution efficiency of hard-to-place deceased donor kidneys: Predicting probability of discard or delay. Am J Transplant 2010;10:1613-20.
25. Wolfe RA, LaPorte FB, Rodgers AM, Roys EC, Fant G, Leichtman AB. Developing organ offer and acceptance measures: when 'good' organs are turned down. American Journal of Transplant 2007;7:1404-11.

26. Rogers MF, Simonds RJ, Lawton KE, et al. Guidelines for Preventing Transmission of Human Immunodeficiency Virus Through Transplantation of Human Tissue and Organs. *CDC MMWR Recommendations and Reports*. 1994; May 20/ 43(RR-8):1-17.