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Special Feature

Organ Donation and Utilization in the United States, 1999–2008

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Despite the Organ Donation Breakthrough Collaborative's work to engage the transplant community and the suggested positive impact from these efforts, availability of transplanted organs over the past 5 years has declined. Living kidney, liver and lung donations declined from 2004 to 2008. Living liver donors in 2008 dropped to less than 50% of the peak (524) in 2001. There were more living donors that were older and who were unrelated to the recipient. Percentages of living donors from racial minorities remained unchanged over the past 5 years, but percentages of Hispanic/Latino and Asian donors increased, and African American donors decreased. The OPTN/UNOS Living Donor Transplant Committee restructured to enfranchise organ donors and recipients, and to seek their perspectives on living donor transplantation. In 2008, for the first time in OPTN history, deceased donor organs decreased compared to the prior year. Except for lung donors, deceased organ donation fell from 2007 to 2008. Donation after cardiac death (DCD) has accounted for a nearly 10-fold increase in kidney donors from 1999 to 2008. Use of livers from DCD donors declined in 2008 to 2005 levels. Understanding health risks associated with the transplantation of organs from 'high-risk' donors has received increased scrutiny.

Key words: Deceased donors, donation after cardiac death, expanded criteria donors, living donors, organ donation, organ procurement, Organ Procurement and Transplantation Network, Scientific Registry of Transplant Recipients, United Network for Organ Sharing

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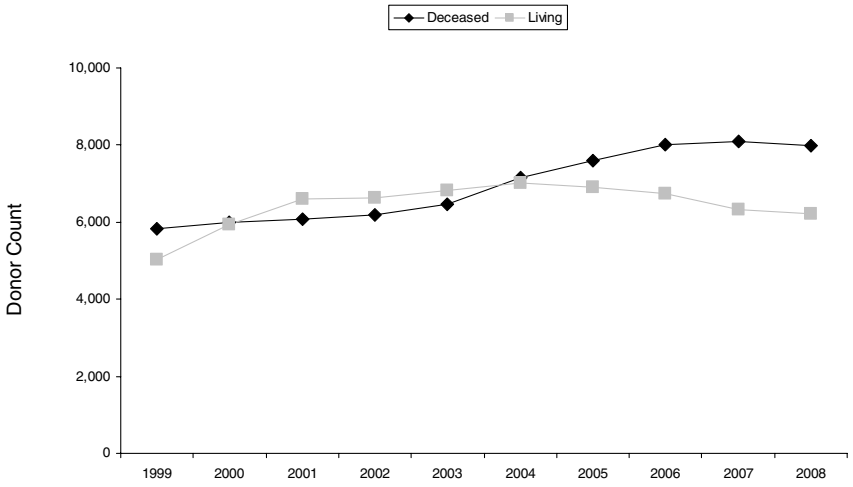
Introduction

The success of solid organ transplantation is, ironically, the single factor most responsible for the critical shortage that currently exists in the supply of transplantable organs. Improved survival rates and the expectation that organ replacement will enhance quality of life has encouraged an increasing number of doctors and their patients who suffer from organ failure to opt for transplantation. Unfortunately, the donation of organs has not kept pace with the rising demand. A number of strategies have been suggested to address the obstacles responsible for this shortfall. Among the barriers which have been identified are: (1) disincentives for living organ donation; (2) low consent rates for deceased organ donation, driven in part by inaccurate mythology surrounding the donation process and/or training gaps for personnel who request consent; (3) failure to enfranchise the public in the development of transplant policies; (4) lack of transparency in the disclosure and analysis of center-specific and organ procurement organization (OPO)–specific performance data and (5) a limited ability to accurately discriminate donor quality based upon currently available preprocurement testing which may lead to discarding potentially transplantable organs.

Although identifying the barriers is a key element in solving the donor crisis, the outcomes have been mixed. For instance, compared to open donor nephrectomy, minimally invasive techniques for living donor transplant nephrectomy are associated with decreased postoperative pain requiring narcotic analgesia, decreased rehabilitation times and more rapid return to work and resumption of daily activities. It was anticipated that such benefits would remove important disincentives for living kidney donations. Thus, it is surprising that despite the shift from open to minimally invasive transplant nephrectomy in many transplant programs, living kidney donation has declined each year since 2004. On the other hand, focused education and counseling within minority communities have successfully dispelled some of the persistent misinformation surrounding organ donation and procurement. In some cases these efforts have been translated into improved consent rates for deceased organ donation within these communities.

Informing the public and promoting transparency of the organ donation and transplantation process and performance are viewed by many as critical to narrowing the donor



Source: *2009 OPTN/SRTR Annual Report*, Table 1.1.

Figure 1: Deceased donor and living donor donation were both more common in 2008 than they were in 1999, but less common than they were in 2007. Living donors were more common than deceased donors in 2001–2003, but since then donation by deceased donors has been more common.

organ gap. Activity within the Organ Procurement and Transplantation Network and United Network for Organ Sharing (OPTN/UNOS) has recently focused on the development of resource documents for the evaluation of living donors that serve to educate prospective donors as well as the health care professionals who care for these individuals. By extending the required donor follow-up period from 1 to 2 years and developing center-specific reports which quantify the thoroughness of each program's follow-up, the OPTN/UNOS has affirmed the validity of continuously reassessing the risks associated with live organ donation. The effectiveness of these and other actions designed to give prospective donors as much insight as possible into the ramifications of voluntary live organ donation remains to be seen.

There are two issues confronting the transplant community which potentially negate otherwise successful interventions to augment the organ donor pool. The first is the apparent disconnect between: (1) strategies designed to expand the organ supply through the use of expanded criteria donors (ECD) and high-risk donors and (2) the absence of adequate risk adjustment in the analysis of patient outcomes. For some organ types, establishing accepted criteria for ECD organs is still in the formative stages, thus statistically handicapping outcomes when such organs are used is not yet practical. Currently, transplant professionals and transplant programs must weigh the patient benefit derived from the appropriate use of organs that, at least by conventional wisdom, have a higher risk of posttransplant dysfunction with the recognition that they may be penalized by the Centers for Medicare and Medicaid (CMS) and insurance carriers if their patient and graft survival rates fall below expected benchmarks. Additionally, in most cases there is no financial adjustment made for the utilization of higher risk donors or recipients, despite data that support the need for additional medical resources and the likelihood of higher patient care costs.

Secondly, the enthusiasm for utilizing organs procured from high-risk donors has been tempered by the mandate to avoid disease transmission through organ donation. Although the scrutiny given to this potential complication has been heightened, the transplant community, the public, the Centers for Disease Control and Prevention (CDC) and CMS have yet to agree upon what constitutes an acceptable risk (e.g. 1 chance in 1000 or 1 chance in 10 00 000) of acquiring an infectious disease from a donor. Defining the universe of diseases that should be screened, especially uncommon ones (rabies, West Nile virus, etc.) as well as the methodology for the testing itself (e.g. nucleic acid testing [NAT]) are issues currently under review. Until consensus is achieved, however, it will be difficult to fully realize the efficacy of other initiatives designed to expand the pool of donated organs.

Trends in Living Donation

Despite an increase in the number of living donors every year from 1999 to 2004, living donation has decreased progressively since 2004 (Figure 1). In 2008 there were 6219 living donors, which was 1181 more donors than in 1999, but 785 fewer donors than in 2004 *[Table 1.1*]. All of the increase in the number of living donors between 1999 and 2008 can be attributed to the 1243 additional living kidney donors during that time. Donation of other organs by living donors decreased between 1999 and 2008 *[Table 1.1]*. In 2008, kidney donors accounted for 96% of all living donors. Four percent of living donors donated livers in 2008, and pancreas donors accounted for less than 1% of the living donor population.

Living kidney donation

As with the overall trend in living donation, the number of living kidney donors increased between 1999 and 2004 and has decreased each year since. In 2008 there were

5968 living kidney donors, an increase of 26% since 1999. Donation increased in all age groups over the age of 18, though over the past 10 years living kidney donors have increasingly been older donors *[Table 2.9]*. Donation by 18–34 year olds once accounted for 34% of living kidney donation, but in 2008 it accounted for only 31% of donation. Likewise, the percentage of living kidney donors who were 35–49 years of age decreased from 47% in 1999 to 43% in 2008. In place of these younger donors, donation by 50–64 year olds has become more common; 24% of living kidney donors were 50–64 years of age in 2008 compared to only 18% in 1999. Furthermore, though donation by individuals aged 65 years or older is rare (and accounted for only 1.5% of living kidney donors in 2008), there were over twice as many donors aged 65 years or older in 2008 than there were in 1999.

The relationship between living kidney donors and their recipients changed substantially over the past decade. The most common relationships in 1999 were full sibling (35%), followed by parent (17%) and offspring (16%) *[Table 2.9]*. In 2008 unrelated, nonspousal relationships such as friends, in-laws or anonymous donors were most common (26%), followed by full sibling (24%) and offspring (17%). Parents only accounted for 10% of living kidney donors in 2008. A small part of the increase in unrelated, nonspouse relationships may be attributed to the emergence of kidney chains, though chains are still relatively new and cannot account for the entire increase. However, if chains become more common in the future, it is possible that this increasing trend in unrelated living kidney donation will continue.

Donation by other relatives remained relatively stable over the decade and in 2008 8% of all living kidney donors were relatives outside of the immediate family. Likewise, donation by spouses was largely unchanged between 1999 and 2008 (12% of all living kidney donors in both years). Finally, for 3% of living kidney donors in 2008, their relationship to the recipient was unknown.

Living kidney donation by men increased by 19% between 1999 and 2008 (1981 vs. 2350, respectively) *[Table 2.9]*. Living kidney donation by women increased slightly more between 1999 and 2008, when there were 3618 female donors (61% of all living kidney donors). Furthermore, though living kidney donation among men decreased each year since 2004, donation among women decreased in 2006 and 2007 but increased modestly in 2005 and 2008.

Donation by racial/ethnic minority groups as a percentage of all living donors has not changed significantly over the past 5 years (30.9% in 2004 and in 2008). During this time the number of African American living donors decreased by 23% (from 937 to 717 donors); Hispanic/Latino living donors decreased by 1.6% (833 to 820 donors) and Asian donors increased by 5% (226 to 237 donors). In 2008, 69% of donors were white. Twelve percent of living kidney donors were African American in 2008 (a decrease from 15% in 1999), whereas 14% were Hispanic/Latino (an increase from 11% in 1999). Asian Americans accounted for 4% of living kidney donation in 2008, and 1% of donors were multiracial or of other racial/ethnic groups.

Living pancreas donation

In 2008 there was one living pancreas donation, which was down from seven in 1999 *[Table 1.1]*.

Living liver donation

Living liver donation decreased very slightly between 1999 and 2008. However the number of living liver donors in 2008 was less than 50% of the 2001 peak when there were 524 donors *[Table 1.1]*. The decrease in living liver donors was most evident in younger adults *[Table 2.10]*. In 2001, 253 of living liver donors were aged 18–34 years, compared to only 122 donors in 2008. Donation by 35–49 year olds decreased as well, though they still accounted for 38% of living liver donors.

Parents were the most common group of living liver donors in 1999, but decreased by nearly half, to 20% of all donors in 2008. As a result, offspring (24%) were the most common donors in 2008. Thirteen percent of living liver donors were full siblings, 2% were half siblings and 12% were other relatives. Spouses accounted for 4% of living liver donors. As with living kidney donors, the percentage of living liver donors who were unrelated to their recipients increased substantially between 1999 and 2008 (10% vs. 21%, respectively).

In 2008, 48% of living liver donors were female and 52% were male. The numbers of males (129) and females (121) who donated livers in 2008 were very similar to the numbers that donated in 1999 (133 and 120 respectively). Seventy-nine percent of living liver donors were white in 2008, an increase from 70% in 1999. Black/African American donors accounted for 7% of living liver donors (down from 9%). Donation by Hispanic/Latino donors decreased from 17% in 1999 to 9% in 2008. Donation by Asian living liver donors increased from 2% in 1999 to 5% in 2008.

Living intestine donation

Living intestine donation has been rare over the past 10 years, and there were no living intestine donors in 2008 *[Table 2.11]*.

Living lung donation

The number of living lung donors trended downward over the past decade from 58 in 1999. In 2008 there were no living lung donors *[Table 2.11]*.

OPTN/UNOS Living Donor Transplant Highlights

In 2006 the Secretary of the U.S. Health and Human Services formally acknowledged the mandate for the

OPTN/UNOS to develop policies for living organ donation and transplantation designed to promote safety, education, data collection and oversight. The OPTN/UNOS Living Donor Transplant Committee has been restructured to engage a larger percentage of and more demographically diverse cohort of live organ donors, donor family members and transplant recipients. The goal of this reorganization is to enfranchise organ donors and recipients and to actively seek their perspectives on living donor transplantation. Over the past 2 years, the OPTN/UNOS Living Donor Transplant Committee has promulgated standards and resources that address the processes of patient education, living donor consent, medical evaluation of the living donor and benchmarks for living donor and recipient follow-up and data collection. For purposes of clarity, OPTN/UNOS policies specifically relevant to living donor transplantation have recently been collated to form a new OPTN/UNOS policy section. Highlights of OPTN/UNOS activities directed toward living donation include the following:

1) Resource documents for the medical evaluation and consent of kidney and liver living donors have been created and approved. These tools were designed as a resource for transplant centers with the intention that educational materials most appropriate for nonmedical readers (e.g. potential living organ donors) would soon follow.
2) An accurate discussion of the risks and benefits is considered to be a fundamental component of the living donor transplant process. This requires a quantitative assessment of postoperative events experienced by former donors. To improve this process, the OPTN/UNOS has increased the mandatory follow-up period for living donors from 1 to 2 years and has committed resources to encourage compliance with the mandate for thorough donor follow-up.
3) Assessment of postdonation risks and complications has been hampered by incomplete submissions of follow-up data. Although OPTN/UNOS policy requires follow-up data submission for living organ donors, this obligation can currently be met by designating the donor as 'lost to follow-up'. Of the 6732 living donors who donated an organ in 2006, more than 30% were lost to follow-up. There is significant variation among centers in terms of the percentage of donors for whom follow-up data is missing with some centers declaring no available follow-up for 100% of their donors. This year, as a first step to improve compliance, transplant program directors and their hospital CEOs were notified in writing of their center's performance regarding donor follow-up. This was intended to be primarily educational but the expressed long-term goal is to establish benchmarks for complete donor follow-up and to publish center-specific performance.

It has been suggested that one of the downstream benefits linked to these OPTN/UNOS initiatives will be the elimination of potential disincentives for future potential living organ donors for whom education and full and transparent disclosure of risk is essential.

Trends in Deceased Organ Donation and Utilization

The number of deceased donors increased each year in the last decade between 1999 and 2007 *[Table 1.1]*. The increase was most impressive in the years between 2003 and 2006, increasing from 6457 in 2003 to 8019 in 2006. However, in the last 3 years the procurement rate has reached a plateau, and for the first time in 2008 there was a slight decrease to 7984. The total number of organs recovered from deceased donors peaked at 28 405 in 2007 and decreased to 27 958 this past year *[Table 1.2]*. The explanations offered for this decline include: (1) loss of momentum built by the Transplant Collaborative; (2) concerns regarding the financial and programmatic implications of utilizing high risk or ECD donors and (3) failure to successfully enfranchise the public in the processes and policy making of organ donation and transplantation.

The trend has shown a decrease in the percentage of organs obtained from young donors between 6 and 17 years of age (from 11.9% to 6.8%) and a corresponding increase in donors between the ages of 50 and 64 (from 21.9% to 27.7%) *[Table 2.1]*. Despite an aging population and individual centers reporting their experience with older donors, the percentage of donors above the age of 65 years has remained largely unchanged over the last decade at around 9.0%.

Substantial resources have been focused on increasing organ donation rates among minorities, both in the African American and Hispanic/Latino populations. The number of donors in both groups has almost doubled *[Table 2.1]*. The number of African American donors increased from 653 to 1278 between 1999 and 2008, and the number of Hispanic/Latino donors increased from 612 to 1112 in the same period. Despite the increase in minority donors they have not kept pace with the growing number of minorities on the transplant waiting list.

Donation after cardiac death (DCD) has increased progressively over the past decade (from 87 to 848 donors) and currently accounts for 10.6% of all deceased donors *[Table 2.1]*. However the growth has been variable across geographic regions in the United States.

Trends in kidney donation and utilization

The number of deceased kidney donors decreased by 56 this past year, bringing it back to the level observed in 2006 *[Table 1.1]*. Kidneys not used from recovered donors remained near historic peak in 2008 at 2268 *[Table 3.2]*. An increasing number of organs were not used after recovery (12% in 1999 vs. 16% in 2008). Over a third of kidney

Table 1: Percentage of all deceased kidney donors who were expanded criteria donors (ECD) by region of utilization and year of recovery

	Year of recovery					
UNOS region	2004	2005	2006	2007	2008	Total
1	22.3%	25.6%	25.4%	22.1%	23.5%	23.8%
2	31.0%	32.0%	29.0%	32.4%	29.2%	30.7%
3	21.5%	24.9%	23.9%	23.0%	28.0%	24.3%
4	20.5%	19.6%	18.8%	22.9%	18.8%	20.2%
5	19.5%	20.7%	19.2%	21.6%	19.5%	20.1%
6	17.9%	20.4%	23.4%	16.3%	18.9%	19.4%
7	25.3%	23.1%	26.4%	25.0%	27.9%	25.5%
8	18.2%	21.1%	17.0%	18.5%	19.3%	18.8%
9	30.7%	32.9%	33.0%	32.3%	33.7%	32.6%
10	20.9%	24.7%	24.8%	21.0%	24.1%	23.1%
11	20.3%	22.8%	22.7%	26.1%	23.3%	23.1%
Total	22.6%	24.3%	23.6%	24.2%	24.4%	23.9%

Note: Includes ECD–DCD organs and donors recovered for transplant but not transplanted.

discards are due to biopsy findings. Not unexpectedly, the lowest transplant rate is among ECD kidneys, at 57.5% in 2008 *[Table 2.13]*. Though there has been a resurgence of pulsatile perfusion, the utilization of these kidneys has not increased. Furthermore, though procurement of ECD kidneys grew by 1289 over the past 10 years, this translated into only 677 additional kidney transplants performed. On the other hand DCD kidney utilization has increased dramatically from 131 in 1999 to 1181 in 2008. The percentage of DCD kidneys transplanted has remained fairly high, between 81% to 90%.

Despite the growing waiting list of more than 80 000 patients *[Table 1.3]* and the implementation of DonorNet® to improve the efficiency of organ allocation, the fraction of kidneys discarded due to the inability to find a recipient increased from 72 patients (5.6%) in 1999 to 296 patients (13.1%) in 2008 *[Table 3.2]*. The majority of donated organs are used locally (58.2% in 2008) *[Table 3.1]*. The UNOS Board recently approved a proposal to remove mandatory sharing for zero antigen mismatches except for highly sensitized patients and children. This policy, along with one that abolishes kidney 'paybacks' has not gone into effect. The ramifications of these policy changes in terms of local versus shared organ distribution remain to be seen.

Growth in standard donor procurement has not kept pace with ECD or DCD procurement. As a result standard kidney donors as a fraction of the deceased donor pool has declined each year from 1999 (78.1%) to 2008 (65.7%) *[Table 2.2]*. There has been a corresponding increase in the percentage of DCD donation from 1.4% to 9.9%, as well as a more modest growth in ECD donation (20.3% to 22.7%). Overall, ECD kidney utilization has been static at approximately 23% of all deceased donor kidneys for the last 5 years. However there are wide variations among different regions in the country (Table 1). The lowest utilizations are in UNOS Regions 6 and 8 at 19.4% and 18.8%, respectively whereas Regions 2 and 9 have the highest percentage of ECD transplants at 30.7% and 32.6% respectively. Interestingly, these geographic patterns have been stable over the past 5 years. ECD utilization did not correlate with waiting list time either by region or by donation service area (DSA).

Importantly, the utilization of an ECD kidney had a significant negative relation to both 1-year and 3-year patient survival. This may reflect the advanced age of ECD recipients. The mean age of patients receiving an ECD kidney in 2008 was significantly higher at 60.2 versus 48.4 among nonECD donors. However, it was interesting to note that there was a wide range from 19 to 84 years of age, suggesting that there is still considerable variability in how ECD kidneys are utilized by different programs. There was also a significant difference in the panel reactive antibodies (PRA) of recipients who received an organ from an ECD versus standard donor. In 2008, the mean PRA of recipients who received an ECD kidney was 14.4% versus 23.0% among standard donors (p-value 0.0001).

Trends in deceased pancreas donation and utilization

The number of pancreas donors has been relatively unchanged for the last 10 years. Following an initial growth from 1628 to a peak level of 2043 in 2005, pancreas donation has declined each of the ensuing 3 years to 1830 donors in 2008 *[Table 1.1]*. Compared to almost 60% of kidneys utilized locally, only 51% of the procured pancreata are transplanted locally *[Table 3.4]*. Despite a significant interest among several programs in islet transplantation, the number of pancreas glands procured for islets has not changed over the last decade. In 2008, only 57 pancreata (3.1%) were procured for islets compared to 46 (2.8%) in 1999. The overall number of glands not recovered continues to increase, with close to 5000 in 2008 *[Table 3.6]*. On the other hand, the overall number of pancreas glands not used after recovery has decreased this past year, from 458 discards in 2007 to 389 in 2008 *[Table 3.5]*. The transplant rate for procured pancreas glands has declined from 79.5% in 1999 to 71.6% in 2008, a rate that is low compared to

other organs *[Table 2.14]*. Less than half the glands procured from DCDs were utilized in 2008 (47.8%).

Trends in deceased liver donation and utilization

Deceased liver donation has declined in each of the past 2 years *[Table 1.1]*. The majority of livers are transplanted locally (61.4%) and the number of livers discarded after recovery, primarily based upon histological findings (e.g. extensive steatosis), has remained relatively stable (6.2% in 2008) *[Table 3.7]*. DCD liver donation has increased more than 10 fold in the past decade (38 in 1999 to 406 in 2008) but even these numbers are lower than in 2006 *[Table 2.15]*. However, the transplantation of DCD livers has declined progressively over the past 5 years and currently is at 68% compared to 90.3% for livers from brain death donors. This may be attributable to concern regarding an increased incidence of biliary complications and inferior long-term outcomes (1). The number of livers not procured from consented donors has increased from 689 to 956 donors over this past decade *[Table 3.9]*. In 18% of the cases the reason for nonrecovery has been attributed to the list being exhausted or a recipient being unavailable. In most instances failure to transplant a liver has been attributed to poor organ quality.

Utilization of high-risk donors

Whereas ECD criteria have been well defined for kidney donors, a similar validated model has not been applied to and accepted for liver donors. Three categories of high-risk donors were analyzed: (1) CDC high risk, (2) donor risk index (DRI) >1.6 as described by Feng et al. (2) and (3) liver allografts turned down by another center based on quality. The CDC definitions of high-risk organ donors were initiated in 1994 and have remained intact since their introduction. A criticism of these guidelines is that they have not integrated recent advances in donor screening such as NAT testing. Nationwide, 8.37% of the donors were classified as CDC high risk. The incidence fluctuated by UNOS region. The lowest CDC scores were in the southern part of the country with Regions 3 and 11 having only 6.13% and 5.89%, respectively, of their donors classified as high risk, whereas in Region 1 the incidence was 14.89%. There were no differences in model for end-stage liver disease (MELD) score for recipients who received a liver from a CDC-classified low- or high-risk donor (20.42 vs. 20.06).

There were considerably larger fluctuations across the country when donor risk was measured by DRI (Table 2). In 2008, 57.89% of the donors in Region 9 had a DRI >1.6, compared to a national average of 32.04%. As was observed with the CDC high-risk classification, there was no correlation between DRI >1.6 and MELD score. In 2008, the MELD for recipients who received a liver from a donor with DRI less than or greater than 1.6 was 20.84 versus 19.43 respectively. The utilization of high-DRI organs had a significant negative relation with both 1- and 3-year patient survival.

Table 2: Average adult liver recipient lab MELD scores at transplant between January 1, 2004–December 31, 2008 by donor risk index greater than 1.6 and CDC high risk guidelines

	MELD score	
	Average lab MELD	Number of transplants
Number of refusals		
Accepted without quality refusal	21.21	2522
Accepted after quality refusal	19.21	2237
Number of refusals		
Accepted after 0–3 quality refusals	21.04	3426
Accepted after four or more quality refusals	18.29	1333
Sharing		
Local transplant	20.21	3509
Regional or national sharing	20.43	1250

In 2007 3331 livers were transplanted without quality refusal versus 2650 accepted after quality refusal by at least one center (other livers were transplanted without the liver match run allocation process). The graft survival in these instances was similar, 86.28% in the former group versus 83.62% in the group accepted after quality refusal. This group was analyzed further looking at organs accepted after four or more quality refusals. There were 1538 livers transplanted after four or more quality refusals. The 1-year graft survival in this group was 84.07% versus 85.46% among 4443 livers accepted after 0–3 refusals. Interestingly the average MELD of adult patients receiving organs turned down more than four times for quality was 18.29 versus 21.04 in the group with a lower concern about quality.

Trends in deceased heart donation and utilization

Heart donation is singular in that there have been no significant changes in the number of organs donated over the last decade; 2226 hearts were procured in 2008 versus 2316 in 1999 *[Table 1.1]*. Revised UNOS allocation policies have shifted organ utilization from 66.9% local in 2000 to 46.5% in 2008 *[Table 3.13]*. Compared to abdominal organs very few hearts, (only 13) were discarded after procurement *[Table 3.14]*. This probably reflects the more objective work-up of the heart with echocardiograms and cardiac catheterization. On the other hand, consistent with the increasing number of donors above the age of 55 years, many consented donors (3779 in 2008) are not considered as candidates for cardiac procurement *[Table 3.15]*. Only 5.5% (161) of donors above the age of 50 qualified as heart donors.

Trends in deceased lung donation and utilization

The number of lungs recovered from deceased donors has increased steadily from 1445 in 1999 to 2599 in 2008 although recent gains have been modest *[Table 1.2]*. Not surprisingly there are very few donors in the extremes of age. Less than 1% of donors were at least 65 years old

and only 2% were less than 11 years of age *[Table 2.7]*. Fifty-one percent of the organs were utilized locally *[Table 3.16]*. Similar to hearts, acceptance of lungs is based on much more objective criteria compared to abdominal organs, and as a result very few lungs are being discarded after recovery. However, a growing number of lungs are not procured at all after consent. This has increased from 7972 in 1999 to 10 832 in 2008 *[Table 3.18]*. The vast majority (60.7%) are excluded for poor organ function. There has been a slow trend to utilize DCD lung donors. There were no DCD lungs recovered until 2001, 10 donors in 2007 and 19 donors in 2008 *[Table 2.7]*. From the 19 DCD donors, 34 lungs were transplanted, a utilization of 94.4% compared to 97.5% utilization of brain death donors *[Table 2.18]*. Almost 20% (19.2%) of lung donors in 2008 were from African Americans compared to only 14.9% of kidney donors *[Tables 2.7, 2.2]*. This represents a significant increase both in actual donors and the relative percentage of donors over the last decade, and a trend in the last few years.

Trends in deceased intestinal donation and utilization

Fewer intestinal allografts were procured in 2008 *[Table 1.1]*. With CMS guidelines requiring the performance of 10 transplants a year, only a handful of centers have been able to sustain this volume and thus most intestinal transplants are shared (73.1%) rather than local *[Table 3.10]*. More than 90% of the intestinal donors are less than 35 years of age and none of them occur as DCD *[Tables 2.5, 2.16]*. There was a growing number of consented donor intestines not recovered, 6399 in 2008 *[Table 3.12]*. In 30% of cases the organs were not procured for quality, and 38% were not procured for lack of recipients.

Donation After Cardiac Death

Comparing DCD data from 2007 to 2008, there have been increases in: the number of DCD donors (from 791 to 848); the total number of organs recovered from DCD donors (2036 to 2161); the percentage of all donors that are categorized as DCD, (9.8% to 10.6%) and the number of organs transplanted from DCD donors (1521 to 1648) *[Table 2.1, SRTR special analysis]*.[1] Organ-specific changes over the past year are summarized in Table 3. With the exception of liver donors, a smaller percentage of procured DCD organs were discarded.

Overall, the rate of DCD organs transplanted/DCD organs recovered increased from 74.7% to 76.3%. The organs recovered and organs transplanted per DCD donor remained relatively unchanged. From 2007 to 2008, there were increases in the number of actual DCD kidney donors in age groups under 70 years of age. The greatest increases were seen in donors less than 10 years of age and in donors between the ages of 50–59 years which increased to 35.3% and 20.1%, respectively. Similarly the number of kidneys transplanted from donors less than 10 years of age and between the ages of 50–59 years increased to 34.5% and 18.1%, respectively. Importantly, during this same time frame there were decreases in both the number of actual DCD liver donors as well as the number of livers transplanted in all age groups with the exception of donors less than 19 years of age. The number of DCD liver donors between the ages of 60–69 years decreased by 72.2% and the utilization of the livers from these donors decreased by 84.6%.

Comparing 2007 to 2008, there were wide variances in the number of DCD donors recovered by each OPO. Thirty-two (55%) of the 58 OPOs experienced an increase in the number of DCD donors recovered (ranging from 1 to 36 more DCD donors) whereas 23 (40%) of the OPOs experienced a decrease in the number of DCD donors recovered (ranging from 1 to 15 less DCD donors). In 2006, only 17 OPOs met or exceeded the Organ Donation and Transplantation Collaborative goal of 10% of all donors from DCD sources. In 2007 and 2008, 26 and 30 OPOs, respectively met or exceeded this goal.

Organ Preservation and Perfusion

Organ preservation begins with deceased donor management. The goals of deceased donor management are to (1) increase the likelihood of potential donors proceeding toward procurement, (2) increase the yield of transplantable organs per donor, and (3) optimize organ function following transplantation. The pathophysiology of brain death has been studied both experimentally and clinically (3). Hormonal derangements resulting from collapse of the hypothalamic-pituitary axis have profound physiologic affects at the molecular, cellular and tissue levels (4,5). Although data suggests that these hormonal derangements can be mitigated by aggressive hormonal resuscitation (6), the efficacy of hormonal therapy in this setting has not been conclusively established. Hormonal resuscitation protocols utilizing intravenous steroids, vasopressin, thyroid hormone and insulin have been recommended for optimal deceased donor management (7). We queried the SRTR data to determine how often these hormonal resuscitation protocols have been utilized and whether or not they are being utilized with increasing frequency.

For all the years from 2004 through 2008 some hormonal replacement was more likely to be utilized in standard criteria donors (SCD) than ECDs ($p < 0.001$). Not surprisingly, hormonal replacement therapy was used much less frequently in DCD donors for whom hormonal resuscitation may be less important physiologically. In 2008 less than

[1] The numbers of organs recovered and transplanted from DCD donors in this section include ECD-DCD kidneys, and therefore, do not match the numbers published in the 2009 OPTN/SRTR Annual Report data tables.

Table 3: Changes in organ-specific DCD donation 2007–2008

	Year		
	2007	2008	% Change
Kidney			
Number of donors	758	832	9.8%
Number of organs recovered	1505	1651	10%
Number of organs transplanted	1171	1306	12%
Percent of organs that were discarded	22.2%	20.9%	
Liver			
Number of donors	443	406	−8%
Number of organs recovered	443	406	−8%
Number of organs transplanted	306	276	−9.8%
Percent of organs that were discarded	30.9%	32.3%	
Pancreas			
Number of donors	65	67	3%
Number of organs recovered	65	67	3%
Number of organs transplanted	25	32	28%
Percent of organs that were discarded	61.5%	52.2%	
Lung			
Number of donors	10	19	90%
Number of organs recovered	19	36	89%
Number of organs transplanted	16	34	113%
Percent of organs that were discarded	15.8%	5.6%	
Heart			
Number of donors	4	1	−75%
Number of organs recovered	4	1	−75%
Number of organs transplanted	3	0	−300%
Percent of organs that were discarded	25%	100%	

Source: *2008 OPTN/SRTR Annual Report*, Tables 2.14–2.18 and SRTR analysis. DCD includes DCD–ECD. Discarded organs include those not used, used for research and used for unknown or other purposes.

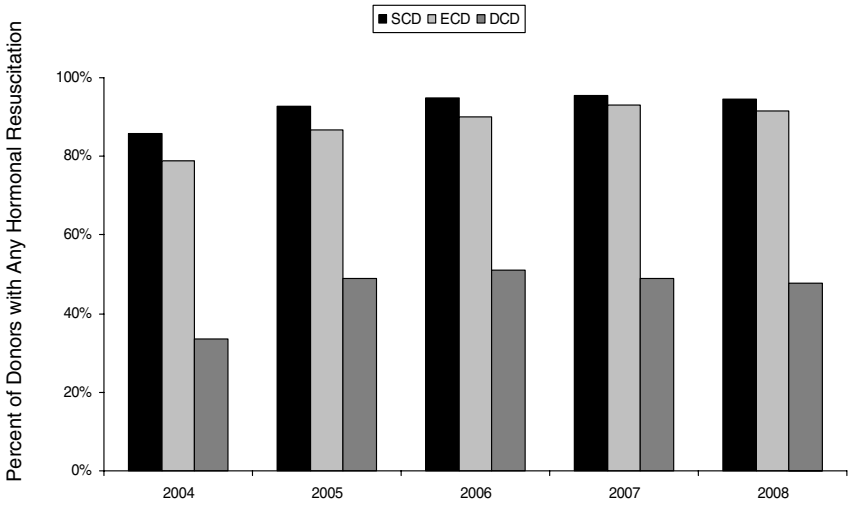
50% of DCD donors were administered some form of hormonal resuscitation. For SCD donors where at least one organ was transplanted, utilization of hormonal replacement increased each year in a statistically significant fashion until 2007. From 2007 to 2008 there was a decline in the percentage of donors in which hormonal replacement therapy was administered ($p = 0.0206$). A similar trend was noted for ECD donors.

In 2004, hormonal resuscitation was employed in the management of ≥80% of deceased donors (in which one organ or more was transplanted) in only 7 of 11 UNOS Regions. However, by 2006 and each year subsequently, some hormonal resuscitation was administered in ≥80% of all donors in all 11 UNOS Regions (Figure 2). At the level of the individual OPOs, there remains quite a degree of variability in the use of hormonal resuscitation. In 2008, 9 of 58 OPOs (15.5%) utilized some hormonal resuscitation in ≤80% of their donors, whereas three OPOs administered some form of hormonal therapy to 100% of their donors.

Following aortic crossclamping in the deceased donor, hypothermic perfusion remains the standard-of-care for the preservation of deceased donor organs. A number of preservation solutions are available for this purpose. The two commercially available preservation solutions that are most frequently used for intraabdominal organs are Viaspan® (University of Wisconsin or UW solution) and Custodiol® (HTK solution) (Figure 3). Viaspan® has long been the dominant preservation solution and remains so. However, Custodiol® has gained a substantial portion of the market. For thoracic organs, a variety of proprietary plegia solutions are utilized. However, Viaspan® and Celsior® are also commonly used.

Recently there has been some controversy regarding the relative efficacy of Custodiol® versus Viaspan® in pancreas transplantation, or kidney transplantation with prolonged ischemic times (8,9). For the years 2005–2008, there were no significant differences in the rates of renal allograft delayed graft function based on which of these preservation solutions were used (Figure 4). The impact of preservation solution on both delayed graft function and primary nonfunction in extrarenal organs has also been debated, but clear definition of these terms and the relatively low incidence of the endpoints have made this difficult to evaluate.

Machine preservation versus static cold storage of deceased donor kidneys has received renewed interest. A recent landmark multicenter randomized study by Moers et al. demonstrated that machine preservation reduced the incidence of delayed graft function and was associated with lower recipient creatinine values in the first 2 weeks posttransplantation (10). However, machine preservation



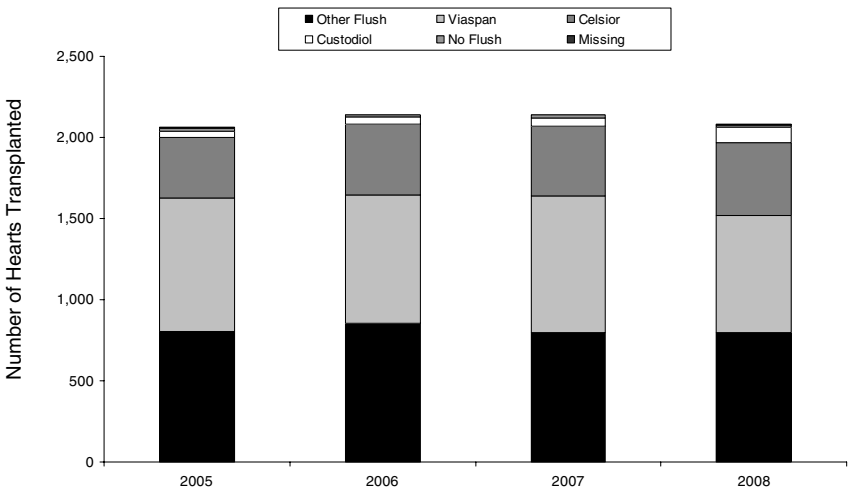
Source: SRTR analysis. Data as of May, 2009.

Figure 2: Utilization of some form of hormonal resuscitation for deceased donors differs by type of deceased donor. Hormonal resuscitation has been employed less for DCD donors than for SCD or ECD donors. Hormonal resuscitation was used with increasing frequency for all deceased donor types from 2004–2006.

remains limited in its use due to its increased expense and logistical demands. In the United States, machine preservation of kidneys has increased substantially over the last 5 years. For SCD kidneys, machine preservation increased each year from 2004 to 2007 ($p \leq 0.004$ for each year). ECD kidneys were machine pumped with a statistically significant increasing frequency in years 2006 and 2008 ($p < 0.001$ for both years). DCD kidneys were machine pumped a higher percentage of the time and saw a statistically significant increase in machine preservation in 2008 ($p = 0.003$) (Figure 5).

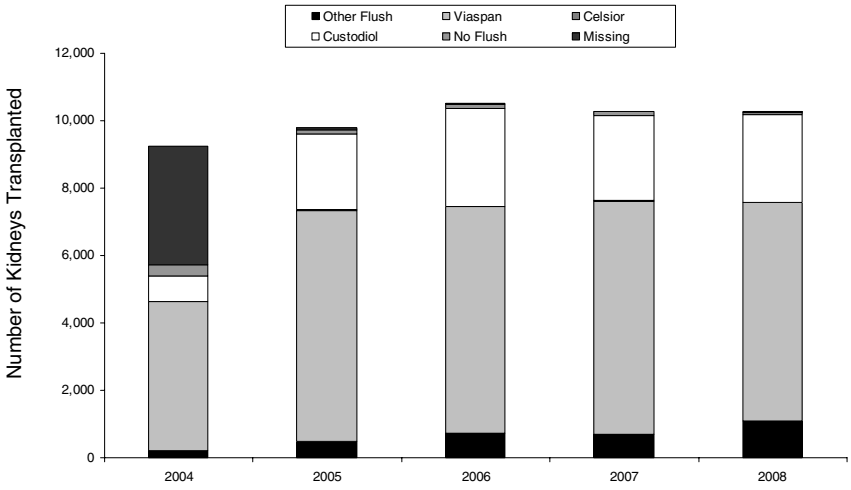
Cold ischemic times tended to be longer for pumped kidneys than for kidneys maintained with static cold storage. The mean cold ischemic time for a cold stored kidney in 2008 was 17.71 h compared to 21.22 h for the machine-perfused kidney. The incidence of delayed graft function did not differ between machine-perfused kidneys and cold stored kidneys in years 2004–2007. However, in 2008 the incidence of delayed graft function was significantly higher in the kidneys that had been maintained on machine perfusion, (25.9%) compared to that seen with cold storage (24.0%) ($p = 0.045$). This may reflect the fact that machine preservation was utilized in a greater proportion of DCD and ECD donors than with SCD donors. Similarly, 1- and 3-year patient and graft survival rates were slightly lower in patients receiving the machine preserved kidneys over the 5 years from 2004 to 2008.

There is no data currently available in the SRTR databases regarding machine preservation of extrarenal organs. However, Dr. James Guarrera and colleagues at Columbia University have recently completed a federally funded phase I trial of what is believed to be the first clinical utilization



Source: SRTR analysis. Data as of May, 2009.

Figure 3: Celsior and Viaspan are the commercially available preservation solutions that are used most frequently for cardiac transplantation. However, nearly one third of all heart allografts are preserved with other proprietary solutions.



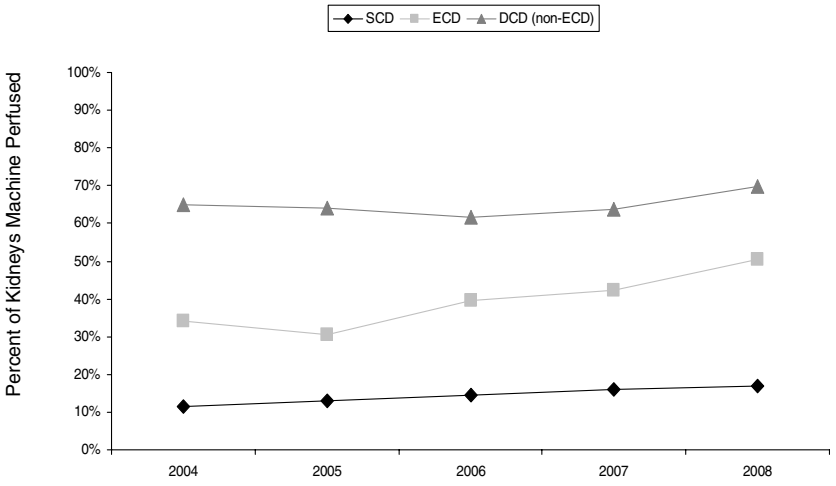
Source: SRTR analysis. Data as of May, 2009.

Figure 4: Viaspan followed by Custodiol have been the most commonly used preservation solutions for deceased donor abdominal organs.

of machine preservation for human hepatic allografts (11). Additionally, investigators at the University of Toronto have published experimental series of *ex vivo* normothermic machine preservation in pulmonary grafts (12). This group and others are poised to apply this technology to human lung allografts. Thus one can expect broader application of machine preservation in the not too distant future.

Trends in OPO Performance

A well-accepted measure of OPO effectiveness is the volume of deceased donors produced in the DSA covered by the OPO. Three performance measures currently applied to OPOs are: (1) the number of donors per million living population in the DSA; (2) the conversion rate or the ratio of actual donors to identified eligible donors multiplied by 100 and (3) the number of solid organs transplanted from each donor (organs transplanted per donor [OTPD]). Based on these three performance measures, the results across OPOs during 2008 showed mixed evidence of success. Overall, the conversion rate increased significantly between 2003 and 2008. During this period, conversion increased from 52.21% in 2003 to 66.41% in 2008 (Table 4). A yearly increase of 2%–4% points in conversion rates between 2003 and 2007 appeared to level off in 2008 during which the conversion rate was 66.41% compared to 67.05% in 2007. Whether the slight decline in conversion rate between 2007 and 2008 becomes a trend awaits future performance. The aggregate number of all deceased donors per million population (donors PMP) showed an 18% increase from 22.07 in 2003 to 25.97 in 2008 (Table 4). However, of some concern is the fact that donors PMP actually decreased from 26.63 in 2006 to 26.58 in 2007 and 25.97 in 2008.



Source: *2009 OPTN/SRTR Annual Report*, Table 1.1.

Figure 5: Machine perfusion is most commonly used for kidneys from DCD donors, followed by ECD donors. However, for DCD, ECD and SCD donor kidneys, the incidence of machine perfusion increased overall from 2004–2008.

Table 4: Nationwide indicators of OPO performance by year, 2003–2008

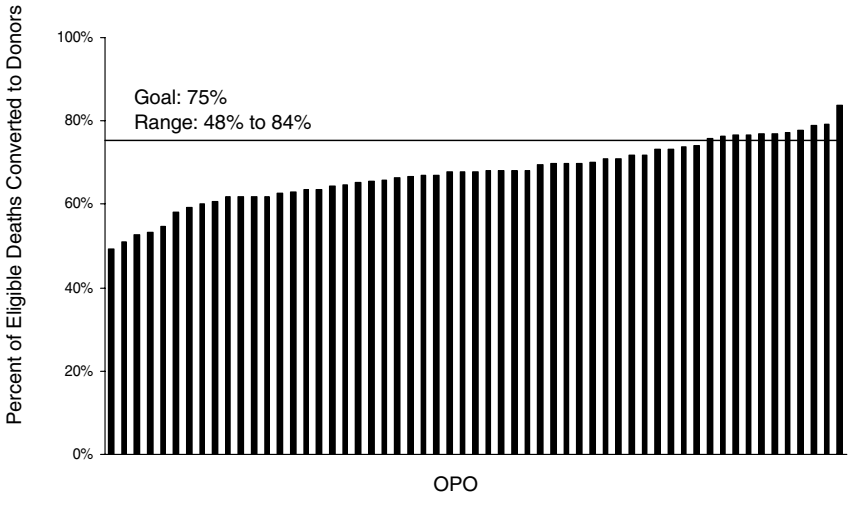
	2003	2004	2005	2006	2007	2008
Conversion	52.21%	56.82%	58.92%	64.24%	67.05%	66.41%
Donors per million	22.07	24.18	25.45	26.63	26.58	25.97
OTPD	3.15	3.06	3.06	3.05	2.99	3.00

OTPD showed a downward trend in the aggregate between 2003 and 2008 (from 3.15 to 3.00, respectively). The 5% decline in OTPD occurred nearly as a continuous trend with no single year showing a substantial increase (or reversal of trend) between 2003 and 2008. The decline in OTPD may be due to the increase in the proportion of ECD and DCD donors who typically produce a lower OTPD compared to SCD donors.

The aggregate national data on OPO performance measures subsumes substantial variation in the performance within DSAs. In 2008, DSAs had conversion rates ranging from 48% to 84% (Figure 6). The number of donors PMP within the DSA ranged from 14 to 40 donors in 2008 (Figure 7), and the OTPD ranged from 2.2 to 3.5 across DSAs (Figure 8).

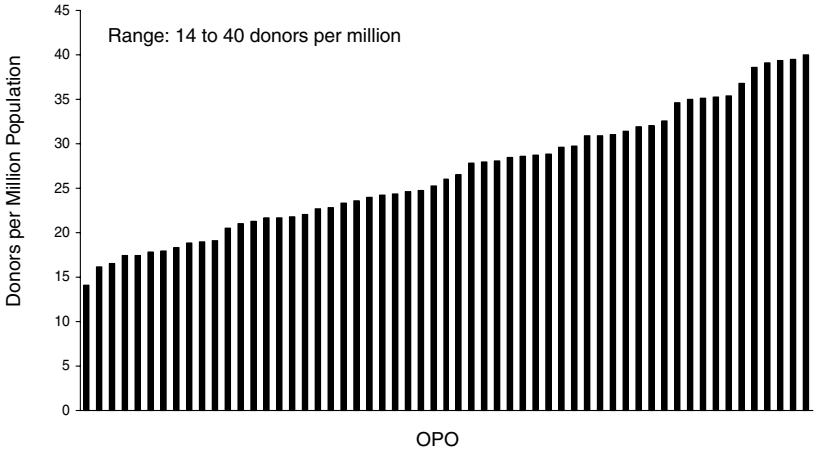
The Organ Donation Breakthrough Collaborative (ODBC) and the Organ Transplantation Breakthrough Collaborative (OTBC) are two Health Resources and Services Administration (HRSA) initiatives developed to address unmet needs in organ donation and transplantation practices. Implicit in the OTBC goal setting is that best practices at transplantation centers and maximum cooperation between the OPO and the transplant centers within the DSA will lead to increased rates of OTPD. The OTBC was initiated in 2005 and established goals of 3.75 OTPD and 75% conversion rate for each OPO. The number of OPOs meeting the goal of 75% conversion rates has increased from 2003 to 2007, (2 to 11 respectively), however there was no further improvement in 2008, and currently the majority of OPOs still do not meet that goal. The OTBC goal of 3.75 OTPD was attained by two OPOs in 2003 but no OPO met the OTPD goal from 2005 to 2008.

The three measures of OPO performance (conversion rate, donors PMP and OTPD) create a tension that OPOs may face in their strategies to increase the number of deceased donors and increase the number of organs recovered. An increasing fraction of deceased donors are ECDs and DCDs who tend to yield lower OTPD compared to SCD. Thus as OPOs strive to increase conversion rates, more ECDs and DCDs are converted leading to a downward pressure on the average OTPD. On the other hand efforts to boost the average OTPD require focusing on high-quality donors who are more likely to have higher than average OTPD, which can only be accomplished at the expense of jettisoning ECDs and DCDs and the overall numbers of converted donors, thus applying a downward pressure on the conversion rate. The tense reality and inherently contradictory goals of the performance measures is evident in how well individual OPOs perform on the three measures during a given year. Only one OPO (the University of Wisconsin Hospital and Clinics) ranked among the top five of all OPOs in each of the three performance measures during any single year between 2003 and 2008. Several other OPOs were consistently ranked in the top five on some measures, but no OPO other than the University of Wisconsin Hospital and Clinics achieved high rankings for all three measures in the same year. In addition to



Source: SRTR analysis. Data as of May, 2009.

Figure 6: In 2008 there was substantial variability between OPOs in the percentage of eligible deaths that are converted to donors. Eleven OPOs exceeded the goal of 75% conversion set by the Organ Transplantation Breakthrough Collaborative.



Source: SRTR analysis. Data as of May, 2009.

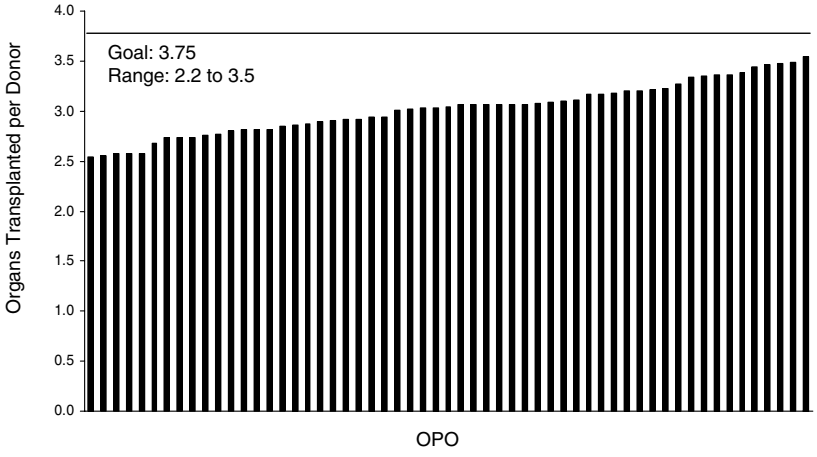
Figure 7: OPOs exhibit substantial variation in their number of deceased donors per 1 million population within the donation service area. OPOs ranged from 14 donors per million population to 40 donors per million population in 2008.

adopting the best practices described in the OPO Collaborate Report, the OPO of the University of Wisconsin Hospital and Clinics have in place several procedures that could account for its extraordinary albeit singular performance. These include: (1) a self-deploying surgical recovery team, including that team's interaction with and dedication to donor families, donor hospital nursing staff and operating room staff; (2) a designated requestor program which empowers the donor hospitals and staff to take an active role in donation; (3) a daily 'morning report' that includes all donor activity and referrals, and is attended by everyone in the OPO and (4) a biannual Doug Miller Symposium which acknowledges donor hospitals and staff and serves as an educational tool for best practices.

Nonetheless, using the conversion rate and OTPD goals set forth by the Collaboratives as a yardstick to evaluate OPOs and transplant centers may be unrealistic. It is fashionable for the defenders of the established donation and transplantation goals to point to the variability in OTPD and conversion rates across DSAs and UNOS regions as evidence that best practices have variable penetration and that there is significant room for improvement. However, this argument ignores the fundamental fact that the donor pool may be inherently variable across all DSAs and UNOS regions. For instance, OTPD tends to be higher among young donors and donors with head trauma than older donors and those who died from anoxia (Table 5). These are attributes that are not controllable and arguably make it difficult, if not impossible, to establish benchmarks that can be logically applied to disparate populations.

Donor Screening Practices

Following the widely publicized transmission of HIV and hepatitis C from an organ donor to four recipients in November of 2007, there have been various efforts initiated to survey OPO practices relating to donor testing/screening for HIV, hepatitis C, Human T-cell



Source: SRTR analysis. Data as of May, 2009.

Figure 8: The average number of organs transplanted per deceased donor (OTPD) within an OPO varies. In 2008 average OTPD ranged from 2.2 to 3.5 across OPOs; no OPO met the Organ Transplantation Breakthrough Collaborative goal of 3.75 OTPD.

Table 5: Differences in OTPD by donor characteristics, 2008

Donor age	Donor cause of death	OTPD
0–14 years old	Anoxia	3.22
	CVA/stroke	4.48
	Head trauma	4.00
	CNS tumor	3.00
	Other	3.74
15–49 years old	Anoxia	2.95
	CVA/stroke	3.13
	Head trauma	4.08
	CNS tumor	3.28
	Other	3.14
50–59 years old	Anoxia	1.82
	CVA/stroke	2.34
	Head trauma	2.45
	CNS tumor	2.00
	Other	2.04
60–69 years old	Anoxia	1.50
	CVA/stroke	1.76
	Head trauma	1.93
	CNS tumor	N/A
	Other	1.33
70 and older	Anoxia	0.86
	CVA/stroke	1.14
	Head trauma	1.26
	CNS tumor	N/A
	Other	0.17

Lymphocyte Virus (HTLV) and the use of NAT testing for Chagas Disease, West Nile Virus, etc.

In early 2008 the OPTN/UNOS OPO Committee, with representatives from the OPTN/UNOS *Ad Hoc* Disease Transmission Advisory Committee (DTAC), the CDC, the OPTN/UNOS Histocompatibility Committee and the Association of Organ Procurement Organizations (AOPO), developed and conducted a survey to determine the use of NAT testing among OPOs. All 58 OPOs participated in the survey and the results indicated that 45 (77.6%) of the OPOs performed NAT testing on either all donors or selected organ donors, whereas 13 (22.4%) of the OPOs never performed NAT testing.

Further results indicated varied OPO practices regarding NAT testing including:

- performing NAT testing on all donors prospectively;
- performing NAT testing on all donors retrospectively;
- performing NAT testing on selected high-risk donors (CDC or local definition) prospectively;
- performing some NAT testing prospectively and
- performing some NAT testing retrospectively.

The most common reasons given for either performing NAT testing on selected donors or for not performing NAT testing at all were logistics, availability of NAT testing in a workable timeframe, and costs associated with the transportation of the specimen and testing. Additional concerns were expressed relating to the potentially high false-positive rate of NAT testing that could potentially lead to the unnecessary discard of organs.

Also in 2007 to early 2008, a commonly used HIV screening test was taken off the market. As a result of this change in testing, many OPOs were at risk for noncompliance with current OPTN/UNOS policy language. In looking for suitable replacement options, many OPOs encountered problems with diagnostic versus screening testing and the possibility of discordant test results. As a result, policy was modified to specify that donors may be tested for transmissible diseases using Federal Drug Administration-licensed, approved, or cleared serological tests capable of determining whether the donor is or has been infected with these specific diseases. After implementation, concerns were raised regarding when it is appropriate to use diagnostic tests in lieu of screening tests. Subsequently, the policy language was further modified to clarify for OPOs when it is permissible to use a diagnostic test in place of a screening test.

The DTAC developed a survey to evaluate the status of screening and diagnostic testing for donor disease transmission that was sent out to all OPOs in the fall of 2008. The survey addressed the availability of screening tests for a number of specific transmissible diseases, current practices and expected future challenges. The DTAC will use the responses from the 55 OPOs that responded to better align screening policy and practice. This should allow predictable organ donor assessment with minimal variation throughout the country. Responses will also be considered as the DTAC proposes modifications to OPTN/UNOS policies 2.0 and 4.0.

Summary

In summary, after increasing throughout the 1990s and early 2000s, living organ donation has trended downward since the mid 2000s. Living kidney donation is still more common than it was one decade ago, but living donation of pancreata, livers, intestines and lungs was less common in 2008 than it was in 1999. During this time the demographics of living donors have changed to include a higher proportion of older individuals who are unrelated to the recipients.

Year 2008 marked the first time that the number of deceased organ donors and the number of organ transplants performed using deceased donor allografts decreased from the previous year. This occurred despite an increase in the number of DCDs. ECD kidney donor utilization has been stable but shows significant variability across different regions in the country. Livers that are transplanted

after being turned down by several transplant programs have equivalent outcomes compared to donor livers transplanted into the recipient who received the initial organ offer. High-risk donors based on DRI have poor outcomes but CDC-defined high-risk donor livers have excellent short-term outcomes.

Over the past 6 years OPO performance has seen mixed results. The conversion rate and the number of donors per million living population both increased between 2003 and 2008. Meanwhile, the number of solid organs transplanted from each donor decreased. Overall, OPOs appear to have difficulty simultaneously increasing the number of donors and increasing the number of OTPD. Moreover, transplant programs appear to be similarly conflicted when they are asked to embrace strategies designed to expand the organ supply through the use of ECD and other high-risk donors in the absence of adequate risk-adjustment in the analysis of their patient outcomes. Reassessment of high-risk donor definitions as well as the benchmarks for donor screening are two areas which could potentially improve the safety, quality and volume of organ procurement in the future.

Acknowledgments

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Conflict of Interest Statement

The authors declare no conflicts of interest.

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