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Deceased Pediatric Donor Livers: How Current Policy Drives Allocation and Transplantation

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Abstract

Each year, approximately 60 children, representing 12% of waitlist candidates, die awaiting liver transplantation. The current allocation algorithm for pediatric donor livers prioritizes local/regional adults over national children. We attempted to better understand the impact of the present algorithm on pediatric candidates. We analyzed pediatric donor liver offers from 2010 to 2014. Donors and recipients were classified based on age. We mapped allocation and acceptance patterns and used subgroup analyses to explore the significance of donor service areas (DSAs) with low pediatric transplant volumes. We used Cox proportional hazard regressions to evaluate posttransplantation outcomes: 3,318 pediatric donor livers were transplanted into 3,482 recipients, and 45% (1,569) were adults. Of the 1,569 adults, 25% (390) received a pediatric organ that was *never* offered to children; 52% (204) of these 390 pediatric organs originated in the 37 DSAs, with ≤25 pediatric liver transplantations; 278 children died or were delisted due to illness during the same time, with higher mortality rates in the 37 DSAs (10% versus 6%, $P < 0.01$). Compared to adults, pediatric recipients aged <12 years had lower risks of posttransplant mortality (hazard ratio, 0.62; 95% confidence interval, 0.46-0.81; $P < 0.01$).

Conclusions: We found that 45% of pediatric donor livers were transplanted into adults: 390 adults were transplanted with pediatric organs never offered to children, while 278 children died or were delisted due to illness, which was more apparent in DSAs with low pediatric transplant volumes; we advocate for a change to allocation policies to allow pediatric organs to be offered to national children with status 1B or Model for End-Stage Liver Disease/Pediatric End-Stage Liver Disease >15 before being offered to local/regional + circle non–status 1A adults.

Each year, up to 60 children die awaiting liver transplantation, representing 12% of the total US national pediatric waitlist. Most of these children are under 5 years of age, with mortality rates highest among children under 1 year of age.[(1)] Although the number of liver transplants

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in children represents only 10% of the total number of liver transplants performed in the United States each year, pediatric waitlist candidates remain a uniquely vulnerable population due to their small size; they, above all others on the waitlist, truly depend upon the pediatric donor pool for timely access to transplantation. In fact, 80% of children receiving deceased donor liver transplants on the liver waitlist are transplanted with livers from pediatric donors.[2]

The current US national liver allocation algorithm was designed to distribute donor livers based on degree of illness and proximity to the donor. It does not, however, address the vulnerability of pediatric liver waitlist candidates or prioritize their access to suitable liver donors. Our group has previously demonstrated that 316 children died or were removed from the list for being too ill, while 1,667 adults were transplanted with livers from pediatric-age donors.[2] Of those adults, 97% received pediatric donor livers that had been allocated locally or regionally before they could be offered to higher-acuity pediatric candidates on the national waitlist.[2]

The aim of this study was to understand how the present algorithm for allocation of pediatric deceased donor livers might impact risk on the waitlist.

Participants and Methods

We evaluated all US deceased liver donors <18 years old from January 1, 2010, through December 31, 2014. Donors were followed until removal from the offer list or the end of the study period (December 31, 2014). Pediatric donors were classified into two groups: age <12 years and age 12-17 years. This delineation was used because United Network for Organ Sharing (UNOS) allocation rules governing pediatric donors diverge at 12 years of age. Data on recipients, deceased liver donors, and match-run information were obtained from the UNOS/Organ Procurement and Transplantation Network (OPTN) standard transplant analysis and research and potential transplant recipient files as of March 31, 2016. The institutional review board at the University of California–San Francisco approved this study.

DECEASED DONOR CHARACTERISTICS

Donors were characterized by age, sex, race/ethnicity, height, hepatitis C virus (HCV) antibody status, Public Health Service (PHS) increased risk donors, cause of death, and donation after cardiac death. Split-liver allocations were noted in the analyses but were not treated differently from whole-liver allocations in calculations of outcomes. Characteristics of each donor liver were available only at transplant; therefore, we obtained these data by matching the donor identification number at offer with that at transplantation.

RECIPIENT CHARACTERISTICS

Recipients were divided into three categories: pediatric recipients aged <12 years, pediatric recipients aged 12-17 years, and adult recipients aged ≥18 years, following UNOS-designated allocation policy differences governing recipients in these age groups. Baseline demographic data of pediatric and adult recipients included age, sex, race/ethnicity, height, weight, and body mass index. Clinical variables included recipient ABO blood type, etiology of liver disease, if any exception points were ever granted, allocation Model for End-Stage Liver Disease (MELD) or Pediatric End-Stage Liver Disease (PELD) score at transplantation, transplant date, graft failure date, composite death date, and UNOS region of listing.

Race/ethnicity was classified into the following categories: non-Hispanic white, Hispanic, black, Asian, or other/multiracial. Etiologies of liver disease were categorized as chronic liver diseases (including chronic cholestatic diseases such as primary biliary cirrhosis and primary sclerosing cholangitis), pediatric cholestatic diseases (including biliary atresia, hypoplasia, and familial cholestasis), malignancy/tumor, inborn errors of metabolism, acute hepatic necrosis, graft failure, and others.

CENTER AND GEOGRAPHIC CHARACTERISTICS

We divided donor service areas (DSAs) into those containing centers that had performed >25 pediatric transplants over the 5-year study period and those that had not. This translates into an average of fewer than five transplants per year. In previous studies, pediatric patients listed at these low-volume centers had a severely reduced likelihood of transplantation, increased waitlist mortality, and increased posttransplant mortality.[(3)] We identified the cutoff at 25 pediatric transplants as there is a substantial drop-off in the number of transplants starting at this number during the study period (Fig. 1). A similar definition was used in a previous analysis.[(2)] For DSAs with low pediatric transplant volumes, defined as <25 pediatric transplants over the 5-year study period, distance between the DSA and the closest pediatric transplant center was calculated based on the direct airspace distance between the most common city of origin for pediatric donors in that DSA and the closest city outside of the low-volume DSA with a pediatric transplant center.

STATISTICAL ANALYSES

Pediatric donor livers that were ultimately transplanted into any recipient were grouped by recipient age (<12 years, 12-17 years, and adults ≥18 years). Clinical characteristics and laboratory data for donors were summarized by medians and interquartile ranges (IQRs) for continuous variables or numbers and percentages for categorical variables. Comparisons among groups were performed using chi-squared and Kruskal-Wallis tests. Donors were also classified based on age at donation (<12 years or 12-17 years). Recovery and transplant rates were calculated through matching of deceased donor data with match-run data. Number of offers made, initial allocation (defined as the first offer from the donor standpoint), and ultimate acceptance allocation (status 1A, status 1B, MELD/PELD category, organ procurement organization [OPO], regional or national level share) at transplantation were extracted from match-run data. These figures were then used to calculate acceptance rates by dividing the number of acceptances within each category by the total number of offers.

Posttransplant outcomes included patient mortality and graft failure. We made comparisons between adult and pediatric recipient groups using Cox proportional hazards regression models to estimate graft failure and survival rates. Covariables evaluated in the posttransplant Cox models included race/ethnicity, recipient ABO status, etiology of liver disease, any exception points granted, allocated MELD/PELD at transplantation, cold ischemic time, and UNOS region. Two-sided *P* values <0.05 were considered statistically significant in all analyses. Analyses were performed using STATA statistical software, version 13.0 (StataCorp, College Station, TX).

The data reported here have been supplied by the UNOS as the contractor for the OPTN. The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy of or interpretation by the OPTN or the US government.

Results

During the 5-year study period between January 1, 2010, and December 31, 2014, there were 4,292 deceased pediatric donors, of whom 55% (2,374) were age <12 years and 45% (1,918) were between the ages of 12 and 17 years. The recovery rate for livers from all pediatric donors was 81% (3,508/4,292). Of those 3,508 pediatric donor livers recovered, 95% (3,318) were ultimately transplanted into 3,482 recipients (inclusive of split allocations). Of the 3,482 recipients, 49% (1,692) were age <12 years, 6.3% (221) were between the ages of 12 and 17, and 45% (1,569) were adults aged ≥18 years. The percentage of pediatric donor livers going to adults varied between 32% and 66% among regions and between 17% and 100% among DSAs.

BASELINE CHARACTERISTICS OF PEDIATRIC DONORS

Donor baseline characteristics are presented in Table 1 as an aggregate and by recipient category (pediatric recipients <12 years, pediatric recipients 12-17 years, and adults ≥18 years). Pediatric donors had a median age of 12 years (IQR 3-16). Twenty-one percent of pediatric donors were African American, 0.3% were HCV antibody–positive, and 0.5% were hepatitis B virus core antibody–positive. Seven percent of pediatric donors were deemed to be PHS increased risk donors. Blood type breakdowns for pediatric donors were as follows: 51% O, 35% A, 12% B, and 3% AB. Mechanisms of death were 39% from anoxic brain injury, 6% from cerebrovascular accident, 51% from trauma, and 4% from other causes; 5% were donated after cardiac death. Median cold ischemic time was 6.5 hours, with the median distance between donor and recipient being 143 miles. One hundred and eighty-one pediatric donor livers (6%) were split.

Compared to pediatric donors whose livers were transplanted into adults, those whose livers were transplanted into children <12 years were younger (median 3 versus 15 years), were shorter (median 137 versus 168 cm), and weighed less (median 40.0 versus 64.0 kg). Pediatric candidates <12 years were more likely to receive an O liver (55% versus 46%) compared to adults. They were also more likely to receive a liver from a pediatric donor who died of anoxia (42% versus 35%) compared to adults. Cold ischemic times were higher and distances between donor and recipient were longer for pediatric recipients <12 years versus adults (median 7.0 versus 6.1 hours, and median 285 versus 57 miles). Pediatric donor livers transplanted into children <12 years were more likely to be split (12% versus 8%).

BASELINE CHARACTERISTICS OF RECIPIENTS

Recipient baseline characteristics are presented in Table 2. Pediatric recipients aged <12 years were less likely to be non-Hispanic white (51% versus 65%) and more likely to have type O blood (48% versus 42%) compared to adult recipients. The most common indications for transplantation for pediatric recipients aged <12 years were pediatric cholestatic diseases (44%), followed by inborn errors of metabolism (14%) and malignancy/tumors (10%). The most common indications for transplantation for adult recipients were chronic liver diseases (56%), followed by malignancy/tumors (27%). Pediatric recipients aged 12-17 years were more likely to receive any exception points (46%) compared to pediatric recipients aged <12 years (36%) and adult recipients (37%). The median allocation PELD score for pediatric recipients aged <12 years was 32. The median allocation MELD scores for pediatric recipients aged 12-17 years and adult recipients were similar at 25 and 26, respectively.

While the proportions of multiorgan recipients were similar across all age categories at 11% for pediatric recipients aged <12 years, 12% for pediatric recipients aged 12-17 years, and 12% for adult recipients, the combination of multiorgan transplantations differed greatly among the age categories. Of the 189 pediatric multiorgan recipients aged <12 years, 75% (141) and 71% (135) received an intestinal and/or pancreatic transplant. Of the 191 adult multiorgan recipients, 86% (162) received a simultaneous kidney transplant.

DONOR LIVER ALLOCATION PATTERNS

Initial allocation (defined as the first offer from the donor standpoint), ultimate acceptance, and acceptance rates for pediatric donor livers, separated by clinical status and geography, are shown in Table 3. Of the 3,318 pediatric livers offered, 82% were initially allocated to children and 18% to adults. Out of the 82% initially allocated to children, 5%, 56%, and 21% were made in the OPO, regional, and national matches, respectively. Eight percent of pediatric livers originating in high–pediatric volume DSAs (defined as those with >25 pediatric transplants over the 5-year study period) were offered in the pediatric OPO match compared to 2% of pediatric livers originating in low–pediatric volume DSAs (defined as those with <25 pediatric transplants over the 5-year study period). With regard to clinical status, pediatric status 1A received 25% of the initial allocations; this was followed by pediatric candidates with MELD/PELD scores >35 at 15%. Adults received 8% of initial allocation as status 1A and 2% as MELD score >35.

Pediatric candidates eventually accepted and were transplanted with 55% (1,913) of all pediatric donor livers, while adults accepted and were transplanted with 45% (1,569). By share type and geography, pediatric recipients received 6%, 33%, and 16% of all pediatric donor livers in the OPO, regional, and national matches, respectively. Adult recipients, in contrast, received 37%, 8%, and 1% of all pediatric donor livers in the OPO, regional, and national matches, respectively. In low–pediatric volume DSAs, pediatric candidates were transplanted with 3% of OPO-allocated livers; this is in contrast to 9% in high–pediatric volume DSAs. The greatest proportion of pediatric donor livers were accepted by adults with MELD scores between 26 and 35 at 20% of the overall pediatric donor pool. When subdivided into low–pediatric volume and high–pediatric volume DSAs, 25% of pediatric donor livers originating from low-volume DSAs and 15% of those originating from high-volume DSAs went to adults.

Acceptance rates of pediatric donor livers originating from low-volume DSAs ranged from 5% to 17% for pediatric candidates and from 1% to 23% for adult candidates depending on candidate clinical status. Candidates with clinically advanced disease, such as status 1A or MELD/PELD scores >35, were more likely to accept offers of pediatric livers. By type of allocation, the highest donor liver acceptance rates for pediatric candidates occurred in the OPO match at an overall rate of 20%. Similarly, the highest donor liver acceptance rates for adult candidates also occurred in the OPO match at an overall rate of 9%. Detailed acceptance rates by candidate clinical status and allocation type are featured in Table 3.

TRANSPLANT RECIPIENT ACCEPTANCE PATTERNS

Of the 1,569 adults who received a liver transplant from a pediatric-age donor, 25% (390/1,569) were transplanted with a pediatric donor liver that was *never* offered to a child (Fig. 2). Of these 390, 9% (35/390) originated from a pediatric donor aged <12, and 91% (355/390) originated from a pediatric donor aged 12-17. Twenty-one percent (83/390) of these adult recipients were allocated under status 1A, and 8% (32/390) were allocated to adults with a MELD score ≥35 at transplantation.

Fifty-two percent (204/390) of the pediatric donor livers allocated to adults without being offered to children originated in the 37 DSAs in which <25 pediatric transplantations were conducted during the 5-year study period. Of note, these low-volume DSAs made up of 64% (37/58) of all DSAs and were the origin of 47% (1,581/3,318) of all pediatric donor livers during the 5-year study period. A detailed map of DSAs with low pediatric transplant volumes is shown in Fig. 3. These DSAs with low transplant volumes were concentrated in regions 3 (8 DSAs), 11 (6 DSAs), and 10 (4 DSAs) and correspond with lower allocation MELD scores in general.[1] A greater proportion of those transplanted with pediatric donor livers were adults in the 37 low-volume DSAs (defined as a DSA with <25 pediatric transplants during the study period) [48% versus 42%, $P < 0.01$]) compared to those in the 21 higher-volume DSAs (defined as a DSA with >25 pediatric transplants during the study period).

A total of 278 children died or were delisted due to illness during the study period—158 (57%) were delisted due to death, and 120 (43%) were delisted due to illness. A higher rate of death or delisting due to illness was seen in the 37 DSAs with <25 pediatric transplants versus high-volume DSAs (10% versus 6%, $P < 0.01$). Of these 278 children who died or were delisted due to illness on the waitlist, only 29 (10%) were listed with any exception points. For those 158 children who were delisted due to death, 46 (29%) died from multiorgan failure, 24 (15%) died from cardiac causes, 15 (9%) died from infection, 15 (9%) died from hemorrhage, and 58 (38%) for other causes. The median distance between these 37 DSAs with low pediatric transplant volumes and the nearest city in a high-volume DSA with a pediatric transplant center was 165 miles (IQR 112-229).

Table 4 displays the acceptance rates categorized by donor age, recipient age, and clinical priority (e.g., status 1A or 1B, MELD/PELD scores). Acceptance rates varied greatly from <1% for adult men with MELD scores <15 who were offered livers from donors aged <12 years to 41% for status 1A candidates aged 6-11 who were offered livers from donors aged 12-17. Degree of illness (status 1A or 1B, MELD/PELD ≥35) and age matching (e.g., recipients aged 12-17 accepting livers from donors aged 12-17) correlated with higher acceptance rates. Adult women consistently accepted pediatric donor liver offers at higher rates compared to adult men (6.8% versus 4.2% overall), except in higher-acuity recipients receiving donor liver offers from children aged 12-17 years, where rates were clinically similar (23% versus 21%).

Notably, pediatric candidates listed in low–pediatric volume DSAs accepted pediatric donor offers at similar rates compared to pediatric candidates listed in high–pediatric volume DSAs (10% versus 10%). These rates did not differ significantly when pediatric candidates were segmented into various age groups: 9% versus 9% for age <6 years, 8% versus 8% for ages 6-11 years, and 17% versus 15% for ages 12-17 years, respectively, for candidates listed in low–pediatric volume DSAs versus those listed in high–pediatric volume DSAs. Adult candidates listed in low–pediatric volume DSAs, however, accepted pediatric donor offers at double the rate of adult candidates listed in high–pediatric volume DSAs (8% versus 4%).

POSTTRANSPLANT OUTCOMES

Median follow-up posttransplant was 825 days (IQR 371-1,330) across the three groups. Compared to adult recipients, pediatric recipients aged <12 years (hazard ratio [HR], 1.11; 95% confidence interval [CI], 0.78-1.55; $P = 0.58$) and aged 12-17 years (HR, 0.95; 95% CI, 0.54-1.67; $P = 0.87$) had similar rates of graft failure in multivariable analyses. Compared to adult recipients, pediatric recipients aged <12 years had a lower risk of posttransplant mortality (HR, 0.62; 95% CI, 0.46-0.81; $P < 0.01$) in multivariable analyses. For pediatric recipients aged 12-17 years, the lower risk of posttransplant mortality was not demonstrated (HR, 0.63, 95% CI, 0.38-1.05, P = 0.07) in multivariable analyses.

When compared to a subgroup of adult recipients with MELD ≥25 at transplantation, pediatric recipients aged <12 years (HR, 1.06; 95% CI, 0.66-1.74; $P = 0.79$) and aged 12-17 years (HR, 0.97; 95% CI, 0.51-1.87; $P = 0.94$) had similar rates of graft failure in multivariable analyses. Compared to the same subgroup of adults with MELD ≥25, pediatric recipients aged <12 years had a significantly lower risk of posttransplant mortality (HR, 0.67; 95% CI, 0.45-0.99; $P = 0.04$) in multivariable analyses. Pediatric recipients aged 12-17 years had similar risks of posttransplant mortality (HR, 0.76; 95% CI, 0.43-1.32; $P = 0.33$) in multivariable analyses.

Discussion

Using national registry data over a 5-year period, encompassing nearly 3,500 liver transplants from pediatric donors, we found that 45% of livers from pediatric donors were transplanted into adult recipients. A total of 390 adults were transplanted with a liver from a pediatric donor before *any* child on the liver waitlist was offered access to this life-saving opportunity. The majority (71%) of these adults were of lower acuity (MELD <35, non–status 1A). In this same time period, 278 children died or were delisted due to illness while awaiting liver transplantation. Moreover, the vast majority (90%) of these children were not listed with an exception. We observed this pattern despite the fact that the US liver distribution system created an allocation policy with the intent to prioritize pediatric candidates for liver offers from pediatric donors.[(4)] Our analysis identifies a geographic, DSA-based explanation for these deviations from the original stated intent of the liver allocation policy, which occur when the allocation of pediatric donor livers favors adults listed locally and regionally above children listed nationally.

The United States is divided into 58 DSAs that are serviced by OPOs, which are assessed and designed every 4 years.[(5)] As pediatric liver transplantation becomes concentrated in high-volume areas, there is growing geographic disparity in access to smaller livers despite being within reasonable distances for transplantation. Sixty-four percent of DSAs have low pediatric transplant volume, where fewer than five pediatric liver transplants take place annually. In addition, we found that pediatric candidates who were listed in DSAs with low pediatric transplant volumes did not differ greatly in terms of liver acceptance rates when they were offered pediatric livers. Despite willingness on the part of pediatric candidates to accept pediatric livers even in low-volume DSAs, we found that 52% of the pediatric donor livers that were offered to and accepted by an adult waitlist candidate originated in these relative deserts of care.

Pediatric livers that were accepted by adults prior to being offered to children were likely to be from older, taller donors. It is possible that these livers were not size-appropriate for the small numbers of children awaiting liver transplantation in the originating DSA of the donor but would have been acceptable for a child on the waitlist in a neighboring region or DSA. Even if many of these pediatric donor liver offers were likely larger than the children who died, access to technical variant transplantation would have given a majority of the 278 children who died or were delisted during the study period an opportunity for transplantation.

The median distance between a low–pediatric volume DSA and the nearest high–pediatric volume DSA was only 169 miles. To place this figure in context, the median donor–recipient distance for a nationally placed adult liver is 528 miles.[(6)] While recent UNOS policy changes ratified in December 2017 will implement a 150–nautical mile radius sharing circle around a donor hospital, 150 nautical miles is approximately 172 standard miles—a figure similar to our calculated median distance between low–pediatric volume and high–pediatric volume DSAs. While the UNOS policy changes will eliminate DSA/OPO matching for pediatric donor livers in favor of region + circle matching, region + circle adult candidates will still be prioritized in favor of potentially sicker national pediatric candidates.[(7)]

Our findings support a widely held concern that children under 12 years of age remain an exquisitely vulnerable and disadvantaged waitlist population, with an 18% higher median allocation PELD score despite a 38% lower risk of posttransplant mortality when compared to all adult recipients of pediatric donor livers. When compared to adults with relatively high

MELD scores (≥25), children under 12 years of age still show significant benefits, with a 33% lower risk of posttransplant mortality. Despite these clear advantages in outcomes, children's access to the steadily decreasing pool of livers from deceased pediatric donors has been limited while the adult demand for these livers is rising.[1]

We believe that broader sharing of pediatric livers to children on the national waitlist has the potential to impact offer acceptance behavior. The changes that we have observed in liver acceptance among medically urgent candidates in adult programs after broader sharing is implemented (e.g., Share 35)[8,9] may surface in the pediatric community. While some medically urgent national pediatric candidates may turn down more offers with broader sharing, we believe a substantial number of underserved pediatric candidates, especially in low-volume DSAs, will benefit. It is, thus, of utmost importance to analyze the impact of changing acceptance practice as well as potential unintended consequences of a wider national sharing practice for the scarce resource of pediatric organs. In an ideal state, every child in this country is given an equal chance at transplantation and survival, regardless of center size or geographic differences.

As with any analysis relying upon UNOS registry data, this analysis is limited by the use of a large database that may contain data input errors. By analyzing UNOS registry data, we restricted our analysis only to pediatric donor livers that were "acceptable" for transplantation. This study also only assessed successful donors and recipients—donors whose livers were ultimately transplanted and recipients who received donor livers. These analyses do not allow for any conclusions surrounding donors whose livers were discarded prior to being offered or surrounding patients who remained on the waitlist without transplantation or patients who were not listed for transplantation. Despite these limitations, the UNOS/OPTN database remains the most used resource in transplantation to evaluate pretransplant and posttransplant outcomes and survival.

In conclusion, our analyses demonstrate that our current liver allocation system allows pediatric donor livers to be distributed to adult candidates prior to being offered to pediatric candidates waiting at centers in neighboring DSAs. We advocate for a change to the UNOS allocation policy to allow pediatric deceased donor livers (age <18 years) to be offered nationally to children with status 1B or a MELD/PELD allocation score >15 before they are offered to non–status 1A adults within region + circle area. While this policy change may have an impact on pediatric liver availability to adults, previous work has demonstrated that this impact may be minimal.[10] We recognize that there will likely be an impact on adults who are listed for multiorgan transplants; however, such a policy change may also likely benefit children with multiorgan needs. In addition, these pediatric donor livers would still be offered to adult candidates if turned down by all pediatric candidates nationally. More importantly, these pediatric livers would be prioritized to children who have a "time-limited opportunity for growth and development and may suffer lifelong consequences if not expeditiously transplanted," a principle that has been articulated by the OPTN/UNOS Pediatric Transplantation and Ethics Committees.[11] We urge the liver transplant community to begin the debate to implement these changes to reduce death among children on the liver transplant waitlist.

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Abbreviations:

CI	confidence interval
DSA	donor service area
HCV	hepatitis C virus; HR, hazard ratio
IQR	interquartile range
MELD	Model for End-Stage Liver Disease
OPO	organ procurement organization
OPTN	Organ Procurement and Transplantation Network
PELD	Pediatric End-Stage Liver Disease
UNOS	United Network for Organ Sharing

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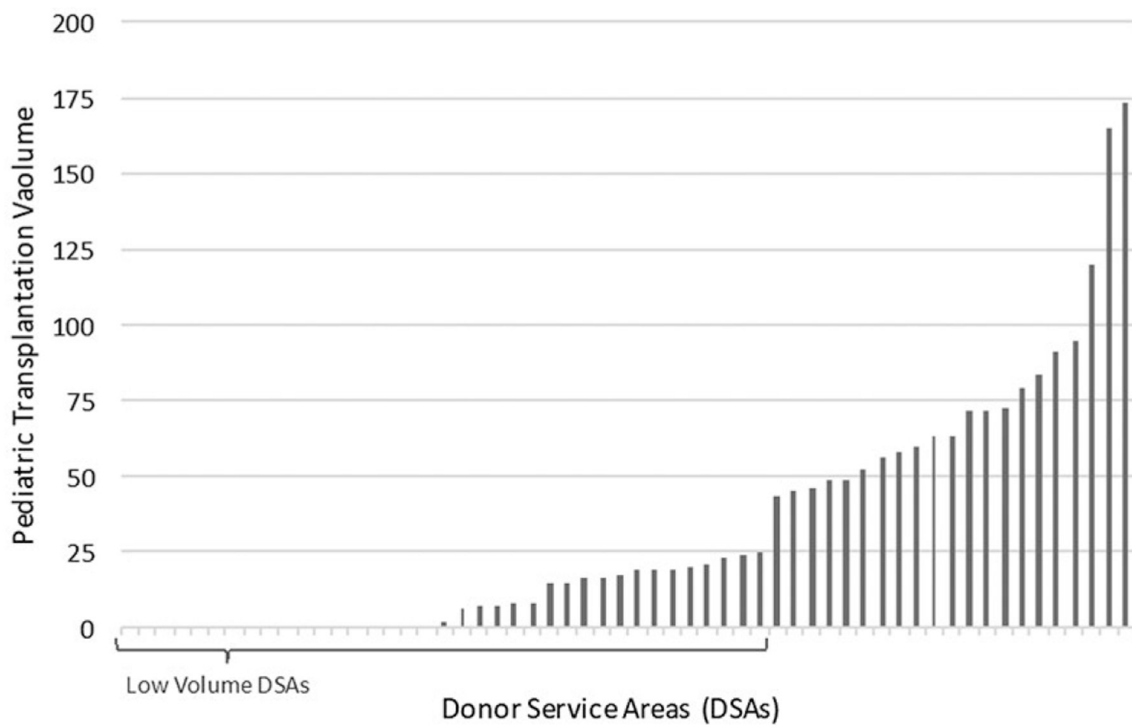

FIG. 1.
Distribution of pediatric transplantation volume by DSAs over the 5-year study period.

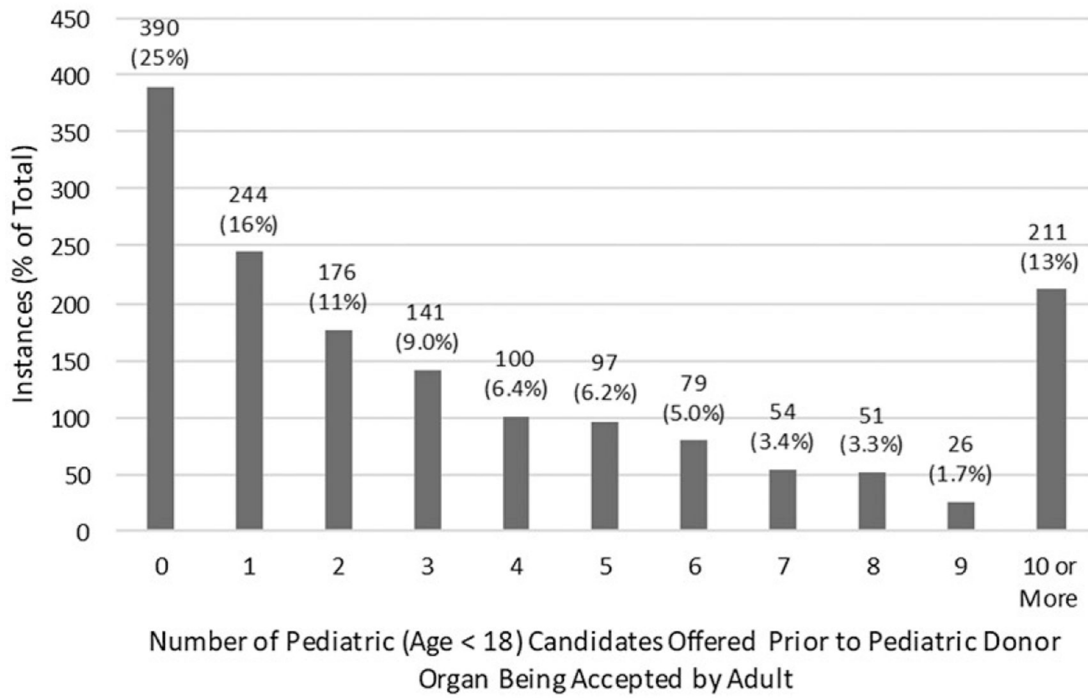

FIG. 2.

Number of pediatric candidates offered prior to a pediatric donor liver was transplanted into an adult recipient.

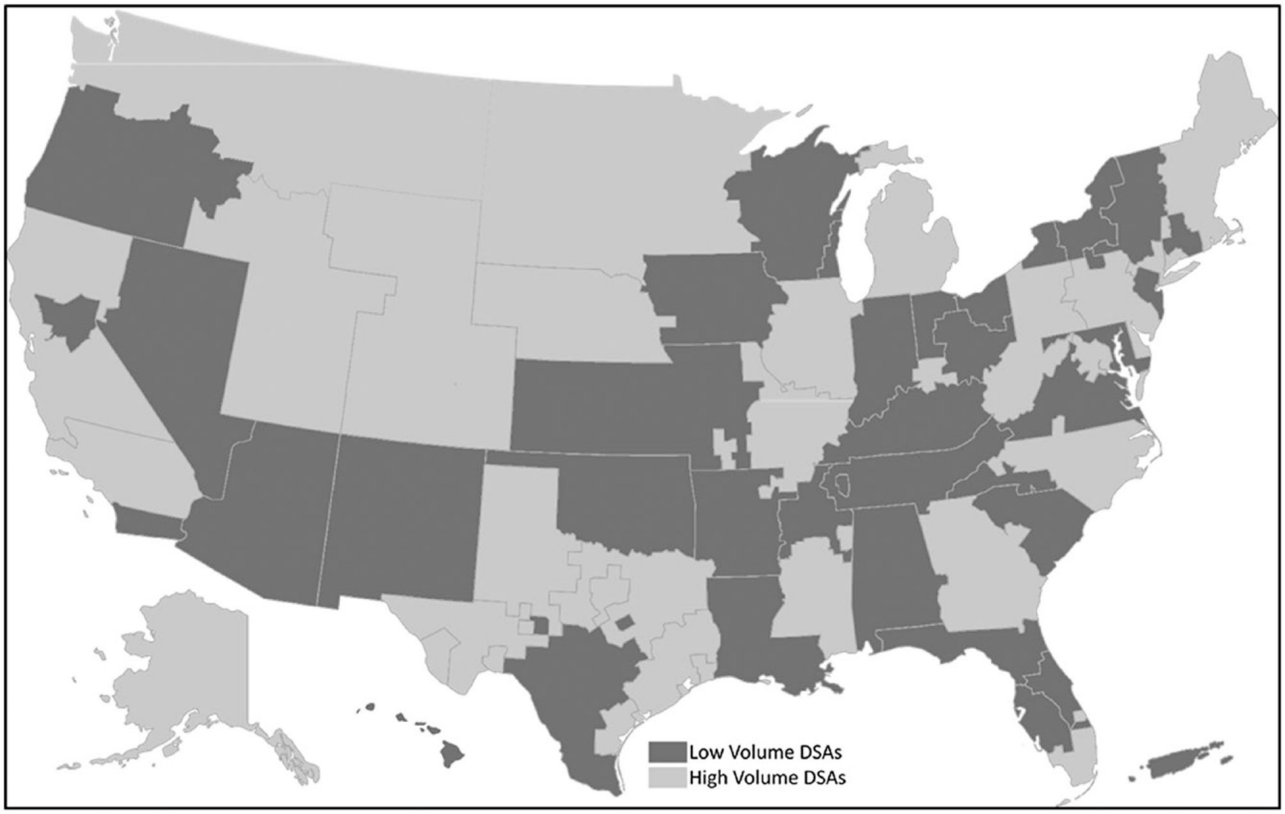

FIG. 3.
Distribution of low-volume DSAs.

TABLE 1.

Baseline Characteristics of Pediatric Deceased Donors Whose Livers Were Ultimately Transplanted

	All Recipients (n = 3,318)	Pediatric <12 years (n = 1,692)	Pediatric 12-17 years (n = 221)	Adult Recipients (n = 1,569)	*P*
Median age in years (IQR)	12 (3-16)	3 (1-9)	15 (11-16)	15 (13-17)	<0.01
African American race (%)	708 (21)	352 (21)	43 (19)	340 (22)	0.69
Median donor height, cm (IQR)	163 (140-174)	137 (117-163)	165 (150-175)	168 (157-178)	<0.01
Median donor weight, kg (IQR)	60.0 (40.0-72.0)	40.0 (26.0-60.0)	60.0 (47.9-70.0)	64.0 (51.3-76.0)	<0.01
Median body surface area (IQR)	1.66 (1.32-1.86)	1.32 (0.97-1.69)	1.69 (1.45-1.84)	1.74 (1.53-1.91)	<0.01
Median donor ALT (IQR)	40.5 (24-79)	38 (24-72)	38 (23-74)	42 (25-83)	<0.01
Donor on inotropes (%)	1,688 (51)	889 (53)	131 (59)	763 (49)	<0.01
Positive HCV antibody (%)	9 (0.3)	0 (0)	0 (0)	9 (0.6)	<0.01
Positive HBV core antibody (%)	15 (0.5)	3 (0.2)	0 (0)	12 (0.8)	0.02
CDC high risk (%)	237 (7)	109 (6)	14 (6)	120 (8)	0.38
Donor ABO (%)					<0.01
O	1,678 (51)	925 (55)	128 (58)	716 (46)	
A	1,162 (35)	566 (33)	69 (31)	581 (37)	
B	389 (12)	174 (10)	17 (8)	216 (14)	
AB	89 (3)	27 (2)	7 (3)	56 (4)	
Mechanism of death (%)					<0.01
Anoxia	1,299 (39)	714 (42)	71 (32)	543 (35)	
Cerebrovascular accident	196 (6)	90 (5)	18 (8)	98 (6)	
Trauma	1,694 (51)	813 (48)	124 (56)	877 (56)	
Other	129 (4)	75 (4)	8 (4)	51 (3)	
Split liver (%)	187 (6)	202 (12)	16 (7)	123 (8)	<0.01
Donation after cardiac death (%)	164 (5)	10 (0.6)	3 (1)	152 (10)	<0.01
Median cold ischemia time, hours (IQR)	6.5 (5.1-8.1)	7.0 (5.6-8.5)	6.4 (5.0-8.5)	6.1 (4.6-76)	<0.01
Median distance between Donor/recipient, miles (IQR)	143 (14-370)	285 (102-562)	106 (8-298)	57 (4-164)	<0.01
Median donor risk index (IQR)	1.36 (1.15-1.73)	1.76 (1.53-2.02)	1.29 (1.15-1.52)	1.25 (1.10-1.55)	<0.01
Multiple organ recipient	406 (12)	189 (11)	26 (12)	191 (12)	0.67
Heart	8 (0.2)	2 (0.1)	2 (0.9)	4 (0.3)	0.07
Intestine	171 (5)	141 (8)	8 (4)	22 (1)	<0.01

	All Recipients (n = 3,318)	Pediatric <12 years (n = 1,692)	Pediatric 12-17 years (n = 221)	Adult Recipients (n = 1,569)	***P***
Kidney	233 (7)	52 (3)	16 (7)	165 (11)	<0.01
Lung	3 (0.1)	0 (0)	1 (0.5)	2 (0.1)	0.07
Pancreas	167 (5)	135 (8)	10 (5)	22 (1)	<0.01

Abbreviations: ALT, alanine aminotransferase; CDC, Centers for Disease Control and prevention; HBV, hepatitis B virus.

TABLE 2.

Baseline Characteristics of Pediatric and Adult Recipients of Pediatric Donor Livers

	Pediatric <12 years (n = 1,692)	**Pediatric 12-17 years (n = 221)**	**Adult Recipients (n = 1,569)**	***P***
Median age at listing, years (IQR)	1 (0-4)	14 (13-16)	55 (48-61)	<0.01
Race/ethnicity, no. (%)				<0.01
White	855 (51)	122 (55)	1,003 (65)	
Black	251 (15)	40 (18)	193 (12)	
Hispanic	407 (24)	42 (19)	231 (15)	
Asian	106 (6.3)	10 (4.5)	101 (6.5)	
Other	58 (3.4)	6 (2.7)	27 (1.7)	
Median height, cm (IQR)	75.5 (63.7-107)	157.5 (148.6-165)	167.6 (160.0-177)	<0.01
Median weight, kg (IQR)	10.4 (6.8-19.4)	51.7 (39.8-64.2)	75.7 (62.6-91)	<0.01
Median body mass index, kg/m^2 (IQR)	16.7 (15.2-18.4)	20.3 (17.7-24.0)	26.5 (23.0-31.1)	<0.01
Waitlist candidate ABO status, no. (%)				<0.01
O	804 (48)	113 (51)	658 (42)	
A	579 (34)	73 (33)	587 (37)	
B	229 (14)	18 (8.1)	238 (15)	
AB	80 (4.7)	17 (7.7)	86 (5.5)	
Etiology of liver disease, no. (%)				<0.01
Chronic liver diseases	151 (8.9)	67 (30)	878 (56)	
Pediatric cholestatic diseases	743 (44)	37 (17)	49 (3.1)	
Malignancy/tumor	177 (10)	23 (10)	418 (27)	
Inborn errors of metabolism	240 (14)	23 (10)	40 (2.5)	
Acute hepatic necrosis	124 (7.3)	19 (8.6)	90 (5.7)	
Graft failure	43 (2.5)	5 (2.2)	18 (1.1)	
Other	214 (13)	47 (21)	76 (4.8)	
Any exception points, no. (%)	611 (36)	102 (46)	576 (37)	<0.01
Median PELD/MELD at transplantation (IQR)	30 (23-40)	25 (19-32)	26 (22-33)	<0.01

TABLE 3.

Initial Allocation, Ultimate Transplant Acceptance, and Acceptance Rates for Pediatric Donor Livers Originating From Low– and High–Pediatric Volume DSAs

	Initial Allocation Status			**Ultimate Acceptance Allocation**			**Acceptance Rate**		
	Low DSA	**High DSA**	**Overall**	**Low DSA**	**High DSA**	**Overall**	**Low DSA**	**High DSA**	**Overall**
Pediatric recipient									
Status 1A	24%	25%	25%	6%	7%	6%	17%	24%	21%
Status 1B	14%	15%	14%	9%	9%	9%	16%	17%	17%
<15	9%	6%	7%	7%	7%	7%	5%	5%	5%
16-25	11%	10%	10%	11%	13%	12%	12%	13%	13%
26-35	15%	15%	15%	13%	14%	14%	10%	11%	10%
>35	10%	11%	11%	6%	7%	7%	5%	6%	6%
Total	82%	82%	82%	52%	58%	55%	9%	10%	10%
Adult recipient									
Status 1A	7%	10%	8%	2%	3%	3%	22%	22%	22%
<15	0%	0%	0%	2%	1%	2%	1%	1%	1%
16-25	5%	2%	4%	14%	15%	14%	3%	4%	4%
26-35	4%	3%	3%	25%	15%	20%	22%	8%	13%
>35	2%	2%	2%	6%	7%	6%	23%	20%	21%
Total	18%	18%	18%	48%	42%	45%	5%	5%	5%
Pediatric recipient									
OPO	2%	8%	5%	3%	9%	6%	21%	20%	20%
Region	56%	55%	56%	32%	35%	33%	11%	10%	10%
National	24%	19%	21%	17%	14%	16%	6%	7%	7%
Total	82%	82%	82%	52%	58%	55%	9%	10%	10%
Adult recipient									
OPO	10%	11%	11%	37%	37%	37%	12%	8%	9%
Region	7%	6%	7%	10%	5%	8%	3%	2%	3%
National	0%	0%	0%	1%	1%	1%	0%	1%	0%
Total	18%	18%	18%	48%	42%	45%	5%	5%	5%

TABLE 4.

Acceptance Rates for Pediatric Donor Livers by Donor Age and Recipient Characteristics

	Allocation Category						
	Status 1A	Status 1B	MELD/PELD <15	MELD/PELD 16-25	MELD/PELD 26-35	MELD/PELD ≥35	Total
All donors							
Recipient age <6 years	20%	16%	5%	11%	9%	6%	9%
Recipient age 6-11 years	22%	20%	5%	11%	14%	4%	8%
Recipient age 12-17 years	19%	27%	8%	22%	14%	6%	15%
Adult female recipient	29%	N/A	1%	7%	13%	23%	7%
Adult male recipient	11%	N/A	0%	4%	8%	21%	4%
Overall	21%	17%	2%	6%	10%	9%	7%
Donors aged <12 years							
Recipient age <6 years	20%	17%	8%	14%	10%	7%	11%
Recipient age 6-11 years	19%	26%	8%	12%	15%	4%	10%
Recipient age 12-17 years	9%	20%	5%	14%	7%	3%	9%
Adult female recipient	21%	N/A	1%	4%	4%	13%	3%
Adult male recipient	2%	N/A	0%	1%	2%	3%	1%
Overall	19%	18%	2%	5%	7%	6%	6%
Donors aged 12-17 years							
Recipient age <6 years	20%	8%	2%	6%	7%	3%	5%
Recipient age 6-11 years	41%	10%	4%	8%	11%	3%	6%
Recipient age 12-17 years	32%	37%	13%	25%	20%	9%	22%
Adult female recipient	31%	N/A	2%	9%	18%	26%	12%
Adult male recipient	17%	N/A	1%	7%	12%	27%	8%
Overall	27%	11%	3%	8%	13%	15%	9%

Abbreviation: N/A, not available.