A Retrospective Evaluation of Organ Donation in the United States: Trends in Donors and Organ Utilization Over 15 Years

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Background

- There prevalence of chronic comorbid conditions is increasing amongst the general population in the United States
  - Obesity (body mass index >30 kg/m^2) affects > 40% of the population
  - Hypertension is present in up to 45% of the population
  - Diabetes affects 10-12% of the population (*data from www.cdc.gov*)
- Chronic medical conditions are associated with end-organ damage which may affect quality of organs prior to donation

Aims of the present study:

1. To determine if changes in the donor population were reflective of changes in the health of the general population
2. To evaluate the effects of changing donor health on donor and organ utilization

Methods

Study Population

- UNOS/OPTN Standard Transplant Analysis and Research (STAR) file
- 132,783 potential organ donors identified between 2005-2019
  - Included all ages and donation types (DBD vs DCD)
  - Evaluated demographic characteristics, medical and social history, and terminal laboratory values

Donor Utilization– determined by transplantation of at least one organ from a single donor

Data Analysis

- Three Eras: Era 1 (2005-2009), Era 2 (2010-2014), Era 3 (2015-2019)
- Donor characteristics compared using T-tests, ANOVA, and Wilcoxon Rank-Sum tests as appropriate
- Multi-Variable Modeling-- Logistic Regression for Donor Utilization
  - Donors cohorted by donor type (DBD vs DCD)
  - Created individual models for each era
  - Created a composite model to evaluate across eras

Donor Characteristics	2005-2009 (n= 39,728)	2010-2014 (n= 41,100)	2015-2019 (n= 51,955)	p-Values
Age, years (median, IQR)	43 (24.5 – 55)	42 (25 – 54)	41 (27 – 62)	0.002
Gender, female (n, %)	16,186 (40.7%)	16,753 (40.7%)	20,663 (39.7%)	0.001
BMI, kg/m^2	25.8 (22.4 – 30.2)	26.5 (22.8 – 31.1)	26.9 (23.1 – 31.8)	<0.001
BMI >30 kg/m^2	9,259 (25.7%)	10,525 (29.6%)	13,666 (32.5%)	<0.001
Ethnicity				<0.001
White	26,758 (67.3%)	27,261 (66.3%)	34,241 (65.8%)	
Black	6,259 (15.8%)	7,086 (17.2%)	8,501 (16.4%)	
Hispanic	5,574 (14.0%)	5,517 (13.4%)	7,440 (14.3%)	
Asian	892 (2.2%)	995 (2.4%)	1,329 (2.6%)	
Other	262 (0.7%)	261 (0.6%)	496 (1.0%)	
Blood Type				0.695
O	19,136 (48.2%)	19,629 (47.7%)	24,937 (48.0%)	
A	14,603 (36.7%)	15,111 (36.8%)	19,201 (36.9%)	
B	4,656 (11.7%)	4,954 (12.1%)	6,102 (11.7%)	
AB	1,348 (3.4%)	1,423 (3.5%)	1,764 (3.4%)	
DCD Donor	3,768 (9.5%)	5,607 (13.6%)	9,930 (19.1%)	<0.001
Cause of Death				<0.001
Anoxia	7,620 (19.2%)	12,177 (29.6%)	21,809 (41.9%)	
Trauma	14,466 (36.4%)	13,375 (32.5%)	14,353 (27.6%)	
CVA/Stroke	16,391 (41.2%)	14,364 (34.9%)	14,243 (27.4%)	
Other	1,268 (3.2%)	1,204 (2.9%)	1,602 (3.1%)	
Hx of Hypertension	13,986 (35.4%)	14,417 (35.3%)	18,133 (35.2%)	<0.001
Hx of Diabetes	4,344 (11.0%)	4,951 (12.1%)	6,287 (12.2%)	<0.001
Prior MI	1,642 (4.1%)	1,389 (3.4%)	2,153 (4.1%)	<0.001
HCV-Positive	1,631 (4.1%)	1,783 (4.3%)	4,053 (7.8%)	<0.001
HBV-Positive	2,169 (5.5%)	1,962 (4.8%)	2,636 (5.1%)	<0.001
Heavy Alcohol Use	6,471 (16.3%)	6,877 (16.7%)	9,674 (18.6%)	<0.001
Cigarette Smoker[a]	11,793 (29.7%)	9,249 (22.5%)	10,738 (20.7%)	<0.001
Any Drug Use	11,726 (29.5%)	16,128 (39.2%)	24,980 (48.0%)	<0.001
Serum Creatinine	1.0 (0.8 – 1.5)	1.0 (0.7 – 1.5)	1.0 (0.7 – 1.7)	<0.001
Serum AST	47 (28 – 88)	47 (28 – 91)	47 (26 – 95)	0.020
Serum ALT	35 (22 – 66)	38 (22 – 75)	40 (22 – 83)	<0.001
Total Bilirubin	0.7 (0.5 – 1.2)	0.7 (0.4 – 1.1)	0.7 (0.4 – 1.1)	<0.001
INR	1.28 (1.10 – 1.43)	1.27 (1.10 – 1.40)	1.23 (1.10 – 1.40)	<0.001
Serum Sodium	146 (141 – 152)	147 (142 – 153)	148 (142 – 153)	<0.001

Abbreviations: ALT- alanine aminotransferase; AST- aspartate aminotransferase; BMI- body mass index; CVA- cerebrovascular disease; DCD- donation after circulatory death; HBV- hepatitis B virus; HCV- hepatitis C virus; Hx- history; INR- international normalized ratio; MI- myocardial infarction
[a]History of smoking >20 pack-years

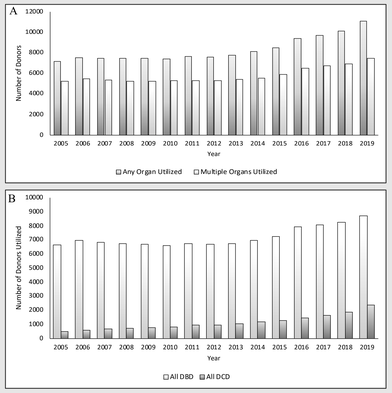

Figure 1. Number of Organ Donors in the United States, 2005-2019.

A) Donors with at least one organ utilized for transplant and those with two or more organs utilized for transplant.

B) Number of donation after brain death (DBD) and donation after circulatory death (DCD) donors annually.

	Era 1 2005-2009	Era 2 2010-2014	Era 3 2015-2019	p-Values
Organ Donor	37,167 (93.5%)	38,688 (94.1%)	48,874 (94.0%)	0.001
Multi-Organ Donor	26,575 (66.9%)	26,943 (65.5%)	33,576 (64.6%)	<0.001
# Organs per Donor	3.02 ± 1.77	3.05 ± 1.78	3.04 ± 1.78	0.027
Kidneys				<0.001
Transplanted	30,487 (76.7%)	32,044 (77.9%)	40,483 (77.8%)	
Recovered- Not Transplanted	5,082 (12.8%)	5,385 (13.1%)	7,354 (14.1%)	
Not Recovered	4,176 (10.5%)	3,691 (9.0%)	4,170 (8.0%)	
Liver				<0.001
Transplanted	30,543 (76.9%)	30,444 (74.0%)	37,830 (72.7%)	
Recovered- Not Transplanted	3,616 (9.1%)	3,338 (8.1%)	3,773 (7.3%)	
Not Recovered	5,586 (14.1%)	7,338 (17.9%)	10,404 (20.0%)	
Heart				<0.001
Transplanted	11,193 (28.2%)	12,453 (30.3%)	16,383 (31.5%)	
Recovered- Not Transplanted	111 (0.3%)	111 (0.3%)	149 (0.3%)	
Not Recovered	28,441 (71.6%)	28,556 (69.5%)	35,475 (68.2%)	
Lungs				<0.001
Transplanted	6,855 (17.3%)	8,617 (21.0%)	11,493 (22.1%)	
Recovered- Not Transplanted	102 (0.3%)	330 (0.8%)	576 (0.2%)	
Not Recovered	32,788 (82.5%)	32,173 (78.2%)	39,938 (76.8%)	
Pancreas				<0.001
Transplanted	6,676 (16.8%)	5,304 (12.9%)	5,013 (9.6%)	
Recovered- Not Transplanted	2,739 (6.9%)	1,831 (4.5%)	1,574 (3.0%)	
Not Recovered	30,330 (76.3%)	33,985 (82.7%)	45,420 (87.3%)	
Intestine				<0.001
Transplanted	901 (2.3%)	633 (1.5%)	580 (1.1%)	
Recovered- Not Transplanted	56 (0.1%)	44 (0.1%)	37 (0.1%)	
Not Recovered	38,788 (97.6%)	40,443 (98.4%)	51,390 (98.8%)	

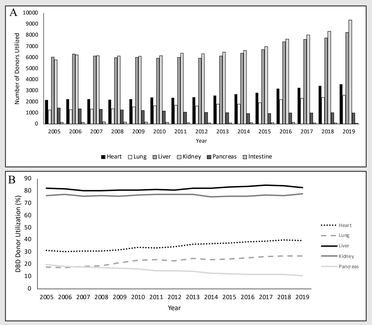

Figure 2. Annual Organ Utilization, 2005-2019

A) Number of donors utilized for transplant for all organs– heart, lung, liver, kidney, pancreas, and intestine.

B) Annual donor utilization rate by organ type. DBD donors only.

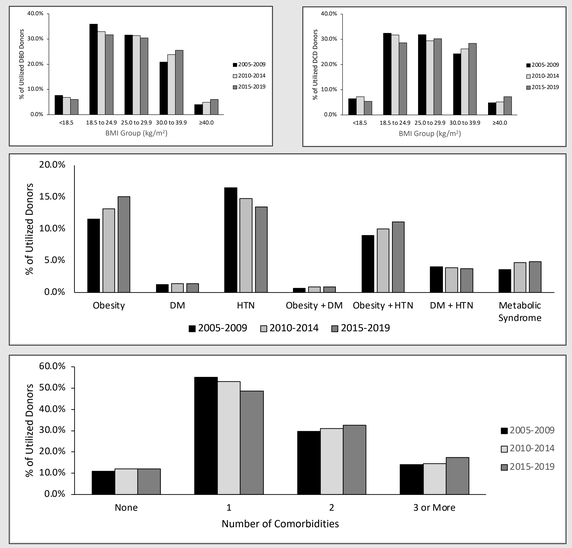

Figure 3. Donor Utilization by Era. Donor utilization rates by donor BMI subgroups for (A) DBD and (B) DCD donors. C) Donor utilization rate by comorbid conditions contributing to metabolic syndrome (obesity + hypertension + diabetes mellitus). D) Donor utilization rate by number of comorbidities– obesity, hypertension, diabetes, hepatitis C virus, hepatitis B virus, prior myocardial infarction, or prior cancer diagnosis.

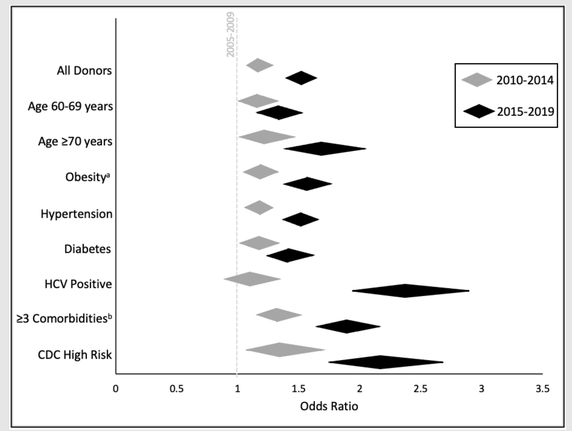

Figure 4. Likelihood of Donor Utilization Across Eras for DBD Donors. A composite model consisting of factors associated with donor utilization in any era was used as base model. Donor utilization was then assessed in specific marginal subgroups (i.e.. older age, obese donors, comorbid conditions, etc.). Likelihood of donor utilization within each subgroup was assessed using Era 1 (2005-2009) as reference group. Odds ratios (OR) and 95% confidence intervals are shown for Era 2 (2010-2014, gray diamonds) and Era 3 (2015-2019, black diamonds). DCD donors were evaluated separately (results not shown).

	2005-2009			2010-2014			2015-2019		
	OR	95% CI	p-Value	OR	95% CI	p-Value	OR	95% CI	p-Value
Age Groups			<0.001			<0.001			<0.001
<10 years	0.476	0.174 – 1.302		0.254	0.082 – 0.783		0.246	0.098 – 0.617	
11 to 17 years	0.720	0.229 – 2.257		0.880	0.188 – 4.113		2.251	0.297 – 17.071	
18 to 29 years	Reference			Reference			Reference		
30 to 39 years	0.310	0.157 – 0.614		0.223	0.105 – 0.472		0.720	0.387 – 1.340	
40 to 49 years	0.206	0.110 – 0.385		0.136	0.067 – 0.276		0.260	0.145 – 0.432	
50 to 59 years	0.140	0.075 – 0.260		0.080	0.040 – 0.161		0.118	0.070 – 0.201	
60 to 69 years	0.052	0.028 – 0.096		0.035	0.017 – 0.071		0.064	0.037 – 0.109	
>70 years	0.024	0.012 – 0.045		0.020	0.010 – 0.042		0.031	0.018 – 0.055	
BMI Groups			<0.001			0.002			<0.001
<18.5 kg/m^2	0.716	0.431 – 1.191		0.908	0.489 – 1.687		0.643	0.343 – 1.201	
18.5 to 24.9 kg/m^2	Reference			Reference			Reference		
25.0 to 29.9 kg/m^2	1.127	0.887 – 1.432		1.101	0.845 – 1.433		0.834	0.644 – 1.080	
30.0 to 39.9 kg/m^2	0.731	0.574 – 0.931		0.772	0.595 – 1.000		0.711	0.551 – 0.918	
>40 kg/m^2	0.407	0.282 – 0.588		0.553	0.379 – 0.808		0.380	0.273 – 0.529	
Race/Ethnicity						0.003			<0.001
White				Reference			Reference		
Black				1.634	1.237 – 2.157		1.571	1.218 – 2.026	
Hispanic				0.914	0.681 – 1.227		1.065	0.812 – 1.396	
Asian				1.115	0.635 – 1.959		0.732	0.466 – 1.149	
Other				0.525	0.190 – 1.448		0.763	0.303 – 1.922	
ABO Group			0.009			0.004			<0.001
O	Reference			Reference			Reference		
A	0.853	0.702 – 1.037		0.856	0.693 – 1.057		1.010	0.827 – 1.233	
B	1.059	0.783 – 1.432		0.697	0.519 – 0.937		0.822	0.665 – 1.169	
AB	0.492	0.318 – 0.760		0.467	0.296 – 0.738		0.467	0.305 – 0.715	
Cause of Death			0.002						<0.001
Anoxia	Reference						Reference		
Trauma	1.794	1.294 – 2.486					1.433	1.049 – 1.955	
CVA/Stroke	1.172	0.903 – 1.520					0.831	0.669 – 1.032	
Other	0.977	0.510 – 1.875					0.609	0.332 – 1.118	
Diabetes	0.484	0.393 – 0.598	<0.001	0.582	0.465 – 0.729	<0.001	0.585	0.480 – 0.714	<0.001
Hypertension	0.720	0.587 – 0.897	0.003	0.654	0.519 – 0.823	<0.001	0.632	0.504 – 0.793	<0.001
HCV-Positive	0.117	0.089 – 0.155	<0.001	0.142	0.106 – 0.190	<0.001	0.198	0.151 – 0.258	<0.001
Creatinine >2mg/dL	0.574	0.460 – 0.715	<0.001	0.618	0.493 – 0.776	<0.001	0.585	0.480 – 0.714	<0.001
Bilirubin >1.2 mg/dL	0.660	0.583 – 0.810	<0.001	0.571	0.459 – 0.711	<0.001	0.571	0.462 – 0.704	<0.001
AST >150mg/dL	0.460	0.351 – 0.602	<0.001	0.625	0.475 – 0.820	<0.001	0.497	0.394 – 0.626	<0.001
INR >1.5							0.487	0.400 – 0.593	<0.001

Abbreviations: AST- aspartate aminotransferase, BMI- body mass index, CI- confidence interval, CVA- cerebrovascular accident, HCV- hepatitis C virus, INR- international normalized ratio, OR- odds ratio

	2005-2009			2010-2014			2015-2019		
	OR	95% CI	p-Value	OR	95% CI	p-Value	OR	95% CI	p-Value
Age Groups			<0.001			<0.001			<0.001
<10 years	0.619	0.129 – 2.976		0.262	0.116 – 0.591		0.162	0.088 – 0.298	
11 to 17 years	2.441	0.305 – 19.565		0.630	0.222 – 1.789		2.551	0.595 – 10.945	
18 to 29 years	Reference			Reference			Reference		
30 to 39 years	0.925	0.336 – 2.546		1.227	0.553 – 2.725		1.415	0.826 – 2.425	
40 to 49 years	0.280	0.134 – 0.587		0.394	0.216 – 0.719		0.706	0.439 – 1.136	
50 to 59 years	0.147	0.072 – 0.299		0.206	0.114 – 0.369		0.262	0.169 – 0.405	
60 to 69 years	0.104	0.046 – 0.238		0.126	0.061 – 0.258		0.153	0.090 – 0.260	
>70 years	0.047	0.009 – 0.242		N/A			N/A		
Cause of Death									<0.001
Anoxia							Reference		
Trauma							1.888	1.308 – 2.725	
CVA/Stroke							0.684	0.519 – 0.902	
Other							0.690	0.440 – 1.083	
Diabetes	0.412	0.259 – 0.653	<0.001	0.465	0.304 – 0.712	<0.001	0.485	0.356 – 0.661	<0.001
Hypertension				0.526	0.372 – 0.744	<0.001	0.578	0.447 – 0.746	<0.001
HCV-Positive	0.096	0.042 – 0.218	<0.001	0.067	0.028 – 0.159	<0.001	0.139	0.093 – 0.208	<0.001
Creatinine >2.0 mg/dL				0.221	0.131 – 0.371	<0.001	0.363	0.252 – 0.523	<0.001

Abbreviations: CI- confidence interval, HCV- hepatitis C virus, OR- odds ratio

Conclusions

- The number of donors is increasing annually to meet the ever present need for organs for transplantation
- The donor population closely reflects the general population in the prevalence of obesity and diabetes, however the prevalence of hypertension is lower in the donor population
- The factors associated with donor utilization have increased over the study period– ALL factors associated with donor utilization in the most recent era (2015-2019) were present in the preceding eras
- There is an increased likelihood of organ utilization from marginal donors in the most recent era (2015-2019)– including use of organs from donors over 60 years old, obese donors, those with hypertension, diabetes, or 3 or more comorbid conditions
- There is a large increase in the utilization of organs from Hepatitis C virus positive donors in 2015-2019, a result of the development of a successful treatments for HCV
- DCD donors account for an increasing proportion of all donors. The factors associated with DCD donor utilization are much more narrow than those for DBD donors
  - There will likely be continued increase in the utilization of DCD donors as machine perfusion modalities and normothermic regional perfusion (NRP) techniques become mainstream