

# Trends in Traumatic Death and Organ Donation during the Early COVID-19 Pandemic

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## Abstract

**Background:** In Texas, the COVID-19 pandemic has coincided with fewer deceased donor transplants. After observing a loss of momentum which might have pushed donation to record highs in early 2020, we sought to clarify the impact of changes in referral cause of death on organ donation during the early COVID-19 pandemic.

**Methods:** A pool of 28,491 referrals to a single organ procurement organization in Texas was used to measure associations between demographics and descriptors of death against donation likelihood. Referrals were compared between January-February 2019 (JF'19) versus 2020 (JF'20) and March-June 2019 (MJ'19) versus 2020 (MJ'20).

**Results:** Comparison between JF'19 and JF'20 revealed a 52.38% (63 to 96) increase in donors relative to a 5.86% decrease referral volume (5150 to 4848). Alternatively, MJ'20 had a 3.44% (9090 to 9403) increase in referral volume and a 8.61% decrease (151 to 138) in donors. In the MJ'20 time period, there was an increase in death referrals due to respiratory causes of death (OR=1.36) and infectious disease (OR=1.38). In contrast to the increase of donor conversion from referrals who died from gunshot (4.52), trauma (OR=4.52), asphyxiation (OR=12.86), and suicide (OR=5.65) from JF'19 to JF'20, there was no increase in donor conversion from MJ'19 to MJ'20.

**Conclusion:** This paper analyzes various changes in organ transplantation trends that occurred.

**Keywords:** Branched-chain amino acids; Bioelectrical impedance analysis; Skeletal muscle mass; Sarcopenia; Zinc

**Abbreviations:** CiOD: circumstance of death; COD: cause of death; CI: confidence interval; FCS: family care specialist; GSW: gunshot wound; ICU: Intensive care unit; JF'19: January through February 2019; JF'20: January through February 2020; MOD: mechanism of death; MJ'19: March through June 2019; MJ'20: March through June 2020; MVA: motor vehicle accident; NT: Nondescript trauma; OPO: Organ procurement organization; OR: odds-ratio; TMC: Texas Medical Center.

## Introduction

The COVID-19 pandemic has caused substantial strain on global healthcare systems. In the United States, the early pandemic coincided with a decrease in organ donation compared to the previous year. This decline is notable in the context of increases in deceased donor volume seen in the previous 9 years [1]. Since the enactment of the National Organ Transplant Act in 1988, deceased donor volume has increased in all but 5 calendar years. In Texas, deceased donor volume has increased for 25 of the past 32 years, including each year since 2013. This momentum continued into 2019, which saw a record-setting 1,036 deceased donors in the state [1].

In order to provide additional context and granularity to reported changes in donation during the early pandemic, we performed a detailed analysis of data collected by the LifeGift organ procurement organization (OPO) in this period. LifeGift, a Houston based OPO, was responsible for 407 deceased donors between July 1, 2018 and June 30, 2019, the fourth most in the nation [2]. LifeGift serves three geographically distinct groups of counties, located in North, West, and Southeast Texas. LifeGift's service area encompasses a unique landscape of small and large-volume transplant centers which serve diverse patient populations in urban, suburban and rural communities. (Figure 1).

During the early pandemic, LifeGift's data demonstrated increases in death referral volume with simultaneous decreases in organ donors. Considering reports of nationwide decreases in organ donation during the COVID-19 pandemic, we sought to provide a more granular look at the pandemic-driven changes in cause of death (COD) and their impact on organ donation [3].

## Materials and Methods

### Donor referral to LifeGift

Data on each death referral was collected by the LifeGift OPO. The clinical triggers requiring OPO notification for potential donation include Glasgow coma scale  $\leq 5$ , loss of one or more brainstem reflexes, any circumstance prompting physician evaluation for brain death, any terminal extubation or withdrawal of life-sustaining therapies, and any death in a hospital. If a referral met criteria for potential donation, a family care specialist (FCS) from LifeGift would then contact the family and discuss authorization for donation. Once authorization was obtained, LifeGift initiated COVID testing simultaneously with medical evaluation of viable donor candidacy. COD determination followed the same approach before and during the pandemic. Table 1 summarized the demographics and circumstances surrounding death of our cohort of referrals.

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Received April 05, 2021; Accepted April 27, 2021; Published May 15, 2021

**Citation:** Kennady EH, Moreno NF, Browning K, Curran C, Dar WA, et al. (2021) Trends in Traumatic Death and Organ Donation during the Early COVID-19 Pandemic. J Clin Exp Transplant 8: 111.

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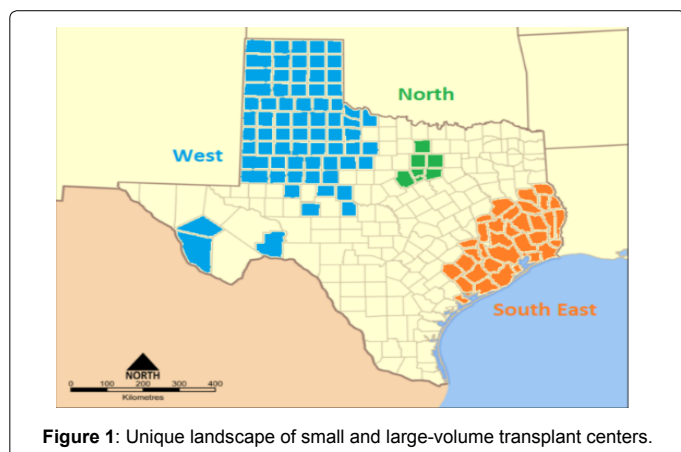


Figure 1: Unique landscape of small and large-volume transplant centers.

### COVID testing protocol

All potential donors required COVID testing, which was performed by LifeGift OPO or the referring hospital. Referrals who tested positive for COVID during hospital treatment were unable to donate until 28 days following a subsequent negative test. However, those candidates are still included in our data as referrals to LifeGift. Samples were obtained by bronchoalveolar lavage, nasopharyngeal swab, or tracheal aspirate depending on capabilities of the referring hospital. Mandatory testing of all potential donors was implemented by LifeGift on March 18, 2020. All samples were sent to ViraCor in Lee’s Summit, Missouri. Prior to the initiation of routine testing, LifeGift tested potential donors on a case-by-case basis dependent on known COVID-19 exposure of the referral due to limited access to testing. Beginning April 11, 2020 samples were sent to Texas Medical Specialty in Dallas, Texas, or Houston Methodist Hospital in Houston, Texas where “2019-nCoV by Real-time RT-PCR” or “COVID-19 Qualitative PCR” were performed, respectively.

### Statistical Analysis

To provide analysis on raw numerical changes in death referrals, a retrospective review of potential donor referrals to LifeGift from January 01, 2019 to June 30, 2019, and January 01, 2020 to June 30, 2020 (n=35,617) was conducted.

Referrals which failed to include sufficient data for statistical analysis were excluded (n=7,128, Table S1). As only one of these referrals proceeded to donation, data entry selection bias by the FCS likely played a role in incomplete data entry.

Available data for each referral includes a COD, mechanism of death (MOD), and circumstance of death (CiOD). Since COD was the best-populated descriptor of death, COD, MOD, and CiOD were consolidated into one variable to allow for more accurate predictions in multivariate analysis (Table 2).

Logistic regression analysis for the entire cohort was performed to measure associations between independent and dependent variables (Table 1). Significant associations in bivariate analysis (p<0.05) were included in multivariate analysis and reported as odds-ratio (OR) with 95% confidence interval (CI). Bivariate comparisons were made against referrals that did not include the tested attribute. Multivariate comparisons were made against a “Reference Referral,” formulated from the most populous independent variables; a white 61-75 year old male from the Southeast region, with death due to cardiac causes and who was not a trauma referral or a registered organ donor. In

Table 1: Yearly number of referrals, donors, and organs transplanted, and number of referrals described with regards to sex, age in years, race, organ donor registry status, cause of death, mechanism of death, and circumstance of death.

	2019		2020	
	N	%	N	(%)
Referrals	14,239	-	14,251	-
Organ Donors	214	1.50%	234	1.64%
Organs Transplanted	784	-	863	-
Sex				
Male	8,127	57.08%	8,257	57.94%
Female	6,112	42.92%	5,994	42.06%
Age				
0-20 years	1,258	8.83%	1,148	8.06%
21-60 years	3,694	25.94%	3,974	27.89%
61-75 years	4,864	34.16%	4,809	33.75%
76+ years	4,423	31.06%	4,320	30.31%
Race				
Caucasian or White	8,341	58.58%	7,804	54.76%
Black or African American	2,908	20.42%	3,091	21.69%
Hispanic or Latino	2,529	17.76%	2,785	19.54%
Asian	430	3.02%	524	3.68%
American Indian or Alaskan Native	24	0.17%	32	0.22%
Native Hawaiian or Pacific Islander	7	0.05%	15	0.11%
Registered Organ Donor				
Yes	1,867	13.11%	1,613	11.32%
No	12,372	86.89%	12,638	88.68%
Cause of Death				
Cardiac Causes	6,804	47.78%	6,420	45.05%
Respiratory Causes	1,935	13.59%	2,389	16.76%
Infectious Disease	1,316	9.24%	1,666	11.69%
Cancer	1,457	10.23%	1,054	7.40%
ICB / ICH / SAH	736	5.17%	806	5.66%
Fetal Demise or SIDS	739	5.19%	721	5.06%
Nondescript Natural Causes	326	2.29%	330	2.32%
Nondescript trauma	315	2.21%	261	1.83%
GSW	216	1.52%	232	1.63%
MVA	187	1.31%	131	0.92%
ESLD or ESRD	129	0.91%	119	0.84%
Overdose	80	0.56%	122	0.86%
Mechanism of Death				
Natural Causes	3,371	23.67%	3,641	25.55%
Cardiovascular	763	5.36%	526	3.69%
ICH / Stroke	439	3.08%	475	3.33%
None of the Above	643	4.52%	192	1.35%
Gun Shot Wound	218	1.53%	233	1.64%
Blunt Injury	239	1.68%	176	1.24%
Drug Intoxication	80	0.56%	122	0.86%
Asphyxiation	47	0.33%	43	0.30%
Drowning	20	0.14%	32	0.22%
Seizure	20	0.14%	16	0.11%
Electrical	4	0.03%	5	0.04%
Stab	5	0.04%	1	0.01%
No MOD Listed	8,391	58.93%	8,788	61.67%
Circumstance of Death				
Natural Causes	4,444	31.21%	4,615	32.38%
None of the Above	825	5.79%	322	2.26%
Accident, Non-MVA	223	1.57%	174	1.22%
MVA	205	1.44%	144	1.01%
Suicide	116	0.81%	117	0.82%
Homicide	76	0.53%	81	0.57%
Child Abuse	8	0.06%	11	0.08%
No CiOD Listed	8,343	58.59%	8,787	61.66%

**Table S1:** Exclusion criteria for referrals with incomplete data, with the number of referrals and donors excluded corresponding to each criterion listed, broken down between January - June 2019 and January - June 2020.

	January-june 2019		January-june 2020	
	Referrals	Donors	Referrals	Donors
Raw data	17,139	217	18478	235
Exclude if sex = "--"	-145	0	-142	0
Exclude if race = "--"	-148	0	-302	0
Exclude if COD and MOD and CiOD= "--" or none of the above	-2540	0	-3716	-1
Exclude if referral facility name = "***Duplicate referral"	0	0	-2	0
Exclude if age category= "--"	-22	0	-7	0
Exclude if organ donor= 0 and organs recovered>=1	-42	0	-59	0
Exclude if organ donor= 1 and organs transplanted=0	-3	-3	0	0
Trimmed data	14239	214	14250	234

**Table 2:** Organ Donation Odds. Univariate and Multivariate analysis to determine risk factors of organ donation for the entire cohort (n=28491) of referrals analyzed in this study. Odds-ratios (OR) and 95% confidence intervals (CI) are calculated from bivariate and multivariate logistic regression. CI that do not include 1 and p < 0.05 indicate statistical significance. Abbreviations: American Indian/Alaskan Native (AI/AN), Native Hawaiian/Pacific Islander (NH/PI), intracranial hemorrhage/intracranial bleed/subarachnoid hemorrhage (ICH/ICH/SAH), fetal demise or sudden infant death syndrome (FD or SIDS), nondescript natural causes, nondescript trauma (NT), gunshot wound (GSW), motor vehicle accident (MVA), end-stage liver disease or end-stage renal disease (ESLD or ESRD)

Independent Variable	Organ Donor Likelihood						
	Referrals (N)	Donors (N)	Donor Conversion (%)	Bivariate OR (95% CI)	P-Value	Multivariate OR (95% CI)	P-Value
Sex							
Male	16,385	273	1.67%	1.16 (0.95-1.40)	0.14		
Female	12,106	175	1.45%	0.87 (0.71-1.05)	0.14		
Age							
0-20	2,406	80	3.33%	2.37 (1.84-3.03)	<0.01	10.81 (6.29 - 18.58)	<0.01
21-60	7,669	328	4.28%	7.6 (6.17-9.40)	<0.01	6.99 (4.64 - 10.53)	<0.01
61-75	9,673	40	0.41%	0.18 (0.13-0.25)	<0.01	Reference Group	
76+	8,743	3	0.03%	0.01 (0.005-0.05)	<0.01	0.08 (0.02 - 0.34)	<0.01
Race							
White	16,145	230	1.42%	0.80 (0.67-0.97)	0.02	Reference Group	
Black	6,000	88	1.47%	0.92 (0.72-1.16)	0.45		
Hispanic	5,314	120	2.26%	1.61 (1.30-1.99)	<0.01	1.07 (0.83-1.33)	0.66
Asian	954	9	0.94%	0.59 (0.30-1.14)	0.09		
American Indian or Alaskan Native	56	1	1.79%	1.14 (0.16-8.2)	0.90		
Native Hawaiian/ Pacific Islander	22	0	0.00%	Omitted	N/A		
Registered							
Yes	3,480	199	5.72%	6.03 (4.99-7.29)	<0.01	3.21 (2.46-4.21)	<0.01
No	25,014	252	1.01%	0.17 (0.14-0.20)	<0.01	Reference Group	
Trauma Referral							
Yes	1,259	148	11.76%	11.96 (9.73-14.69)	<0.01	0.99 (0.55 - 1.77)	0.98
No	27,232	300	1.10%	0.08 (0.07-0.10)	<0.01	Reference Group	
Cause of Death							
Cardiac Causes	13,224	82	0.62%	0.25 (0.20-0.32)	<0.01	Reference Group	
Respiratory Causes	4,324	16	0.37%	0.20 (0.12-0.34)	<0.01	0.63 (0.32-1.23)	0.18
Infectious Disease	2,982	1	0.03%	0.02 (0.003-0.13)	<0.01	Omitted	
Cancer	2,511	0	0.00%	Omitted	N/A		
ICB / ICH / SAH	1,542	144	9.34%	9.03 (7.35-11.09)	<0.01	14.82 (10.50 - 20.93)	<0.01
Fetal Demise or SIDS	1,460	1	0.07%	0.04 (0.006-0.29)	<0.01	0.05 (0.01 - 0.37)	<0.01
Nondescript Natural Causes	656	16	2.44%	1.59 (0.96-2.63)	0.09		
Nondescript trauma	576	55	9.55%	7.39 (5.50-9.93)	<0.01	5.44 (2.98 - 9.93)	<0.01
GSW	448	58	12.95%	10.54 (7.86-14.14)	<0.01	7.29 (3.49 - 15.20)	<0.01
MVA	318	48	15.09%	12.34 (8.94-17.04)	<0.01	7.79 (3.60 - 16.89)	<0.01
ESLD or ESRD	248	0	0.00%	Omitted	N/A		
Overdose	202	27	13.37%	10.21 (6.73-15.49)	<0.01	6.48 (3.64 - 11.53)	<0.01
No COD Listed	0	0	0.00%	Omitted	N/A		
Region							
SE	18,374	251	1.37%	0.69 (0.57-0.83)	<0.01	Reference Group	
North	6,644	144	2.17%	1.54 (1.26-1.88)	<0.01	1.56 (1.19-2.03)	<0.01
West	3,473	56.000	1.61%	1.03 (0.78-1.37)	0.84		
Not listed	3	0.000	0.00%	Omitted	N/A		

\* Values in bold indicate statistic significance p < 0.05

\*\* Mechanism of death and circumstance of death documentation was recorded for 39.70% and 39.88% of the referrals respectively

multivariate logistic regression, independent variables with  $p < 0.05$  were considered significant, and were reported as OR with 95% CI. All OR listed in the text reflect multivariate analysis and are significant unless otherwise specified.

Changes in referral count, donor count, and referral to donor conversion between January to February 2019 (JF'19) vs. January to February 2020 (JF'20) and March to June 2019 (MJ'19) vs. March to June 2020 (MJ'20) were compared using univariate logistic regression. All OR listed in the text referring to Tables 3 and 4 reflected univariate analysis and are statistically significant unless noted otherwise. (Tables 3 & 4).

Statistical analysis and visualization of data was performed using Microsoft Excel<sup>®</sup> and STATA<sup>®</sup> version 15.1 (Stata Corp, College Station, TX, USA).

## Results

### Data characteristics

The cohort before exclusion criteria was applied ( $n=35,617$ ) demonstrated a 5.10% (5,898 to 6,199) increase in referrals between JF'19 and JF'20 (150.5 per month), and a 9.23% (11,241 to 12,279) increase in referrals between MJ'19 and MJ'20 (259.5 per month). Following application of the exclusion criteria, 28,491 referrals were included in further analysis. (Table S1).

### Demographics of all referrals

Demographics by sex, age, race, organ donation registry status, COD, MOD, and CiOD are listed in Table 1.

### Odds of Organ Donation by Death Descriptors and Demographics.

Descriptors and demographics associated with increased odds of organ donation during the study period were determined and OR were calculated (Table 2). Descriptive statistics which invariably led to an outcome (e.g. referral with cancer always leading to non-donor status)

were omitted.

Referrals from ages 0-20 (OR =10.81), and ages 21-60 (OR = 6.99) had significantly greater odds to become organ donors than the reference population, while referrals over 76 years old (OR = 0.08) had significantly lower odds than the reference population to become donors. Referrals who were registered organ donors had increased odds of donation (OR = 3.21), though most donors were not registered. Referrals with death due to intracranial bleed, intracranial hemorrhage, or subarachnoid hemorrhage (OR= 14.82) had the greatest odds of becoming organ donors. Referrals who died in motor vehicle accidents (MVA) (OR = 7.79), were killed by gunshot wounds (GSW) (OR = 7.29), or by nondescript trauma (NT) (OR = 5.44) had increased odds of becoming organ donors. Referrals who died due to overdose also had increased odds to donate (OR = 6.48). Causes of death which decreased odds of organ donation included cardiac causes (bivariate OR = 0.25), respiratory causes (OR = 0.63), and fetal demise or sudden infant death syndrome (OR = 0.05). The findings are summarized in Table 2.

### Changes in death referral and organ donor volume from JF'2020 compared to JF'19 and MJ'20 compared with MJ'19

Comparison between JF'19 and JF'20 revealed a 52.38% (63 to 96) increase in donors relative to a 5.86% decrease referral volume (5150 to 4848). To investigate changes in referral volume, organ donor volume and conversion of referrals into donors, bivariate analysis was performed (Table 3). There were increased odds for referrals who died from GSW to become donors (OR=4.52). Between these periods, referrals with death due to cardiac causes (OR=0.91) and cancer (OR=0.87) had decreased odds to become donors, while those with respiratory (OR=1.13) and nondescript natural causes (OR=1.23) had increased odds to donate (Table 3). There were increased referrals due to overdose (23 to 43) between these periods (OR=1.83) relative to all other causes of death. Analysis of changes in MOD and CiOD was limited by a low percentage of entries filled (Table S2). There were increased odds for trauma referrals to become organ donors (OR=2.60) between JF'19 and JF'20.

**Table 3:** Direct comparisons of descriptive variables to determine changes in referrals, donors and referral conversion into donors for January to February 2019 (JF'19) versus January to February 2020 (JF'20). "Referral Increase" compares a specific cause of death (e.g. cardiac death referrals) to all other causes of death, and determines if there is a significant difference between the two time periods. A positive odds ratio indicates greater odds of a specific cause of death occurring in JF'20 relative to JF'19. "Donor Increase" compares donors with a specific cause of death (e.g. cardiac death donor) against donors with all other causes of death and determines if there are greater odds of a specific cause of death being a donor in the JF'20 time period relative to the JF'19 time period. "Referral to Donor Conversion Increase" compares donors with a specific cause of death (e.g. cardiac death donor) against non-donors with the same cause of death (e.g. cardiac death non-donors) and determines if there are greater odds of referral to donor conversion for a specific death in the JF'20 time period relative to the JF'19 time period.

Descriptive Variable	Jan-Feb'19 vs Jan-Feb '20					
	Referral Increase (OR)	P-value	Donor Increase (OR)	P-value	Referral to Donor Conversion Increase (OR)	P-value
Trauma Referral						
Yes	0.89 (0.73 - 1.08)	0.24	1.42 (0.71 - 2.85)	0.32	2.60 (1.39 - 4.85)	<0.01
Cause of Death						
Cardiac Causes	0.91 (0.84 - 0.98)	0.02	0.50 (0.22 - 1.12)	0.09	0.98 (0.48 - 2.01)	0.95
Respiratory Causes	1.13 (1.01 - 1.27)	0.03	0.65 (0.09 - 4.73)	0.67	0.96 (0.13 - 6.80)	0.96
Infectious Disease	1.13 (0.99 - 1.30)	0.07	N/A	N/A	N/A	N/A
Cancer	0.87 (0.76 - 0.99)	0.04	N/A	N/A	N/A	N/A
ICB / ICH / SAH	1.05 (0.88 - 1.25)	0.58	0.62 (0.31 - 1.24)	0.18	1.12 (0.61 - 2.04)	0.72
Fetal Demise or SIDS	0.96 (0.80 - 1.15)	0.68	N/A	N/A	N/A	N/A
Nondescript Natural Causes	1.32 (1.04 - 1.68)	0.02	0.98 (0.27 - 3.63)	0.98	1.22 (0.34 - 4.43)	0.76
Nondescript trauma	1.00 (0.74 - 1.36)	0.99	1.90 (0.70 - 5.15)	0.19	3.27 (1.21 - 8.83)	0.01
GSW	0.98 (0.72 - 1.33)	0.87	2.50 (0.94 - 6.63)	0.05	4.52 (1.71 - 11.95)	<0.01
MVA	0.77 (0.51 - 1.16)	0.21	0.50 (0.13 - 1.96)	0.32	1.11 (0.28 - 4.43)	0.88
ESLD or ESRD	1.06 (0.70 - 1.62)	0.78	N/A	N/A	N/A	N/A
Overdose	1.83 (1.12 - 3.01)	0.01	2.77 (0.57 - 13.51)	0.17	2.63 (0.51 - 13.50)	0.22

**Table 4:** Direct comparisons of descriptive variables to determine changes in referrals, donors and referral conversion into donors for March to June 2019 (MJ'19) versus March to June 2020 (MJ'20). "Referral Increase" compares a specific cause of death (e.g. cardiac death referrals) to all other causes of death, and determines if there is a significant difference between the two time periods. A positive odds ratio indicates greater odds of a specific cause of death occurring in MJ'20 relative to MJ'19. "Donor Increase" compares donors with a specific cause of death (e.g. cardiac death donor) against donors with all other causes of death and determines if there are greater odds of a specific cause of death being a donor in the MJ'20 time period relative to the MJ'19 time period. "Referral to Donor Conversion Increase" compares donors with a specific cause of death (e.g. cardiac death donor) against non-donors with the same cause of death (e.g. cardiac death non-donors) and determines if there are greater odds of referral to donor conversion for a specific death in the MJ'20 time period relative to the MJ'19 time period.

Mar-Jun'19 vs Mar-Jun'20						
Descriptive Variable	Referral Increase (OR)	P-value	Donor Increase (OR)	P-value	Referral to Donor Conversion Increase (OR)	P-value
Trauma Referral						
Yes	0.85 (0.74 - 0.97)	0.02	1.08 (0.66 - 1.75)	0.76	1.10 (0.72 - 1.68)	0.65
Cause of Death						
Cardiac Causes	0.89 (0.84 - 0.95)	<0.01	1.02 (0.56 - 1.85)	0.96	0.95 (0.55 - 1.64)	0.86
Respiratory Causes	1.36 (1.26 - 1.48)	<0.01	0.53 (0.16 - 1.81)	0.30	0.37 (0.11 - 1.23)	0.09
Infectious Disease	1.38 (1.26 - 1.51)	<0.01	N/A	N/A	N/A	N/A
Cancer	0.62 (0.56 - 0.69)	<0.01	N/A	N/A	N/A	N/A
ICB / ICH / SAH	1.13 (0.99 - 1.28)	0.06	1.38 (0.85 - 2.25)	0.20	0.97 (0.64 - 1.47)	0.89
Fetal Demise or SIDS	0.98 (0.86 - 1.11)	0.73	N/A	N/A	N/A	N/A
Nondescript Natural Causes	0.84 (0.69 - 1.04)	0.10	0.54 (0.10 - 3.00)	0.47	0.57 (0.10 - 3.12)	0.50
Nondescript trauma	0.75 (0.62 - 0.92)	0.01	0.59 (0.28 - 1.25)	0.16	0.71 (0.34 - 1.48)	0.35
GSW*	1.14 (0.90 - 1.44)	0.27	1.27 (0.61 - 2.66)	0.52	0.96 (0.46 - 2.00)	0.91
MVA*	0.66 (0.51 - 0.87)	<0.01	0.82 (0.42 - 1.63)	0.58	1.15 (0.57 - 2.31)	0.70
ESLD or ESRD	0.85 (0.63 - 1.16)	0.31	N/A	N/A	N/A	N/A
Overdose*	1.39 (0.99 - 1.97)	0.06	1.25 (0.47 - 3.33)	0.66	0.76 (0.27 - 2.10)	0.59

**Table S2:** Additional direct comparisons of descriptive variables to determine changes in referrals, donors and referral conversion into donors for January to February 2019 (JF'19) versus January to February 2020 (JF'20).

Jan-Feb'19 vs Jan-Feb '20						
Descriptive Variable	Referral Increase (OR)	P-value	Donor Increase (OR)	P-value	Referral to Donor Conversion Increase (OR)	P-value
Mechanism of Death						
Natural Causes*	1.33 (1.22 - 1.45)	<0.01	0.26 (0.06 - 1.04)	0.04	0.37 (0.10 - 1.43)	0.13
Cardiovascular	0.70 (0.59 - 0.84)	<0.01	0.59 (0.27 - 1.28)	0.18	1.53 (0.75 - 3.13)	0.25
ICH / Stroke	1.13 (0.91 - 1.40)	0.26	0.80 (0.39 - 1.67)	0.56	1.25 (0.64 - 2.45)	0.51
None of the Above	0.16 (0.12 - 0.22)	<0.01	N/A	N/A	N/A	N/A
Gun Shot Wound*	0.96 (0.71 - 1.31)	0.82	2.50 (0.94 - 6.63)	0.05	4.58 (1.73 - 12.10)	<0.01
Blunt Injury	0.84 (0.58 - 1.20)	0.33	0.83 (0.34 - 2.03)	0.68	1.87 (0.74 - 4.68)	0.18
Drug Intoxication*	1.83 (1.12 - 3.01)	0.01	2.77 (0.57 - 13.51)	0.17	2.63 (0.51 - 13.50)	0.22
Asphyxiation	0.90 (0.47 - 1.73)	0.76	3.55 (0.75 - 16.76)	0.07	12.86 (2.23 - 74.08)	<0.01
Drowning	7.45 (0.92 - 60.54)	0.02	N/A	N/A	N/A	N/A
Seizure	0.94 (0.36 - 2.45)	0.91	0.87 (0.19 - 4.02)	0.86	2.00 (0.28 - 14.20)	0.49
Electrical	N/A	N/A	N/A	N/A	N/A	N/A
Stab	1.06 (0.07 - 16.99)	0.97	N/A	N/A	N/A	N/A
No MOD Listed	1.02 (0.94 - 1.10)	0.63	N/A	N/A	N/A	N/A
Circumstance of Death						
Natural Causes*	1.29 (1.18 - 1.40)	<0.01	0.53 (0.28 - 1.01)	0.05	1.04 (0.68 - 1.59)	0.86
None of the Above	0.23 (0.18 - 0.29)	<0.01	N/A	N/A	N/A	N/A
Accident, Non-MVA	0.89 (0.62 - 1.27)	0.52	0.74 (0.31 - 1.78)	0.50	1.53 (0.63 - 3.74)	0.35
MVA*	0.75 (0.50 - 1.11)	0.14	0.64 (0.18 - 2.30)	0.49	1.47 (0.40 - 5.44)	0.56
Suicide	1.39 (0.92 - 2.12)	0.12	3.88 (1.26 - 11.97)	0.01	5.65 (1.74 - 18.32)	<0.01
Homicide	1.38 (0.86 - 2.23)	0.18	2.59 (0.69 - 9.68)	0.13	3.54 (0.89 - 14.08)	0.05
Child Abuse	3.19 (0.33 - 30.66)	0.28	N/A	N/A	N/A	N/A
No CiOD Listed	1.02 (0.95 - 1.11)	0.57	N/A	N/A	N/A	N/A

\* MOD "Natural Causes" was colinear with CiOD "Natural Causes," \* MOD "Gun Shot Wound"

was colinear with COD "GSW," \*MOD "Drug Intoxication" was colinear with COD "Overdose,"

\*CiOD "MVA" was colinear with COD "MVA." and was partially colinear with MOD "Blunt Injury."

The MJ'20 to MJ'19 comparison revealed a 3.44% (9090 to 9403) increase in referral volume and a 8.61% decrease (151 to 138) in donors. MJ'20, which coincided with the rise of the COVID-19 pandemic, had significant increases in death referrals due to respiratory causes of

death (OR=1.36) and infectious disease (OR=1.38) (Table 4). Among the 293 referrals who tested positive for COVID-19 in MJ'20, 74.40% had death attributed to infectious disease and 15.36% due to respiratory causes. There were also decreases in referrals due to cancer (OR=0.63)

and cardiac causes of death (OR=0.89). Interestingly, all four of these causes of death decreased odds of organ donation or produced no donors (Table 2). There were also significant decreases in referrals with death due to NT (OR=0.75) and MVA (OR=0.66). Analysis of changes in MOD and CiOD is described by Table S3.

### Evaluation of Covid Testing and Positivity

The first referral who tested positive for COVID-19 was identified by LifeGift on March 30, 2020. At that time, mandatory testing of potential donors was not yet in place, and referrals tested during hospital care comprised a majority of those tested. Our study-period saw a total of 538 referrals tested for COVID-19, with 293 (55.08%) positive test results and 273 positive results among 470 vented referrals (58.09%). A majority (87.36%) of referrals tested were vented. The COVID positivity rate reflects all referrals who were tested for COVID

including those who were hospitalized due to COVID-19 infection. Patients who tested positive for COVID during hospital treatment and later died were referred to LifeGift as legally mandated and are included in our data, though they were not considered for organ donation without subsequent negative test results at least 2 weeks later. Between March 25th and June 24th the COVID positivity rate among referrals ranged from 0 to 77.78% (Figure 2). The peak number of referrals tested for COVID was 50 in the weeks preceding both April 17 and 24. The peak number of positive results was observed during the week preceding June 12 (n=30). Weekly positivity rate among tested referrals varied with a standard deviation of 12.24%. Our limited data depicts a seemingly antagonistic relationship between COVID positivity rate and donor to referral conversion rate (Figure 2). Monthly positivity rates for vented referrals are described in Figure S1.

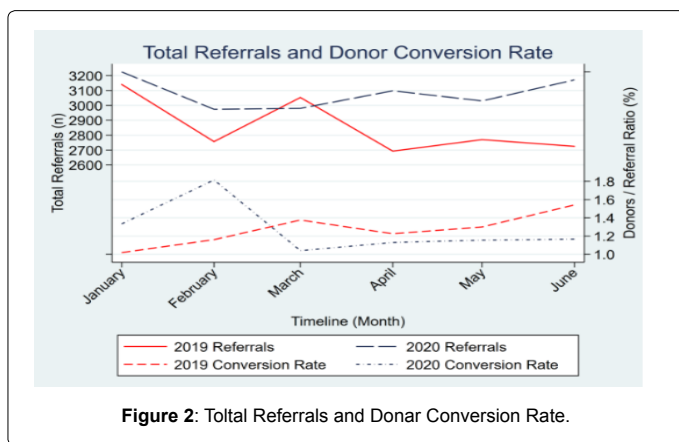


Figure 2: Total Referrals and Donor Conversion Rate.

### Discussion

#### Changes in death referrals and organ donors

Prior to the COVID-19 pandemic, organ donation rates in the LifeGift OPO were at an all-time high. Data from MJ'20 demonstrates a relative slowing in organ donors and a shift in causes of death leading to donation. The absolute number of organ donors in MJ'20 decreased 8.6% relative to 2019, and noticeably, the decline demonstrated a "flattening of the curve" of organ donors relative to increases in donation seen in JF'20.

There were significant decreases in trauma referrals (OR=0.85), referrals with COD NT (OR=0.75) and referrals with COD MVA (OR=0.66) in MJ'20 relative to MJ'19. This may be attributable to the initial societal response to the COVID-19 pandemic, including

Table S3: Additional direct comparisons of descriptive variables to determine changes in referrals, donors and referral conversion into donors for March to June 2019 (MJ'19) versus March to June 2020 (MJ'20)

Mar-Jun'19 vs Mar-Jun'20						
Descriptive Variable	Referral Increase (OR)	P-value	Donor Increase (OR)	P-value	Referral to Donor Conversion Increase (OR)	P-value
<b>Mechanism of Death</b>						
Natural Causes	1.00 (0.93 - 1.07)	0.97	0.54 (0.13 - 2.19)	0.37	0.48 (0.12 - 1.93)	0.29
Cardiovascular	0.67 (0.58 - 0.77)	<0.01	0.91 (0.52 - 1.60)	0.74	1.23 (0.73 - 2.08)	0.45
ICH / Stroke	1.06 (0.90 - 1.25)	0.48	1.14 (0.69 - 1.88)	0.62	0.90 (0.57 - 1.42)	0.64
None of the Above	0.40 (0.33 - 0.49)	<0.01	N/A	N/A	N/A	N/A
Gun Shot Wound*	1.14 (0.90 - 1.44)	0.28	1.36 (0.66 - 2.82)	0.41	1.02 (0.49 - 2.12)	0.95
Blunt Injury*	0.69 (0.55 - 0.87)	<0.01	0.99 (0.56 - 1.74)	0.97	1.35 (0.76 - 2.37)	0.31
Drug Intoxication*	1.39 (0.99 - 1.97)	0.06	1.25 (0.47 - 3.33)	0.66	0.76 (0.27 - 2.10)	0.59
Asphyxiation	0.97 (0.57 - 1.65)	0.90	1.29 (0.42 - 3.94)	0.65	1.23 (0.35 - 4.28)	0.75
Drowning	1.27 (0.70 - 2.31)	0.43	0.27 (0.03 - 2.43)	0.19	0.16 (0.02 - 1.53)	0.07
Seizure	0.70 (0.28 - 1.75)	0.45	N/A	N/A	N/A	N/A
Electrical	1.21 (0.32 - 4.50)	0.78	N/A	N/A	N/A	N/A
Stab	N/A	N/A	N/A	N/A	N/A	N/A
No MOD Listed	1.17 (1.11 - 1.25)	<0.01	N/A	N/A	N/A	N/A
<b>Circumstance of Death</b>						
Natural Causes	0.95 (0.89 - 1.01)	0.10	0.95 (0.59 - 1.50)	0.81	0.89 (0.65 - 1.23)	0.47
None of the Above	0.54 (0.46 - 0.64)	<0.01	N/A	N/A	N/A	N/A
Accident, Non-MVA*	0.73 (0.57 - 0.92)	0.01	1.11 (0.59 - 2.09)	0.74	1.40 (0.74 - 2.65)	0.30
MVA*	0.67 (0.52 - 0.87)	<0.01	0.83 (0.43 - 1.62)	0.59	1.14 (0.58 - 2.25)	0.70
Suicide	0.83 (0.59 - 1.15)	0.26	1.03 (0.49 - 2.17)	0.94	1.12 (0.51 - 2.49)	0.78
Homicide	0.88 (0.58 - 1.34)	0.56	1.33 (0.40 - 4.45)	0.65	1.37 (0.38 - 4.86)	0.63
Child Abuse	1.10 (0.40 - 3.05)	0.85	1.66 (0.27 - 10.06)	0.58	1.50 (0.17 - 13.23)	0.71
No CiOD Listed	1.20 (1.13 - 1.27)	<0.01	N/A	N/A	N/A	N/A

\* MOD "Gun Shot Wound" was colinear with COD "GSW," \*MOD "Drug Intoxication" was colinear with COD "Overdose," \*CiOD "MVA" was colinear with COD "MVA" and had a high degree of colinearity with MOD "Blunt Injury."

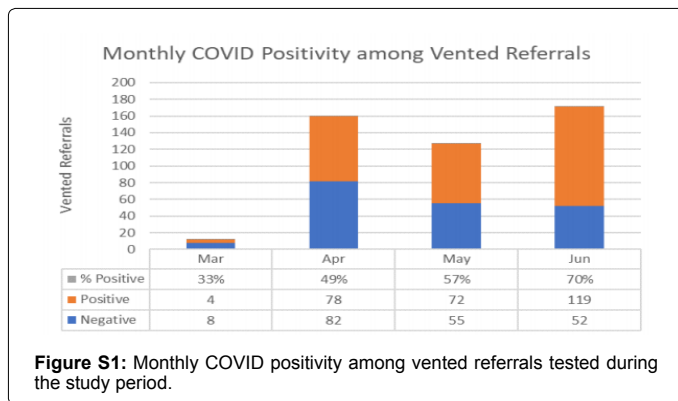


Figure S1: Monthly COVID positivity among vented referrals tested during the study period.

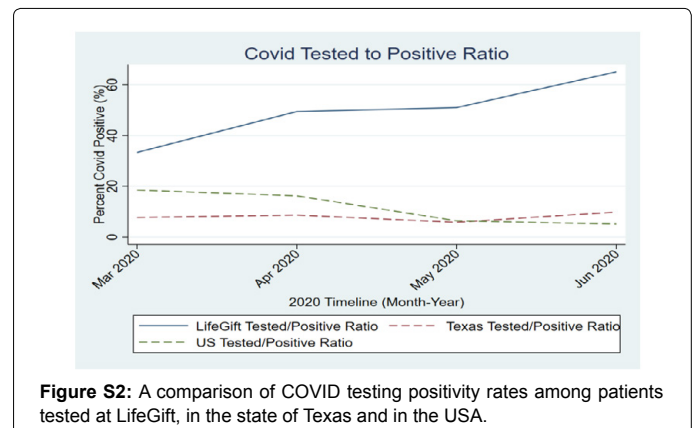


Figure S2: A comparison of COVID testing positivity rates among patients tested at LifeGift, in the state of Texas and in the USA.

reluctance to travel and to seek medical care for non-COVID related medical issues [4].

There was an increase in referrals with COD attributed to respiratory (OR=1.36) and infectious disease (OR=1.38) in MJ'20 compared to MJ'19. The increase in these referrals is hypothesized to be due to the COVID-19 pandemic as COVID-19 deaths were classified under these COD. Respiratory COD showed a non-significant decrease in the number of donors and a non-significant decrease in the conversion of referrals to donors in MJ'20 compared to MJ'19. Alternatively, due to the fact that no referral with an infectious disease COD became a donor in MJ'19 or MJ'20, there was no measurable change in donors or referral conversion.

Hospitals within the OPO have individualized COVID-19 testing protocols, but standardized testing of donors was implemented by LifeGift in accordance with standards set by the American Society of Transplantation. The overall positivity rate of 55.08% among referrals tested for COVID from March 18th to June 30th is noteworthy when compared to positivity rates in the community. In the Texas Medical Center (TMC), data from April 20, 2020 to August 2, 2020 demonstrates COVID positivity rates that fluctuated between 2.8% and 22.2% [5]. Finally, it is important to note that COVID positivity among our cohort reflects patients who died in Texas hospitals, and is not analogous to any healthy subset of the general population, where people may elect to be tested for personal reasons.

While 293 donor referrals were COVID-19 positive in our cohort, it is likely that many of these referrals would not have been medically suitable for organ donation. Among these referrals, 41.98% were in the age category 61-75 years old, and 19.8% were over 76 years old - two factors which strongly decreased odds of organ donation in our whole cohort multivariate analysis (Table 2). It has also been shown that these age groups are at increased risk of mortality due to COVID-19 infection [6]. Therefore, the high COVID positivity rate of LifeGift referrals compared to the general population (Figure S2) in the early COVID-19 pandemic could potentially be skewed due to referral demographics [7]. Additionally, the high week-to-week variation in positivity rates may reflect the necessary bias of hospitals to test patients that are most likely to be infected based on available resources.

The changes observed when comparing JF'19 to JF'20 demonstrated statistically significant increases in rate of converting referrals to donors due to NT (OR=3.27), GSW (OR=4.52), asphyxiation (OR=12.86), and suicide (OR=5.65). These factors were responsible in-part for the increases in donors observed in JF'20 relative to JF'19, however, during the early COVID pandemic, MJ'20, there were no statistically significant increases in referral conversion

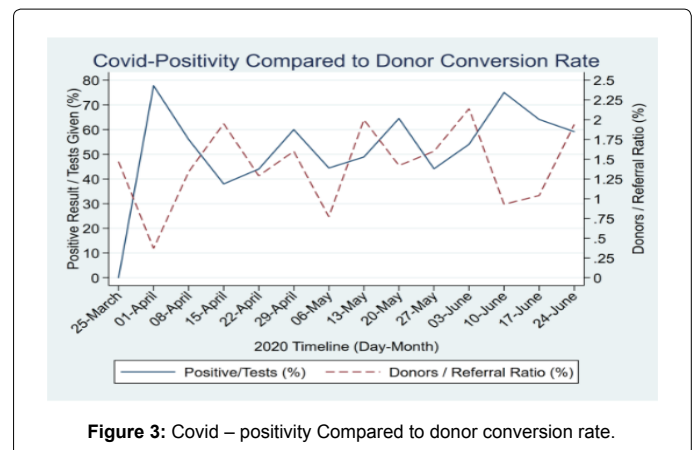


Figure 3: Covid - positivity Compared to donor conversion rate.

to donor compared to the previous year, MJ'19. The increase in conversion efficiency seen in early 2020 was abrogated upon arrival of the COVID-19 pandemic. This could potentially be due to an increased resource utilization in personal protective equipment, ventilators, intensive care unit (ICU) beds, and hospital staffing related to caring for COVID-19 patients in the early pandemic. As of July 20, 2020, COVID patients accounted for 686 (50.9%) of the 1,347 occupied ICU beds in the TMC [8]. ICU beds are an essential resource for post-transplant care, and centers lacking dedicated transplant ICUs may be forced to limit their use of already decreasingly-available organs. Ventilators are also a critical resource for organ recovery and allocation as highlighted by early-pandemic experience of one OPO in New York, which experienced drastic reductions in ventilated referrals due to shifting of the critical resource towards COVID-19 patients [9]. Additionally, access to ancillary testing (e.g. bronchoscopy/biopsies/imaging) was limited during the early COVID-19 pandemic in the setting of limited staffing and available PPE (Figure 3).

Shifting of resources to treat covid patients may have also resulted in underutilization of available organs. During April 2020, LifeGift experienced a 65% kidney utilization rate (39 kidneys transplanted of 60 kidneys recovered) compared to the 78% utilization from January through November 2020. These changes mirror those experienced by one New York OPO, where kidney utilization declined below 40% in April [9]. Transplant programs were more conservative in their kidney acceptance practices overall during this time, especially in the areas hit hardest by the early COVID-19 pandemic.

## Conclusion

After a monumental start of the 2020 year for LifeGift OPO in terms of organ donation, the upward trends were curbed. We analyzed differences in referral volume and odds to donate an organ based on causes of death that shifted between time periods to elucidate meaning from this abrupt change in trend. The volume of death referral and organ donors procured by LifeGift during and prior to the COVID-19 pandemic demonstrate statistically significant changes in causes of death leading to organ transplant referrals, relative number of donors in a category and increased ratio of referrals converted to donors. This data provided demonstrates the impact that each of these factors likely had on organ availability for transplantation. Furthermore, we described the changes in COVID-19 testing and positivity among death referrals in comparison to death referral to organ donor conversion rate.

## Acknowledgements

We are grateful to the staff of LifeGift OPO who invested time and energy to provide data for our study. We would like to thank M. Brent Price and E. Sullivan for their assistance in navigating components of software used in this project.

Finally, we thank all healthcare staff who are actively caring for patients during this challenging time, and to our peers who anonymously reviewed this manuscript.

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