





The effect of recipient BMI on waitlist and post-transplant outcomes after the 2018 heart transplant allocation policy change

Jay N. Patel MD¹  | David G. Rabkin MD²  | Brett W. Sperry MD³  |
Anju Bhardwaj MD⁴  | Joshua S. Chung MD² | Dmitry Abramov MD⁵ 

¹Division of Cardiology, Loma Linda Veterans Administration Healthcare System, Loma Linda, California, USA

²Department of Cardiothoracic Surgery, Loma Linda University Medical Center, Loma Linda, California, USA

³Saint Luke's Mid America Heart Institute, Kansas City, Missouri, USA

⁴Department of Advanced Cardiopulmonary, Therapies and Transplantation, The University of Texas–Houston, Houston, Texas, USA

⁵Department of Medicine, Division of Cardiology, Loma Linda University Medical Center, Loma Linda, California, USA

Correspondence

Dmitry Abramov, MD, Department of Medicine, Division of Cardiology, Loma Linda University Medical Center, Loma Linda, CA, USA.

Email: dabramov@llu.edu

Abstract

Objective: The effects of recipient body mass index (BMI) on waitlist strategies, waitlist outcomes, and post-transplant outcomes among adult patients listed for heart transplantation under the updated 2018 allocation system have not been well characterized.

Methods: The United Network of Organ Sharing data set between October 2015 and March 2021 was analyzed, and patients were grouped based on recipient BMI and whether listing occurred in the old (pre-October 2018) or new allocation system.

Results: Listing strategies differed by BMI group, but trends of increased use of temporary mechanical support and decreased use of durable support remained among all BMI groups, except those with BMI > 35 kg/m². Waitlist outcomes improved among all BMI cohorts in the new allocation system, including among patients with BMI 30–34.9 and >35 kg/m², although patients with higher BMIs continued to have longer waitlist times. Post-transplant outcomes in the new allocation system are worse for patients with BMI > 30 kg/m² (hazard ratio: 1.47; confidence interval: 1.19–1.82; *p* < .001).

Conclusions: The 2018 change to the heart transplant allocation system was associated with similar changes in the use of mechanical support for listing strategy across BMI ranges, except in the most obese, and improved waitlist outcomes across all BMI ranges. Post-transplant outcomes in the new allocation system are worse for patients with BMI > 30 kg/m² compared to patients with BMI < 30 kg/m². These findings have important clinical implications for our understanding of the ongoing influence of BMI on waitlist courses and post-transplant outcomes among patients listed for heart transplantation

KEYWORDS

allocation system, body mass index, heart transplant, mechanical support, post-transplant outcomes, waitlist outcomes

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1 | INTRODUCTION

Body size is an important factor among advanced heart failure patients being evaluated and listed for heart transplantation. Body mass index (BMI) has previously been shown to affect transplant listing strategy,¹ and was associated with increased waitlist mortality,^{1,2} longer wait times before transplantation,² and decreased post-transplant survival.²⁻⁴ In 2018, the United Network of Organ Sharing (UNOS) provided significant changes to the heart transplant allocation system, which resulted in changes in listing strategies (increase in temporary mechanical support and decrease in durable ventricular assist devices), decrease in waitlist times, and variable effects on post-transplant survival.⁵⁻¹¹ BMI may have significant effects on decisions regarding listing strategy and the use of mechanical support, which may affect waitlist times and outcomes. As the impact of BMI on these outcomes under the new allocation system have not been well characterized, we sought to evaluate the role of BMI on listing strategy, waitlist outcomes, and post-transplant outcomes in the current era.

2 | METHODS

The UNOS data set for all patients >18 years of age between October 2015 and March 2021 was analyzed and grouped based on listing in the old (pre-October 2018) or new (post-October 2018) allocation system. Patient demographics, comorbidities, clinical characteristics, and listing status were obtained at the time of listing and donor characteristics were obtained at the time of transplant. Listed patients were followed until one of three competing waitlist outcomes: transplantation, waitlist death, or waitlist removal. Patients who remained on the waitlist at the end of the study period were censored. To avoid bias from changing patterns occurring in anticipation of the allocation change as well as to ensure equal follow-up, patients listed in the year before the allocation change were excluded. To avoid bias among post-transplant outcomes, patients with less than 1 year of follow-up were excluded. Patient characteristics, comorbidities, listing strategies, and outcomes were compared before and after the UNOS allocation change based on BMI at listing. A two-sample *t* test was used to compare continuous variables and χ^2 test for categorical variables. Fine-Gray proportional sub-hazard models were used to estimate the effect of allocation change on competing waitlist outcomes—transplantation, death, or removal from waitlist—among each BMI category, which were the primary outcomes. Unadjusted and adjusted subhazard ratios (SHR) were reported for each competing outcome; multivariable regression models were adjusted for clinical characteristics including age, gender, BMI, education, region, listing strategies, other available comorbidities, and hemodynamics. Cox proportional hazards model was used to evaluate post-transplant outcomes of survival and retransplantation, which was the secondary outcome.

3 | RESULTS

Of the total cohort, 7035 patients meeting inclusion criteria were listed for transplant under the old allocation system and 6965 were listed in the new allocation system. Table 1 demonstrates key patient demographics, comorbidities, and listing strategies among each BMI category before and after the new allocation system. Under the old allocation system, 26.6% and 7.7% were listed with BMI of 30–34.9 and >35 kg/m², respectively, while under the new allocation system, 27.0% and 9.1% had those BMI ranges. There were no clinically relevant differences in baseline patient characteristics before and after the UNOS allocation system change. With respect to transplant listing strategies, the new allocation system resulted in more patients being listed with intra-aortic balloon pump (IABP) and extracorporeal membrane oxygenation, and less patients being listed with inotropic support and durable left ventricular assist device (LVAD). These changes were generally consistent among each BMI category, although patients listed with >35 kg/m² were equally likely to be listed with a durable LVAD under the old and new allocation systems. Under the new allocation system, compared to patients with BMI < 30 kg/m², those with a BMI of >30 kg/m² were less likely to be listed with inotropes (24.6% vs. 34.8%, *p* < .001) or with IABP (10.1% vs. 15.0%, *p* ≤ .001) and more likely to be listed with a durable LVAD (35.9% vs. 24.1%, *p* < .001).

Table 1 also demonstrates the effects of the allocation change on waitlist outcomes by BMI group. The new allocation system was associated with a reduction in waitlist mortality and waitlist removal, and improved transplantation rates among all BMI groups. However, under the new allocation system, patients with BMI > 30 kg/m² continued to have higher median days to transplantation (38 vs. 21 days, *p* < .001), and lower unadjusted (hazard ratio [HR]: 0.75; confidence interval [CI]: 0.70–0.80; *p* < .001) and adjusted (HR: 0.83; CI: 0.77–0.89; *p* < .001) SHRs for transplantation compared to patients with BMI < 30 kg/m². Among patients in the new allocation system with BMI > 30 kg/m², those with BMI > 35 kg/m² had similar median days to transplantation, 38 (11–175) vs. 38 (10–160), *p* = .754, and similar days on the waitlist, 148 (24–365) vs. 120 (19–365), *p* = .108 compared to patients with BMI between 30 and 35 kg/m². Figure 1 highlights the differences in the median days to transplantation based on BMI between the old and new allocation systems.

Table 2 demonstrates donor characteristics among the whole cohort as well as based on recipient BMI. Male donors were more common among recipients with higher BMI. There was an increase in ischemic time and travel distance in the new allocation system, although the increases were similar among BMI cohorts. There were no differences in donor BMI among any cohort between the allocation systems.

Regarding post-transplant outcomes, when accounting for equal follow-up, there were no differences between outcomes in the old versus new allocation system among the whole cohort as well as among the studied BMI cohorts (Table S11). However, post-transplant outcome of death or retransplantation was similar among

TABLE 1 Patient characteristics among the whole cohort and characterized by BMI in the old and new allocation.

Candidate characteristics at listing registration n (%) or mean (SD)	All			BMI < 25.0			BMI 25.0–29.9			BMI 30.0–34.9			BMI 35.0 and above		
	Old UNOS 7035	New UNOS 6965	p Value	Old UNOS 2137	New UNOS 2022	p Value	Old UNOS 2489	New UNOS 2436	p Value	Old UNOS 1869	New UNOS 1876	p Value	Old UNOS 540	New UNOS 631	p Value
Age at listing	53.2 (12.5)	53.0 (52.7)	.262	52.5 (14.1)	52.3 (14.7)	.551	54.9 (11.8)	54.7 (11.9)	.658	52.9 (11.3)	52.8 (11.6)	.790	49.7 (12.3)	49.3 (11.8)	.570
Male gender	5192 (73.8)	5114 (73.4)	.612	1439 (67.3)	1375 (68.0)	.647	1936 (77.8)	1903 (78.1)	.775	1409 (75.4)	1385 (73.8)	.273	408 (75.6)	451 (71.5)	.115
Diabetes	1977 (28.1)	1958 (28.1)	.973	399 (18.7)	269 (18.3)	.721	687 (27.6)	706 (29.0)	.262	677 (36.2)	634 (33.8)	.119	214 (39.6)	249 (39.5)	.953
Dialysis	108 (1.5)	141 (2.0)	.028	39 (1.8)	40 (2.0)	.719	26 (1.0)	50 (2.1)	.004	35 (1.9)	39 (2.1)	.650	8 (1.5)	12 (1.9)	.58
Prior stroke	427 (6.1)	487 (7.0)	.027	146 (6.8)	159 (7.9)	.204	155 (6.2)	160 (6.6)	.614	97 (5.2)	128 (6.8)	.035	29 (5.4)	40 (6.3)	.483
Prior malignancy	619 (8.8)	610 (8.8)	.938	218 (10.2)	196 (9.7)	.581	216 (8.7)	218 (9.0)	.724	151 (8.1)	152 (8.1)	.979	34 (6.3)	44 (7.0)	.643
History of cigarette use	3189 (45.3)	3013 (43.3)	.015	865 (40.5)	804 (39.8)	.63	1205 (48.4)	1030 (42.4)	<.001	871 (46.6)	885 (47.2)	.726	248 (45.9)	294 (46.6)	.820
Prior cardiac surgery (nontransplant)	2773 (39.4)	2715 (39.0)	.611	791 (37.0)	662 (32.7)	.004	1009 (40.6)	984 (40.5)	.956	754 (40.3)	777 (41.4)	.503	219 (40.6)	292 (46.3)	.049
Implantable cardiac defibrillator	5376 (76.4)	4960 (71.3)	<.001	1534 (71.8)	1318 (65.2)	<.001	1914 (76.9)	1749 (72.0)	<.001	1486 (79.5)	1421 (75.8)	.006	442 (81.9)	472 (74.8)	.004
Creatinine	1.27 (0.69)	1.33 (0.95)	<.001	1.19 (0.63)	1.22 (0.81)	.307	1.27 (0.61)	1.39 (1.13)	<.001	1.35 (0.80)	1.36 (0.82)	.717	1.35 (0.82)	1.37 (0.92)	.651
No support	2473 (35.2)	2546 (36.6)	.084	721 (33.7)	741 (36.7)	.050	909 (36.5)	894 (36.7)	.896	678 (36.3)	696 (37.1)	.601	165 (30.6)	215 (34.1)	.200
Inotropes	2287 (32.5)	2167 (31.1)	.076	877 (41.0)	787 (38.9)	.164	741 (29.8)	764 (31.4)	.225	515 (27.6)	472 (25.2)	.096	154 (28.5)	144 (22.8)	.026
IABP	376 (5.3)	921 (13.2)	<.001	151 (7.1)	352 (17.4)	<.001	117 (4.7)	316 (13.0)	<.001	76 (4.1)	197 (10.5)	<.001	32 (5.9)	56 (8.9)	.056
Durable LVAD	2265 (32.2)	1974 (28.4)	<.001	517 (24.2)	386 (19.1)	<.001	828 (33.3)	689 (28.3)	<.001	695 (37.2)	643 (34.3)	.063	225 (41.7)	256 (40.6)	.704
Temporary LVAD	100 (1.4)	108 (1.6)	.526	35 (1.6)	38 (1.9)	.555	35 (1.4)	37 (1.5)	.736	20 (1.1)	25 (1.3)	.461	10 (1.9)	8 (1.3)	.418
ECMO	107 (1.5)	212 (3.0)	<.001	45 (2.1)	68 (3.4)	.013	28 (1.1)	73 (3.0)	<.001	23 (1.2)	50 (2.7)	.001	11 (2.0)	21 (3.3)	.177
Ventilator support at listing	117 (1.7)	131 (1.9)	.329	42 (2.0)	42 (2.1)	.798	29 (1.2)	41 (1.7)	.125	33 (1.8)	34 (1.8)	.914	13 (2.4)	14 (2.2)	.830
Waitlist outcomes for listed patients—follow-up censored at 1 year															
Median days on waitlist (Wilcoxon's rank-sum test)	151 (40–365)	66 (13–340)	<.001	96 (26–321)	32 (8–187)	<.001	149 (44–365)	65 (12–336)	<.001	207 (63–365)	120 (19–365)	<.001	238 (63–365)	148 (24–365)	<.001

TABLE 1 (Continued)

Candidate characteristics at listing registration n (%) or mean (SD)	BMI < 25.0			BMI 25.0–29.9			BMI 30.0–34.9			BMI 35.0 and above					
	Old UNOS 7035	New UNOS 6965	p Value	Old UNOS 2489	New UNOS 2436	p Value	Old UNOS 1869	New UNOS 1876	p Value	Old UNOS 540	New UNOS 631	p Value			
Old UNOS cohort listed: 10/18/15–10/17/17 vs. new UNOS cohort listed: 10/18/18–10/17/20	102 (30–286)	26 (8–118)	<.001	67 (20–210)	18 (6–70)	<.001	110 (34–293)	27 (8–121)	<.001	138 (42–328)	38 (11–175)	<.001	150 (44–365)	38 (10–160)	<.001
Median days to transplantation	3854 (54.8)	4369 (62.7)		1308 (61.2)	1407 (69.6)		1413 (56.8)	1533 (62.9)		907 (41.9)	1094 (58.3)		226 (41.9)	335 (53.1)	
Transplanted	322 (4.6)	203 (2.9)		95 (4.5)	60 (3.0)		100 (4.0)	61 (2.5)		87 (4.7)	62 (3.3)		40 (7.4)	20 (3.2)	
WL death	858 (12.2)	741 (10.6)		252 (11.8)	215 (10.6)		299 (12.0)	267 (11.0)		238 (12.7)	189 (10.1)		69 (12.8)	70 (11.1)	
Removed from waitlist	2001 (28.4)	1652 (23.7)		482 (22.6)	340 (16.8)		677 (27.2)	575 (23.6)		637 (34.1)	531 (28.3)		205 (38.0)	206 (32.7)	
Remains on waitlist	29.9 (29.0–30.9)	43.8 (42.5–45.1)		39.8 (37.7–42.0)	63.2 (60.0–66.6)		31.0 (29.4–32.6)	44.3 (42.1–46.6)		23.5 (22.0–25.0)	34.6 (32.6–36.7)		19.5 (17.1–22.2)	29.7 (26.7–33.1)	
Transplantation rate (per 10,000 patient-days) (95 CI)	1.46 (1.40–1.53)	2.0 (1.8–2.3)	<.001	1.59 (1.47–1.71)	2.7 (2.1–3.5)	<.001	1.43 (1.33–1.54)	1.8 (1.4–2.3)	<.001	1.48 (1.35–1.61)	2.0 (1.5–2.5)	<.001	1.52 (1.28–1.81)	1.8 (1.1–2.7)	<.001
Transplantation rate ratio (95 CI)	2.5 (2.2–2.8)	2.0 (1.8–2.3)		2.9 (2.4–3.5)	2.7 (2.1–3.5)		2.2 (1.8–2.7)	1.8 (1.4–2.3)		2.2 (1.8–2.8)	2.0 (1.5–2.5)		3.5 (2.5–4.7)	1.8 (1.1–2.7)	
Death rate (per 10,000 patient-days)	0.81 (0.68–0.97)	0.81 (0.68–0.97)	.021	0.93 (0.66–1.30)	0.93 (0.66–1.30)		0.80 (0.58–1.12)	0.80 (0.58–1.12)		0.87 (0.62–1.22)	0.87 (0.62–1.22)		0.51 (0.28–0.90)	0.51 (0.28–0.90)	.013
Death rate ratio (95 CI)	Competing-risks regression SHR—transplantation														
Unadjusted	1.41 (1.35–1.47)	1.41 (1.35–1.47)	<.001	1.45 (1.35–1.56)	1.45 (1.35–1.56)	<.001	1.36 (1.27–1.46)	1.36 (1.27–1.46)	<.001	1.46 (1.33–1.59)	1.46 (1.33–1.59)	<.001	1.51 (1.28–1.79)	1.51 (1.28–1.79)	<.001
Adjusted for demographics, hemodynamics, comorbidities, and listing strategy	1.46 (1.40–1.53)	1.46 (1.40–1.53)	<.001	1.54 (1.42–1.66)	1.54 (1.42–1.66)	<.001	1.43 (1.33–1.55)	1.43 (1.33–1.55)	<.001	1.45 (1.32–1.59)	1.45 (1.32–1.59)	<.001	1.58 (1.33–1.89)	1.58 (1.33–1.89)	<.001

(Continues)

TABLE 1 (Continued)

Candidate characteristics at listing registration n (%) or mean (SD)	BMI < 25.0			BMI 25.0–29.9			BMI 30.0–34.9			BMI 35.0 and above					
	Old UNOS 7035	New UNOS 6965	p Value	Old UNOS 2489	New UNOS 2436	p Value	Old UNOS 1869	New UNOS 1876	p Value	Old UNOS 540	New UNOS 631	p Value			
Old UNOS cohort listed: 10/18/15–10/17/17 vs. new UNOS cohort listed: 10/18/18–10/17/20	All														
Competing-risks regression SHR—death															
Unadjusted	0.63 (0.53–0.75)	<.001	0.66 (0.48–0.92)	.013	0.62 (0.45–0.85)	.003	0.70 (0.51–0.98)	.035	0.42 (0.24–0.71)	.001					
Adjusted for demographics, hemodynamics, comorbidities, and listing strategy	0.59 (0.49–0.70)	<.001	0.61 (0.43–0.86)	.004	0.54 (0.38–0.77)	.001	0.69 (0.49–0.97)	.035	0.36 (0.19–0.65)	.001					
Competing-risks regression SHR—WL removal															
Unadjusted	0.87 (0.79–0.96)	.005	0.90 (0.75–1.08)	.253	0.92 (0.78–1.08)	.308	0.78 (0.64–0.94)	.009	0.87 (0.62–1.21)	.398					
Adjusted for demographics, hemodynamics, comorbidities, and listing strategy	0.85 (0.76–0.94)	.001	0.87 (0.72–1.05)	.148	0.89 (0.75–1.06)	.190	0.78 (0.64–0.95)	.013	0.90 (0.63–1.29)	.562					
Old UNOS cohort listed and transplanted: 10/18/15–10/17/17 vs. new UNOS cohort listed and transplanted: 10/18/18–10/17/20	All														
Recipient characteristics at transplant registration n (%) or mean (SD)	Old UNOS 3519	New UNOS 4138	p Value	Old UNOS 1218	New UNOS 1339	p Value	Old UNOS 1257	New UNOS 1452	p Value	Old UNOS 835	New UNOS 1029	p Value	Old UNOS 209	New UNOS 318	p Value
Age at transplantation	53.9 (12.6)	53.3 (13.0)	.037	53.4 (13.8)	52.6 (14.8)	.152	55.4 (12.0)	54.8 (12.1)	.181	52.9 (11.3)	52.8 (11.8)	.863	50.9 (12.3)	50.3 (11.0)	.55
ABO blood group			.124			.229			.523						.058
A	1494 (42.5)	1703 (41.2)		512 (42.0)	544 (40.6)		541 (43.0)	594 (40.9)		353 (42.3)	450 (43.7)		88 (42.1)	115 (36.2)	
B	549 (15.6)	669 (16.2)		202 (16.6)	226 (16.9)		181 (14.4)	224 (15.4)		120 (14.4)	167 (16.2)		46 (22.0)	52 (16.4)	

TABLE 1 (Continued)

Recipient characteristics at transplant registration n (%) or mean (SD)	All			BMI < 25.0			BMI 25.0–29.9			BMI 30.0–34.9			BMI 35.0 and above		
	Old UNOS 3519	New UNOS 4138	p Value	Old UNOS 1218	New UNOS 1339	p Value	Old UNOS 1257	New UNOS 1452	p Value	Old UNOS 835	New UNOS 1029	p Value	Old UNOS 209	New UNOS 318	p Value
Old UNOS cohort listed and transplanted: 10/18/15–10/17/17 vs. new UNOS cohort listed and transplanted: 10/18/18–10/17/20	241 (6.9)	242 (5.9)		81 (6.7)	68 (5.1)		89 (7.1)	93 (6.4)		58 (7.0)	51 (5.0)		13 (6.2)	30 (9.4)	
AB	1235 (35.1)	1524 (36.8)		423 (34.7)	501 (37.4)		446 (35.5)	541 (37.3)		304 (36.4)	361 (35.1)		62 (29.7)	121 (38.1)	
Hospitalization status			<.001			<.001			<.001			<.001			<.001
In ICU	1367 (28.9)	2619 (55.7)		455 (37.4)	875 (65.4)		405 (32.2)	837 (57.6)		243 (29.1)	570 (55.4)		53 (25.4)	156 (49.1)	
Hospitalized—not in ICU	773 (16.3)	565 (12.0)		214 (17.6)	142 (10.6)		185 (14.7)	152 (10.5)		116 (13.9)	116 (11.3)		47 (22.5)	54 (17.0)	
Not Hospitalized	2599 (54.8)	1518 (32.3)		549 (45.1)	322 (24.1)		667 (53.1)	463 (31.9)		476 (57.0)	343 (33.3)		109 (52.2)	108 (34.0)	
No support	430 (12.2)	655 (15.8)	<.001	153 (12.6)	198 (14.8)	.102	165 (13.1)	228 (15.7)	.058	96 (11.5)	175 (17.0)	.001	16 (7.7)	54 (17.0)	.002
Inotropes	1455 (41.4)	1785 (43.1)	.114	589 (48.4)	693 (51.8)	.086	504 (40.1)	612 (42.2)	0.279	297 (35.6)	374 (36.4)	.728	65 (31.1)	106 (33.3)	.592
IABP	337 (9.6)	1364 (33.0)	<.001	133 (10.9)	513 (38.3)	<.001	111 (8.8)	467 (32.2)	<.001	78 (9.3)	306 (29.7)	<.001	15 (7.2)	74 (24.5)	<.001
Durable LVAD	1473 (41.9)	1180 (28.5)	<.001	400 (32.8)	278 (20.8)	<.001	546 (43.4)	416 (28.7)	<.001	404 (48.4)	355 (34.5)	<.001	123 (58.9)	131 (41.2)	<.001
Temporary LVAD	106 (3.0)	115 (2.8)	.544	32 (2.6)	35 (2.6)	0.983	38 (3.0)	38 (2.6)	.523	27 (3.2)	32 (3.1)	.879	9 (4.3)	10 (3.1)	.484
ECMO	37 (1.05)	247 (6.0)	<.001	15 (1.2)	82 (6.1)	<.001	11 (0.9)	88 (6.1)	<.001	9 (1.1)	54 (5.3)	<.001	2 (1.0)	23 (7.2)	.001
Ventilator support	38 (1.1)	100 (2.4)	<.001	17 (1.4)	34 (2.5)	.039	10 (0.8)	36 (2.5)	<.001	8 (1.0)	21 (2.0)	.060	3 (1.4)	9 (2.8)	.294
Creatinine	1.25 (0.92)	1.21 (0.60)	.024	1.21 (1.28)	1.13 (0.77)	.065	1.25 (0.77)	1.22 (0.44)	.138	1.29 (0.49)	1.28 (0.56)	.588	1.29 (0.43)	1.27 (0.53)	.700
Total bilirubin	0.93 (1.47)	1.05 (2.09)	.004	1.04 (1.94)	1.05 (1.71)	.897	0.85 (0.86)	1.03 (2.25)	.007	0.87 (1.41)	1.10 (2.49)	.0192	0.97 (1.39)	0.98 (1.05)	.941
Cardiac hemodynamics															
PA systolic	39.3 (13.5)	40.5 (13.3)	<.001	39.2 (13.6)	40.4 (13.1)	.025	39.0 (13.6)	40.4 (13.4)	.007	39.8 (13.1)	40.9 (13.5)	.092	39.4 (13.2)	39.7 (13.7)	.804
PA diastolic	18.8 (8.2)	19.9 (8.5)	<.001	18.7 (8.2)	19.5 (8.0)	.006	18.5 (8.1)	19.7 (8.4)	<.001	19.2 (8.2)	20.6 (8.9)	.001	19.1 (8.9)	19.7 (9.1)	.485
Mean PA	26.7 (9.6)	27.7 (9.8)	<.001	26.5 (9.8)	27.5 (9.5)	.009	26.4 (9.5)	27.5 (9.7)	.002	27.3 (9.4)	28.3 (10.2)	.037	26.6 (10.0)	27.4 (10.4)	.411
Mean PCWP	17.4 (8.5)	18.4 (8.4)	<.001	17.6 (8.8)	18.3 (8.2)	.032	17.0 (8.3)	18.2 (8.3)	<.001	17.7 (8.2)	18.8 (8.7)	.007	17.7 (8.7)	18.2 (8.7)	.443
CO	4.51 (1.41)	4.35 (1.45)	<.001	4.04 (1.23)	3.98 (1.34)	.294	4.56 (1.37)	4.38 (1.37)	<.001	4.91 (1.44)	4.62 (1.40)	<.001	5.31 (1.42)	4.98 (1.54)	.014

Note: Bold values are statistical significance at $p < 0.05$. Abbreviations: BMI, body mass index; CI, confidence interval; CO, cardiac output; ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump; ICU, intensive care unit; IQR, interquartile range; LV, left ventricular; LVAD, left ventricular assist device; PA, pulmonary artery; PCWP, pulmonary capillary wedge pressure; SHR, subhazard ratio; UNOS, United Network of Organ Sharing; WL, waitlist.

Median Days to Transplantation by BMI

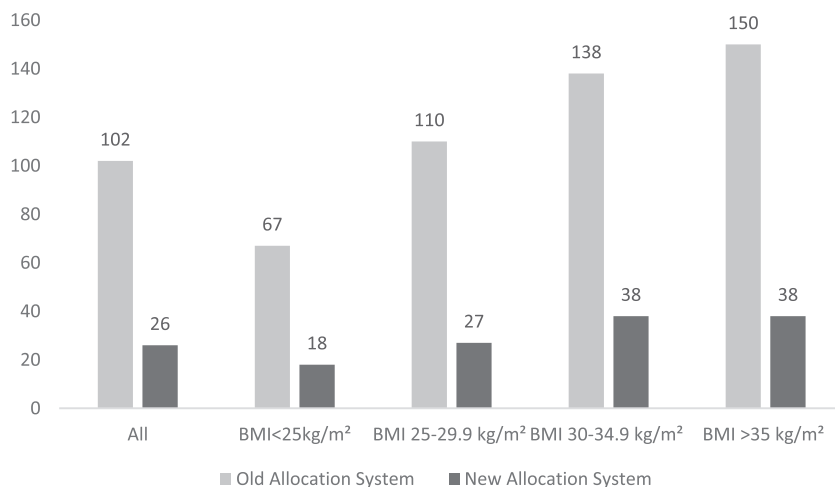


FIGURE 1 Median days to transplantation among the whole cohort and characterized by body mass index in the old and new allocation systems.

patients with BMI > 30 kg/m² compared to BMI < 30 kg/m² in the old UNOS (HR: 1.22; CI: 0.96–1.56; *p* = .101), but significantly higher in the new UNOS system (HR: 1.47; CI: 1.19–1.82; *p* < .001). Among patients in the new system with BMI > 30 kg/m², those with BMI > 35 kg/m² had similar rates of post-transplant adverse events compared to the BMI group of 30–35 kg/m² (HR: 1.15; CI: 0.79–1.57; *p* = .457).

4 | DISCUSSION

The present work demonstrates several important findings. Changes in listing strategies associated with the new allocation system were similar across BMI ranges, although differences between the systems were less prominent among patients with BMI of >35 kg/m². Under the new allocation system, compared to patients with BMI < 30 kg/m², those with a BMI of >30 kg/m² were less likely to be listed with inotropes or with IABP and more likely to be listed with a durable LVAD. Median days on the waitlist decreased significantly in the new allocation system for all BMI ranges, although they remain highest for patients with BMI > 30 kg/m². Finally, post-transplant outcomes in the new allocation system were similar compared to the old allocation system for all BMI ranges, although when categorized with a BMI cutoff of <30 vs. >30 kg/m², those with BMI of >30 kg/m² experienced the worst outcomes under the new allocation system, but not under the old allocation system. These findings have important clinical implications for our understanding of the ongoing influence of BMI on waitlist course and post-transplant outcomes among patients listed for heart transplantation.

These findings support prior studies showing an increase in waitlist times² and increase in post-transplant mortality^{3,4} among patients with obesity, although prior studies demonstrated that the increase in post-transplant mortality among obese patients is modest and not consistent among all studies. Longer waitlist times for patients with BMI > 30 kg/m² may occur due to the requirement for adequate donor–recipient size matching as well as due to

variation in listing strategy where obese patients may be listed at lower status (due to higher use of durable LVAD, higher rate of listing without mechanical/inotropic support, and lower use of IABP). However, the median days to transplantation and transplantation rate for patients with BMI > 30 kg/m² and particularly BMI > 35 kg/m² have improved significantly under the new allocation system and are now better in this population than these parameters were for any BMI under the old allocation system.

The current analysis, when ensuring for equal follow-up, demonstrates similar 1-year outcomes after implementation of the new allocation system change among all patients, and extends these findings based on BMI cohorts. However, under the new allocation system, patients with BMI > 30 kg/m² (and particularly those with BMI > 35 kg/m²) had higher rates of post-transplant death or retransplantation. The differences in increased adverse events in patients with BMI > 30 kg/m² are more pronounced after changes in the allocation system, and the current study did not demonstrate this adverse effect of BMI > 30 kg/m² under the old allocation system. Censoring at 1 year to allow for equal follow-up as well as the inclusion of multivariable analyses in establishing the effects of BMI on outcomes may explain the difference between these findings and prior publications examining the effect of obesity on post-transplant outcomes.

Taken together, the improved waitlist outcomes with a more pronounced increase in post-transplant adverse events under the new allocation system have important implications for the care of obese patients being considered for heart transplantation. Improved waitlist outcomes and decreased waitlist times can provide reassurance that transplant remains a feasible strategy among adequately selected patients with obesity, including those with BMI > 35 kg/m². Patients with BMI > 30 kg/m² experience higher post-transplant adverse events compared to patients with BMI < 30 kg/m². Optimizing BMI and associated risk factors before transplant as well as increased focus on post-transplant care may therefore be important targets to improve the outcomes in advanced heart failure patients with elevated BMI being considered for transplantation.

TABLE 2 Donor and transplant characteristics among the whole cohort and characterized by BMI in the old and new allocation systems.

Old UNOS cohort listed and transplanted: 10/18/15-10/17/17 vs. new UNOS cohort listed and transplanted: 10/18/18-10/17/20	BMI < 25.0			BMI 25.0-29.9			BMI 30.0-34.9			BMI 35.0 and above				
	Old UNOS	New UNOS	p Value	Old UNOS	New UNOS	p Value	Old UNOS	New UNOS	p Value	Old UNOS	New UNOS	p Value		
All	3519	4138		1218	1339		1257	1452		835	1029		209	318
Donor age	32.1 (11.1)	32.2 (10.5)	.544	31.7 (11.5)	31.4 (10.7)	.400	32.2 (11.1)	32.4 (10.7)	.559	32.3 (10.5)	32.4 (10.0)	.817	32.5 (10.7)	34.3 (10.6)
Donor male gender	2341 (66.5)	2980 (72.0)	<.001	695 (57.1)	903 (67.4)	<.001	873 (69.5)	1056 (72.7)	.060	607 (72.7)	779 (75.7)	.139	166 (79.4)	242 (76.1)
Recipient-donor gender mismatch	856 (24.3)	919 (22.2)	.029	362 (29.7)	314 (23.5)	<.001	284 (22.6)	330 (22.7)	.934	172 (20.6)	202 (19.6)	.604	38 (18.2)	73 (23.0)
Donor body mass index	27.6 (6.4)	27.9 (6.2)	.101	26.0 (5.9)	26.1 (5.4)	.424	27.5 (6.2)	27.7 (6.0)	.577	29.5 (6.4)	29.5 (6.7)	.845	30.6 (7.3)	30.7 (6.9)
Diabetes	165 (3.5)	172 (3.6)	.692	38 (3.1)	42 (3.1)	.984	41 (3.3)	47 (3.2)	.968	34 (4.1)	42 (4.1)	.992	9 (4.3)	15 (4.7)
History of cocaine use	1156 (24.4)	1282 (27.2)	.002	270 (22.2)	358 (26.8)	.004	288 (23.0)	397 (27.4)	.026	222 (26.6)	289 (28.1)	.706	61 (29.2)	92 (28.9)
Creatinine	1.52 (1.58)	1.67 (1.78)	<.001	1.37 (1.36)	1.56 (1.67)	.001	1.54 (1.69)	1.70 (1.81)	.018	1.66 (1.65)	1.68 (1.72)	.790	1.72 (1.74)	2.00 (2.22)
Total bilirubin	1.03 (1.20)	1.04 (1.46)	.599	1.04 (1.34)	1.03 (1.40)	.929	1.00 (1.13)	1.10 (1.63)	.064	1.05 (1.14)	1.01 (1.35)	.469	1.06 (1.02)	0.96 (1.22)
LV ejection fraction	61.6 (6.6)	61.5 (6.8)	.407	61.6 (6.7)	61.4 (6.7)	.376	61.7 (6.5)	61.7 (6.9)	.914	61.4 (6.3)	61.5 (6.6)	.732	62.1 (7.1)	61.2 (7.2)
Ischemic time	3.06 (1.05)	3.45 (1.07)	<.001	3.08 (1.03)	3.42 (1.03)	<.001	3.07 (1.09)	3.41 (1.07)	<.001	2.99 (1.04)	3.49 (1.04)	<.001	3.09 (0.97)	3.62 (1.29)
Distance (miles) from Tx center, median (IQR)	72 (12-144)	231 (86-405)	<.001	84 (13-291)	230 (84-405)	<.001	80 (12-250)	224 (79-394)	<.001	50 (8-192)	234 (101-405)	<.001	70 (15-238)	251 (104-439)

Note: Bold values are statistical significance at $p < 0.05$. Abbreviations: BMI, body mass index; IQR, interquartile range; UNOS, United Network of Organ Sharing.

Additional analyses will be needed to explore the contributors to increased adverse post-transplant outcomes among those with higher BMI, particularly as noted in the new allocation system.

There are limitations to this study, including those which are inherent to the use of large data sets for analyses. The UNOS data set is reliant on entry from individual transplant centers and lacks important information that may affect decision making surrounding the care of patients based on their BMI. Patients who were not listed for transplant because of their BMI or offered destination therapy LVAD options as opposed to transplant listing are not evaluated in this study.

5 | CONCLUSION

In summary, the 2018 change to the UNOS allocation system resulted in changes in waitlist management and improved waitlist outcomes that were generally similar based on BMI cohorts, including among patients with BMI of 30–35 kg/m². Patients with BMI > 30 kg/m² experience worse post-transplant outcomes compared to patients with BMI < 30 kg/m² under the new allocation system.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ORCID

Jay N. Patel  <https://orcid.org/0000-0001-9588-1880>

David G. Rabkin  <http://orcid.org/0000-0002-3083-9566>

Brett W. Sperry  <https://orcid.org/0000-0002-8210-6401>

Anju Bhardwaj  <https://orcid.org/0000-0003-2322-2442>

Dmitry Abramov  <https://orcid.org/0000-0003-0571-3109>

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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