



Published in final edited form as:

Circ Heart Fail. 2013 July ; 6(4): 785–791. doi:10.1161/CIRCHEARTFAILURE.111.000358.

Preoperative Serum Albumin Levels Predict 1-Year Postoperative Survival of Patients Undergoing Heart Transplantation

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Abstract

Background—Serum albumin concentration has been recognized as a marker of nutrition, severity of inflammation, and hepatic function in patients with various chronic diseases. The purpose of this study was to investigate the impact of pretransplant serum albumin concentration on post-transplant outcome in heart transplant recipients.

Methods and Results—Preoperative laboratory variables, including albumin concentration and donor-related information, were obtained from 822 consecutive patients undergoing heart transplant at Columbia University Medical Center between 1999 and 2010. The association between pretransplant albumin concentration and post-transplant 1-year survival was analyzed. Available data from the United Network for Organ Sharing (n=13 671) were also analyzed to evaluate the impact of preoperative albumin levels on post-transplant outcome. In our cohort, multivariable analysis revealed that preoperative albumin (mg/dL; hazard ratio, 0.46; $P<0.0001$) and preoperative total bilirubin (mg/dL; hazard ratio, 1.26; $P=0.0002$) were associated with post-transplant 1-year mortality. This implied that for every 1 mg/dL increase in albumin concentration, the post-transplant 1-year mortality rate decreased by 54%. The Kaplan–Meier analysis based on our patients cohort and the United Network for Organ Sharing dataset showed lower survival rate at 1-year post-transplant in patients with albumin levels ≤ 3.5 mg/dL compared with those with >3.5 mg/dL (our patients, 91.3 versus 72.4%; $P<0.0001$; United Network for Organ Sharing, 88.4 versus 84.8%; $P<0.0001$).

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Disclosures

None.

Conclusions—Pretransplant serum albumin concentration is a strong prognostic marker for post-transplant survival in heart transplant recipients.

Keywords

albumin; heart transplantation; prognosis

Serum albumin concentration has been recognized as a marker of nutrition, inflammation, hepatic function, and overall catabolic state.^{1–3} Hypoalbuminemia has been reported to be associated with poor prognosis in patients with chronic disease, such as end-stage renal disease,⁴ malignancy,⁵ and heart failure (HF).^{6,7} In addition, there is a well-documented association between preoperative hypoalbuminemia and increased postoperative mortality in patients undergoing cardiac and non-cardiac surgery.^{8–10} Hypoalbuminemia, indeed, is a part of Acute Physiology and Chronic Health Evaluation IV prognostic system, which predict critically ill medical and surgical patients.¹¹

Heart transplantation (HTx) provides a considerable survival benefit for patients with advanced HF.^{12,13} In response to remarkable improvements in immunosuppression regimens and patient management, post-transplant survival has been significantly improved, with 1 and 5 years survival exceeding 85% and 70%, respectively.¹² Post-transplant outcomes have been reported to be associated with a number of pretransplant recipient comorbidities^{12,14}; however, an impact of pretransplant serum albumin concentration on outcome after HTx has not been fully elucidated. Therefore, we investigated the association between pretransplant serum albumin concentration combined with other pre- and perioperative factors and post-transplant survival in patients undergoing HTx.

Methods

The present study was approved by the institutional review board of Columbia University Medical Center.

Participants and Measurements

Data on a total of 822 consecutive patients who underwent HTx at Columbia University Medical Center between November 1999 and September 2010 were retrospectively reviewed, and 1-year post-transplant survival outcome of patients was analyzed. Pretransplant clinical characteristics of patients and laboratory examinations, including serum albumin concentration within 30 days before the surgery, were obtained from medical records. For patients with multiple laboratory measurements before the transplants, the results obtained at the closest date to the surgery were used for the present study. Laboratory variables of each patient used in the analysis were measured at the same day. Pretransplant clinical characteristics reviewed in the present study included age, sex, status at the United Network for Organ Sharing (UNOS), race, body mass index, primary heart disease, with or without left ventricular assist device (LVAD), and serology of cytomegalovirus at the time of HTx. Donor-related information, including donor age, sex, cytomegalovirus serology, and the number of donor/recipient HLA mismatches, was also obtained.

Analysis of the UNOS Dataset

Standard transplant analysis and research files with follow-up were provided by the UNOS. A total number of 42 803 patients of the UNOS dataset undergoing HTx between October 1987 and February 2010 were obtained of whom only 13 671 (31.9%) had pretransplant albumin levels and were included in the present analysis. Post-transplant 1-year survival of patients with preoperative hypoalbuminemia was compared with those with normal albumin concentration as described above using the same cutoff value derived from our patients' cohort.

Statistical Analysis

Data are presented as mean±SD and frequency (percentage). Normality was evaluated for each variable on the basis of normal distribution plots and histograms and by the Kolmogorov–Smirnov test. Clinical characteristics and laboratory data were compared between groups using Student unpaired 2-tailed *t* test or χ^2 analysis. For continuous variables which were not normally distributed, the Mann–Whitney *U* test was performed to test group differences. The cutoff value of 3.5 mg/dL of pretransplant albumin levels was used, as it is the lower limit of the reference value at our institution. Specifically, albumin levels of ≤ 3.5 mg/dL were defined as hypoalbuminemia and albumin levels >3.5 mg/dL were defined as normal albumin concentration throughout the study. A multivariable Cox proportional hazards model was built using a stepwise selection method with an entry significance level of 0.25 and a stay significance level of 0.15 to assess the independent effect of each variable on 1-year mortality after transplant. Pretransplant variables included into the stepwise selection methods were age, sex, UNOS status (1A=1, other status=0), race (black=1, others=0), cytomegalovirus serology before transplant (positive=1, negative=0), pretransplant albumin, sodium, hematocrit, creatinine, and total bilirubin concentrations. Peritransplant variables included in the analysis were ischemic time, donor age, donor sex, cytomegalovirus serology mismatch (positive donor to negative recipients=1, other combination=0), HLA mismatch (6 or 5 mismatch=1, <5 mismatch=0). The proportionality assumption in the Cox proportional hazards model was checked with time-dependent covariate, martingale residual plot and Schoenfeld residual plot. Survival up to 1-year after HTx was compared between patients with hypoalbuminemia and normal albumin using Kaplan–Meier analysis and log-rank test. In all analyses, the value 0.05 was used as the significance level.

All statistical analyses were performed using JMP version 7.0 software (SAS Institute).

Results

Analysis of Clinical Factors Associated with Post-transplant Mortality

Pretransplant clinical characteristics, laboratory variables, and donor-related information derived from the single-center Columbia University database are summarized in Table 1 along with the results from univariate Cox proportional hazards regression analysis of their risks on 1-year survival after transplantation. In univariate analysis, body mass index, pretransplant albumin, sodium, total bilirubin and direct bilirubin, hematocrit, donor sex, and HLA mismatch were significantly associated with 1-year survival.

Comparison of Patients With and Without Hypoalbuminemia

Patients were divided into 2 groups: those with preoperative hypoalbuminemia (<3.5 mg/dL) and those with normal albumin (>3.5 mg/dL). In our cohort, 208 patients (25.3%) showed hypoalbuminemia preoperatively, including 21 patients (2.6%) with an albumin concentration <2.5 mg/dL. A total of 614 patients showed normal albumin levels (>3.5 mg/dL). The comparison of pre- and perioperative factors between the groups is shown in Table 2. Body mass index was lower, the proportions of patients at UNOS Status 1A and those requiring LVAD support at the time of HTx were larger in patients with preoperative hypoalbuminemia than those with normal albumin concentration. Preoperative sodium concentration was lower, total and direct bilirubin concentration was higher, total cholesterol and triglyceride levels were lower, and hematocrit was lower in patients with hypoalbuminemia than those with normal albumin concentration. Perioperative variables were not significantly different between patients with and without hypoalbuminemia. Overall survival duration was longer in patients with normal albumin than those with hypoalbuminemia.

There were a total of 223 post-transplant deaths, 134 (21.8%) in the normal albumin group and 89 (42.8%) in the hypoalbuminemia group. Among the 223 patients who died, 109 deaths occurred during the first year after transplantation with 52 patients (8.5%) in the normal albumin group and 57 (27.4%) in the hypoalbuminemia group. The remaining 114 deaths occurred after 1-year after transplantation, and the mortality rates were similar between the 2 groups, with 82 (15.7%) in the normal albumin group and 32 (22.4%) in the hypoalbuminemia group ($P=0.07$). Kaplan–Meier survival curves of patients with and without hypoalbuminemia revealed that patients with normal albumin concentration showed better survival compared with those with hypoalbuminemia (1 and 5 years; 91.3% with SE 0.01 versus 72.4% with SE 0.03; 79.5% with SE 0.02 versus 58.0% with SE 0.04, respectively; $P<0.0001$). Figure 1 illustrates the survival of both groups of patients 1 year after transplant. The death in patients with hypoalbuminemia occurred most commonly in the early postoperative period in our cohort. Only limited data were available on the specific causes of death. However, on the basis of an obtainable data, the leading cause of death within 1 year after transplant was infection and the second leading cause was primary graft failure, which was not significantly different between patients with hypoalbuminemia and those with normal albumin concentration (24/57, 42.1% versus 17/51, 33.3% for infection; 6/57, 10.5% versus 4/51, 7.8% for primary graft failure, respectively; $P=NS$). The 1-year mortality rates after transplant in patients with hypoalbuminemia and normal albumin concentration were 27.6% with SE 0.031 versus 8.7% with SE 0.012 ($P<0.0001$), respectively.

Analysis of Factors Associated with Post-transplant 1-Year Mortality

A multivariable analysis for pretransplant factors associated with 1-year post-transplant mortality was performed by stepwise selection analysis, which selected age, sex (men=1, women=0), race (black=1, others=0), cytomegalovirus serology (positive=1, negative=0), preoperative albumin, and total bilirubin concentration for the inclusion in a subsequent Cox proportional hazards models. Among the variables, negative cytomegalovirus serology, lower albumin and higher total bilirubin concentration were found to be significantly

associated with post-transplant mortality within a year (Table 3). The factor showing the most significant association with 1-year post-transplant mortality was identified as preoperative serum albumin concentration (hazard ratio, 0.461; 95% confidential interval, 0.341–0.623; $P<0.0001$). This implied that for every 1 mg/dL increase in albumin concentration, the post-transplant mortality rate decreased by >54%.

Multivariable analysis for combination of pre- and peritransplant variables associated with post-transplant mortality was also performed. The stepwise selection methods selected sex (men=1, women=0), cytomegalovirus serology (positive donor to negative recipient=1, other combination=0), preoperative albumin, and total bilirubin concentration for the inclusion in a subsequent Cox proportional hazards models. Among the variables, lower albumin concentration and higher total bilirubin concentration were found to be associated with 1-year post-transplant mortality (Table 4). Donor-related factors were not found to have a significant association with mortality. Neither martingale residual plots nor Schoenfeld residual plots showed a specific trend; therefore, the linearity of the effect of albumin levels on survival and the proportionality of the Cox model were confirmed.

Impact of Hypoalbuminemia on Post-transplant Survival of Patients in the UNOS Dataset

Post-transplant survival of patients in the UNOS dataset with and without hypoalbuminemia was also analyzed using the same cutoff value of pretransplant albumin concentration obtained from our patients cohort (3.5 mg/dL). In a total of 13 671 patients eligible for analysis, 5550 patients (40.6%) had hypoalbuminemia before HTx. In a comparable manner to our single-center cohort, Kaplan–Meier survival curves based on the presence or absence of hypoalbuminemia in the UNOS dataset revealed that patients with normal albumin showed better survival compared with those with hypoalbuminemia (1 and 5 years; 88.4% with SE 0.004 versus 84.8% with SE 0.005, 75.0% with SE 0.005 versus 71.1% with SE 0.007, respectively; $P<0.0001$). Figure 2 illustrates the survival of both groups of patients in the UNOS data set 1 year after transplant.

Discussion

In the present study, we have demonstrated that (1) pretransplant hypoalbuminemia is strongly associated with 1-year post-transplant mortality by multivariable analysis including pre- and perioperative factors and (2) the association of hypoalbuminemia and reduced 1-year post-transplant survival was also seen in the UNOS database.

Albumin is a hepatic protein, and its concentration is controlled by several factors, including rate of synthesis, catabolic state, and distribution between the intra- and extravascular spaces in the body. Many conditions, such as malnutrition, catabolism, liver, and renal dysfunction, as well as systemic infection, reduce serum albumin concentrations.^{1–4,15} Hypoalbuminemia has been reported to be associated with poor prognosis in patients with chronic disease states, such as renal disease, malignancy, and HF.^{6,16–18} In patients with HF, the prevalence of hypoalbuminemia has been reported to be ≈20% to 30% and it has emerged as an independent risk factor of death.^{6,19–21} The association of preoperative hypoalbuminemia and postoperative mortality in patients undergoing cardiac surgery has also been reported.^{8,9,22} The present study, for the first time, describes the impact of pretransplant

hypoalbuminemia on 1-year post-transplant survival in HTx recipients. In addition, our investigation revealed that preoperative hypoalbuminemia remained to be a risk factor for postoperative mortality within a year by multivariable analysis on the basis of preoperative and perioperative factors. The death in patients with hypoalbuminemia occurred mostly in the early postoperative period when we dichotomized patients on the basis of albumin levels of ≤ 3.5 or >3.5 mg/dL (Figure 1). We speculate that preoperative hypoalbuminemia was related to preoperative severity of HF which was also linked to direct causes of early postoperative death in HTx recipients.^{12,14} Indeed, patients with preoperative hypoalbuminemia had more severe HF compared with those with normal albumin concentration in our cohort; the proportion of patients with UNOS status 1A and those with concomitant LVAD placements was larger in patients with hypoalbuminemia. In addition, previously described prognostic markers in patients with HF, such as low sodium, high total bilirubin, low total cholesterol, and anemia,^{23–25} were also found in our patients with hypoalbuminemia.

Hypoalbuminemia has also been linked to systemic inflammation, sepsis, and infection.^{4,26,27} Serum albumin has been shown to selectively inhibit tumor necrosis factor- α -induced vascular cell adhesion protein-1 expression, monocyte adhesion, and nuclear factor- κ B activation in endothelial cells suggesting a role in anti-inflammatory biological mechanisms.²⁶ Therefore, patients with preoperative hypoalbuminemia may present with a persistent proinflammatory state even after cardiac transplant, which might contribute to early postoperative death. A continuous inflammatory state in patients with preoperative hypoalbuminemia increases susceptibility to infection,²⁷ primary graft failure,²⁸ and early development of transplant coronary artery disease,²⁹ which are well-known causes of early postoperative death.¹² In addition, patients with preoperative hypoalbuminemia have poor wound healing, which further increases the risk of infection.³⁰ Malnutrition, as reflected by low albumin concentration, may also play a role in poor post-transplant survival. We could only obtain limited information about the causes of death; therefore, we could not demonstrate an actual comparison analysis of causes of death between patients with and without hypoalbuminemia. However, although our data were limited, the infection rate which was a leading cause of death within a year after transplant tended to be higher in patients with hypoalbuminemia.

Albumin has been incorporated into a number of risk stratification models to predict outcomes after LVAD implantation as well.^{31,32} Although these models cannot be validated in the transplant population to predict the specific clinical outcome because some of the transplant recipients were already treated with LVADs for bridge-to-transplantation, preoperative serum albumin levels are an useful marker for risk stratification in patients with advanced HF. Of note, albumin levels are routinely obtained preoperatively, but it is not considered a biomarker while it has distinct prognostic power for predicting the outcome of patients with advanced HF undergoing surgical interventions. Multiple factors contribute to impaired outcome of patients with hypoalbuminemia and our analysis cannot determine whether albumin is truly an independent risk factor for prognosis because of its interdependency on other outcome factors, such as malnutrition, inflammation, and liver dysfunction. The serum albumin level is, however, a simple integrative factor with apparent clinical usage.

Our observation was based on single-center, retrospective analysis. One of the limitations of this study was the lack of pretransplant hemodynamic data. We could not define whether hypoalbuminemia in our cohort was driven by congestion or a low cardiac output state. Further study, especially serial measurements of albumin concentration in patients undergoing LVAD as a bridge-to-transplantation, would provide greater clinical relevance whether modifying hemodynamics could further improve hypoalbuminemia and post-transplant outcome. The association between pre-transplant hypoalbuminemia and post-transplant survival was also found in the available UNOS data set which included >13 000 transplant recipients with reported pretransplant albumin levels. The analysis derived from the UNOS dataset contains limitations. Detailed pre- and post-transplant clinical information were not available for all patients because of incomplete listings in the data set. Our analysis only includes the subset of 31.9% of all patients in the actual UNOS database whose preoperative albumin levels were reported. This may cause a smaller difference of survival of patients with and without hypoalbuminemia in the UNOS dataset compared with our single-center analysis in which we evaluated all patients in a consecutive manner. Another limitation of the study was that the albumin level is a time-variant value, which may not be an ideal parameter to be included in the proportional hazard model. However, we used the value obtained closest to the surgery in the present study, and we think that this level would reflect the overall preoperative condition of a patient. Attention to correct nutrition, inflammation, and hepatic function to normalize serum albumin concentration before transplant could be an effective way to improve post-transplant survival.

In conclusion, we found that pretransplant albumin concentration was independently associated with post-transplant survival of HTx recipients. Our finding may be useful in discussing the risks and timing of transplant listing for patients with advanced HF.

Acknowledgments

We thank Norio Sugimoto (Sugimoto Data Analysis Service) for his statistical review of the article.

Sources of Funding

This work was supported by grants from the National Heart, Lung, and Blood Institute (K23 HL095742-01, P30 HL101272-01, UL1 RR 024156, and HL073029) and the Herbert and Florence Irving Scholar Award to Dr Schulze.

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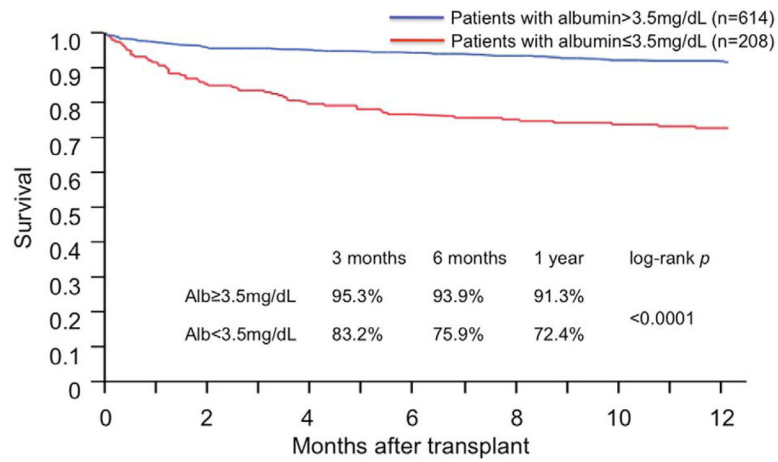
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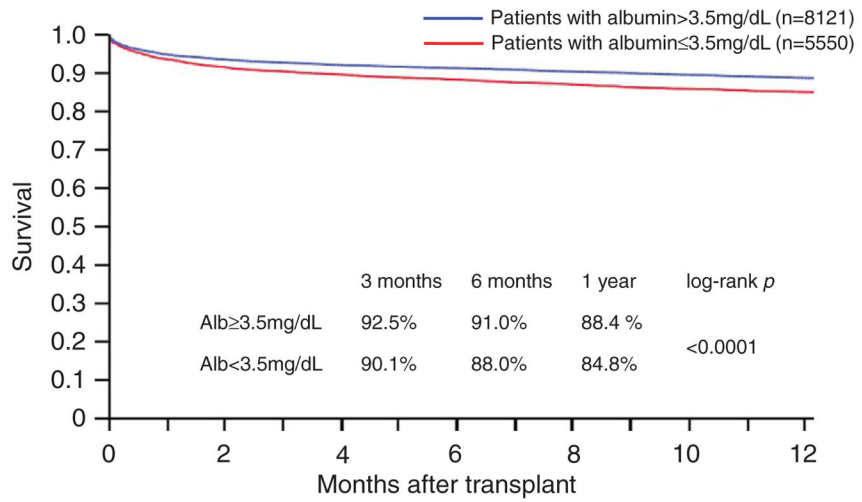
CLINICAL PERSPECTIVE

Low serum albumin levels have been recognized as a marker of malnutrition, severity of inflammation, and hepatic dysfunction in patients with various chronic diseases. We investigated the impact of pretransplantation serum albumin levels on post-transplantation outcome in heart transplant recipients on the basis of 822 consecutive patients undergoing heart transplant at Columbia University Medical Center. Further, we tested the impact of low serum albumin levels on survival on the dataset from the United Network for Organ Sharing (n=13 671). In our single-center cohort, multivariable analysis revealed that preoperative albumin (mg/dL; hazard ratio, 0.46; $P<0.0001$) and preoperative total bilirubin (mg/dL; hazard ratio, 1.26; $P=0.0002$) were associated with post-transplantation 1-year mortality. The Kaplan–Meier analysis based on our patient cohort and the United Network for Organ Sharing dataset showed lower survival at 1-year post-transplantation in patients with albumin levels ≤ 3.5 mg/dL compared with those with levels >3.5 mg/dL (both $P<0.0001$). Therefore, pretransplantation serum albumin concentration is a strong prognostic marker for survival after heart transplant.



Number at risk	2 M	4M	6M	8M	10M	12M
Alb≥3.5mg/dL	614	580	566	554	540	529
Alb<3.5mg/dL	208	178	164	156	150	147

Figure 1. Kaplan–Meier survival curves of patients with and without pretransplant hypoalbuminemia. Blue line indicates patients with normal albumin concentration defined as >3.5 mg/dL, and red line indicates patients with hypoalbuminemia (≤ 3.5 mg/dL).



Number at risk	2 M	4 M	6 M	8 M	10 M	12 M
Alb ≥ 3.5mg/dL	8121	7496	7365	7284	7186	7108
Alb < 3.5mg/dL	5550	5026	4909	4830	4751	4684

Figure 2. Kaplan–Meier survival curves of patients with and without pretransplant hypoalbuminemia based on the United Network for Organ Sharing dataset. Blue line indicates patients with normal albumin concentration defined as >3.5 mg/dL, and red line indicates patients with hypoalbuminemia (≤ 3.5 mg/dL).

Table 1

Clinical Characteristics, Laboratory, and Donor-Related Information

	All Patients (N=822)	1-Y Survival After Transplant	
		Hazard Ratio (95% CI)	P Value
Clinical characteristics at the time of transplant			
Age, y	53.0±12.3	1.016 (1.000–1.033)	0.054
Sex (men, %)	637 (77.5%)	0.673 (0.446–1.017)	0.060
Race (black, %)	140 (17.0%)	1.302 (0.822–2.062)	0.261
BMI, kg/m ²	26.1±4.9	0.919 (0.883–0.957)	<0.0001
Primary disease (ischemic, %)	367 (44.7%)	1.040 (0.714–1.516)	0.838
UNOS status (1A, %)	317 (38.6%)	1.352 (0.927–1.972)	0.118
LVAD requirement, %	268 (32.6%)	1.300 (0.882–1.916)	0.184
CMV serology (positive, %)	496 (61.7%)	0.726 (0.495–1.064)	0.101
Pretransplant laboratory examination			
Albumin, mg/dL	3.9±0.6	0.452 (0.339–0.602)	<0.0001
Sodium, mEq/L	137.5±7.3	0.952 (0.931–0.974)	<0.0001
Potassium, mEq/L	4.3±0.5	0.857 (0.595–1.235)	0.409
BUN, mg/dL	29.4±15.7	1.005 (0.993–1.016)	0.444
Cre, mg/dL, n=820	1.4±0.7	0.988 (0.762–1.282)	0.929
Total bilirubin, mg/dL	1.2±1.0	1.222 (1.074–1.390)	0.002
Direct bilirubin, mg/dL	0.4±0.5	1.640 (1.310–2.054)	<0.0001
AST, IU/L	34.8±56.6	1.0 (0.997–1.003)	0.838
ALT, IU/L	32.5±52.7	1.0 (0.997–1.003)	0.897
Total cholesterol, mg/dL (n=814)	145.7±48.0	0.997 (0.993–1.002)	0.219
Triglyceride, mg/dL (n=820)	124.1±64.6	1.0 (0.997–1.003)	0.904
Hematocrit, %	36.3±5.9	0.966 (0.935–0.997)	0.034
Perioperative and donor-related information			
Ischemic time, min (n=503)	192.8±56.4	1.003 (0.998–1.007)	0.289
Donor age, y	34.2±13.3	1.012 (0.997–1.027)	0.105
Donor sex, men, %	453 (58.2%)	0.619 (0.421–0.911)	0.015
CMV serology (D ⁺ /R ⁻ %), n=807	178 (22.1%)	1.432 (0.933–2.199)	0.100
HLA mismatch (5, %), n=763	227 (29.8%)	1.834 (1.229–2.736)	0.003
Survival after transplant, d	1649±1188

ALT indicates alanine aminotransferase; AST, aspartate aminotransferase; BMI, body mass index; BUN, blood urea nitrogen; CI, confidence interval; CMV, cytomegalovirus; D⁺/R⁻, serology-positive donor to serology-negative recipients; HLA, histocompatibility locus antigen; LVAD, left ventricular assist device; and UNOS, United Network for Organ Sharing.

Table 2

Comparison of Pre- and Peritransplant Factors Between Patients With Hypoalbuminemia and Those With Normal Albumin

	Hypoalbuminemia (n=208)	Normal Albumin (n=614)	P Value
Clinical characteristics at the time of transplant			
Age, y	54.2±11.5	52.6±12.5	0.097
Sex (men, %)	156 (75.0%)	481 (78.3%)	0.319
Race (black, %)	40 (19.2%)	100 (16.3%)	0.329
BMI, kg/m ²	23.1±4.7	27.1±4.5	<0.0001
Primary disease (ischemic, %)	101 (48.6%)	266 (43.3%)	0.189
UNOS status (1A, %)	117 (56.3%)	200 (32.6%)	<0.0001
LVAD requirement, %	95 (45.7%)	173 (28.2%)	<0.0001
CMV serology (positive, %)	130 (63.7%)	366 (61.0%)	0.489
Perioperative and donor-related information			
Albumin, mg/dL	3.1±0.4	4.2±0.4	<0.0001
Sodium, mEq/L	130.0±6.1	140.1±5.7	<0.0001
Potassium, mEq/L	4.3±0.5	4.3±0.5	0.792
BUN, mg/dL	27.3±16.3	30.0±15.4	0.031
Cre, mg/dL (n=820)	1.3±0.8	1.4±0.7 (n=612)	0.234
Total bilirubin, mg/dL	1.4±1.5	1.1±0.8	0.009
Direct bilirubin, mg/dL	0.5±0.7	0.3±0.4	<0.0001
AST, IU/L	40.7±96.1	32.8±33.9	0.082
ALT, IU/L	39.3±85.5	30.3±35.1	0.033
Total cholesterol, mg/dL (n=814)	133.4±48.5	149.9±47.1 (n=606)	<0.0001
Triglyceride, mg/dL (n=820)	114.2±57.1	127.5±66.6 (n=612)	0.010
Hematocrit, %	32.6±5.4	37.5±5.5	<0.0001
Perioperative and donor-related information			
Ischemic time, min (n=503)	183.3±56.7 (n=122)	195.9±56.4 (n=381)	0.032
Donor age, y	35.6±13.7	33.7±13.2	0.080
Donor sex (men, %)	114 (58.2%)	339 (58.2%)	0.997
CMV serology (D ⁺ /R ⁻ , %, n=807)	41 (20.3%; n=202)	137 (22.6%; n=605)	0.486
HLA mismatch (5, %, n=763)	66 (34.2%; n=193)	161 (28.3%; n=570)	0.118

ALT indicates alanine aminotransferase; AST, aspartate aminotransferase; BMI, body mass index; BUN, blood urea nitrogen; CMV, cytomegalovirus; D⁺/R⁻, serology-positive donor to serology-negative recipients; HLA, histocompatibility locus antigen; LVAD, left ventricular assist device; and UNOS, United Network for Organ Sharing.

Table 3

Multivariable Analysis for Preoperative Factors Associated With Post-transplant 1-Year Mortality

	HR (95% CI)	P Value
Age, y	1.018 (1.001–1.036)	0.039
Sex (men=1, women=0)	0.729 (0.476–1.117)	0.147
Race (black=1, others=0)	1.385 (0.859–2.235)	0.182
CMV serology (positive=1, negative=0)	0.621 (0.420–0.920)	0.017
Preoperative albumin, mg/dL	0.461 (0.341–0.623)	<0.0001
Preoperative total bilirubin, mg/dL	1.264 (1.115–1.431)	0.0002

CI indicates confidential interval; CMV, cytomegalovirus; and HR, hazard ratio.

Table 4

Multivariable Analysis for Pre- and Perioperative Factors Associated With Post-transplant 1-Year Mortality

	HR (95% CI)	P Value
Sex (men=1, women=0)	0.741(0.483–1.135)	0.168
CMV serology (D ⁺ /R ⁻ =1, other combination=0)	1.471 (0.956–2.262)	0.079
Preoperative albumin, mg/dL	0.445 (0.330–0.599)	<0.0001
Preoperative total bilirubin, mg/dL	1.193 (1.050–1.355)	0.007

CI indicates confidential interval; CMV, cytomegalovirus; D⁺/R⁻, serology-positive donor to serology-negative recipients; and HR, hazard ratio.