Biol Blood Marrow Transplant 25 (2019) 41–46

Biology of Blood and Marrow Transplantation

journal homepage: www.bbmt.org

ASBMT American Society for Blood and Marrow Transplantation

Significant Nationwide Variability in the Costs and Hospital Mortality Rates of Autologous Stem Cell Transplantation for Multiple Myeloma: An Analysis of the Nationwide Inpatient Sample Database

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Article history:
Received 11 June 2018
Accepted 29 August 2018

Key Words:
Multiple myeloma
Stem cell transplantation
Healthcare disparity

A B S T R A C T

Autologous hematopoietic stem cell transplantation (AHCT) is the standard of care for eligible patients with multiple myeloma (MM). In this study, we explored disparities in hospital cost and in-hospital mortality among patients with MM who underwent AHCT. Data were obtained from the Nationwide Inpatient Sample database for 2005 to 2014. International Classification of Diseases, Ninth Edition, Clinical Modification diagnosis and procedure codes were used to identify patients. Hospitals were divided into quintiles according to the weighted volume of AHCTs performed in patients with MM. Multiple imputation with chained equation was used for missing data. Linear trend analysis of age- and sex-adjusted mortality, as well as inflation-adjusted hospital cost, was performed. Univariate regression screening followed by stepwise multivariate regression was performed for dependent variables, including mortality and inflation-adjusted hospital cost. Identified significant predictors underwent sensitivity analyses. Overall age- and sex-adjusted mortality rates and inflation-adjusted hospital costs decreased between 2005 and 2014; however, tremendous nationwide variability exists. Patients who underwent AHCT at very-low-volume hospitals (Q1) had significantly higher in-hospital mortality. Both geographic location and hospital type had impacted age- and sex-adjusted mortality rates and inflation-adjusted hospital costs. Despite an overall improvement in mortality and decreased cost of AHCT for patients with MM, nationwide variability in care exists. Further study is needed to identify correctable factors that contribute to the identified correlation.

INTRODUCTION

Multiple myeloma (MM) is a rare cancer with an annual incidence of 30,000, representing 1% of all cancers in the United States [1]. Recent advances in MM treatment and supportive care have improved overall survival (OS) outcomes for patients; however, the causes of variation in survival outcomes among treatment centers have not yet been extensively evaluated.

Autologous hematopoietic stem cell transplantation (AHCT) in eligible patients with MM is considered standard of care and has been shown to prolong progression-free survival (PFS) and OS [2-5]. From 2005 to 2014, the number of AHCTs performed to treat MM grew steeply, from approximately 3000 to more than 7000 annually, in large part because patients over age 70 are now considered eligible to receive stem cell transplantation [6].

Previous studies have shown that higher volume is associated with better outcomes, as exemplified by surgical procedures in oncologic patients [7]. Similar studies have also emerged in medical management. MM treatment facility volume, an indirect measure of treating physician experience with the disease, has been shown to affect mortality [8]. AHCT is most frequently performed on an inpatient basis, and thus hospital setting may serve as a surrogate for resources available for supportive care and also may have an impact on clinical outcomes [9]. Finally, disparities in care quality and resource accessibility for MM care nationwide may result in geographically determined outcomes [10-13].

We set out to explore nationwide differences in MM care and to evaluate their association with survival outcomes and

Financial disclosure: See Acknowledgments on page 46.

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https://doi.org/10.1016/j.bbmt.2018.08.030
1083-8791/

hospitalization costs. We hypothesized that a low annual facility AHCT volume would have an impact on survival outcomes and hospitalization cost. We also explored whether hospital geographic location or hospital type (public vs private) had any effect on hospitalization costs or clinical outcomes in this patient population.

METHODS

Data Source

Data were obtained from the Nationwide Inpatient Sample (NIS) database for 2005 to 2014. Sponsored by the Agency for Healthcare Research and Quality as a part of Healthcare Cost and Utilization Project, the NIS is the largest publicly available all-payer inpatient care database in the United States. It contains discharge-level data from approximately 8 million hospitals stays from approximately1000 hospitals designed to approximate a 20% stratified sample of all US community hospitals. Criteria used for stratified sampling of hospitals into the NIS include hospital ownership, patient volume, teaching status, urban or rural location, and geographic region. All hospitalization costs were adjusted for inflation to 2014 US dollars using the medical care component of the US Consumer Price Index.

Study Population

We used the International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM) diagnosis codes 203, 203.0, 203.00, 203.01, and 203.02 to identify all patients age ≥18 years with MM who were admitted to the hospital between 2005 and 2014 and underwent an AHCT (ICD-9-CM procedure code 41.01, 41.04, 41.06, 41.17, or 41.09) during the hospitalization.

Patient Characteristics

Demographic data (including age, sex, race, and household income), elective versus nonelective admission, hospital volume percentile, primary payer status, hospital region, hospital teaching status, total Charlson Comorbidity Index, crude mortality, and length of stay were collected.

Study Objectives

The outcomes of interest for this study were all-cause in-hospital mortality, defined as "died" during the hospitalization encounter in the NIS database, and inflation-adjusted hospitalization cost using the yearly inflation rate, the total hospitalization charge, and the cost-to-charge ratio. The 10-year trends in age- and sex-adjusted hospital mortality, as well as inflation-adjusted hospitalization cost, were calculated.

A hospital's weighted AHCT value was calculated using hospital discharge weight and number of AHCTs performed in patients with MM in that hospital. We summarized the total weighted AHCT values per hospital per year over the study period and divided them into quintiles: Q1, ≤10; Q2, >10 and ≤25; Q3, >25 and ≤45; Q4, >45 and ≤90; and Q5, >90. The number of annual unweighted AHCTs in each hospital quintile is roughly one-fifth of the weighted cases: Q1, ≤; Q2, 3 to 5; Q3, 6 to 9; Q4, 9 to 18; Q5, >18.

The primary predictor of interest was hospital volume. The secondary predictors of interest included hospital region and hospital ownership. Other variables controlled for in the mortality model were age, sex, race, household income, hospital teaching status, hospitalization year, and Charlson Comorbidity Index. Other variables controlled for in the inflation-adjusted hospitalization cost model were age, sex, race, household income, hospital teaching status, hospitalization year, Charlson Comorbidity Index, survival, and length of stay.

Statistical Analysis

Statistical analysis was performed using STATA/MP 14.2 (StataCorp, College Station, TX). A 2-sided P value <.05 was used to assess for statistical significance in all analyses. Categorical variables are expressed as percentage and continuous variables are expressed as mean ± SD. Odds ratio (OR) and 95% confidence interval (CI) were used to report the results of logistic regression analysis. NIS is based on a complex sampling design that includes stratification, clustering, and weighting, and the software facilitates analysis to produce nationally representative unbiased results, variance estimates, and P values.

Baseline characteristics were compared using Pearson's chi-square test for categorical variables and Student's t test for continuous variables. Stepwise logistic regression analysis was used to identify independent predictors of in-hospital mortality, and stepwise multivariate regression analysis was used to identify independent predictors of inflation-adjusted total hospitalization cost. In this study, cost does not follow a normal distribution, and thus log transformation was used to ensure normal distributions. Results pertaining to cost were rounded up to a single digit. The Cochran-Armitage test was used to calculate trends.

Missing Data

All variables used were examined for missing data.

Hospital characteristics had a very low percentage of missing data (<.01%), except for hospital ownership (20.58%). The NIS database had a different data format for the variable "hospital ownership" before 2008, which led to a high percentage of missing data from 2005 to 2007. Therefore, we performed additional analyses based on the data from 2008 to 2014. Win this 7-year analysis (2008 to 2014), only .008% of the observations had a missing value for hospital ownership, and hospital bed size, hospital location, and hospital teaching status all had .006% missing data.

Patient characteristics also had a low percentage of missing data (<.01%), except for race, with 14.42% of data missing, and median income in patient's zip code, with 2.6% of data missing. Elective admission, insurance status, and sex had .002%, .003%, and .001% missing data, respectively.

Chained multiple imputation was carried out with 20 iterations for missing information in patients that were included in the analysis using variables from each regression analysis, as well as all hospital characteristics that was used to stratify sampling of the hospital universe.

The results for outcomes, as well as predictor variables, were compared before and after accounting for missing data. Outcomes were also compared between the 7-year analysis (2008 to 2014) and the 10-year analysis (2005 to 2014) and found to be similar. Unless noted otherwise, the results presented herein have accounted for missing data using multiple imputation estimation with the 10-year data.

RESULTS

Our cohort included 8143 patients with MM who underwent AHCT, which was equivalent to an estimated 39,733 nationwide admissions between 2005 and 2014. These patients were admitted to 633 hospitals, with admission to the same hospital in different years is considered different. Data from hospitals in the VA system are not included in the NIS database; thus, admissions to the 3 VA stem cell transplantation centers (Nashville, Houston, and Seattle) were not included in our analysis. The mean age was 58.9 years (median, 60 years; interquartile range, 53 to 66 years), and 57.1% were men. Most patients underwent AHCT in a teaching hospital (97.3%). The median weighted volume across all hospitals all years was 35 patients per year. Hospitals were divided into quintiles according to the weighted volume of AHCT (Table 1). The majority (61.89%) of the patients were treated in Q5 hospitals, which had a median weighted AHCT volume of 195 patients.

The data from 2005 to 2014 show a trend toward deceasing age-and sex-adjusted in-hospital mortality for patients with MM who underwent AHCT (Figure 1). The inflation-adjusted hospitalization cost also decreased over the decade (Figure 2).

The quintile-specific characteristics of the patients are summarized in Table 1. Compared with Q1 hospitals, the higher-volume hospitals (Q2 to Q5) were more likely to be teaching hospitals, as well as public nonfederal hospitals, and to have patients who were electively admitted and privately insured.

The crude mortality rate varied by hospital volume groups: 3.56% for Q1, .73% for Q2, 1.06% for Q3, .80% for Q4, and 1.71% for Q5 (Table 1). A low-volume (Q1, ≤10 weighted patients/year) of AHCT for MM was independently associated with higher in-hospital mortality (Figure 3). Compared with Q1 hospitals, the adjusted OR after multiple imputation estimation for all hospitals combined in Q2 to Q5 was .22 (95% CI, .08 to .62). Detailed crude OR and adjusted OR of each quintile (Q2 to Q5) against Q1 are listed in Table 2. The crude mortality among public nonfederal hospitals, private nonprofit hospitals, and private investor-owned hospitals were 2.86%, .73%, and .79%, respectively. In univariate analysis, admission to a public nonfederal hospital was associated with significantly higher mortality compared with private nonprofit hospitals (OR, .29; 95% CI, .13 to .63) and private investor-owned hospitals (OR, .27; 95% CI, .08 to .88). In multivariate analysis, admission to a public nonfederal hospital was associated with significantly higher mortality compared with a private nonprofit hospital (OR, .28; 95% CI, .15 to .52) and showed a trend toward a significantly higher mortality compared with private investor-owned hospitals (OR, .33; 95% CI, .10 to 1.09) (Table 2). Regionally, the crude mortality in

Northeast, Midwest, South, and West hospitals was 1.11%, 1.31%, 2.28%, and .60%, respectively. The crude OR for mortality did not differ across the regions. In multivariate analysis, admission to a Northeast hospital was associated with higher in-hospital mortality compared with admission to a hospital in the West region (OR, .31; 95% CI, .11 to .85) (Table 2).

With reference to healthcare resource utilization, no cost difference was found among hospitals in different quintiles. The inflation adjusted total hospitalization cost (in US dollars) in Q1 to Q5 ranged between $52,000 and $59,000 (Table 3). In both univariate and multivariate regression analysis, inflation-adjusted total hospitalization costs in Q2 to Q5 hospitals did not differ significantly from those in Q1 hospitals (Table 3). In addition, the inflation-adjusted total hospitalization cost was lower in hospitals in the South compared with the Northeast. The total costs in Northeast, Midwest, South, and West hospitals ranged from $42,000 to $67,000. In univariate regression analysis, hospital costs were lower in the Midwest and South compared with the Northeast. In multivariate regression analysis, compared with Northeast hospitals, hospitals in South had significantly lower costs, a median of $17,585 (range, $9471 to $25,699) lower (Table 3). The statistical significance was verified with analysis using log-transformed cost as dependent variable. Moreover, compared with public nonfederal hospitals, private hospitals (both nonprofit and investor-owned) had significantly lower inflation-adjusted total hospitalization cost. The mean inflation-adjusted total hospitalization cost in public nonfederal, private nonprofit, and private investor-owned hospitals was $67,834 (95% CI, $56,323 to $79,345), $53,156 (95% CI, $49,907 to $56,405), and $42,959 (95% CI, $33,979 to $51,939), respectively. In univariate regression analysis, compared with public nonfederal hospitals, the cost of admission to private nonprofit

Table 1
Characteristics of Patients with MM Undergoing AHCT According to Hospital Volume (Estimated Total NIS Universe)

Characteristic	Q1	Q2	Q3	Q4	Q5
Patients/yr, n	≤10.00	>10.00 and <25.00	≥25.00 and <45.00	≥45.00 and ≤85.97	>89.57
Patient distribution, %	2.10	5.25	10.74	20.01	61.89
Hospitals, n	128	126	126	127	126
Female sex, n (%)	385 (46.0)	822 (39.4)	1763 (41.3)	2758 (45.0)	8095 (42.3)
Age, yr, mean (SD)	58.85 (.7)	59.56 (.5)	59.97 (.3)	59.45 (.3)	58.47 (.2)
Race, n (%)					
White	480 (65.4)	1110 (62.4)	2333 (62.6)	4982 (69.2)	14,493 (70.6)
Black	126 (17.0)	368 (20.6)	712 (19.1)	1332 (18.5)	2912 (14.3)
Hispanic	72 (9.5)	160 (9.1)	395 (10.6)	467 (6.5)	1846 (8.9)
Asian and Pacific Islander	10 (1.4)	44 (2.5)	68 (1.8)	133 (1.8)	445 (2.1)
Native American	5 (.7)	15 (.8)	4 (.1)	34 (.5)	82 (.4)
Other	44 (6.0)	82 (4.5)	218 (5.9)	252 (3.5)	834 (4.1)
Year of admission, n (%)					
2005	19 (2.3)	75 (3.6)	230 (5.4)	306 (3.8)	2273 (9.2)
2006	24 (2.9)	143 (6.9)	350 (8.1)	302 (3.8)	1271 (5.2)
2007	28 (3.4)	135 (6.5)	123 (2.9)	393 (5.0)	2817 (11.5)
2008	28 (3.4)	56 (2.7)	159 (4.0)	664 (8.3)	2939 (12.0)
2009	6 (.7)	87 (4.2)	254 (6.0)	513 (6.5)	3160 (12.9)
2010	10 (1.2)	75 (3.6)	111 (2.6)	469 (5.9)	3380 (13.8)
2011	5 (.6)	24 (1.2)	167 (3.9)	246 (3.1)	3202 (13.1)
2012	270 (32.4)	421 (20.1)	946 (22.1)	1605 (20.2)	1955 (8.0)
2013	226 (27.0)	509 (24.4)	989 (23.2)	1490 (18.7)	2200 (9.0)
2014	219 (26.4)	560 (26.8)	926 (21.7)	1967 (24.7)	1482 (6.0)
Elective admission, n (%)	504 (60.7)	1444 (69.1)	3240 (75.9)	6413 (81.3)	21,412 (87.1)
Charlson Comorbidity Index, n (%)					
≤3	644 (77.0)	1716 (82.3)	3556 (83.3)	6735 (84.7)	21,094 (85.8)
4-5	167 (20.1)	322 (15.4)	636 (14.9)	1113 (14.0)	3186.6 (13.0)
6-7	19 (2.3)	40 (1.9)	72 (1.7)	107 (1.3)	258 (1.1)
>8	5 (.6)	10 (.5)	5 (.1)	0 (0)	48 (.2)
Annual median household income, n (%)					
≤$38,999	240 (29.62)	495 (24.36)	844 (20.21)	1599 (20.53)	4985 (20.85)
$39,000-$47,999	190 (23.59)	468 (23.05)	1064 (25.53)	1928 (24.77)	5469 (22.87)
$48,000-$62,999	178 (22.17)	488 (23.96)	1026 (24.66)	2276 (29.26)	6096 (25.49)
≥$63,000	197 (24.62)	584 (28.63)	1235 (29.60)	1982 (25.45)	7366 (30.80)
Admission to teaching hospital, n (%)	731 (87.4)	1908 (91.8)	4045 (96.3)	7698 (96.8)	24,110 (98.7)
Insurance type, n (%)					
Medicare	262 (31.49)	717 (34.48)	1399 (32.84)	2600 (33.05)	6741 (27.42)
Medicaid	99 (11.95)	214 (10.36)	416 (9.73)	551 (7.03)	1755 (7.14)
Private including HMO	392 (47.02)	1034 (49.57)	2243 (52.63)	4319 (54.9)	16,462 (59.56)
Self-pay	10 (1.2)	10 (.48)	35 (.83)	25 (.31)	313 (1.28)
No charge	0 (0)	0 (0)	0 (0)	0 (0)	36 (.15)
Other	71 (8.33)	107 (5.1)	153 (3.97)	369 (4.71)	1094 (4.45)
Hospital ownership (2005-2014), n (%)					
Public, nonfederal	79 (10.36)	327 (19.06)	578 (16.18)	1669 (24.47)	4904 (26.66)
Private, nonprofit	628 (81.32)	1313 (76.33)	2648 (74.22)	4407 (63.42)	12,578 (68.36)
Private, investor-owned	63 (8.32)	79 (4.61)	342 (9.60)	842 (12.11)	917 (4.98)
Hospital region, n (%)					
Northeast	119 (14.28)	505 (24.20)	934 (21.86)	1756 (22.11)	4820 (19.60)
Midwest	215 (25.93)	405 (19.35)	1113 (26.04)	2217 (27.90)	7712 (31.36)
South	334 (39.81)	660 (31.53)	1633 (38.22)	2440 (30.68)	7597 (30.89)
West	169 (19.97)	521 (24.92)	592 (13.88)	1538 (19.32)	4466 (18.16)
Crude mortality, %	3.56	.73	1.06	.80	1.71
Length of stay, d, mean (SD)	17.73 (.99)	16.76 (.61)	17.00 (.52)	17.51 (.51)	18.20 (.64)

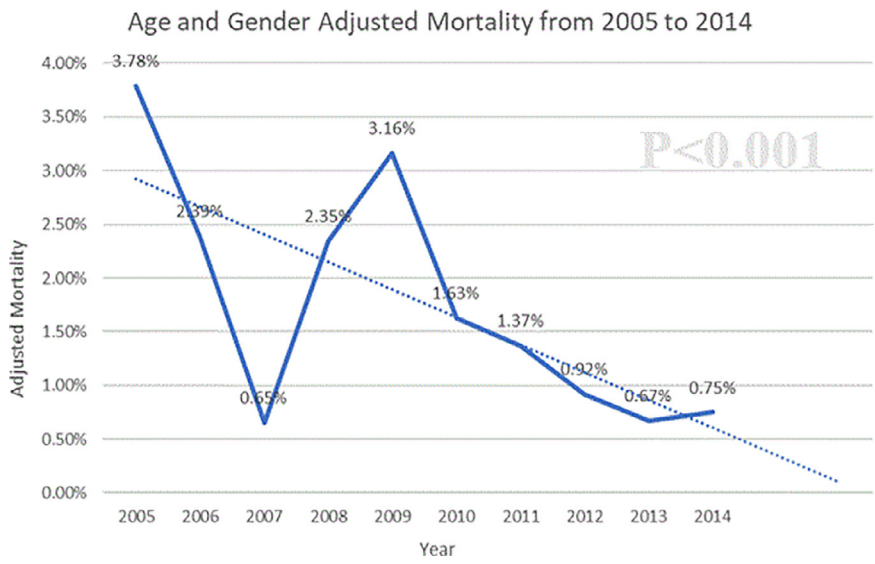

Figure 1. In-hospital mortality after AHCT for MM, 2005 to 2014. Z = 10.132; $P < .001$.

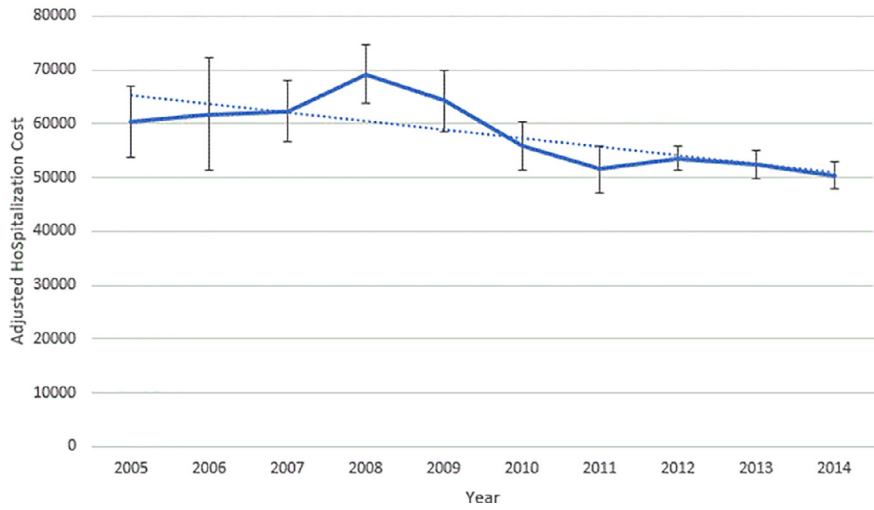

Figure 2. Trend analysis for inflation-adjusted hospitalization cost of AHCT for MM, 2005 to 2014. $P < .01$.

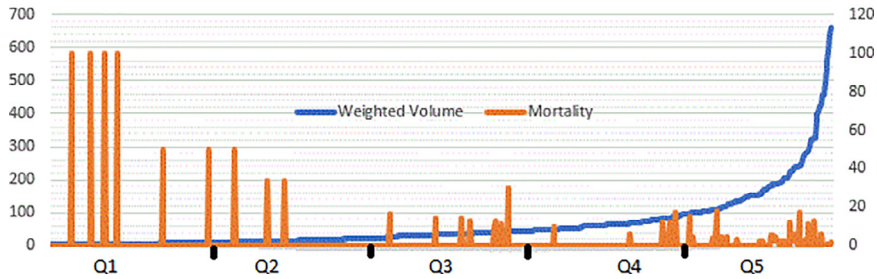

Figure 3. Weighted volume versus mortality in AHCT for MM.

hospitals and private investor-owned hospitals was $14,775 and $26,997 lower, respectively ($P < .05$). In multivariate regression analysis, compared with public nonfederal hospitals, the cost of admission to private nonprofit hospitals and private investor-owned hospitals was $7396 and $16,860 lower, respectively ($P < .05$). Log-transformation of the cost was also performed, and multivariate regression repeated with log-transformed cost yielded similar results (Table 3).

Table 2
Predictors of Interest for All-Cause Mortality

Predictors	Values				
Facility volume	Q1	Q2	Q3	Q4	Q5
Crude OR (95% CI)	Reference	.20 (.05-.80)	.29 (.10-.87)	.22 (.07-.72)	.47 (.17-1.33)
Adjusted OR (95% CI)	Reference	.13 (.03-.61)	.21 (.06-.66)	.18 (.05-.68)	.26 (.09-.75)
Hospital ownership	Government, nonfederal		Private, nonprofit		Private, Investor-Owned
Crude OR (95% CI)	Reference		.29 (.13-.63)		.27 (.08-.88)
Adjusted OR (95% CI)	Reference		.28 (.15-.52)		.33 (.10-1.09)
Hospital region	Northeast	Midwest		South	West
Crude OR (95% CI)	Reference	1.18 (.54-2.61)		2.07 (.71-6.10)	.54 (.22-1.33)
Adjusted OR (95% CI)	Reference	.92 (.41-2.07)		1.03 (.47-2.27)	.31 (.11-.85)

Table 3
Resource Utilization

Factors	Additional inflation-adjusted total hospitalization cost				
Volume	Q1	Q2	Q3	Q4	Q5
Crude mean (95% CI)	Reference	−1725.46 (−13,058.43 to 9607.52)	−4363.24 (−15,326.36 to 6599.88)	−738.91 (−13,503.84 to 12,026.01)	2750.17 (−9049.99 to 14,550.33)
Adjusted mean (95% CI)	Reference	−682.99 (−6755.19 to 5389.21)	−2617.69 (−8734.08 to 3498.69)	−1966.74 (−8467.37 to 4533.90)	−4731.53 (−11,781.11 to 2318.05)
Coefficient with log-transformed cost	Reference	.05 (−.08 to .17)	.03 (−.10 to .16)	.05 (−.09 to .19)	.05 (−.09 to .20)
Hospital region	Northeast	Midwest	South	West	
Crude mean (95% CI)	Reference	−10,838.02 (−21,662.16 to −13.88)	−14,618.47 (−29,252.85 to 15.91)	−4290.87 (−16,038.17 to 7456.44)	
Adjusted mean (95% CI)	Reference	−9724.80 (−17,541.98 to −1907.62)	−17,886.82 (−26,047.01 to −9726.62)	−6860.39 (−16,329.63 to 2608.86)	
Coefficient with log-transformed cost	Reference	−.12 (−.25 to .01)	−.37 (−.50 to −.23)	−.10 (−.26 to .06)	
Hospital ownership	Government, nonfederal		Private, nonprofit	Private, investor-owned	
Crude mean (95% CI)	Reference		−14,775.01 (−25,286.98 to −4263.04)	−26,997.43 (−39,459.29 to −14,535.57)	
Adjusted mean (95% CI)	Reference		−7343.78 (−11,318.56 to −3369.00)	−17,018.76 (−24,035.62 to −10,001.91)	
Coefficient with log-transformed cost	Reference		−.16 (−.23 to −.10)	−.30 (−.43 to −.18)	

DISCUSSION

In this analysis, we found poor survival outcomes in patients who underwent AHCT at very low-volume centers, suggesting that lack of experience with the procedure could be associated with worse outcomes. Similar observations for surgical procedures have been reported, with higher volume linked to better clinical outcomes by the Institute of Medicine [14]. Volume-outcome relationships in the medical management of hematologic cancers have also been studied [15-17] Higher patient volumes also have been associated with better clinical outcomes in patients with newly diagnosed MM [8]. AHCT is typically performed early in the treatment paradigm for MM, increasing the importance of our findings in the era of rapidly evolving therapy and improving overall survival outcomes for MM patients.

Our analysis included 8,143 patients over 10 years in the NIS database, which represents an estimated 40,000 patients in US hospitals. The Center for International Blood and Marrow Transplant Research (CIBMTR) collects actual data on all AHCTs performed and has records on 39,691 patients who underwent autologous transplantation in the same period as our study, suggesting that our estimates of patient volumes are valid [6]. In addition, we saw a trend toward decreasing in-hospital mortality over the past decade for patients with MM who underwent AHCT, consistent with the results published in the CIBMTR's 2016 report. Our evaluation of the NIS data showed that survival after AHCT for MM was independent of sociodemographic and geographic factors, comorbidities, and hospital characteristics. We also found that patients who underwent AHCT in a public nonfederal hospital had higher costs and worse mortality outcomes compared with those who did so in a private nonprofit hospital. Finally, we observed regional differences in costs of care, with higher costs of hospitalization in the Northeast compared with the South.

Our study has several limitations. The NIS database contains only inpatient data, and thus we had no information on outcomes after discharge from the hospital. In-hospital mortality might not completely reflect AHCT success rate and can only be considered as a surrogate. In addition, in-hospital mortality does not include those patients who were discharged to hospice. Furthermore, including only inpatient data also could have altered a center's volume figures. Our observations could be further explored using a database specialized in bone marrow transplantation, such as CIBMTR, or other oncology databases, such as SEER. In our study, the patients with MM who underwent AHCT in very low-volume hospitals had significantly higher mortality compared with their peers in higher-volume hospitals, but patients who underwent AHCT in high-volume hospitals had higher mortality than those who did so in low-intermediate- and intermediate-volume hospitals. The precise reasons for this observation are not clear but may be related to a higher-risk patient pool in tertiary care hospitals and major cancer centers that would not be captured by the Charlson Comorbidity Index. MM-specific risk stratification based on cytogenetics or undergoing previous AHCT are not available in the NIS database. Other factors, including hospital ownership, hospital region, patient comorbidity score, and patient socioeconomic background, could have contributed to

the distorted distribution of crude mortality. Even though crude mortality was not statistically different between Q1 and Q5 due to the sample size of Q1, when adjusted for different factors in our regression model, the adjusted OR for mortality does show a statistically and clinically significant difference. With covariate adjustment, the difference between Q2 and Q5 was also minimized, which is consistent with our hypothesis. Therefore, we believe that adjusted OR is more representative of actual differences. Of note, the Charlson Comorbidity Index is not the best available comorbidity assessment tool. In real-world clinical practice, we prefer to use the Hematopoietic Cell Transplantation-Specific Comorbidity Index (HCT-CI) [18]. However, the NIS database does not contain the laboratory and diagnostic test results needed to calculate HCT-CI.

In summary, our analyses suggest significant real-world disparity in AHCT care for patients with MM nationwide, with direct impacts on costs and outcomes. In an era of rapidly evolving therapy for MM, these data suggest that further improvements in patient survival are possible by seeking care at higher-volume centers that perform at least 3 AHCTs for MM annually, because Q1 hospitals that perform $\leq$2 unweighted AHCTs annually in patients with MM do significantly worse in terms of mortality.

ACKNOWLEDGMENTS

Preliminary results were presented at the American Society of Hematology's annual meeting, Atlanta, Georgia, December 9-15, 2017.

Financial disclosure: Nothing to report.

Conflict of interest statement: There are no conflicts of interest to report.

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