



ORIGINAL STUDIES

Hospital teaching status and transcatheter aortic valve replacement outcomes in the United States: Analysis of the national inpatient sample

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Abstract

Background: Evidence suggests that medical service offerings vary by hospital teaching status. However, little is known about how these translate to patient outcomes. We therefore sought to evaluate this gap in knowledge in patients undergoing Transcatheter aortic valve replacement (TAVR) in the United States.

Methods: This study was conducted using the National Inpatient Sample (NIS) in the United States from 2011 to 2014. Teaching status was classified, as teaching vs. nonteaching and end-points were clinical outcomes, length of stay and cost. Procedure-related complications were identified via ICD-9 coding and analysis was performed via mixed effect model.

Results: An estimated 33,790 TAVR procedures were performed in the U.S between 2011 and 2014, out of which 89.3% were in teaching hospitals. Mean (SD) age was 81.4 (8.5) and 47% were females. There was no significant difference between teaching versus nonteaching hospitals in regards to the primary outcome of in-hospital mortality and secondary outcomes of several cardiovascular and other end points except for a high rates of acute kidney injury (AKI) (OR: 1.34 [95% CI, 1.04–1.72]) and lower rate for use of mechanical circulatory support devices in teaching vs. nonteaching centers. The mean length of stay was significantly higher in teaching hospitals (7.7 days) vs. nonteaching hospitals (6.8 days) ($P = 0.002$) and so was the median cost of hospitalization (USD 50,814 vs. USD 48,787, $P = 0.02$) for teaching vs. nonteaching centers.

Conclusion: Most TAVR related short-term outcomes including all cause in-hospital mortality are about the same in teaching and nonteaching hospitals. However, AKI, length of hospital stay and TAVR related cost were significantly higher in teaching than nonteaching hospitals. There was more use of mechanical circulatory support in nonteaching than teaching hospitals.

KEYWORDS

aortic stenosis, hospital teaching status, transcatheter aortic valve replacement

1 | INTRODUCTION

Transcatheter aortic valve replacement (TAVR) has become the standard of care in appropriate high and intermediate surgical risk patients with severe symptomatic aortic stenosis [1]. Since its advent, the

volume of patients undergoing TAVR has been increasing with concomitant improvement in outcomes and in-hospital mortality [2]. However, certain complications such as vascular, cardiac, neurological, respiratory, renal, and even death remain [3]. In a concerted attempt to mitigate complications and improve outcomes, a multidisciplinary heart

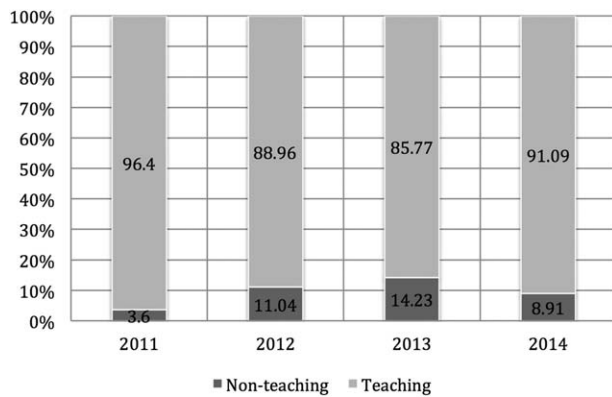


FIGURE 1 Trend in percentage of TAVR procedures performed per year between nonteaching and teaching hospitals (2011–2014). TAVR, Transcatheter aortic valve replacement

TABLE 1 Baseline characteristics of patients hospitalized for transcatheter aortic valve replacement, stratified by hospital teaching status

	Total	Nonteaching	Teaching	P value
Unweighted No. (%)	6,778 (100)	727 (10.7)	6,051 (89.3)	
Weighted No. (%)	33,790 (100)	3,621 (10.7)	30,169 (89.3)	
Age, mean (SD)	81.4 (8.5)	81.5 (8.3)	81.4 (8.6)	0.59
Female, %	46.1	44.8	46.1	0.49
Race, %				
White	87.4	92.0	86.8	
Black	4.1	2.5	4.4	
Hispanic	3.4	1.3	3.6	<0.001
Asia	1.1	1.3	1.0	
Others	4.1	2.9	4.2	
Obesity, %	14.6	13.5	14.7	0.37
Diabetes, %	34.9	33.8	35.0	0.55
PVD, %	28.2	23.5	28.7	0.003
Hypertension, %	79.6	76.6	79.9	0.04
Congestive heart failure, %	12.8	11.4	13.0	0.24
Chronic lung disease, %	32.6	29.0	33.0	0.03
Renal failure, %	36.7	39.8	36.3	0.06
Liver disease, %	2.7	2.1	2.8	0.26
Cerebrovascular disease, %	10.0	9.9	10.1	0.86
Rheumatologic disease, %	4.8	4.8	4.8	0.98
Elixhauser comorbidity index, %				
0–1	9.6	12.4	9.2	
2–3	37.6	39.6	37.4	0.004
≥4	52.8	48.0	53.4	
Median household income, %				
1 st quartile	20.7	22.0	20.6	
2 nd quartile	24.9	31.5	24.1	<0.001
3 rd quartile	25.5	22.7	25.9	
4 th quartile	28.9	23.8	29.5	
Hospital bed size, %				
Small	4.3	12.8	3.3	
Medium	15.5	23.5	14.5	<0.001
Large	80.2	63.7	82.2	
Hospital region, %				
Northeast	25.7	13.9	27.1	
Midwest	22.3	25.6	22.0	<0.001
South	34.4	41.1	33.6	
West	17.6	19.4	17.3	

PVD, Peripheral vascular disease; TAVR, Transcatheter aortic valve replacement.

team approach mainly comprising dedicated invasive and noninvasive cardiologists and cardiac surgeons in the establishment of a structural heart disease interventional program has been proposed [4]. The large majority of such programs initially emerged in teaching centers and a few in nonteaching centers.

In-hospital mortality and rates of complications post TAVR were compared in teaching vs. nonteaching U.S. centers in a prior study that reported a lower rate of in-hospital complications in teaching vs. nonteaching centers (42% vs. 50% respectively, $P < 0.001$) [5]. However, these outcomes reflect only one-year data from 2012 when only very few nonteaching centers had TAVR programs. We sought to explore the evolution of this important theme in a more comprehensive four-year TAVR outcome analysis using data from the NIS registry (2011 to 2014).

2 | METHODS

2.1 | Data source

Study was conducted using the NIS of the Health Care Utilization Project (HCUP). Details of the design and description of the NIS is available online (<https://www.hcup-us.ahrq.gov/nisoverview.jsp>). In brief, NIS is the largest national database representative of all hospital discharges in the United States since 1998. It is a 20% stratified sampling of discharges from U.S. community hospitals, excluding rehabilitation and long-term acute care hospitals. Each year, over 7 million hospital stays are sampled nationwide which, when weighted, estimates more than 35 million hospitalizations per year.

2.2 | Patient population

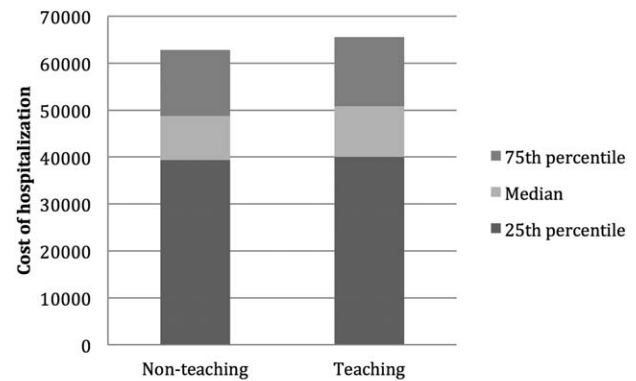
Our study utilizes information on adult patients (age ≥ 18 years) who underwent TAVR across the United States between 2011 and 2014. Only patients who underwent endovascular (i.e. trans-femoral or trans-aortic) approach were included. Patients who underwent the transapical route were excluded due to available evidence indicating a significant difference in the pattern and rate of procedure-related outcomes compared to the transfemoral route [6–8]. In addition, recent evidence from the STS/ACC TAVR registry indicates a declining trend in the use of the transapical approach [9]. Patients were identified using International Classification of Diseases-Ninth Revision, Clinical Modification (ICD-9-CM) procedure code 35.05. Patients were then classified into 2 major groups based on the teaching status as teaching and nonteaching centers. Baseline characteristics and postprocedure outcomes were compared between the two groups.

2.3 | Covariates

Data on patient and hospital-level characteristics were provided for each patient in the NIS. However, identifiable variables were not included in order to preserve both patient and hospital privacy. Patient-level factors including demographics, diagnoses, co-morbidities, in-hospital procedures, disposition and so forth, as well as hospital level factors including bed-size, location, total number of hospitalizations and so forth were available via the NIS database

2.4 | Endpoints

The primary endpoint was in-hospital mortality defined as death at any time during the index hospitalization; secondary endpoints were post TAVR complications including acute myocardial infarction, neurologic complications, acute kidney injury, pacemaker placement, mechanical circulatory support, cardiac complications, vascular complications, hemorrhage requiring transfusion, sepsis, post-op venous thromboembolism, respiratory complications and nonroutine discharge. In addition, our study also examined the length of hospital stay and hospital cost. As recommended by HCUP, the cost of hospitalization was indirectly estimated from the hospital charge that was reported. Information on cost was obtained from the hospital accounting reports collected by the Centers for Medicare and Medicaid Services (CMS) and these were



Values (USD) for Figure 2.

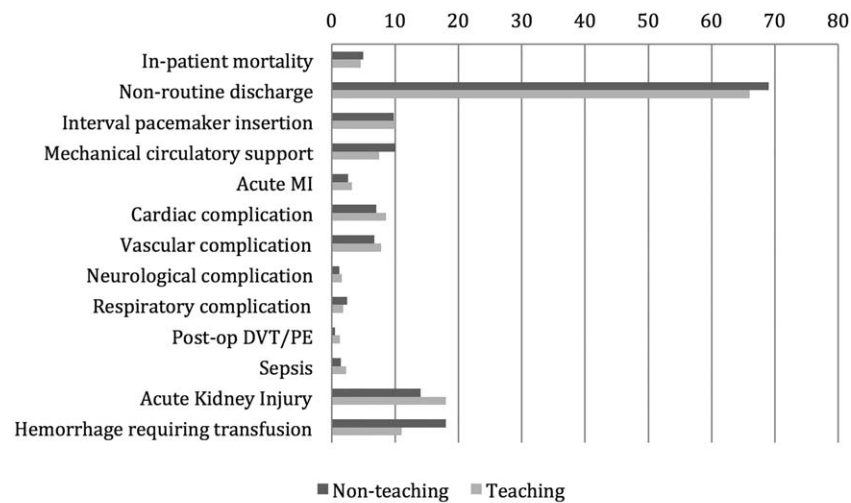
	Non-teaching	Teaching
25th percentile	39341	40024
Median	48787	50814
75th percentile	62796	65552

FIGURE 2 Cost of hospitalization for TAVR between hospital teaching status (p for difference = 0.02). USD, United States dollars

used to generate hospital-specific cost-to-charge ratio that were applied to the hospital charge in order to estimate the cost.

2.5 | Statistical analysis

Using the hospital-level trend (or discharge) weight provided for the NIS, we estimated national estimates including sum, rates and measure of central tendency. Comorbidity burden per hospitalization was quantified via the Elixhauser comorbidity index. To compare baseline patient- and hospital-level characteristics between nonteaching and teaching hospital, we used chi-square test for categorical variables, unpaired t-test for normally distributed continuous variables, and Wilcoxon rank-sum test for continuous variables with skewed distribution. Thereafter, we compared procedure-related outcomes between hospital teaching types using mixed effect models. This model enabled us to account for the potential correlation of observations within each hospital. As patient-level factors are nested within hospital-level factors, we built hierarchical model with unique hospital identification number as random effect in the model. Patient-level covariates including age, gender, Elixhauser comorbidity index, median household income, insurance status/expected payer, weekend admission; as well as hospital-level covariates including hospital bed size, hospital region and hospital location; and year of data collection were adjusted for in a multivariable analysis. Difference in cost and length of stay was evaluated via linear mixed model while other outcomes were evaluated via logistic mixed effect model. We performed complete case analysis using only observations with nonmissing values for all the variables involved in the analyses, and analyses were performed using STATA 14 (StataCorp, College Station, Texas) with level of significance set at 0.05.



Values for figure 3

	Non-teaching	Teaching
In-patient mortality	4.94	4.59
Non-routine discharge	69	66
Interval pacemaker insertion	9.8	10
Mechanical circulatory support	10	7.5
Acute MI	2.6	3.2
Cardiac complication	7	8.6
Vascular complication	6.7	7.8
Neurological complication	1.2	1.6
Respiratory complication	2.4	1.8
Post-op DVT/PE	0.47	1.3
Sepsis	1.4	2.3
Acute Kidney Injury	14	18
Hemorrhage requiring transfusion	18	11

FIGURE 3 Rates (%) of TAVR-associated complications. Acute MI, Acute Myocardial infarction; DVT/PE, Deep vein thrombosis/Pulmonary embolism

3 | RESULTS

From 2011 to 2014 a total of 33,790 transfemoral and transaortic TAVR procedures were performed in the United States. The overwhelming majority of TAVR procedures were performed in teaching centers (89.3%) (Figure 1). There was a steady increase in the proportion of TAVR volumes in nonteaching hospitals from 2011 to 2013 but a slight decline from 2013 to 2014. There was no significant difference in the mean age or gender distribution between teaching and nonteaching hospitals. More patients had Elixhauser comorbidity index ≥ 4 (53.4% in teaching centers vs. 48.0% in nonteaching centers) (Table 1). There was no significant difference in the rates of primary outcome (all cause in-hospital mortality) (OR 1.03 and (95% CI 0.70, 1.47) between teaching vs. nonteaching hospitals. The mean lengths of hospital stay (7.7 days vs. 6.7 days ($P=0.002$)) and cost of hospitalizations (USD 50,814 vs. USD 48,787 ($P=0.02$)) were higher for teaching centers

versus nonteaching centers (Figure 2). When we evaluated secondary endpoints, use of mechanical circulatory support was significantly lower in teaching hospital (OR 0.69 (95% CI 0.47, 0.99)) while rate of acute kidney injuries (AKI) was higher in teaching centers OR 1.34 (95% CI 1.04, 1.72). However, there was no significant difference between the two hospital teaching statuses for all other secondary endpoints (Figures 3 and 4).

4 | DISCUSSION

The salient findings of our study may be summarized as follows: I) The primary outcome of all cause in-hospital mortality post TAVR was not significantly different between teaching and nonteaching hospitals, II) The secondary outcomes of post TAVR complications including acute myocardial infarction, neurologic complications, pacemaker placement, cardiac complications, vascular complications, hemorrhage requiring

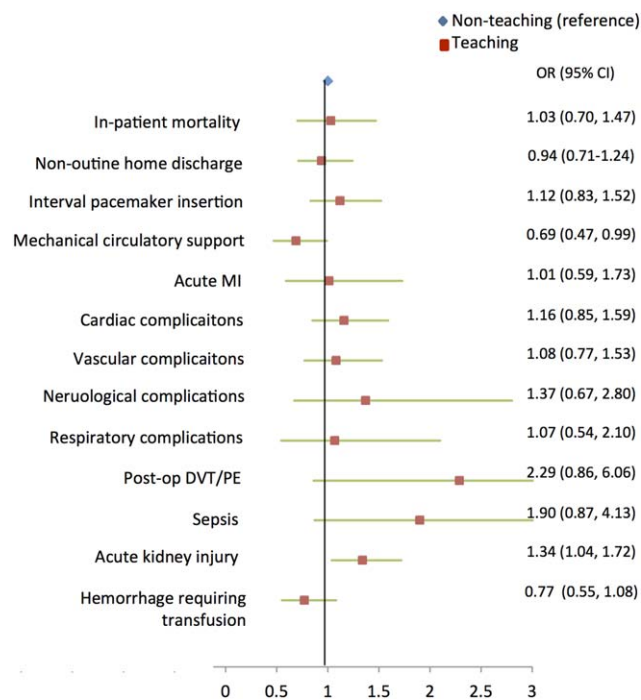


FIGURE 4 Comparing TAVR-associated complications between teaching and nonteaching hospital. DVT/PE, Deep vein thrombosis/Pulmonary embolism [Color figure can be viewed at wileyonlinelibrary.com]

transfusion, sepsis, post-op venous thromboembolism, respiratory complications and nonroutine discharge post TAVR did not differ significantly between teaching and nonteaching hospitals. III) Teaching hospital status was associated with higher risk of AKI and lower rates for use of mechanical circulatory support. IV) In teaching hospitals mean length of stay and median cost of hospitalization were significantly higher compared with nonteaching hospitals.

Our findings are consistent with the findings of a previous study by Pant et al, who analyzed 7,405 TAVR procedures from the NIS performed in 2012 and also found no significant difference in all-cause in-hospital mortality. However, unlike our study, the previous study from 2012 showed lower rates of TAVR related complications in teaching vs. nonteaching hospitals in the United States. Our study suggests that over the years, the difference in the rates of major TAVR related complications between teaching and nonteaching hospitals has narrowed considerably. This may be possibly explained by an increase in procedural volumes and operator expertise with ensuing reductions in complication rates, in nonteaching hospitals. This contrasting observation, deviating significantly from a prior report is a notable addition to the existing body of literature. Currently available data on the impact of teaching status on in-hospital outcomes after interventional cardiology procedures are limited. Our data demonstrated that the majority of TAVR patients were seen in teaching hospitals, consistent with a higher volume of procedures performed in these institutions.

Operator and hospital volumes have been shown to be inversely related to complications post TAVR as indicated by a previous analyses of in-hospital outcomes [10]. However, the Centers of Medicare & Medicaid Services established specific procedural volume requirements

that hospitals with and without TAVR experience must meet. Specifically, the initiation of a TAVR program requires ≥ 50 aortic valve replacements, ≥ 1000 catheterizations and ≥ 400 percutaneous coronary interventions in the year prior to TAVR initiation [11]. Therefore, teaching and nonteaching hospitals are now expected to have similar case volumes and experience with interventional cardiology and cardiothoracic surgery procedures in order to begin and continue a TAVR program.

Differences not only in volume but also implementation of guidelines and appropriate use criteria can positively impact patient-related outcomes. Registry data suggest variations in performance measures in teaching vs. nonteaching hospitals with greater adherence to standard guidelines for cardiovascular diseases, such as coronary artery disease and heart failure in teaching vs. nonteaching hospitals [12,13]. However, recent registry data suggest no significant association between hospital teaching status and adherence to guidelines among hospitals enrolled in the “Get With The Guidelines”-Heart Failure program [14]. These findings may be due to gradually increasing emphasis on implementation of protocolized guidelines, metrics and performance indicators for evaluation of comprehensive care delivery.

In addition to educational and research responsibilities, teaching hospitals are typically located in urban settings, serving populations with a lower socioeconomic and educational status and provide care as tertiary referral centers to patients with complicated cardiac conditions and multiple comorbidities. Although, we did not identify significant differences in the demographic characteristics or the comorbidity burden, our results should be interpreted with caution as many potential confounders may be unmeasured and missing.

The lack of difference in mortality between teaching and nonteaching hospitals was demonstrated in a meta-analysis of 132 observational cohort studies. However, the authors observed large between-study heterogeneity that precluded meaningful conclusion about other nonfatal outcomes [15]. Therefore, based on the evidence summarized above, the focus should be shifted away from identification of differences in mortality and other hard cardiovascular outcomes between teaching and nonteaching hospitals but instead concentrated toward implementation of guidelines, appropriate use criteria, utilization of standardized quality measures and reduction of TAVR-related health care expenditures. Most importantly, although teaching in a healthcare facility does not seem to directly improve short-term patient outcomes, it is an integral part of cardiology, improves the level of knowledge and experience of future physicians in both teaching and nonteaching hospitals and as such should be strongly encouraged and supported.

Potential limitations of our study should also be considered. First, due to the observational nature of the study, we cannot claim a causal link between teaching status and any of the endpoints because other unmeasured covariates may have contributed to this association. However, we limited the potential bias in the associations by adjusting for multiple patient- and hospital-level covariates that might have confounded the associations. Second, our analysis was limited to in-patient data and, hence, we are not able to make any inference about patient outcomes in the immediate postdischarge period that may be related

to in-patient care. Despite these limitations, NIS remains a large, easily accessible dataset that has been widely used to estimate national trends in in-patient outcomes.

5 | CONCLUSION

We found no substantial differences between teaching and nonteaching hospitals in regards to in-hospital mortality and other procedure-related complications post TAVR. However, we identified high rates of post TAVR AKI, longer hospital stay and higher cost of hospitalization in teaching centers. The use of mechanical circulatory support post TAVR was more frequent in nonteaching compared to teaching hospitals.

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