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Mortality, Length of Stay, and Cost Implications of Procedural Bleeding After Percutaneous Interventions Using Large-Bore Catheters

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IMPORTANCE Bleeding complications after percutaneous transcatheter interventions that used large-bore catheters are frequent and associated with high mortality and morbidity.

OBJECTIVE To describe the incidence of bleeding complications among patients undergoing contemporary endovascular interventions involving large-bore catheters and its association with in-hospital mortality, length of stay, and health care cost.

DESIGN, SETTING, AND PARTICIPANTS This retrospective cohort study analyzed all 17 672 patients from the Healthcare Cost and Utilization Project's National Inpatient Sample database who were recorded as having undergone a transcatheter aortic valve replacement (n = 3223), an endovascular aneurysm repair (n = 12 633), or a percutaneous left ventricular assist device implant (n = 1816) between January 1, 2012, and December 31, 2013. *Bleeding complication* was defined as any transfusion, any hemorrhage or hematoma, or the need for percutaneous or surgical intervention to control the bleeding event. Health care costs were determined by multiplying the total charge for each visit by the cost to charge ratios reported for each hospital code in the database. Data were collected from the database on April 29, 2016.

MAIN OUTCOMES AND MEASURES Adjusted association between bleeding complications and mortality was determined by multivariable logistic regression. Length of stay and total health care costs were compared using multivariable linear regression between patients who did and patients who did not have bleeding complications.

RESULTS Bleeding complications occurred in 3128 patients (17.7%) (1984 men and 1144 women, with a mean [SD] age of 75.6 [11.9] years). Bleeding was associated with higher mortality (adjusted odds ratio, 2.70; 95% CI, 2.27-3.22; $P < .001$) and longer hospital stay (adjusted multiplicative difference, 2.14; 95% CI, 2.06-2.16; $P < .001$). Median (interquartile range) total health care costs were $48 663 ($32 620-$71 547) for patients with bleeding complications compared with $29 968 ($21 924-$43 287) for patients without a bleeding complication (adjusted multiplicative difference, 1.55; 95% CI, 1.52-1.59; $P < .001$).

CONCLUSIONS AND RELEVANCE Periprocedural bleeding was common among patients who underwent transcatheter intervention using large-bore catheters and was associated with a statistically significant increase in mortality, length of stay, and cost.

Supplemental content

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Several endovascular techniques involving transcatheter devices have emerged as treatment alternatives for patients with cardiovascular disease, including transcatheter aortic valve replacement (TAVR), endovascular aneurysm repair (EVAR), and percutaneous ventricular assist device (PVAD) implant. These procedures require the use of large-bore catheters, which are intrinsically associated with bleeding complications.[1,2] Comprising a large cohort of consecutive real-world patients, this study describes the prevalence of bleeding complications among patients who underwent contemporary transcatheter therapies that used large-bore catheters and assesses the effects of bleeding complications and transfusions on in-hospital mortality, length of stay, and health care cost.

Key Points

Question What are the incidence of and association with mortality, length of stay, and health care cost of bleeding complications after percutaneous interventions using large-bore catheters?

Findings In this retrospective cohort study of 17 672 consecutive patients who underwent a transcatheter aortic valve replacement, endovascular aneurysm repair, or percutaneous left ventricular assist device implant, 18% experienced bleeding complications. Patients with bleeding complications (compared with those without) had increased in-hospital mortality, length of stay, and health care cost.

Meaning Bleeding complications after percutaneous interventions using large-bore catheters are common and associated with poor prognosis and increased cost.

Methods

Study Cohort

We included all patients in the Healthcare Cost and Utilization Project's National Inpatient Sample (NIS) database who were documented as having undergone TAVR, EVAR, or a PVAD implant between January 1, 2012, and December 31, 2013. The NIS is a sample of all discharges from hospitals participating in the Healthcare Cost and Utilization Project, which includes more than 7 million inpatient stays per year and has a sampling frame that covers more than 95% of the US population. No institutional review board or patient informed consent approval was requested, granted, or waived for this study because the NIS database contained no patient identifying information. Data were collected from the database on April 29, 2016.

Definitions

Bleeding complication was defined as any transfusion (*International Classification of Diseases, Ninth Revision* [*ICD-9*] procedure codes 99.00-99.09 or *ICD-9* diagnosis code V58.2, E873.0, E934.7, or E876.0), any hemorrhage or hematoma (*ICD-9* diagnosis code 998.11 or 998.12), or the need for percutaneous or surgical intervention to control the bleeding event (*ICD-9* procedure code 34.09, 21.01-21.09, 42.33, 45.43, 44.44, 54.19, 39.41, 60.94, 6.02, 34.03, 54.12, 49.95, or 57.93). For patients who received multiple transfusions, transfusion event count was determined by the total number of procedure codes entered for blood product transfusions. Health care costs were derived by multiplying the total charge for each visit by the cost to charge ratios reported for each hospital code in the NIS database.

Objectives

We sought to (1) determine the incidence of bleeding complications among patients who underwent transcatheter interventions using large-bore catheters and (2) study the association of bleeding complications (more precisely, transfusion) with in-hospital mortality risk, length of stay, and overall health care cost.

Statistical Analysis

We compared variables between patients with and patients without bleeding complications using the χ^2 test (categorical) or unpaired, 2-tailed *t* test (continuous). A 2-sided $P < .05$ was considered statistically significant. Multivariable comparisons of patients with and patients without bleeding complications as well as per number of documented transfusion events were performed by logistic regression (mortality) and linear regression (log-transformed total health care costs and length of stay) and were adjusted for the covariates listed in eTable 1 in the Supplement, with treating center as a random effect. To determine whether bleeding complications affected the outcomes differently depending on the procedure (TAVR, EVAR, or PVAD), we included interaction terms in the statistical models. Sensitivity analyses were conducted using a propensity score derived from the variables in eTable 1 in the Supplement.

Results

Study Cohort

Between January 1, 2012, and December 31, 2013, there were 17 672 patients who underwent TAVR (n = 3223), EVAR (n = 12 633), or PVAD implant (n = 1816). Bleeding complications occurred in 3128 patients (17.7%) (1984 men and 1144 women, with a mean [SD] age of 75.6 [11.9] years), 2525 (80.7%) of whom required at least 1 transfusion (**Figure**). The incidence of bleeding was 30.2% (972 of 3223) among patients who underwent TAVR, 13.4% (1687 of 12 633) among patients who underwent EVAR, and 25.8% (469 of 1816) among patients who had a PVAD implant. Among patients who received a transfusion, the proportion of patients who had more than 1 transfusion event was 16.6% (130 of 782) among patients who underwent TAVR, 20.1% (288 of 1435) among patients who underwent EVAR, and 27.6% (85 of 308) among patients who had a PVAD implant.

In-Hospital Mortality, Length of Stay, and Health Care Cost

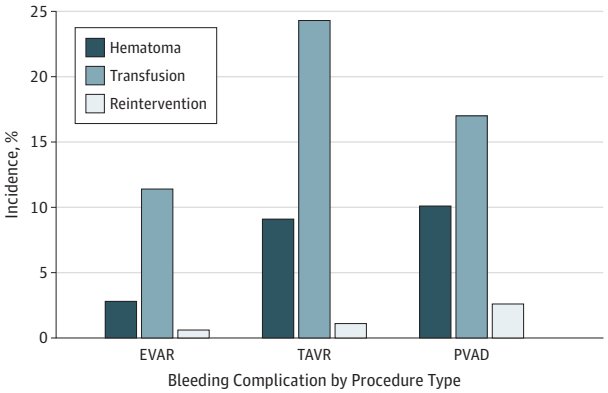
Data on in-hospital mortality were available for 17 670 of 17 672 patients (99.9%) in the cohort. For the entire cohort, 993 of 17 670 patients (5.6%) died in the hospital (402 of 3128 patients [12.9%] with vs 591 of 14 542 patients [4.1%] without a bleeding event; $P < .001$); the median (interquartile range [IQR])

length of stay was 7 (3-12) days for patients with a bleeding complication and 2 (1-5) days for patients without a bleeding complication; $P < .001$; and the median (IQR) health care costs were $48 663 ($32 620-$71 547) for patients with a bleeding complication and $29 968 ($21 924-$43 287) for patients without a bleeding complication; $P < .001$. When stratified by procedure type, unadjusted and adjusted in-hospital mortality, length of stay, and health care costs were considerably greater for patients with than for patients without a bleeding complication (**Table 1**; eTable 2 in the Supplement).

Impact of Transfusion

Receiving 1 or more transfusions was associated with increased in-hospital mortality (adjusted odds ratio, 1.92; 95% CI, 1.63-2.21; $P < .001$), length of stay (adjusted multiplicative difference, 2.10; 95% CI, 11.96-2.25; $P < .001$), and health care cost (adjusted multiplicative difference, 1.72; 95% CI, 1.64-1.81; $P < .001$), compared with receiving no transfusion. The risk of dying (22.02% to 38.56% vs 8.21%), length of stay (median [IQR], 8 [2-15] to 13 [7-15] days vs 6 [3-11] days), and health care cost (median [IQR], $55 874 [$37 706-$83 460] to $76 855 [$61 877-$138 596] vs $45 498 [$31 100-$64 387]) were all higher for patients who had more than 1 transfusion event than for patients who had only 1 documented transfusion event (**Table 2**).

Figure. Incidence of Bleeding Complications



Among patients who had endovascular aneurysm repair (EVAR), the incidence of hematoma and/or hemorrhage without the need for blood transfusion or reintervention was 2.8%, the incidence of blood transfusion was 11.4%, and the incidence of reintervention was 0.6%. Among patients who underwent transcatheter aortic valve replacement (TAVR), the incidence rates were 9.1%, 24.3%, and 1.1%, respectively. The incidence rates for patients who had percutaneous ventricular assist device (PVAD) implant were 10.1%, 17%, and 2.6%, respectively.

Discussion

To our knowledge, this study represents the largest study of the effect of bleeding complications after contemporary transcatheter therapies that used large-bore catheters. The principal findings were as follows: (1) Bleeding complications were common, occurring in almost 1 of 5 patients who underwent transcatheter therapies; (2) bleeding complications were associated with a more than 2-fold higher adjusted risk of dying, longer hospitalization, and higher health care cost; and (3) the mortality risk, duration of hospital stay, and costs increased as the number of transfusions increased.

This study shows that almost 1 in 5 patients who had a transcatheter intervention using a large-bore catheter had a periprocedural bleeding complication, with approximately 1 in 7 patients requiring at least 1 transfusion, a finding consistent with findings in previous (smaller) studies.[4] One may argue that improvement in transcatheter technology over time would reduce the risk of bleeding.[5,6] However, the widening adoption of percutaneous devices, often being used by less experienced operators, is likely to counterbalance the expected benefits of technological improvements.[4,7,8]

Table 1. Unadjusted and Adjusted Comparisons Between Patients With vs Patients Without Bleeding Stratified by Procedure Type

Outcome by Procedure Type	Bleeding Complication		*P* Value	OR or Mean Multiplicative Difference (95% CI)	*P* Value for Interaction[a]
	Patients With	Patients Without			
In-hospital mortality, No./total No. (%)				OR	
EVAR	167/1687 (9.9)	111/10 945 (1.0)	<.001	9.628 (7.465-12.416)	
TAVR	69/972 (7.1)	81/2251 (3.6)	<.001	1.812 (1.302-2.523)	<.001
PVAD implant	166/469 (35.4)	399/1346 (29.6)	<.001	1.105 (0.847-1.442)	<.001
Length of stay, mean (SD), d[b]				Mean Multiplicative Difference	
EVAR	5 (2-10)	2 (1-3)	<.001	2.443 (2.367-2.521)	
TAVR	8 (5-13)	5 (4-8)	<.001	1.622 (1.556-1.6883)	<.001
PVAD implant	10 (4-18)	6 (2-12)	<.001	1.837 (1.690-1.997)	<.001
Health care cost, mean (95% CI), $[b]				Mean Multiplicative Difference	
EVAR	37 485 (26 731-54 353)	26 549 (20 294-34 689)	<.001	1.633 (1.590-1.679)	
TAVR	56 976 (44 700-75 825)	48 920 (38 030-62 646)	<.001	1.370 (1.323-1.418)	<.001
PVAD implant	79 518 (55 146-134 451)	55 484 (39 317-83 431)	<.001	1.591 (1.492-1.693)	.52

Abbreviations: EVAR, endovascular aneurysm repair; OR, odds ratio; PVAD, percutaneous ventricular assist device; TAVR, transcatheter aortic valve replacement.

[a] Compared with patients who had EVAR.

[b] The estimates for length of stay and health care cost were retransformed from their effect on the log scale back to their original scale of days and dollars by bootstrapping Duan smearing estimates[3] to obtain the mean, 95% CI, and *P* value.

Table 2. Adjusted Adverse Events Risk by Number of Transfusion Events

No. of Transfusion Events	In-Hospital Mortality, No./Total No. (%)	Adjusted Odds Ratio (95% CI)	*P* Value[a]	*P* Value[b]
No transfusion	689/15 145 (4.55)	1 [Reference]		<.001
1 Transfusion	166/2022 (8.21)	1.701 (1.358-2.131)	<.001	
2 Transfusions	72/327 (22.02)	4.989 (3.413-7.292)	<.001	<.001
3 Transfusions	59/153 (38.56)	16.044 (10.092-25.508)	<.001	<.001
≥4 Transfusions	7/23 (30.43)	7.598 (2.5-23.093)	.003	.009
	Length of Stay, Median (IQR), d[c]	**Adjusted Multiplicative Difference (95% CI)**		
No transfusion	2 (1-5)	1 [Reference]		<.001
1 Transfusion	6 (3-11)	2.036 (1.974-2.095)	<.001	
2 Transfusions	8 (4-14)	2.289 (2.119-2.461)	<.001	<.001
3 Transfusions	8 (2-15)	2.030 (1.753-2.332)	<.001	.009
≥4 Transfusions	13 (7-15)	3.119 (2.296-4.100)	.002	.009
	Health Care Cost, Median (IQR), $[c]	**Adjusted Multiplicative Difference (95% CI)**		
No transfusion	30 483 (22 129-44 703)	1 [Reference]		<.001
1 Transfusion	45 498 (31 100-64 387)	1.437 (1.402-1.475)	<.001	
2 Transfusions	55 874 (37 706-83 460)	1.679 (1.582-1.781)	<.001	<.001
3 Transfusions	64 403 (40 842-91 099)	1.909 (1.7344-2.093)	<.001	<.001
≥4 Transfusions	76 855 (61 877-138 596)	2.561 (2.115-3.077)	<.001	.001

Abbreviation: IQR, interquartile range.

[a] Compared with no transfusion.

[b] Compared with 1 transfusion.

[c] The estimates for length of stay and health care cost were retransformed from their impact on the log scale back to their original scale of days and dollars by bootstrapping Duan smearing estimates[3] to obtain the adjusted multiplicative difference, 95% CI, and *P* value.

The occurrence of bleeding complications was associated with an adjusted risk of in-hospital mortality that was more than double compared with no bleeding complications, which is consistent with previous reports.[4,9] Patients who had a bleeding complication were hospitalized more than 3 times as long as patients who did not have a bleeding complication, with health care costs being almost twice as high. Furthermore, having more than 1 transfusion considerably affected in-hospital survival, length of stay, and cost, underscoring the detrimental effect of more severe bleeding that has been described in several clinical settings, including the intensive care unit and surgical theater.[4,10-12]

Of note, the mortality risk was relatively low for patients who underwent TAVR or EVAR and did not experience bleeding, but the risk increased dramatically if a bleeding complication occurred, particularly for patients who underwent EVAR. Better preventive and bleeding avoidance strategies are needed if the full benefits of these new techniques are to be achieved.[5,13-15]

Limitations

The NIS database does not contain detailed information on the exact nature of the bleeding, such as its origin or the magnitude of the reduction in plasma hemoglobin level, or on the specific device type or profile used, which precludes us from performing a more detailed analysis. In addition, a single transfusion could require multiple units of bloods, which may lead to an underestimation of the effect of blood transfusions on the variables evaluated. Despite these limitations, the present study consists of a large, consecutive, and unselected population of all-comers patients, which provides considerable statistical power to evaluate the effect of bleeding events on hard end points, such as mortality, length of stay, and health care cost.

Conclusions

Procedural bleeding complications were common among patients who underwent transcatheter interventions that used large-bore catheters and were associated with a significant increase in mortality, length of stay, and health care cost. Given the growing adoption of these procedures, bleeding avoidance strategies are needed, including earlier detection and better management of bleeding events.

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