Impact of Aortic Stenosis on Postoperative Outcomes After Noncardiac Surgeries

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Background—Preoperative management of patients with aortic stenosis (AS) who need noncardiac surgery (NCS) remains controversial. We sought to determine the impact of AS on the postoperative outcomes after NCS.

Methods and Results—Patients undergoing NCS with moderate AS (valve area: 1.0–1.5 cm²) or severe AS (valve area: <1.0 cm²) were identified using the surgical and the echocardiographic databases. Using propensity score analysis, we obtained 4 matched control patients without AS for each patient with AS undergoing NCS. The propensity score matching used the 6 revised cardiac risk index criteria, in addition to age and sex. Primary outcome was a composite of 30-day mortality and postoperative myocardial infarction. We matched 634 patients with AS undergoing NCS to 2536 controls. There were 244 patients with severe AS and 390 patients with moderate AS. Thirty-day mortality was 2.1% for AS patients compared with 1.0% in non-AS controls (P=0.036). Postoperative myocardial infarction was more frequent in patients with AS compared with controls (3.0% versus 1.1%; P=0.001). Combined primary outcome was significantly worse for both moderate and severe AS patients compared with respective controls (4.4% versus 1.7%; P=0.002; and 5.7% versus 2.7%; P=0.02, respectively). High-risk surgery, symptomatic severe AS, coexisting mitral regurgitation, and preexisting coronary disease were significant predictors of primary outcome in patients with AS.

Conclusion—Presence of AS adversely affects postoperative outcomes among patients undergoing NCS, evidenced by a higher 30-day mortality and postoperative myocardial infarction after NCS. (Circ Cardiovasc Qual Outcomes. 2013;6:193-200.)

Key Words: aortic stenosis ◼ noncardiac surgery ◼ postoperative mortality ◼ postoperative myocardial infarction ◼ propensity score

The incidence of noncardiac surgeries (NCSs) in patients with preexisting aortic stenosis (AS) has significantly increased over the past few decades.1,2 Aortic valve replacement is sometimes not performed before the planned NCS. This may be attributable to asymptomatic cardiac status of the patient, patient refusal, relative urgency of the NCS, prohibitive risk arising from the cardiac surgery, or multiple patient comorbidities.

Current American College of Cardiology/American Heart Association guidelines have identified severe AS as the greatest risk for NCS.2 It has been recommended that in patients with severe symptomatic AS, elective NCS should be cancelled or postponed for definitive correction of AS, before intended NCS.2 Although the current guidelines recommend significant caution before elective NCS in patients with severe AS, especially with symptomatic AS, the evidence behind this recommendation is limited. The optimal management of asymptomatic patients with severe AS is even more controversial, with few available data to determine the best clinical approach. There have been only a few observational studies that have examined the impact of severe AS on the postoperative outcomes in patients undergoing NCS.3-7 Most of these were small observational studies with conflicting results. Moreover, recent advances in anesthesia for high-risk patients, intraoperative monitoring, and postoperative management techniques limit the relevance of these studies to contemporary practice.

With this background, we aimed to compare the postoperative outcomes after nonemergent NCS in patients with AS and patients without AS.

Methods

Patient Population
All adult patients undergoing elective NCS at the Cleveland Clinic, Cleveland, OH, between January 1998 and January 2009 were considered for inclusion. The patient population was derived from those attending the Internal Medicine Preoperative Assessment and Consultation clinic at the Cleveland Clinic before the planned NCS.
WHAT IS KNOWN

- Patients with severe, asymptomatic aortic stenosis (AS) are identified as being at elevated risk for noncardiac surgeries by the current American College of Cardiology/American Heart Association guidelines.
- The recommendation is based on the results of a few small observational studies that have nonuniformly demonstrated adverse outcomes in patients with AS undergoing noncardiac surgeries.

WHAT THE STUDY ADDS

- Using contemporary data from a large tertiary-care institution, we found a significantly higher incidence of short-term mortality or postoperative myocardial infarction in patients with moderate and severe AS groups compared with respective controls.
- High-risk surgery, symptomatic severe AS, coexisting mitral regurgitation, and preexisting coronary disease were identified as significant factors associated with primary outcome in patients with AS.
- Our study serves as a springboard for future studies to investigate the impact of correction of AS before the intended high- or intermediate-risk noncardiac surgery, especially if the surgery is elective.

Outcomes

The primary outcome was a composite of 30-day mortality and myocardial infarction (MI). Secondary outcomes studied included 30-day mortality, long-term mortality, MI, heart failure, stroke, and length of stay. Postoperative MI was defined as rise of cardiac biomarkers (creatine kinase-MB >8.8 ng/mL or troponin T >0.1 ng/mL) in the appropriate clinical context of chest pain or anginal equivalent and electrocardiographic changes. Postoperative heart failure was identified based on clinical signs and symptoms along with chest radiography indicative of pulmonary edema. Stroke was defined as new-onset focal neurological symptoms confirmed by imaging studies (computed tomography or magnetic resonance imaging of the brain). Long-term mortality was assessed using electronic medical record review and Social Security Death Index.

Statistical Analysis

The continuous variables were expressed as means and the categorical variables as proportions. Student t test was used to compare continuous variables, and χ² test was used to compare categorical variables between the 2 study groups. Kaplan-Meier survival analysis was used to compare the long-term mortality between the 2 groups.

A multivariable logistic regression analysis with backward stepwise elimination of covariates was performed to determine independent predictors of primary outcome in patients with AS. We performed multivariable linear regression analysis with length of stay as dependent variable to determine significant predictors of length of hospital stay in patients with AS. Statistical analysis was performed using the statistical software Stata v. 12.0 (Stata Corporation, College Station, TX).

Results

Patient Characteristics

Of all the patients undergoing NCS at the Cleveland Clinic from January 1998 and January 2009, we identified 244 patients with severe AS and 390 patients with moderate AS. Of the remaining 7204 patients without any evidence of AS on preoperative echocardiogram, 2536 matched controls were selected using propensity matching as described above. The propensity matching was successful in eliminating the bias arising from differences in baseline characteristics between the 2 groups (Table 1). The baseline characteristics between the 2 groups before and after propensity matching are shown in Table 1.

From the entire study cohort, 29.5% (n=72) of the patients with severe AS reported having typical symptoms of AS, including angina, syncope, and dyspnea. Figure 1 shows the reasons for proceeding with NCS without correcting the severe AS. The most common reason was multiple medical comorbidities (70.8%) or advanced age >80 years (37.5%). The distribution of the surgical procedures in the study population is demonstrated in Table 2. There was no significant difference in the proportion of high-risk surgeries between the propensity-matched groups (Table 1).

Outcomes

The primary outcome was observed in 31 patients (4.9%) with AS, which was significantly higher than that observed in the corresponding control population (2.1%; P<0.001). This difference was seen in postoperative MI as well as 30-day mortality. Thirty-day mortality was 2.1% for AS patients compared with 1.0% in non-AS controls (P=0.036). Postoperative MI was more frequent in patients with AS compared with controls (3.0% versus 1.1%; P=0.001). No significant differences in
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Postoperative heart failure and stroke were observed between the 2 groups. When moderate and severe AS patients were analyzed separately, similar results were found (Table 3). Although the 30-day mortality rate was lower in the severe AS group (1.6%) as compared with the moderate AS group (2.3%), the difference failed to reach statistical significance (P=0.56). In addition, there were no significant differences in the incidence of primary outcome between the elective and the urgent surgery cohorts among patients with moderate or severe AS.

Table 4 gives the postoperative outcomes in the severe AS group stratified by presence or absence of symptoms at the time of preoperative screening compared with the outcomes in the corresponding non-AS population. In comparison with the non-AS group (2.7%), the incidence of primary outcome was significantly higher in the symptomatic severe AS group (8.3%; P=0.007). The difference in primary outcome was largely attributable to the higher incidence of postoperative MI in the symptomatic severe AS group (5.6%) as compared with the non-AS group (1.4%; P=0.009).

Table 5 demonstrates the comparison of hemodynamic parameters between the patients with primary outcome and those without primary outcome, stratified by moderate or severe AS. In the severe AS category, there was a significantly higher incidence of coronary artery disease (71.4%) among patients experiencing primary outcome in comparison with those without the primary outcome (40.4%; P=0.02). In the moderate AS patients with primary outcome, there was a significantly larger proportion of patients with ejection fraction <40% (35.3%) and moderate or severe mitral regurgitation (29.4%) as compared with those without the primary outcome (P<0.001 for both comparisons). Of all patients with moderate

Table 1. Baseline Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Moderate AS</th>
<th>Propensity-Matched Controls Without AS</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>390</td>
<td>1560</td>
<td></td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>171 (43.9)</td>
<td>693 (44.4)</td>
<td>0.8</td>
</tr>
<tr>
<td>Mean (SD) age, y</td>
<td>71.6 (10.6)</td>
<td>70.8 (10.5)</td>
<td>0.2</td>
</tr>
<tr>
<td>History of heart failure, n (%)</td>
<td>41 (10.5)</td>
<td>82 (5.3)</td>
<td>0.4</td>
</tr>
<tr>
<td>History of CAD, n (%)</td>
<td>111 (28.5)</td>
<td>425 (27.2)</td>
<td>0.6</td>
</tr>
<tr>
<td>History of CVA, n (%)</td>
<td>46 (11.8)</td>
<td>194 (12.4)</td>
<td>0.7</td>
</tr>
<tr>
<td>Renal failure, n (%)</td>
<td>38 (9.7)</td>
<td>157 (10.1)</td>
<td>0.9</td>
</tr>
<tr>
<td>Diabetes mellitus requiring insulin, n (%)</td>
<td>51 (13.1)</td>
<td>205 (13.1)</td>
<td>1.0</td>
</tr>
<tr>
<td>High-risk surgery, n (%)</td>
<td>30 (7.7)</td>
<td>116 (7.4)</td>
<td>0.9</td>
</tr>
<tr>
<td>Severe mitral regurgitation, n (%)</td>
<td>14 (3.6)</td>
<td>47 (3.0)</td>
<td>0.6</td>
</tr>
</tbody>
</table>

AS indicates aortic stenosis; CAD, coronary artery disease; and CVA, cerebrovascular accident.
Severe AS was defined as aortic valve area <1.0 cm². Moderate AS was defined as aortic valve area between 1.0 and 1.5 cm².
P value indicates statistical significance in comparison to the corresponding control group.
*Symptoms refers to symptoms typical to AS, including angina, syncope or dyspnea.
AS experiencing primary outcome in the postoperative period (n=17), 5 patients were noted to have aortic valve area of 1.0 cm² and 6 patients were noted to have ejection fraction <40%. This might imply that moderate AS patients with high-risk features like depressed ejection fraction, a greater degree of stenosis, or coexisting mitral regurgitation were more prone to developing primary outcome as compared with others without high-risk features.

Impact of Surgical Complexity

Figure 2 demonstrates the outcomes in patients without AS and with AS, stratified by the complexity of the NCS. Among patients undergoing high-risk or intermediate-risk surgery, the incidence of primary outcome was significantly higher in the severe AS and moderate AS groups compared with the non-AS group.

Table 2. Characteristics of the Noncardiac Surgeries

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Severe AS (n=244)</th>
<th>Corresponding Controls (n=976)</th>
<th>Moderate AS (n=390)</th>
<th>Corresponding Controls (n=1560)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Categorized by complexity of surgery, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High risk</td>
<td>25 (10.2)</td>
<td>93 (9.5)</td>
<td>30 (7.7)</td>
<td>116 (7.4)</td>
</tr>
<tr>
<td>Intermediate risk</td>
<td>173 (70.9)</td>
<td>729 (74.7)</td>
<td>252 (64.6)†</td>
<td>1432 (91.8)</td>
</tr>
<tr>
<td>Low risk</td>
<td>46 (18.9)</td>
<td>154 (15.8)</td>
<td>108 (27.7)†</td>
<td>12 (0.8)</td>
</tr>
<tr>
<td>Categorized by type of surgery, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular surgery</td>
<td>33 (13.5)</td>
<td>177 (18.1)</td>
<td>46 (11.8)†</td>
<td>302 (19.4)</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>7 (2.9)</td>
<td>19 (1.9)</td>
<td>24 (6.2)</td>
<td>81 (5.2)</td>
</tr>
<tr>
<td>Colorectal surgery</td>
<td>50 (20.5)†</td>
<td>91 (9.3)</td>
<td>21 (5.4)</td>
<td>115 (7.4)</td>
</tr>
<tr>
<td>Orthopedic surgery</td>
<td>71 (29.1)</td>
<td>254 (26.0)</td>
<td>107 (27.4)</td>
<td>399 (25.6)</td>
</tr>
<tr>
<td>ENT surgery</td>
<td>7 (2.9)</td>
<td>24 (2.5)</td>
<td>27 (6.9)†</td>
<td>30 (1.9)</td>
</tr>
<tr>
<td>Urologic surgery</td>
<td>28 (11.5)</td>
<td>108 (11.1)</td>
<td>48 (12.3)*</td>
<td>152 (9.7)</td>
</tr>
<tr>
<td>Gynecologic surgery</td>
<td>17 (7.0)</td>
<td>56 (5.7)</td>
<td>29 (7.4)</td>
<td>78 (5.0)</td>
</tr>
<tr>
<td>Thoracic surgery</td>
<td>11 (4.5)*</td>
<td>93 (9.5)</td>
<td>19 (4.9)†</td>
<td>150 (9.6)</td>
</tr>
<tr>
<td>General surgery, not otherwise classified</td>
<td>20 (8.2)†</td>
<td>154 (15.8)</td>
<td>69 (17.7)</td>
<td>253 (16.2)</td>
</tr>
</tbody>
</table>

AS indicates aortic stenosis; and ENT, ear, nose, and throat.

AS indicates aortic stenosis; and MI, myocardial infarction.

Table 3. Postoperative Outcomes in the Moderate AS and Severe AS Groups in Comparison With the Corresponding Control Population

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Moderate AS</th>
<th>No AS</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>390</td>
<td>1560</td>
<td></td>
</tr>
<tr>
<td>Primary outcome (30-d mortality or postoperative MI), n (%)</td>
<td>17 (4.4)</td>
<td>27 (1.7)</td>
<td>0.002</td>
</tr>
<tr>
<td>30-d mortality, n (%)</td>
<td>9 (2.3)</td>
<td>13 (0.8)</td>
<td>0.01</td>
</tr>
<tr>
<td>Postoperative MI, n (%)</td>
<td>9 (2.3)</td>
<td>15 (1.0)</td>
<td>0.03</td>
</tr>
<tr>
<td>Postoperative heart failure, n (%)</td>
<td>17 (4.4)</td>
<td>63 (4.0)</td>
<td>0.8</td>
</tr>
<tr>
<td>Postoperative stroke, n (%)</td>
<td>4 (1.1)</td>
<td>38 (2.4)</td>
<td>0.1</td>
</tr>
<tr>
<td>Mean (SD) length of stay, d</td>
<td>5.0 (8.7)</td>
<td>5.7 (6.6)</td>
<td>0.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Severe AS</th>
<th>No AS</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>244</td>
<td>976</td>
</tr>
<tr>
<td>Primary outcome (30-d mortality or postoperative MI), n (%)</td>
<td>14 (5.7)</td>
<td>26 (2.7)</td>
</tr>
<tr>
<td>30-d mortality, n (%)</td>
<td>4 (1.6)</td>
<td>13 (1.3)</td>
</tr>
<tr>
<td>Postoperative MI, n (%)</td>
<td>10 (4.1)</td>
<td>14 (1.4)</td>
</tr>
<tr>
<td>Postoperative heart failure, n (%)</td>
<td>23 (9.4)</td>
<td>111 (11.4)</td>
</tr>
<tr>
<td>Postoperative stroke, n (%)</td>
<td>2 (0.8)</td>
<td>24 (2.5)</td>
</tr>
<tr>
<td>Mean (SD) length of stay, d</td>
<td>6.8 (8.8)</td>
<td>5.5 (6.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Asymptomatic Severe AS</th>
<th>No AS</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>172</td>
<td>976</td>
<td></td>
</tr>
<tr>
<td>Composite outcome (30-d mortality or postoperative MI), n (%)</td>
<td>8 (4.7)</td>
<td>26 (2.7)</td>
<td>0.2</td>
</tr>
<tr>
<td>30-d mortality, n (%)</td>
<td>2 (1.2)</td>
<td>13 (1.3)</td>
<td>0.9</td>
</tr>
<tr>
<td>Postoperative MI, n (%)</td>
<td>6 (3.5)</td>
<td>14 (1.4)</td>
<td>0.06</td>
</tr>
<tr>
<td>Postoperative heart failure, n (%)</td>
<td>15 (8.7)</td>
<td>111 (11.4)</td>
<td>0.3</td>
</tr>
<tr>
<td>Postoperative stroke, n (%)</td>
<td>1 (0.6)</td>
<td>24 (2.5)</td>
<td>0.1</td>
</tr>
<tr>
<td>Mean (SD) length of stay, d</td>
<td>6.0 (8.9)</td>
<td>5.5 (6.2)</td>
<td>0.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symptomatic Severe AS</th>
<th>No AS</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>72</td>
<td>976</td>
</tr>
<tr>
<td>Composite outcome (30-d mortality or postoperative MI), n (%)</td>
<td>6 (8.3)</td>
<td>26 (2.7)</td>
</tr>
<tr>
<td>30-d mortality, n (%)</td>
<td>2 (2.8)</td>
<td>13 (1.3)</td>
</tr>
<tr>
<td>Postoperative MI, n (%)</td>
<td>4 (5.6)</td>
<td>14 (1.4)</td>
</tr>
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<td>8 (11.1)</td>
<td>111 (11.4)</td>
</tr>
<tr>
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<td>1 (1.4)</td>
<td>24 (2.5)</td>
</tr>
<tr>
<td>Mean (SD) length of stay, d</td>
<td>8.6 (12.4)</td>
<td>5.5 (6.2)</td>
</tr>
</tbody>
</table>

AS indicates aortic stenosis; and MI, myocardial infarction.
Among patients undergoing low-risk surgeries, there was a significantly higher incidence of primary outcome in the severe AS group as compared with the non-AS group ($P=0.04$; Figure 2A). In this subgroup, the incidences of primary outcome in the moderate AS and the non-AS groups were found to be similar ($P=0.8$).

### Predictors of Primary Outcome and Length of Stay

Multivariable logistic regression analyses in patients with AS demonstrated that high-risk surgery (odds ratio [95% confidence interval], 7.3 [2.6–20.6]), moderate or severe mitral regurgitation (odds ratio [95% confidence interval], 9.8 [3.1–20.4]), symptomatic severe AS (odds ratio [95% confidence interval], 2.7 [1.1–7.5]), and preexisting coronary artery disease (odds ratio [95% confidence interval], 2.7 [1.1–6.2]) were significant predictors of occurrence of primary outcome in the postoperative period after the NCS. In addition, we observed that occurrence of the primary outcome was the strongest predictor of the length of hospital stay among patients with AS. We observed that the mean (SD) length of hospital stay among the AS patients with primary outcome was 5.8 (1.9) days longer as compared with those without the primary outcome ($P=0.002$). In addition, patients undergoing high-risk surgery or intermediate-risk surgery had, on average, 6.2 (3.9) and 4.7 (5.3) days longer hospital stays in comparison with those undergoing low-risk surgery ($P<0.001$ for both comparisons). Furthermore, patients with symptomatic severe AS undergoing NCS had, on average, 3.2 (2.5) days longer hospital stays in comparison with asymptomatic patients with AS ($P=0.02$).

### Long-term Mortality

Differences in long-term mortality were compared using the Kaplan-Meier survival curves (Figure 3). The long-term mortality was significantly higher in the severe AS and moderate AS groups as compared with the non-AS group (log-rank test, $P<0.001$ for both comparisons). The difference in mortality between the AS and the non-AS groups was evident as early as 6 months of follow-up after the NCS (Figure 3).

### Discussion

Our study was aimed to determine the impact of AS on postoperative outcomes after NCS. We have demonstrated an increased incidence of primary outcome comprising 30-day mortality or postoperative MI among patients with AS (4.9%) undergoing NCS. High-risk surgery, symptomatic severe AS, coexisting mitral regurgitation, and preexisting coronary disease were significant predictors of primary outcome in patients with AS.

In 1977, Goldman et al. published one of the first multifactorial indices of cardiovascular risk in patients undergoing NCS in which they demonstrated a 13% rate of cardiac mortality in patients with AS in comparison with 1.6% in patients without AS. Subsequently, several studies have been conducted demonstrating conflicting results. In 1989, O’Keefe et al. demonstrated a reasonably low risk among patients with severe AS undergoing NCS. High-risk surgery, symptomatic severe AS, coexisting mitral regurgitation, and preexisting coronary disease were significant predictors of primary outcome in patients with AS.

In 1998, Torsher et al. demonstrated a postoperative mortality rate of 11% in a cohort of 19 patients with severe AS undergoing NCS. The authors reported that intraoperative hypotensive
episodes requiring vasopressors were rather frequent, occurring in 14 of 19 patients. More recently in 2004, Kertai et al\textsuperscript{12} demonstrated a 14\% incidence of perioperative death or MI in patients with moderate or severe AS undergoing NCS, which was significantly higher than the 2\% rate of perioperative events among patients without AS. Similarly, using the National Hospital Discharge Survey database, Zahid et al\textsuperscript{7} demonstrated a 55\% greater risk for perioperative MI in patients with a diagnosis of AS compared with those without AS. However, severity of AS was not defined in this study.

What constitutes a reasonable risk for the particular NCS is dependent on the clinical situation and the risk-benefit considerations of surgery, but risk of death and MI >5\% is generally agreed on as a high risk.\textsuperscript{2,8} It is also important to note that in the current era, most of the surgeries are performed with much less than 5\% risk. This is consistent with our data that showed that the control population had a 2\% risk, which is much lower than reported risk in control population in prior studies. Although the risk of adverse events in the AS patients undergoing NCS is relatively less in our study, it was still ≈5\% and was more than double compared with the control population. This perspective should be kept in mind when assessing the risks and benefits of NCS in patients with AS.

Our study has demonstrated a significantly higher long-term mortality among patients with AS undergoing NCS as compared with controls. Although this was not the main focus of our study, the results are not surprising. The higher long-term mortality in the AS group is likely attributable to the underlying valvular heart disease rather than the NCS per se. This observation is supported by several studies detailing the natural course of medically managed severe AS. In a recently published study from the Medicare claims analysis, elderly patients with severe AS undergoing medical management had mean survival duration of 1.8 years with overall mortality of 88.4\% at the end of 5 years.\textsuperscript{13}

The current American College of Cardiology/American Heart Association guidelines on perioperative cardiovascular evaluation and care for NCS provide a few broad recommendations.\textsuperscript{2} In patients with severe symptomatic AS, surgical aortic valve replacement is recommended before elective NCS.\textsuperscript{2} However, such a recommendation is not available for asymptomatic patients. Similar to the American College of Cardiology/American Heart Association guidelines, the European Society of Cardiology recommends careful assessment of clinical symptoms, the severity of the valvular lesion, and the relative urgency of the NCS.\textsuperscript{14} In patients requiring urgent NCS, careful invasive hemodynamic monitoring is warranted.\textsuperscript{14} The European Society of Cardiology guidelines recommend that asymptomatic patients with severe AS undergoing elective NCS of low to moderate risk may undergo the procedure relatively safely. However, if a high-risk surgery is being contemplated, the patients should be evaluated for a possible surgical aortic valve replacement and coronary revascularization, if needed, before the intended surgery (Recommendation Class IIb, Level of Evidence C).\textsuperscript{14}

Our study provides substantial evidence for this strategy for the first time in the contemporary era. It demonstrates that even in the current era the risk of NCS in AS patients compared with non-AS patients is considerably higher. It is clear that we needed a large patient population to demonstrate this difference in risk, which was possible because of a large tertiary-care center with comprehensive surgical expertise. Our study serves as a springboard for future meticulous large-scale studies to

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Comparison of postoperative outcomes after non-cardiac surgery in patients without aortic stenosis (AS), with moderate AS, and with severe AS, stratified by degree of surgical risk. A, Postoperative outcomes in the 3 categories of patients undergoing low-risk surgery. B, Postoperative outcomes in the 3 categories of patients undergoing intermediate-risk surgery. C, Postoperative outcomes in the 3 categories of patients undergoing high-risk surgery. The numbers on top of the bars represent the count in that particular category. The \textit{P} value obtained on comparison of the AS and non-AS categories is depicted in the AS category bar. MI indicates myocardial infarction.}
\end{figure}
study the impact of correction of the valvular abnormality before the intended high- or intermediate-risk NCS, especially if the surgery is elective. In patients who are deemed to be poor surgical candidates, the recently approved percutaneous transcatheter aortic valve replacement may be considered as a potential therapeutic option before the NCS.

Limitations
Our study is a retrospective cohort study and is limited by the inherent biases of nonrandomized observational studies, including residual confounding. Propensity scores were used to create matched pairs that helped balance several observed covariates between the 2 study groups. However, unlike random assignment of treatments, adjustment for the propensity score might not account for unobserved covariates and does little for residual confounding. The extent of residual confounding is hard to assess, especially in retrospective cohort studies. The magnitude of residual confounding is known to decline with a decline in the frequency of outcome. Therefore, we estimate that the magnitude of residual confounding in our study was modest at most, secondary to relatively few primary outcome events. Another limitation of propensity score analysis is that a covariate related to the treatment assignment but not to the outcome is handled in a similar fashion to a covariate with the strong relationship to the treatment assignment and the outcome. This feature may result in the inclusion of irrelevant covariates, which might reduce the efficiency of the control on the relevant covariates.

Our definition of severe AS was based solely on an aortic valve area <1.0 cm². With preoperative recognition of severe AS, there is usually more assiduous intraoperative monitoring and anesthesia. However, assuming this is so, this would provide conservative estimates, which would be biased toward the null. According to the standard postoperative practices of our institution, cardiac biomarkers were not routinely measured in all patients undergoing NCS. Cardiac biomarkers were measured if the clinical scenario indicated the possibility of acute coronary syndrome like development of chest pain or shortness of breath or electrocardiographic changes or arrhythmias. A nonuniform measurement of the cardiac biomarkers might have served as a source of bias. In addition, heightened anesthetic management in patients with severe AS is extremely relevant to current surgical practice and represents the norm rather than the exception. Furthermore, the study was performed at a tertiary-care center with significant surgical expertise and sophisticated anesthetic monitoring techniques; this may limit its generalizability to smaller surgical centers.

Conclusions
Patients with moderate or severe AS undergoing NCS demonstrated an increased incidence of death or MI at 30 days as compared with those without AS. High-risk surgery, presence of symptoms related to AS, coexisting significant mitral regurgitation, and coronary artery disease were significant predictors of occurrence of primary outcome in patients with AS undergoing NCS.

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involved with the data analysis and data collection. Dr Griffin was involved with manuscript writing and proofreading. Dr Catacutan was involved with data collection. Dr Svensson was involved with manuscript writing and proofreading. Dr Kapadia is the principal investigator and senior author.

Disclosures

None.

References

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