New-Generation Transcatheter Aortic Valves in Patients With Small Aortic Annuli — Comparison of Balloon- and Self-Expandable Valves in Asian Patients —

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**Background:** Asian patients have smaller aortic annuli. Although 20-mm balloon-expandable (BE) transcatheter heart valves (THV) are manufactured for transcatheter aortic valve implantation (TAVI) in these cases, the supra-annular design of self-expandable (SE) THV is considered more suitable; however, real-world comparative data are scarce.

**Methods and Results:** Consecutive TAVI cases (n=330) in a single Japanese center were reviewed. Based on the cutoff for the new-generation 20-/23-mm BE-THV, a small aortic annulus was defined as <330 mm². A considerable number of patients had small annuli: 49/302 (16%). Of these, 33 BE-THV and 13 SE-THV using new-generation valves were compared. Although the SE-THV group had smaller annulus area (median 297 (interquartile range, 280–313) vs. 309 (303–323) mm² (P=0.022)), it had more favorable post-procedural parameters; for SE-THV and BE-THV, respectively, effective orifice area (EOA), 1.5 (1.3–1.6) vs. 1.1 cm² (0.9–1.3) (P=0.002); mean pressure gradient, 7.6 (5.6–11.0) vs. 14.2 mmHg (11.2–18.8) (P=0.001); and peak velocity, 1.8 (1.6–2.4) vs. 2.7 m/s (2.3–3.1) (P=0.001). Although new left bundle branch block was higher with SE-THV (24% and 62%, P=0.02), patient-prosthesis mismatch (PPM) ≥ moderate (indexed EOA <0.85 cm²/m²) was significantly less with SE-THV than with BE-THV (8% vs. 55%; P=0.04). Hemodynamic findings were consistent up to 1 year.

**Conclusions:** Small annuli are often seen in Asian patients, for whom SE-THV implantation results in favorable hemodynamics with less PPM.

**Key Words:** Aortic annulus; Aortic valve replacement; Computed tomography; Complications; Valve prosthesis

Transcatheter aortic valve implantation (TAVI) is increasingly used throughout the world, and in a variety of races, and its indication is shifting towards lower surgical risk. Although this catheter treatment is maturing and outcomes are improving, some controversies persist.

Prosthesis-patient mismatch (PPM) is one of the major concerns following TAVI. The term was invented in 1978, and has been established as a mortality predictor after surgical aortic valve replacement (SAVR). TAVI results in a larger effective orifice area (EOA) compared with SAVR, and fewer cases of PPM are reported. The incidence rate of PPM following SAVR ranges from 20% to 70%, whereas moderate and severe PPM (moderate PPM: indexed EOA between 0.65 and 0.85 cm²/m², and severe PPM: indexed EOA <0.65 cm²/m²) after TAVI were reported by Miyasaka et al in 8.9% and 0.7%, respectively, and in 25% and 12% by Herrmann et al. Although the incidence rates of PPM following TAVI are lower, a recent study of a large cohort reported that severe PPM was associated with higher rates of mortality and heart failure rehospitalization at 1 year. Furthermore, another study showed PPM was an independent predictor of structural valve deterioration, which may be a significant concern as the TAVI indication expands into lower risk and younger patients in whom the valves are expected to perform better.
TAVI emerged from Western countries, and now many procedures are being performed in Asian countries as well. Asian patients have much smaller aortic annuli than Caucasians. Watanabe et al. reported that annulus diameter was significantly smaller in a Japanese cohort than in a French cohort,\(^1\) and a small annulus is an independent predictor for PPM.\(^2\) A strategy for gaining larger EOA and avoiding PPM is important for patients with small annuli.

The hemodynamic outcomes of the balloon-expandable (BE) transcatheter heart valve (THV) are related to the native annular area,\(^3\) and the minimum size of the BE-THV (20 mm) reveals a high mean gradient and a considerable risk for an increased rate of PPM.\(^4\),\(^5\) On the other hand, the supra-annular design (Figure 1) of the self-expandable (SE) THV enables expansion of the EOA and is considered to be suitable for small annuli; however, there is little data comparing the hemodynamic outcomes between the SE-THV and BE-THV in patients with small annuli. This study sought to evaluate the acute hemodynamic and clinical outcomes between BE- and SE-THV in Asian patients with small annuli.

### Methods

#### Study Population and Design

This study retrospectively reviewed 330 consecutive patients undergoing TAVI from January 2016 to March 2019 in a single center in Japan (Figure 2). Valve-in-valve TAVI and patients without annulus assessment by contrast computed tomography were excluded. The BE-THV devices were Sapien XT and Sapien 3 (Edwards Lifesciences, Irvine, CA, USA), and the SE-THV were Corevalve, Evolut R, and Evolut Pro (Medtronic, Minneapolis, MN, USA). The selection of valve type and other procedural strategies were decided by a multidisciplinary heart team including cardiothoracic surgeons, anesthesiologists, interventional cardiologists and echocardiography cardiologists. During this

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**Figure 1.** Design of the balloon- and self-expandable transcatheter valves. (A) Side view: (Left) balloon-expandable valve (20-mm Sapien 3), (Right) self-expandable valve (23-mm Evolut R). Top view of the (B) balloon-expandable valve and (C) self-expandable valve.

**Figure 2.** Flow chart of patient selection. TAVI, transcatheter aortic valve implantation; THV, transcatheter heart valve.
study period, there were 8 TAVI operators who were involved in the heart team conference. The selection of BE- or SE-THV was multifactorial. Examples of factors that can influence device selection are: BE-THV preferred cases have low coronary height, small sinus of Valsalva, horizontal aorta and preoperative right bundle branch block, whereas SE-THV preferred cases have low pressure gradient aortic stenosis, high risk of annulus rupture due to severe calcification, high risk for rapid pacing (severe carotid artery stenosis or other severe valve disorder etc.) and small peripheral access. All procedures were performed under general anesthesia using transesophageal echocardiography assessment.

For our comparison of BE-THV and SE-THV, we selected patients with the newer generation devices (Sapien 3, Evolut R and Evolut Pro). A small annulus was defined as having an area <330 mm² based on the cutoff for the minimum size BE-THV (20-mm Sapien 3). Procedural, in-hospital, 30-day and 1-year outcomes were reviewed. Echocardiography was performed prior to the procedure, 1–2 days after the procedure and at the 30-day and 1-year follow-ups. Outcomes of newer generation BE-THV and SE-THV in small annuli were compared.

The study was conducted with approval from the institutional review board. All patients agreed to participate in the study and written informed consent was given by all patients. The investigation was performed according to the Declaration of Helsinki.

**Endpoint Definition**

Outcome data was reviewed up to 1-year follow-up. Endpoints were defined based on the Valve Academic Research Consortium-2 definition.

PPM occurs in the setting of a morphologically normal valve and is considered to be hemodynamically insignificant if the indexed EOA is >0.85 cm²/m², moderate if between 0.65 and 0.85 cm²/m², and severe if <0.65 cm²/m².

The composite endpoints are briefly described. Device success was defined as (1) absence of procedural death, (2) correct positioning of a single prosthetic heart valve into the proper anatomical location and (3) the intended performance of the prosthetic heart valve (no PPM and mean aortic valve gradient <20 mmHg or peak velocity <3 m/s and no moderate or severe prosthetic valve regurgitation).

Endpoints for early safety were defined as (1) all-cause death, (2) all stroke (disabling and non-disabling), (3) life-threatening bleeding, (4) acute kidney injury – stage 2 or 3 (including renal replacement therapy), (5) coronary artery obstruction requiring intervention, (6) major vascular complications, and (7) valve-related dysfunction requiring a repeat procedure. Clinical efficacy was defined as (1) all-cause death, (2) all stroke (disabling and non-disabling), (3) life-threatening bleeding, (4) acute kidney injury – stage 2 or 3 (including renal replacement therapy), (5) coronary artery obstruction requiring intervention, (6) major vascular complications, and (7) valve-related dysfunction requiring a repeat procedure. Clinical efficacy was defined as (1) mean aortic valve gradient <20 mmHg or peak velocity <3 m/s and no moderate or severe prosthetic valve regurgitation).

Statistical Analysis

The data was collected retrospectively, and all the analyses were performed using the data from the as-treated population. Quantitative variables are expressed as median values (interquartile range), and qualitative variables are expressed as numbers with percentages. The Mann-Whitney U-test was used for quantitative variables, and Fisher’s exact test.
was used for qualitative variables.

A P value ≤0.05 was considered statistically significant. The data were analyzed with SPSS software (PASW v18, SPSS, Inc.)

### Results

**Patient Population**

Of the 330 consecutive cases of TAVI, there were 302 in which preprocedural contrast CT assessments had been performed. There was a considerable number of patients with a small annulus (49 (16%)) and of them, a new-generation THV was used in 46 cases: 33 BE-THV and 13 SE-THV (Figure 2).

**Differences in Hemodynamics Between Devices**

Native annulus area and the post-TAVI hemodynamics of each device were reviewed (Figure 3). Smaller THV were implanted in smaller annuli, and smaller THV revealed inconvenient parameters for both BE- and SE-THV. Although annulus area was the smallest in the 23-mm SE-THV group (275 (264–291) mm²), the worst hemodynamics was in the 20-mm BE-THV group: pressure gradient, 14.6 (11.8–21.3) mmHg; peak velocity, 2.69 (2.4–3.2) m/s; EOA, 1.03 (0.9–1.2) cm².

**Comparison of BE-THV and SE-THV**

BE-THV and SE-THV were compared in patients with a small annulus. Table 1 shows a comparison of the baseline characteristics of the 2 groups. At the baseline, there were no significant differences in age, height, weight, or body surface area, except that annulus area was significantly smaller in the SE-THV group compared with the BE-THV group: 297 (280–313) mm² vs. 309 (303–323) mm² (P=0.022) (Table 1).

Procedural and in-hospital outcomes are shown in Table 2. We used the 20-mm and 23-mm BE-THV in 19 and 14 patients, respectively, and the 23-mm and 26-mm SE-THV in 5 and 8 patients, respectively. There was no case of a 20-mm BE-THV being implanted using an underfilled balloon, but there were 2 cases of using an overfilled balloon with 0.5–1 mL. On the other hand, most cases of 23-mm BE-THV (12 cases) were implanted using an underfilled balloon with 1–2 mL. The rates of post-implant dilatation and greater than mild paravalvular leak were not significantly different between groups (9% vs. 8%, and 3% vs. 3%).

### Table 1. Baseline Characteristics

<table>
<thead>
<tr>
<th></th>
<th>BE (n=33)</th>
<th>SE (n=13)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>84.0 (79.5–88.5)</td>
<td>84.0 (82.5–87.0)</td>
<td>0.72</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>146.0 (140.5–149.5)</td>
<td>140.0 (137.0–149.5)</td>
<td>0.19</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>43.0 (40.5–52.5)</td>
<td>46.0 (42.4–51.1)</td>
<td>0.98</td>
</tr>
<tr>
<td>BSA (cm²)</td>
<td>1.4 (1.3–1.5)</td>
<td>1.3 (1.3–1.4)</td>
<td>0.55</td>
</tr>
<tr>
<td>STS score</td>
<td>4.8 (3.5–8.2)</td>
<td>5.6 (3.6–5.9)</td>
<td>0.96</td>
</tr>
<tr>
<td>Hemoglobin g/dL</td>
<td>11.4 (10.0–12.0)</td>
<td>11.7 (11.1–12.7)</td>
<td>0.09</td>
</tr>
<tr>
<td>Creatinine (mg/dL)</td>
<td>0.8 (0.7–1.0)</td>
<td>0.7 (0.6–1.0)</td>
<td>0.31</td>
</tr>
<tr>
<td>Bilirubin</td>
<td>0.5 (0.4–0.7)</td>
<td>0.6 (0.5–0.7)</td>
<td>0.19</td>
</tr>
<tr>
<td>Annulus area (mm²)</td>
<td>309 (303–323)</td>
<td>297 (280–313)</td>
<td>0.022</td>
</tr>
<tr>
<td>EF (%)</td>
<td>69.0 (62.5–73.5)</td>
<td>67.0 (65.0–71.0)</td>
<td>0.46</td>
</tr>
<tr>
<td>MPG (mmHg)</td>
<td>43.8 (30.7–61.4)</td>
<td>29.4 (23.4–48.6)</td>
<td>0.12</td>
</tr>
<tr>
<td>Aortic valve area (cm²)</td>
<td>0.5 (0.4–0.7)</td>
<td>0.6 (0.5–0.7)</td>
<td>0.41</td>
</tr>
<tr>
<td>Aortic valve area index (cm²/m²)</td>
<td>0.4 (0.3–0.5)</td>
<td>0.4 (0.4–0.5)</td>
<td>0.22</td>
</tr>
</tbody>
</table>

BE, balloon-expandable valve; BSA, body surface area; EF, ejection fraction; MPG, mean pressure gradient; MR, mitral regurgitation; SE, self-expandable valve.
BE- and SE-THV in Small Annuli

THV group had better hemodynamic parameters for EOA, EOAI, mean pressure gradient and peak velocity, as reflected in the in-hospital outcomes. The rate of PPM ≥ moderate was significantly higher in the BE-THV than the SE-THV group: 19 (59) vs. 2 (18) (P=0.018). Moreover, the 30-day follow-up revealed significantly higher incidence of severe PPM as well in the BE-THV group compared with the SE-THV group: 9 (28) vs. 0 (P=0.05). The 1-year follow-up found 1 patient in the SE-THV group had died due to intestinal obstruction; however, the difference in mortality was not significant (Table 4). Other findings were consistent with the 30-day follow-up.

Discussion

For treatment of aortic stenosis, various options are becoming available and there are strategies for the prevention and management of PPM in patients with small annuli. Regarding SAVR, most of the valves have stents and sewing rings that reduce the EOA, but the design of the prosthesis can improve this inconvenience. Externally mounted pericardium (Mitroflow (Sorin Group), Trifecta (Abott Vascular)) can maximize transvalvular flow. In addition, the surgical technique can enable implantation of a larger valve. Supra-annular implantation has been associated with hemodynamic improvement over conventional intra-annular positioning of the prosthesis. Aortic root enlargement, such as the Nicks technique, is an effective option for small annulus. Patients undergoing aortic enlargement reportedly have a lower incidence of PPM ≥ moderate:

<table>
<thead>
<tr>
<th>Table 2. Procedural and In-Hospital Outcomes</th>
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<tbody>
<tr>
<td>Valves</td>
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<tr>
<td>Valve size</td>
</tr>
<tr>
<td>BE20</td>
</tr>
<tr>
<td>BE23</td>
</tr>
<tr>
<td>SE23</td>
</tr>
<tr>
<td>SE26</td>
</tr>
<tr>
<td>Underfilled balloon</td>
</tr>
<tr>
<td>Post-implant dilatation</td>
</tr>
<tr>
<td>Percutaneous closure device failure</td>
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<tr>
<td>Procedural death</td>
</tr>
<tr>
<td>Correct positioning of a single valve</td>
</tr>
<tr>
<td>Procedure time (min)</td>
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<tr>
<td>New pacemaker implantation</td>
</tr>
<tr>
<td>New left bundle branch block</td>
</tr>
<tr>
<td>Lowest hemoglobin</td>
</tr>
<tr>
<td>Highest creatinine</td>
</tr>
<tr>
<td>Hospital stay (days)</td>
</tr>
<tr>
<td>Paravalvular leak ≥ moderate</td>
</tr>
<tr>
<td>EOA</td>
</tr>
<tr>
<td>EOAI</td>
</tr>
<tr>
<td>MPG (mmHg)</td>
</tr>
<tr>
<td>Peak velocity (m/s)</td>
</tr>
<tr>
<td>PPM ≥ moderate</td>
</tr>
<tr>
<td>Severe PPM</td>
</tr>
<tr>
<td>Device success</td>
</tr>
</tbody>
</table>

PPM ≥ moderate is indexed EOA <0.85 cm²/m²; severe PPM is indexed EOA <0.65 cm²/m². EOA, effective orifice area; EOAI, effective orifice area index; PPM, patient-prosthesis mismatch. Other abbreviations as in Table 1.

30-Day and 1-Year Follow-up

As for the 30-day outcomes (Table 3), there were no deaths or strokes in either group. Although the BE-THV group had a few cases of life-threatening bleeding (bleeding at access site, gastrointestinal hemorrhage and alveolar hemorrhage) and stage 2 or 3 acute kidney injury, there was no significant difference in the early safety between the BE- and SE-THV groups: 29 (91) vs. 12 (100) (P=0.7), respectively. Changes in ejection fraction and left ventricular diastolic diameter from baseline were measured by echocardiography, and there were no significant differences in these parameters of systolic function and cardiac size: 1.5% (−2.0–5.8) vs. 4% (−2.8) (P=0.16) and 1.5 mm (−2.0–5.8) vs. 1 mm (−3.4), for BE- and SE-THV, respectively. The SE-THV group had better hemodynamic parameters for EOA, EOAI, mean pressure gradient and peak velocity, as reflected in the in-hospital outcomes. The rate of PPM ≥ moderate was significantly higher in the BE-THV than the SE-THV group: 19 (59) vs. 2 (18) (P=0.018). Moreover, the 30-day follow-up revealed significantly higher incidence of severe PPM as well in the BE-THV group compared with the SE-THV group: 9 (28) vs. 0 (P=0.05). The 1-year follow-up found 1 patient in the SE-THV group had died due to intestinal obstruction; however, the difference in mortality was not significant (Table 4). Other findings were consistent with the 30-day follow-up.
Okuyama et al. Therefore, TAVI is a potential strategy for small annuli. TAVI emerged from Western countries, and now many procedures are being performed in Asian countries as well. Asian patients have smaller body size, and the 20-mm BE-THV was specially manufactured for their small annuli; however, comparative data for SE-THV in small annuli are limited. The hemodynamic assessment in the current study showed that less favorable hemodynamics occurred with smaller sized devices, which is consistent with a previous study. In particular, the 20-mm BE-THV revealed high residual pressure and velocity with a small EOA of 1.03 cm² (Figure 3). SE-THV implantation showed significantly higher EOA following SAVR, but the durability of an externally mounted valve is still a concern; some studies revealed accelerated structural valve deterioration and increased reoperation rates with externally mounted valves. Moreover, the aortic root enlargement procedure includes incision of the annulus and patch reconstruction of the root, thus it is more complicated than simple SAVR. There is also expected to be greater chance of bleeding, and longer cardiac-arrest time. The prosthetic valve used in TAVI does not require a sewing ring and thus results in a larger EOA as compared with the surgical valves. Clavel et al revealed lower trans-prosthetic gradient with TAVI compared with SAVR. Therefore, TAVI is a potential strategy for small annuli.

Table 3. 30-Day Outcomes

<table>
<thead>
<tr>
<th></th>
<th>BE (n=32)</th>
<th>SE (n=12)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cause death</td>
<td>0</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Stroke</td>
<td>0</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Life-threatening bleeding</td>
<td>3 (9)</td>
<td>0</td>
<td>0.38</td>
</tr>
<tr>
<td>Acute kidney injury stage 2 or 3</td>
<td>2 (6)</td>
<td>0</td>
<td>0.52</td>
</tr>
<tr>
<td>Requiring hospitalization</td>
<td>2 (6)</td>
<td>0</td>
<td>0.52</td>
</tr>
<tr>
<td>Early safety</td>
<td>29 (91)</td>
<td>12 (100)</td>
<td>0.7</td>
</tr>
<tr>
<td>NYHA class III or IV</td>
<td>0</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Clinical efficacy</td>
<td>19 (59)</td>
<td>12 (100)</td>
<td>0.07</td>
</tr>
<tr>
<td>Echocardiography findings</td>
<td>(n=32)</td>
<td>(n=11)</td>
<td></td>
</tr>
<tr>
<td>EOA</td>
<td>1.1 (0.9–1.3)</td>
<td>1.4 (1.1–1.6)</td>
<td>0.07</td>
</tr>
<tr>
<td>EOAi</td>
<td>0.8 (0.6–1.0)</td>
<td>1.0 (0.9–1.4)</td>
<td>0.09</td>
</tr>
<tr>
<td>MPG</td>
<td>15.0 (12.9–21.6)</td>
<td>9.3 (6.2–12.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Peak velocity</td>
<td>2.7 (2.4–3.2)</td>
<td>2.1 (1.7–2.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Change in EF (%)</td>
<td>1.5 (−2.0–5.8)</td>
<td>4 (2–8)</td>
<td>0.16</td>
</tr>
<tr>
<td>Change in LVDd (mm)</td>
<td>1.5 (−2.0–5.8)</td>
<td>1 (−3–4)</td>
<td>0.63</td>
</tr>
<tr>
<td>PPM ≥ moderate</td>
<td>19 (59)</td>
<td>2 (18)</td>
<td>0.018</td>
</tr>
<tr>
<td>Severe PPM</td>
<td>9 (28)</td>
<td>0</td>
<td>0.05</td>
</tr>
<tr>
<td>Paravalvular leak ≥ moderate</td>
<td>1 (3)</td>
<td>0</td>
<td>0.74</td>
</tr>
<tr>
<td>Valve-related dysfunction</td>
<td>13 (41)</td>
<td>0</td>
<td>0.009</td>
</tr>
</tbody>
</table>

PPM ≥ moderate is indexed EOA <0.85 cm²/m²; severe PPM is indexed EOA <0.65 cm²/m². NYHA, New York Heart Association. Other abbreviations as in Tables 1,2.

Table 4. 1-Year Outcomes

<table>
<thead>
<tr>
<th></th>
<th>BE (n=31)</th>
<th>SE (n=12)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cause death</td>
<td>0</td>
<td>1 (8.3)</td>
<td>0.28</td>
</tr>
<tr>
<td>Heart failure hospitalization</td>
<td>0</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>NYHA Class III or IV</td>
<td>0</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Echocardiography findings</td>
<td>(n=28)</td>
<td>(n=11)</td>
<td></td>
</tr>
<tr>
<td>EOA</td>
<td>1.0 (0.8–1.3)</td>
<td>1.2 (1.2–1.4)</td>
<td>0.08</td>
</tr>
<tr>
<td>EOAi</td>
<td>0.7 (0.6–1.0)</td>
<td>0.9 (0.9–1.0)</td>
<td>0.046</td>
</tr>
<tr>
<td>MPG</td>
<td>17.4 (12.0–20.1)</td>
<td>8.2 (4.2–10.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Peak velocity</td>
<td>2.8 (2.4–3.1)</td>
<td>1.8 (1.5–2.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Change in EF (%)</td>
<td>1.0 (−3.8–6.5)</td>
<td>1.0 (−1–9)</td>
<td>0.42</td>
</tr>
<tr>
<td>Change in LVDd (mm)</td>
<td>0.5 (−3.3–4.0)</td>
<td>0 (−2–3)</td>
<td>0.83</td>
</tr>
<tr>
<td>PPM ≥ moderate</td>
<td>18 (64)</td>
<td>1 (9)</td>
<td>0.02</td>
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<tr>
<td>Severe PPM</td>
<td>10 (36)</td>
<td>0</td>
<td>0.021</td>
</tr>
<tr>
<td>Paravalvular leak ≥ moderate</td>
<td>4 (14)</td>
<td>0</td>
<td>0.25</td>
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</table>

PPM ≥ moderate is indexed EOA <0.85 cm²/m²; severe PPM is indexed EOA <0.65 cm²/m². Abbreviations as in Tables 1–3.

42.6% vs. 69.4% in patients with and without this technique, respectively (P<0.001). These strategies enable an increased EOA following SAVR, but the durability of an externally mounted valve is still a concern; some studies revealed accelerated structural valve deterioration and increased reoperation rates with externally mounted valves. Moreover, the aortic root enlargement procedure includes incision of the annulus and patch reconstruction of the root, thus it is more complicated than simple SAVR. There is also expected to be greater chance of bleeding, and longer cardiac-arrest time. The prosthetic valve used in TAVI does not require a sewing ring and thus results in a larger EOA as compared with the surgical valves. Clavel et al revealed lower trans-prosthetic gradients, higher indexed EOA, and reduced PPM rates with TAVI compared with SAVR. Therefore, TAVI is a potential strategy for small annuli.

TAVI emerged from Western countries, and now many procedures are being performed in Asian countries as well. Asian patients have smaller body size, and the 20-mm BE-THV was specially manufactured for their small annuli; however, comparative data for SE-THV in small annuli are limited. The hemodynamic assessment in the current study showed that less favorable hemodynamics occurred with smaller sized devices, which is consistent with a previous study. In particular, the 20-mm BE-THV revealed high residual pressure and velocity with a small EOA of 1.03 cm² (Figure 3). SE-THV implantation showed signifi-
cantly larger EOA resulting in lower rate of post-proce-
dural PPM compared with BE-THV implantation. It is 
mainly owing to the supra-annular design of the SE-THV 
(Figure 1). Even if the native annulus is small, a higher 
prosthetic annulus enables to acquire extra EOA. This 
larger EOA is the advantage of the SE-THV, especially 
in patients with a small annulus. On the other hand, the 
SE-THV generally shows a higher chance of conduction 
disturbance. In our study as well, the SE-THV group 
showed higher rates of new pacemaker implantation and 
left bundle block. The design of the SE-THV requires deeper 
deployment and larger expansion in the left ventricular 
tract, which can cause this disadvantage. In contrast, the 
shorter metal of BE-THV allows easier access to the coro-

yory artery and less chance of conduction disturbance; 
however, the prosthetic annulus must be accommodated at 
the native annulus level and does not create a larger EOA. 
The difference in the design of the SE- and BE-THV 
contributes to these strengths and weaknesses of each 
device.

A large registry of the Society of Thoracic Surgeons/ 
American College of Cardiology TVT (Transcatheter Valve 
Therapy) registry reported that severe PPM was associated 
with higher mortality and heart failure rehospitalization at 1 
year; mortality was 17.2%, 15.6%, and 15.9% in severe, 
moderate, and no PPM patients, respectively (P=0.02), 
and heart failure rehospitalization respectively occurred in 
14.7%, 12.8% and 11.9% of patients (P<0.001).18 Our study 
did not show worse mortality with severe PPM, potentially 
because of the small number of study subjects. Une et al 
reported that PPM is an independent predictor of redo 
aortic valve replacement due to structural valve 
deterioration (odds ratio: 1.63; 95% confidence interval 
1.01–2.63; P=0.045).19 As there is a widespread trend of 
younger patients undergoing TAVI, avoiding PPM is a 
major concern.

Hahn et al reported that the SAPIEN 3 post-implant 
EOA was progressively larger for each quintile of annular 
area (P<0.001), and similarly for the Evolut R valve, post-
implantation EOA was significantly larger for each quin-
tile of annular perimeter (P<0.001).13 This is consistent 
with our findings for the post-TAVI hemodynamics with 
each device, whereby smaller valves had less favorable 
parameters (Figure 3). Rogers et al reported that the SE-
THV in a small aortic annulus was associated with signifi-
cantly higher dimensionless indexes (0.64 vs. 0.53, P=0.02) 
and lower peak velocities (1.8 vs. 2.4 m/s, P<0.001) and 
a trend towards lower mean gradients (7.5 vs. 10.0 mmHg, 
P=0.07) compared with BE-THV. These differences were 
attenuated and absent in patients with medium to large 
annuli.24 In other words, the difference is vitally important 
in cohorts with small annuli, such as Asian populations.

The report by Rogers et al showed no significant differ-
cence in the PPM rate between BE-THV and SE-THV in 
patients with small annuli; moderate PPM was 8 (42%) vs. 
4 (24%) (P=0.17) and none of the patients had severe 
PPM.24 Our study showed significantly higher rates of 
PPM for BE-THV implantation, potentially because of the 
different definition of a small annulus. In our study, a small 
annulus was defined as an annulus area <330 mm² based 
on the cutoff for the minimum BE-THV (20-mm Sapien 3). 
The previous report divided the patients into textile groups 
based on perimeter, resulting in perimeter cutoffs of 73 and 
80 mm. A small annulus was defined as a perimeter 
<73 mm. As shown in our study, the 20-mm BE-THV had 

Study Limitations

This was a single-center study using retrospectively 
reviewed data and no randomization between the different 
devices was performed. Device selection is multifactorial, 
including anatomical factors, and the decision was at the 
discretion of the heart team. The selection bias is the major 
limitation of this study. As to the baseline characteristics, 
the SE-THV group showed smaller annulus areas. SE-
THV tended to be selected for patients with small annuli, 
which could be the reason for this difference. Although the 
SE-THV group had smaller annuli they showed more 
favorable hemodynamics after TAVI, and the conclusions 
of this study are consistent. Although multiple devices are 
available worldwide, the devices used for the study were 
limited (Sapien 3, Evolut R and Evolut Pro).

Further analysis in a larger multicenter, long-term study 
is warranted to definitively assess this question.

Conclusions

To our knowledge, this is the first study to show that the 
SE-THV had a significantly lower PPM rate compared 
with the BE-THV in patients with a small aortic annulus. 
As the indication for TAVI expands into lower risk and 
younger patients in whom the valves are expected to function 
for a longer period, a strategy to avoid PPM is crucial 
especially in patients with a small annulus. This study will 
provide important information for device selection to maxi-
mize the EOA and mitigate the risk of PPM in these 
patients.

Small aortic annulus is commonly seen in Japanese 
patients, and avoiding PPM following TAVI is an impor-
tant concern. Due to its supra-annular design, SE-THV 
implantation results in a larger EOA with more favorable 
acute hemodynamic parameters with less PPM. This is 
useful information for the device selection process for 
TAVI. Additional research with larger cohorts and long-
term follow-up is required to solidify the conclusions of 
this study.

Disclosure

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Data Availability

The deidentified participant data will not be shared.
References


