



Early outcomes of transcatheter aortic valve implantation for degenerated aortic bioprostheses in Japanese patients: insights from the AORTIC VIV study

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Abstract

Objective The valve-in-valve procedure, in which a transcatheter heart valve (THV) is implanted into a degenerated bioprosthetic valve, is standardized for high-risk patients. However, this procedure is challenging in Japanese patients who have a small aortic annulus. We investigated the feasibility, safety, and therapeutic efficacy of the valve-in-valve procedure involving a degenerated stented bioprosthesis, stentless bioprosthesis, or THV.

Methods We performed a single-center, non-comparative study of the aortic valve-in-valve procedure (AORTIC VIV study). Beginning in October 2016, the aortic valve-in-valve procedure was performed in seven patients with a stented bioprosthesis, in three patients with a stentless bioprosthesis, and in one patient with a THV.

Results No 30-day post-procedure mortality or severe morbidities occurred. The mean echocardiographic gradient in the aortic position improved from 41 (38–48) to 17 (11–22) mmHg at 30 days ($p=0.01$). No paravalvular or mild and more transvalvular leaks were detected. The New York Heart Association functional class improved from 2 (2–2.5) to 1 (1–1) at 30 days postoperatively ($p=0.01$). Although the procedure failed in two patients with an implanted stentless bioprosthesis, the third patient with a stentless bioprosthesis and the one patient with a degenerated THV successfully underwent the valve-in-valve procedure.

Conclusions Feasibility, safety, and potential efficacy of the aortic valve-in-valve procedure were confirmed in selected Japanese patients with a degenerated aortic bioprosthesis. The valve-in-valve procedure for stentless bioprostheses was technically challenging.

Keywords Transcatheter aortic valve implantation · Valve-in-valve · Stentless valve · TAV-in-SAV · TAV-in-TAV

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Introduction

Transcatheter aortic valve implantation has been established as an alternative procedure in high-risk patients with aortic stenosis [1]. In recent years, transcatheter aortic valve implantation for a failed bioprosthesis (valve-in-valve procedure) has been reported. The valve-in-valve procedure in the aortic position is effective for patients with a high risk or contraindication for a surgical reoperation [1, 2]. However, a previous study showed worse outcomes of the valve-in-valve procedure in patients with a small surgical valve (≤ 21 mm) [2]. Moreover, a small surgical valve was correlated not only with pre-existing severe prosthesis–patient mismatch (PPM) but also with post-procedural severe PPM and 1-year mortality after the valve-in-valve procedure [2–4]. In Japan, the estimated

rate of aortic valve replacement (AVR) with these small-sized bioprostheses ranges from 57 to 75% [5, 6]. In these situations, the valve-in-valve procedure in Japanese patients with a small surgical valve is challenging. A clinical study called “A single-institution, exploratory, safety evaluation study of AORTIC Valve-In-Valve transcatheter aortic valve implantation for degenerated bioprosthetic heart valves” (AORTIC VIV study) was launched in our institute to investigate the early clinical outcomes of the valve-in-valve procedure in the aortic position.

Methods

Study design

This study was a prospective, non-comparative, non-randomized, interventional cohort study with off-label use of a commercially available transcatheter heart valve (THV) in high-risk patients with a degenerated bioprosthesis of the aortic position in Japan. The National Cerebral and Cardiovascular Center Institutional Review Board approved the study. Eleven patients with a degenerative bioprosthesis of the aortic position were registered and underwent the valve-in-valve procedure from October 2016 to November 2017. All patients provided written informed consent for surgery and use of their data for diagnostic and research purposes. This study was registered in the University Hospital Medical Information Network Clinical Trials Registry (identifier UMIN000026450).

Patient selection

The study protocol and patient inclusion and exclusion criteria have already been reported [7]. Patients with a degenerated aortic bioprosthesis and high operative risk for redo AVR were screened to ensure that they met all inclusion criteria. The definitions of a degenerated prosthetic valve, including a THV, were stenosis, regurgitation, or both [8]. After confirmation of eligibility, each patient underwent a preoperative screening.

High operative risk was defined as an expected mortality rate of > 8.0% as estimated by the Society of Thoracic Surgeons (STS) score [1] and/or the presence of the following risk factors, which were considered to render the case inoperable (at the surgeons' discretion) [9]: porcelain aorta, mobile atherosclerosis at the aorta, history of mediastinal radiotherapy or mediastinitis, age of > 75 years with a left ventricular ejection fraction of < 40% [10], previous coronary artery bypass grafting, history of two or more cardiac surgeries, or liver cirrhosis.

Study endpoints and follow-up

All patients were followed up for at least 30 days after the procedures. The primary endpoints were intraoperative safety and efficacy (device success) based on Valve Academic Research Consortium-2 (VARC-2) [8]. The secondary endpoints were early safety and therapeutic efficacy based on VARC-2 within 30 days after the procedure.

After the procedure, the patients took 100 mg aspirin and 75 mg clopidogrel daily for 90 days. For patients with a known or suspected allergy to these tablets or a bleeding complication, other antiplatelet or anticoagulant agents were administered.

Valve-in-valve procedures and device selection

The valve-in-valve procedure was performed with the standard method [11]. To improve the hemodynamic function of the aortic position, we aimed for shallow implantation [12, 13]. We defined shallow implantation as placement of the bottom level of the implanted THV within 5 mm below the sewing ring or suture line of the deteriorated surgical bioprosthesis [14].

The surgical procedures were as follows. For a transapical approach, an approximately 5-cm left anterolateral skin incision was performed in the fifth intercostal space. The adhered pericardium was carefully separated from the epicardium, and the pericardium was retracted with silk sutures and left ventricular apex was exposed. The optimal access site was then determined with transesophageal echocardiography and epicardial echocardiography using a VeriQ™ system (Medistim ASA, Oslo, Norway). A temporary epicardial pacing heart wire was attached to the left ventricular wall. Two U stitches using 3–0 polyvinylidene fluoride suture (Asflex; CrownJun Kono Corp., Tokyo, Japan) with Teflon felt strips were placed at the access site of the left ventricle. A catheter and THV delivery system were then inserted. After the valve-in-valve procedure, the delivery sheath was removed under controlled heartbeats and the access site was closed with the U stitches. Finally, a 19-Fr Blake drain was placed and the chest wall was closed.

For the transfemoral approach, a 3-cm transversal incision was made in the groin fold and the subcutaneous tissue was carefully separated. Once the femoral artery was exposed, a noncalcified area was chosen and a catheter and THV delivery system were inserted. After the valve-in-valve procedure, the delivery sheath was removed and the access site was closed with interrupted 5–0 polypropylene sutures. Finally, the access site was assessed under fluoroscopic visualization.

To minimize the invasiveness, the transfemoral approach was chosen as the first access. If iliofemoral

access was unsuitable, the transapical approach was selected. A balloon-expandable THV (SAPIEN XT; Edwards Lifesciences, Irvine, CA, USA) and self-expandable THV (CoreValve Evolut R; Medtronic, Minneapolis, MN, USA) were used. The SAPIEN XT was used as the primary device. Final decisions were made by the institutional heart team.

Statistical analysis

Preoperative and postoperative continuous data are expressed as median with interquartile range, as appropriate. The Wilcoxon test was used for non-normally distributed data. The Chi-square test or Fisher's exact test was used to compare categorical variables. JMP version 10 (SAS Institute Inc., Cary, NC, USA) was used for data analysis. A *p* value of <0.05 was considered statistically significant.

Results

Patients' characteristics

The baseline characteristics of the patients from the AORTIC VIV study are shown in Table 1. The baseline demographics of each patient are shown in Table 2. The median STS score was 7.2% (5.4–9.8%). The most relevant risk factors to avert redo open heart surgery in patients with an STS score of $\leq 8\%$ were alcoholic cardiomyopathy (Patient #1), porcelain aorta (Patients #2 and #8), frailty (Patient #3), advanced age and impaired left ventricular function (baseline left ventricular ejection fraction, 33%) (Patient #5), and chronic obstructive pulmonary disease (Patient #7).

Preoperative echocardiographic findings and computed tomography measurements

Echocardiographic and computed tomography findings are shown in Table 1. Prosthetic valve stenosis was found in 10 patients (Table 2). Of these, five patients had both prosthetic valve stenosis and regurgitation. Patient #9 only had prosthetic valve regurgitation.

Intraoperative safety

The procedure failed in two patients. In Patient #4, we attempted the valve-in-valve procedure via the transfemoral approach with the 23-mm CoreValve Evolut R three times because of malpositioning. Coronary obstruction occurred in Patient #7, who underwent extracorporeal membrane oxygenation and emergent percutaneous coronary intervention. In the other nine patients, the valve-in-valve procedure was successful in terms of intraoperative safety (Table 3).

Table 1 Baseline characteristics

| Variables | Study population (<i>n</i> = 11) |
|--|-----------------------------------|
| Age, (years) | 83 (80–86) |
| Male | 3 (27.3) |
| Height, (cm) | 150 (142–160) |
| Weight, (kg) | 56 (47–60) |
| Body surface area, (m ²) | 1.5 (1.4–1.6) |
| STS predicted risk of mortality, (%) | 7.2 (5.4–9.8) |
| Hypertension | 9 (81.8) |
| Dyslipidemia | 8 (72.7) |
| Diabetes mellitus | 3 (27.3) |
| Chronic lung disease | 7 (63.6) |
| Peripheral vascular disease | 0 (0.0) |
| Prior cerebrovascular event | 1 (9.1) |
| Estimated glomerular filtration rate, (ml/min) | 50 (32–63) |
| Chronic kidney disease | 8 (72.7) |
| Chronic atrial fibrillation | 2 (18.2) |
| NYHA functional class | |
| II | 8 (72.7) |
| III | 3 (27.3) |
| IV | 0 (0.0) |
| Echocardiographic data | |
| LVEF, (%) | 60 (60–66) |
| LVEDD, (mm) | 47 (44–51) |
| LVESD, (mm) | 29 (24–33) |
| Diameter of LVOT, (mm) | 19.0 (17.3–19.7) |
| Peak aortic jet velocity, (m/s) | 4.1 (3.9–4.6) |
| Peak aortic pressure gradient, (mmHg) | 64 (58–81) |
| Mean aortic pressure gradient, (mmHg) | 42 (38–55) |
| Effective orifice area, (cm ²) | 0.8 (0.6–0.9) |
| Indexed effective orifice area, (cm ² /m ²) | 0.53 (0.46–0.66) |
| Transvalvular regurgitation | |
| None | 1 (9.1) |
| Trivial | 1 (9.1) |
| Mild | 3 (27.3) |
| Moderate or worse | 6 (54.5) |
| Paravalvular leakage | 0 (0.0) |
| Computed tomography findings | |
| Prosthetic valve area, (mm ²) | 202 (171–231) |
| Perimeter of prosthetic valve, (mm) | 52.1 (47.5–54.8) |
| Sinus of Valsalva height, (mm) | 17.1 (15.5–18.0) |
| Sinus of Valsalva diameter, (mm) | 28.1 (26.7–29.0) |
| Left coronary ostia height, (mm) | 11.0 (9.6–12.7) |
| Right coronary ostia height, (mm) | 12.7 (9.9–14.8) |
| Diameter of sinotubular junction, (mm) | 25.3 (21.4–29.1) |

Data are expressed as median (interquartile range) or number (%)

STS Society of Thoracic Surgeons, NYHA New York Heart Association, LVEF left ventricular ejection fraction, LVEDD left ventricular end-diastolic diameter, LVESD left ventricular end-systolic diameter, LVOT left ventricular outflow tract

Table 2 Preoperative characteristics

| Pt. Sex | Age (years) | BSA (m ²) | Comorbidities | Baseline NYHA functional class | No. of previous cardiac surgeries | STS PROM (%) | Interval from SAVR (years) | Most relevant risk factor | Degraded bioprosthetic thesis | Implantation technique | Label size (mm) | Internal diameter (mm) ^b | True internal diameter (mm) ^b | Stented or stentless | Mode of degeneration |
|-----------------------|-------------|-----------------------|--|--------------------------------|-----------------------------------|--------------|----------------------------|---------------------------|-------------------------------|----------------------------|-----------------|-------------------------------------|--|----------------------|----------------------|
| 1 Male | 79 | 1.59 | Alcoholic cardiomyopathy, bronchial asthma | II | 1 | 3.6 | 14.1 | Alcoholic cardiomyopathy | CEP | Supra-annular implantation | 25 | 24 | 23 | Stented | Stenosis |
| 2 ^a Female | 82 | 1.33 | Porcelain aorta, CKD | II | 1 | 6.6 | 12.7 | Porcelain aorta | CEP | Supra-annular implantation | 19 | 18 | 17 | Stented | Stenosis |
| 3 ^a Female | 82 | 1.15 | Frailty, CKD | II | 1 | 5.0 | 16.3 | Frailty | Mosaic | Supra-annular implantation | 19 | 17.5 | 16 | Stented | Mixed |
| 4 Male | 80 | 1.67 | Frailty, COPD, CKD | III | 1 | 10.1 | 15.5 | High operative risk | Freestyle | Modified sub-oronary | 21 | 21 | 20 | Stentless | Mixed |
| 5 ^a Female | 77 | 1.56 | Impaired LV function | II | 1 | 4.4 | 11.3 | Impaired LV function | CEP | Supra-annular implantation | 19 | 18 | 17 | Stented | Stenosis |
| 6 Female | 85 | 1.40 | Previous CABG, CKD | III | 2 | 11.1 | 17 | Previous CABG | Mosaic | Supra-annular implantation | 21 | 18.5 | 17 | Stented | Mixed |
| 7 Female | 75 | 1.49 | COPD | II | 1 | 7.2 | 12.6 | COPD | Freestyle | Root inclusion | 21 | 21 | 20 | Stentless | Stenosis |
| 8 Male | 86 | 1.91 | Porcelain aorta, CKD | II | 1 | 5.7 | 16.5 | Porcelain aorta | CEP | Supra-annular implantation | 21 | 20 | 19 | Stented | Regurgitation |
| 9 Female | 92 | 1.48 | Frailty, previous TAVI, CKD | III | 1 | 9.5 | 3.9 | High operative risk | SAPIEN XT | Trans-femoral TAVI | 23 | 23 | 23 | Stented | Stenosis |
| 10 Female | 85 | 1.15 | COPD, CKD | II | 1 | 9.1 | 17.1 | High operative risk | Freestyle | Modified sub-oronary | 21 | 21 | 20 | Stentless | Mixed |

Table 2 (continued)

| Pt. Sex | Age (years) | BSA (m ²) | Comorbidities | Baseline NYHA functional class | No. of previous cardiac surgeries | STS PROM (%) | Interval from SAVR (years) | Most relevant risk factor | Degenerated bioprosthetic thesis | Implantation technique | Label size (mm) | Internal diameter (mm) ^b | True internal diameter (mm) ^b | Stented or stentless | Mode of degeneration |
|-----------|-------------|-----------------------|---------------|--------------------------------|-----------------------------------|--------------|----------------------------|---------------------------|----------------------------------|----------------------------|-----------------|-------------------------------------|--|----------------------|----------------------|
| F1 Female | 83 | 1.47 | Frailty, CKD | II | 1 | 12.1 | 13.5 | High operative risk | CEP | Supra-annular implantation | 19 | 18 | 17 | Stented | Mixed |

Pt patient, BSA body surface area, NYHA New York Heart Association, STS PROM Society of Thoracic Surgeons predicted risk of mortality, SAVR surgical aortic valve replacement, CKD chronic kidney disease, COPD, chronic obstructive pulmonary disease, LV left ventricular, CABG coronary artery bypass grafting, TAVI transcatheter aortic valve implantation, CEP Carpentier–Edwards Perimount pericardial bioprosthesis

^aPatients #2, #3, and #5 were previously described in Reference #16

^bInternal diameter and true internal diameter were retrieved from the Valve in Valve App, version 2.0 (UBQO Limited, London, UK)

Echocardiographic findings following the valve-in-valve procedure

The postoperative echocardiographic prosthetic valve function significantly improved (Fig. 1, Table S1). No patients developed paravalvular leakage. There was no significant difference in the effective orifice area (EOA) between the balloon-expandable and self-expandable THVs (Figure S1). We intended to implant each THV shallowly to obtain a large EOA and indexed EOA (EOAi) (Figure S2). Before the valve-in-valve procedure, three patients had moderate PPM ($0.65 \leq \text{EOAi} < 0.85 \text{ cm}^2/\text{m}^2$) and eight patients had severe PPM ($\text{EOAi} < 0.65 \text{ cm}^2/\text{m}^2$) (Fig. 2). After the procedure, six, four, and three patients had moderate PPM at 1 week, 30 days, and 1 year, respectively, and two, three, and three patients had severe PPM at 1 week, 30 days, and 1 year, respectively, (Fig. 2).

Follow-up and outcomes of secondary endpoints regarding safety and efficacy

Except for day 0, no mortality, vascular complication, stroke, life-threatening bleeding, cardiogenic shock, interventions for coronary artery disease, or prosthetic valve failure occurred within 30 days after the procedure. Furthermore, no late mortality was observed during the latest followed-up period (376 [185–479] days).

In Patient #3, the data for day 30 and 1 year were deficient because she was admitted to a local hospital for a traumatic brain injury on day 30 and underwent subsequent rehabilitation. In Patient #8, the data for day 30 were deficit because he was admitted to a local hospital for fever of unknown origin. Patient #5 underwent redo AVR because of prosthetic valve endocarditis on day 176; except for survival, the 1-year data for this patient were excluded. No other complications or rehospitalization associated with major adverse cardiac or cerebrovascular events occurred in any patients.

The New York Heart Association functional classification significantly improved at 7 days (1 [1, 2], $p = 0.03$), 30 days (1 [1], $p = 0.01$), and 1 year (1 [1], $p < 0.01$) following the valve-in-valve procedure compared with baseline (2 [2–2.5]).

Procedural success and device success

The procedural success rate was 81.8% (9/11) (Table 3). By contrast, the device success rate was 54.5% (6/11). Device failures included device malpositioning (Patient #4), coronary obstruction (Patient #7), a mean aortic pressure gradient of $> 20 \text{ mmHg}$ and/or aortic peak jet velocity of $> 3 \text{ m/s}$ (Patients #2 and #5), and severe PPM (Patients #4 and #8). Shallow implantation was achieved in eight patients (Table 3). The initial THV implantation depth, which

Table 3 Valve-in-valve procedure and postoperative course in each patient

| Pt. | Procedural outcomes | | | | | | | | | | | Postoperative course | |
|----------------|----------------------|-----------------------|-------------|----------------------------|------------------|----------------------|--|---|------------------------------|-------------------|--------------------------------|----------------------|--|
| | Operation time (min) | Successful VIV access | No. of THVs | Successfully implanted THV | Size of THV (mm) | Oversizing ratio (%) | Actual oversizing ratio (%) [†] | Successful implantation depth (mm) [‡] | Intraoperative complications | Procedure success | Hospital stay after VIV (days) | Outcome | |
| 1 | 91 | TF | 1 | SAPIEN XT | 26 | 27.9 | 67.5 | 4.5 | None | YES | 8 | Discharge | |
| 2 ^a | 109 | TF | 1 | SAPIEN XT | 20 | 38.4 | 73.9 | 6.7 | None | YES | 6 | Discharge | |
| 3 ^a | 85 | TF | 1 | SAPIEN XT | 23 | 106.5 | 91.6 | 3.7 | None | YES | 6 | Discharge | |
| 4 | 125 | TA | 3 | SAPIEN XT | 26 | 69.1 | 162.9 | 5.9 | Malpositioning | No | 14 | Discharge | |
| 5 ^a | 140 | TF | 1 | SAPIEN XT | 23 | 82.9 | 158.1 | 4.6 | None | YES | 6 | Discharge | |
| 6 | 93 | TF | 1 | Core Valve Evolut R | 23 | 17.6 | 11.1 | 3.1 | None | YES | 6 | Discharge | |
| 7 | 212 | TA | 1 | SAPIEN XT | 23 | 32.2 | 171.7 | 2.7 | Coronary obstruction | No | 9 | Discharge | |
| 8 | 102 | TF | 1 | Core Valve Evolut R | 23 | 5.3 | 20.5 | 1.6 | None | YES | 8 | Discharge | |
| 9 | 101 | TF | 1 | Core Valve Evolut R | 23 | -13.0 | 11.1 | 4.3 | None | YES | 7 | Discharge | |
| 10 | 120 | TF | 1 | Core Valve Evolut R | 23 | 0.0 | 45.9 | 9.3 | None | YES | 8 | Discharge | |
| 11 | 79 | TF | 1 | Core Valve Evolut R | 23 | 17.6 | 27.6 | 2.0 | None | YES | 8 | Discharge | |

PT patient, VIV valve-in-valve, THV transcatheter heart valve, TF transfemoral, TA transapical

^aPatients #2, #3, and #5 were previously described in Reference #16

^bActual oversizing ratio was calculated by multidetector computed tomography

^cImplantation depths were measured from the sewing ring or sutureline of the deteriorated surgical bioprosthesis to the bottom frame of THV on the left ventricular side

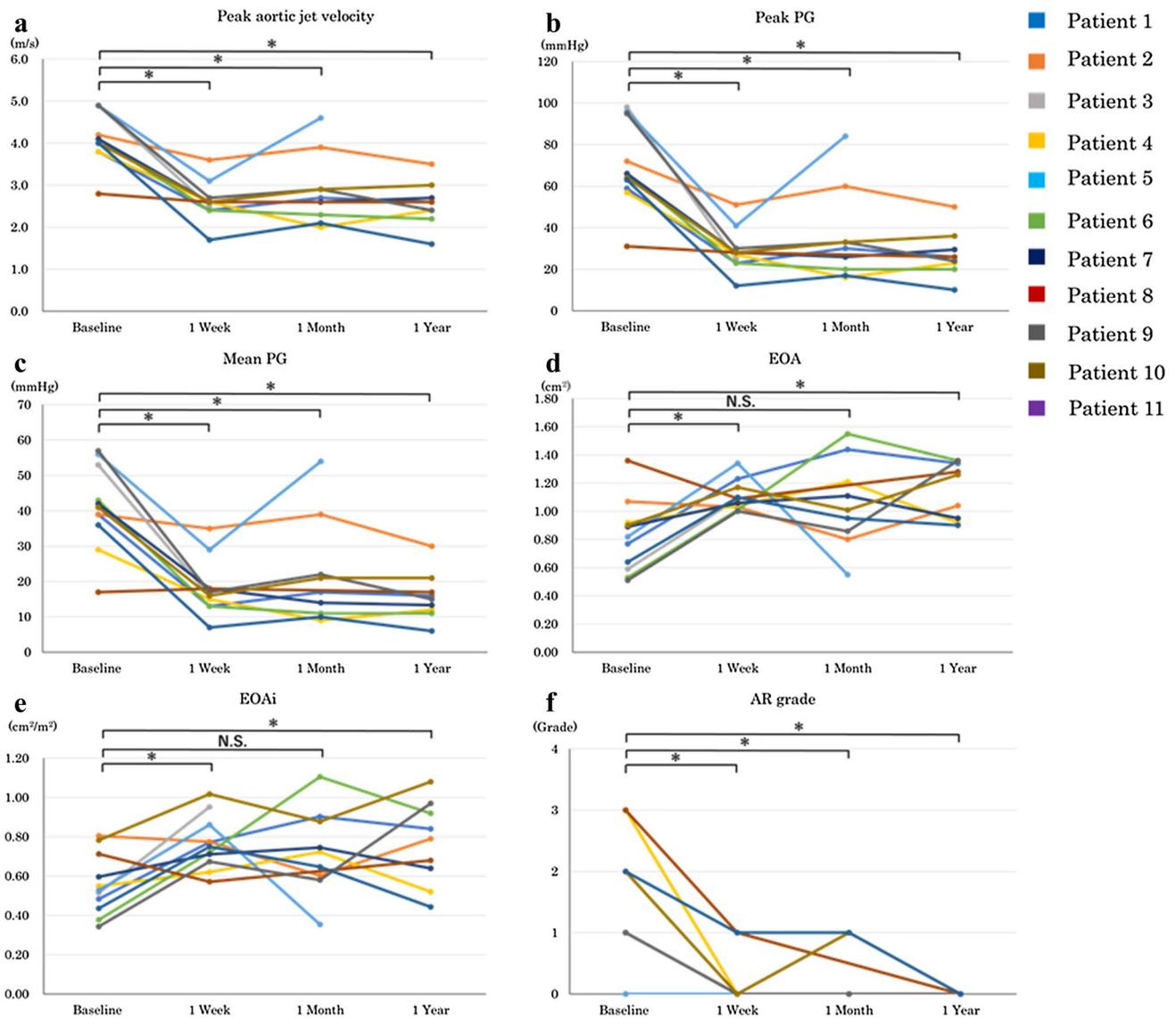


Fig. 1 Serial changes in transthoracic echocardiographic parameters. **a** Peak aortic jet velocity, **b** peak aortic PG, **c** mean aortic PG, **d** EOA, **e** EOAI, **f** AR grade, **g** LVEDD, **h** LVESD, and **i** LVEF. *Statistically significant difference ($p < 0.05$). N.S. not significant, PG

pressure gradient, EOA effective orifice area, EOAI indexed effective orifice area, AR grade, LVEDD left ventricular end-diastolic dimension, LVESD left ventricular end-systolic dimension, LVEF left ventricular ejection fraction

resulted in malpositioning in Patient #4, was 0 mm, and we deployed the fourth THV deeply. In Patient #7, the height of the left coronary ostia was 12.4 mm, the left coronary cusp length of the implanted prosthesis was 10.6 mm, and the length of the sinus of Valsalva was 25.3 mm, which was the smallest in this study.

Method of valve-in-valve procedure for degenerated stentless bioprosthesis

Based on the patients with severe complications who underwent the standard procedure with a stentless bioprosthesis (Patients #4 and #7), we changed the technique

for a degenerated stentless bioprosthesis in Patient #10 (Figure S3). We implanted the THV deeply to avoid malpositioning.

TAV-in-TAV

We performed the valve-in-valve procedure in the degenerated THV (TAV-in-TAV) using the standard technique, and the CoreValve Evolut R was successfully implanted (Figure S3). The THV function greatly improved (Fig. 1), and the patient was discharged without complications (Table 3).

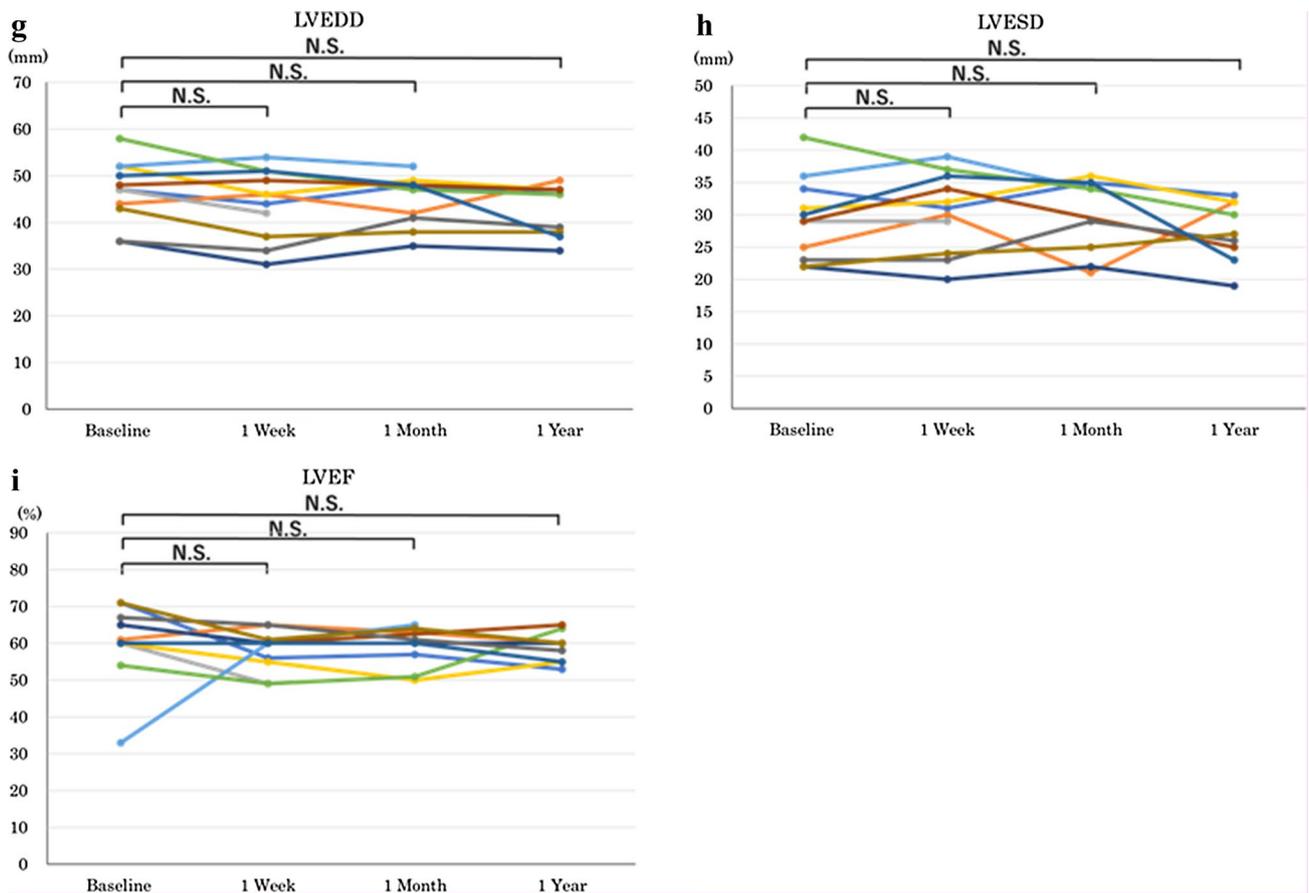
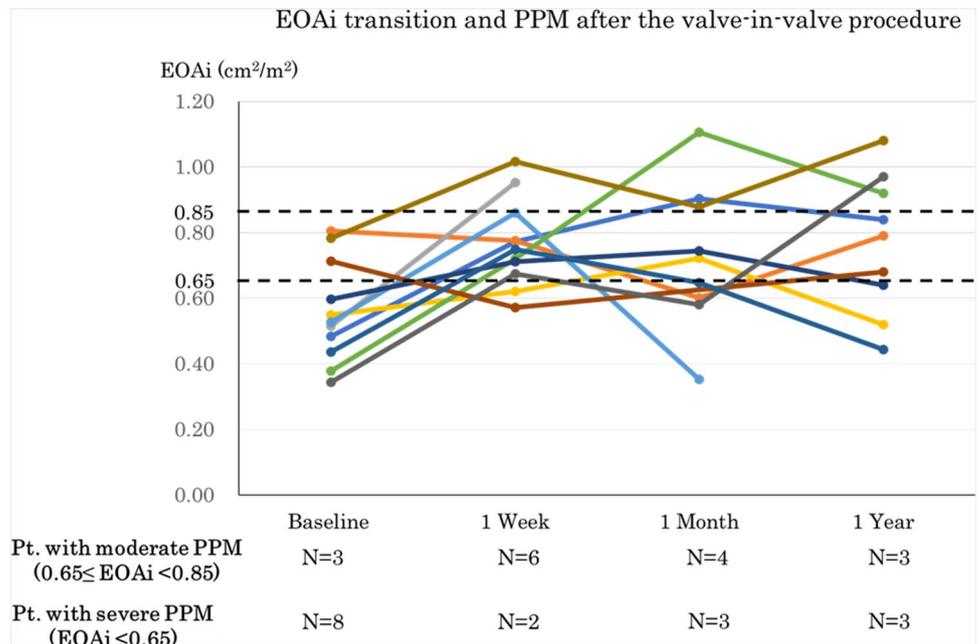


Fig. 1 (continued)

Fig. 2 EOA_i transition and PPM after the valve-in-valve procedure. EOA_i indexed effective orifice area, PPM prosthesis–patient mismatch, Pt patient



Discussion

Safety and efficacy of valve-in-valve procedure

Although intraoperative safety was accomplished in 10 (90.9%) patients because of the coronary obstruction in Patient #7, no 30-day mortality, life-threatening bleeding, major vascular complication, or major stroke occurred. In previous studies, the incidence of 30-day mortality, life-threatening bleeding, major vascular complication, and major stroke were 2.2–7.6%, 6.2–14.6%, 4.1–10.1%, and 0.4–2.7%, respectively [2, 4, 15]. In the present study, we performed the cautious procedures as shown in the Method section. The secure surgical procedures are essential to reduce 30-day mortality and procedure-related complications.

Although procedural success was achieved in nine (81.8%) patients, intended THV performance was achieved in seven (63.6%). Nine (81.8%) patients had a previously implanted small surgical valve, and this proportion is much higher than that in previous reports (26.8–33.4%) [2, 4, 15]. A small surgical valve is a strong risk factor for restricted post-procedural hemodynamics and 1-year mortality [2, 4, 15]. The valve-in-valve procedure for a small surgical bioprosthesis requires shallow implantation to improve the hemodynamics of the aortic position [12, 13, 16], and thus achieve a good outcome. In our study, the aortic pressure gradient, EOA, and EOAI improved significantly after the procedure, and this improvement was sustained for up to 1 year (Fig. 1, Table S1). Although most patients in this study had a small surgical valve, the presence of 30-day post-procedural severe PPM was comparable with that in previous reports (31.8–58.4%) [2, 15]. Although post-procedural PPM is still a concern after the valve-in-valve procedure and should be followed up, shallow implantation may be a useful technique to improve hemodynamics.

However, shallow implantation is a technically demanding procedure. Moreover, in patients with a deteriorated stentless bioprosthesis, it may cause malpositioning because of the lack of calcification around the suture line and stent frame.

Alternative or complementary options for valve-in-valve procedure

Balloon aortic valvuloplasty is less invasive in high-risk patients with multiple comorbidities and contributes to immediate hemodynamic improvement. However, it does not result in sustained clinical improvement because of high recurrence rates within 6 months [9]. Even in patients

with an aortic bioprosthetic stenosis, high recurrence rates and residual aortic regurgitation remain concerns [17]. Therefore, sole aortic balloon valvuloplasty is not recommended for this pathology. If patients have anatomical difficulties or prohibitive risk factors for the valve-in-valve procedure, balloon aortic valvuloplasty may be a palliative option.

On the other hand, bioprosthetic valve fracture is a promising complementary technique of the valve-in-valve procedure in patients with a small surgical valve. In the aortic position, hemodynamic improvement is achieved without fatal complications [18]. This technique may solve post-procedural issues related to hemodynamics. However, data on the use of this technique remain limited to date.

Coronary obstruction

Japanese patients with a small surgical valve frequently have a small sinus of Valsalva and short height of the coronary artery orifice. These features are known as risk factors of coronary obstruction [19]. A self-expandable THV would be better in Japanese patients with a risk of coronary obstruction if a self-expandable THV is eligible. The retrievability of this device is useful to avoid coronary obstruction.

Possibility of TAV-in-TAV

The THV performance gradually deteriorates, and some patients require re-intervention for a deteriorated THV. Barbanti et al. showed the feasibility and good outcomes of TAV-in-TAV [20]. However, the optimal combination of the THV type, the durability, and the efficacy in the long term remain concerns.

Study limitations

This prospective single-center, nonrandomized, non-comparative study involved a small number of patients who were followed up for at least 30 days after the procedures. The THV type and size were selected according to the anatomical eligibility of each THV and discussion by the institutional heart team. The number of patients was too small to analyze reliable predictors of device success, procedural success, or accomplishment of the intended THV performance using a logistic regression model. Cut-off indices for safety and efficacy were not established in this study.

Conclusions

In the AORTIC VIV study, the feasibility, safety, and potential efficacy of the aortic valve-in-valve procedure was confirmed in selected Japanese patients with a degenerated

aortic bioprosthesis. The valve-in-valve procedure for small stented and stentless bioprostheses requires cautious techniques.

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Compliance with ethical standards

Conflict of interest Devices were provided without compensation by Edwards Lifesciences and Medtronic. Tomoyuki Fujita is an advisor of Medtronic. Kizuku Yamashita, Satsuki Fukushima, Yusuke Shimahara, Yasuhiro Hamatani, Hideaki Kanzaki, Tetsuya Fukuda, Chisato Izumi, Satoshi Yasuda, and Junjiro Kobayashi have no conflicts of interest.

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