Renal Replacement Therapy

RESEARCH

Open Access

Comparison of therapeutic strategies for aortic stenosis between transcatheter and surgical aortic valve implantation: a retrospective cohort study in Japanese dialysis patients

Masahiro Sakai[1], Koichi Hayashi[2], Yuki Hara[1], Akihiro Miyake[1], Keisuke Takano[1], Taro Hirai[1], Michi Kobayashi[1], Keita Endo[1], Kaede Yoshino[1], Koichi Kitamura[1], Shinsuke Ito[1], Tatsuya Ikeda[1], Yasuhiro Suzuki[3], Joji Ito[4], Kotaro Obunai[5], Hiroyuki Watanabe[5] and Toshihiko Suzuki[1*]

Abstract

Background Although transcatheter aortic valve implantation (TAVI) is assumed to be a less invasive therapy in high-risk patients with aortic valve stenosis (AS), there have been limited data suggesting its beneficial effects on cardiovascular mortality in Japanese patients receiving dialysis therapy.

Methods Hemodialysis patients with severe AS underwent either TAVI ($n=33$) or surgical aortic valve replacement (SAVR, $n=25$). We compared the postoperative outcomes and perioperative complications, including dialysis-associated parameters [e.g., intradialytic hypotension (IDH)], between TAVI and SAVR.

Results A 30-day and 1-year mortality rate was nearly the same among the TAVI and the SAVR group. Incidence of permanent pacemaker implantation or other events, including stroke, bleeding and vascular complications, in the TAVI group were not different from those in SAVR patients during the 30-day or 1-year postoperative period. The incidence of IDH was increased following SAVR (odds ratio (OR) = 11.29 [95% CI 1.29–98.89]) but was not affected by TAVI (OR = 1.55 [95% CI 0.24–9.94]). Among the patients aged 75 or older, the incidence of IDH was particularly conspicuous in the SAVR group (OR = 15.75 [95% CI 2.30–107.93]). Because there were differences in background data (age, EuroSCORE II, and dialysis duration) between these groups, propensity score-matched analysis was conducted and showed no difference in the composite event-free probability between the TAVI and the SAVR group over one year ($p=0.816$).

Conclusions TAVI offers an alternative strategy to Japanese hemodialysis patients with severe AS, with nearly the same incidence of complications as SAVR during 1-year observation.

Keywords Hemodialysis, Transcatheter aortic valve implantation, Surgical aortic valve replacement, Intradialytic hypotension, Dialysis prescription, Hospitalization

*Correspondence:
Toshihiko Suzuki
toshihikos@jadecom.jp
Full list of author information is available at the end of the article

Background

Advanced stages of aortic valve stenosis (AS) are associated with poor cardiovascular outcomes that could cause life-threatening events, including severe systolic dysfunction and arrhythmia. Among patients with end-stage kidney disease, valvular heart disease is prevalent and aortic valve calcification progresses possibly as a result of prolonged exposure to a deranged electrolyte balance, which occurs earlier than in the general population [1, 2]. In Japan, approximately 350,000 patients receive dialysis therapy [https://docs.jsdt.or.jp/overview/file/2021/pdf/01.pdf], and one-fourth of the patients undergo dialysis for more than 10 years because of a low rate of kidney transplantation [3] [https://docs.jsdt.or.jp/overview/file/2021/pdf/02.pdf]. Given that 36–55% of the dialysis patients are reported to have calcified AS in Western countries [2, 4], a larger number of dialysis patients are anticipated to have AS in Japan where they have a lengthy period of dialysis therapy. Furthermore, the cardiovascular effect of AS appears more conspicuous in hemodialysis patients because of hemodynamic burden during every dialysis session. Traditionally, surgical aortic valve replacement (SAVR) has been the golden standard for the treatment of AS although its implementation still entails high mortality in patients with end-stage kidney disease, particularly on dialysis therapy [5]. These observations strongly urge the necessity for alternative therapeutic strategies that could mitigate the burden associated with the operative procedure in dialysis patients.

A couple of decades have passed since transcatheter aortic valve implantation (TAVI) emerged in 2002 [6]. This therapeutic tool was employed in high-risk patients and the results were deemed favorable, with nearly comparable outcomes and shorter hospital stays than SAVR [7]. Hence, TAVI has become a principal therapeutic modality for symptomatic severe AS with high risk. In patients on maintenance dialysis, however, TAVI is reported to be associated with a higher in-hospital mortality than in those without dialysis therapy [8]. Alternatively, the results from the German Aortic Valve Registry have demonstrated that TAVI confers very promising outcomes, including a 30-day survival rate, when compared with SAVR [9]. Since there are a growing number of patients who undergo dialysis therapy for lengthy periods in Japan [3], the characterization of the peri- and postoperative clinical features and risks entailed among dialysis patients receiving TAVI or SAVR is absolutely required. Nevertheless, to the best of our knowledge, there have hitherto been no studies that attempt to make a direct comparison of the clinical results and outcomes between TAVI and SAVR among Japanese dialysis patients. Hence, the efficacy or safety of TAVI in dialysis patients has not been fully elucidated.

We therefore evaluated the impact of TAVI on peri-/postoperative profiles, including dialysis-associated clinical parameters, length of hospitalization, and cardiovascular events in hemodialysis patients with severe AS. Furthermore, these results were compared with those obtained in patients receiving SAVR.

Methods

This retrospective cohort study evaluates the impact of TAVI or SAVR on clinical course and outcomes in Japanese dialysis patients with AS. The study was approved by the Ethics Committee of Tokyo Bay Urayasu-Ichikawa Medical Center with waiver of the requirement for obtaining informed consent (approval No. 728) and was registered at UMIN (ID: UMIN000046157). The study was conducted in accordance with the Declaration of Helsinki. Information from medical records was deidentified prior to final analysis. The opt-out information is available on the following URL (https://tokyobay-mc.jp/patient-right/).

Study population

During the period between April 2013 and December 2021, a total of 58 hemodialysis patients with severe AS were referred to our medical center for eligibility for TAVI or SAVR. Severe AS was defined as (1) an aortic valve area < 1.0 cm^2, (2) a mean pressure gradient ≥ 40 mmHg, or (3) a peak aortic jet velocity ≥ 4.0 m/sec [10].

In February 2021, the Government of Japan has approved the extended coverage of health insurance over TAVI therapy in dialysis patients with severe AS though only specified facilities (i.e., 36 facilities as of now), including our hospital, are allowed for its implementation. For this reason, all patients who visited our hospital before January 2021 underwent SAVR, and almost all patients have received TAVI thereafter; three patients underwent SAVR. For the procedure of TAVI, an Edwards SAPIEN (Edwards Lifesciences, Irvine, CA) bioprosthesis was used.

The Japanese Circulation Society [10] has made the consensus recommendations for operative procedures for severe AS though it does not cover dialysis patients at present: The patients aged 80 or older should receive TAVI and those aged 75 or younger prefer SAVR, with due consideration for other factors (e.g., EuroSCORE, durability of valves). We therefore determined the operative procedures after providing the thorough information on the consensus recommendations and having full discussion with patients and their families.

Study design

The impact of SAVR or TAVI on dialysis-associated parameters as well as the incidence of the complications was assessed. After the implementation of SAVR or TAVI, the prescription of hemodialysis was adjusted to alleviate hemodynamic instability, and if necessary, continuous renal replacement therapy (CRRT) was conducted. Furthermore, the incidence of intradialytic hypotension during the intermittent dialysis therapy of two-week perioperative periods was assessed. Intradialytic hypotension was defined as a fall in systolic blood pressure ≥ 20 mmHg/mean blood pressure ≥ 10 mmHg from predialysis values and the implementation of two responsive measures (dialysis discontinuation, saline infusion, etc.) [11].

The incidence of adverse events, including all-cause mortality, stroke, bleeding episodes, permanent pacemaker implantation, vascular complications, and readmission, was compared between the TAVI and the SAVR group over one year. Composite events were defined as presenting with one of the above-described events.

Statistical analysis

The results are expressed as the median [lower quartile-upper quartile: IQR]. Data were compared with the Mann–Whitney U test or the Wilcoxon signed-rank test. The chi-square test, Fisher's exact test, or McNemar's test were used to compare categorical variables, as appropriate. Kaplan–Meier analysis was used to generate survival and composite event-free curves in the TAVI and the SAVR group. Comparison between two event-free curves was made using the log-rank test. Subgroup evaluation, including age, EuroSCORE II, and duration of dialysis, was conducted using logistic regression analysis.

To reduce the confounding effects of the covariables affecting the outcomes following SAVR/TAVI, the source data were re-analyzed after propensity score matching. Logistic regression model was applied to generate propensity scores for SAVR or TAVI, with demographic and risk factors as independent variables, and caliper width was set at 0.2 or less of the standard deviation of the logit of the propensity score. The matched pairs were then analyzed with the Wilcoxon signed rank test or the chi-square/Fisher's exact test, as appropriate.

Statistical analyses were performed using Statistical Package for Social Sciences (SPSS) version 25 (IBM Japan Ltd, Tokyo, Japan). P values less than 0.05 were considered statistically significant.

Results

Baseline characteristics on admission

A total of 58 hemodialysis patients were admitted to undergo either SAVR ($n=25$) or TAVI ($n=33$, Table 1). The patients in the TAVI group were older and had shorter duration of dialysis therapy, but there was no difference in BMI, blood pressure, serum Ca/phosphate/intact-PTH, blood hemoglobin, or hemoglobin A1c between these groups. No patients aged 81 y/o or older were enrolled in the SAVR group, whereas 15 (i.e., 45.5%) patients were included in the TAVI group. Before admission for aortic valve operation, seven patients had a history of permanent pacemaker implantation (1 and 6 patients for SAVR and TAVI group, respectively). Regarding the underlying kidney disease, 28.0% and 30.3% of the SAVR and the TAVI group were diabetic nephropathy. Chronic glomerulonephritis predominated among the SAVR group while nephrosclerosis prevailed in the TAVI group.

EuroSCORE II, calculated for evaluation of the risk for cardiac surgery [12], was higher in the TAVI group ($p=0.036$, Table 1). Ejection fraction tended to be lower in the TAVI group ($p=0.091$), with a larger number of patients distributed in the lower categories ($p=0.032$). No difference in aortic valve area or mean aortic pressure gradient was found between the TAVI and the SAVR group.

Changes in cardiac parameters following surgery

Aortic valve areas were improved to nearly the same degree in the SAVR and the TAVI group (Additional file 1: Table S1). The implementation of these therapies ameliorated cardiac functional parameters, including mean aortic orifice pressure gradient, peak aortic jet velocity, and ejection fraction, accordingly. Atrial natriuretic peptide (ANP) concentrations were unaltered in both SAVR and TAVI groups.

Comparison of dialysis-associated parameters

All of the patients who underwent SAVR received CRRT, followed by intermittent dialysis on postoperative day 5 [IQR: 4–5] and thereafter. In contrast, 87.9% (i.e., 29/33 cases) of the TAVI patients were able to undergo intermittent dialysis as a re-initiation of renal replacement therapy, with a median postoperative day 1 [IQR: 1–1]. Length of total hospital stay was 17 [IQR: 13–21] days and 23 [IQR: 18.3–27.0] days for TAVI and SAVR group, respectively.

In patients who underwent SAVR, the blood pressure at the re-initiation of the first postoperative dialysis session was lower than that observed at the session before surgery ($p<0.001$) whereas no significant decrease was seen

Table 1 Baseline characteristics

	SAVR ($n=25$)	TAVI ($n=33$)	*p* value
Age (y/o)	74.0 [68.0–78.0]	79.0 [73.0–82.0]	< 0.001
Male, *n* (%)	15 (60.0%)	24 (72.7%)	0.306
BMI (kg/m^2) [IQR]	20.8 [18.8–22.4]	20.5 [19.7–23.1]	0.869
Duration of dialysis (months) [IQR]	190.0 [92.0–228.0]	81.0 [67.0–152.0]	0.021
Comorbidities			
Diabetes mellitus, *n* (%)	9 (36.0%)	15 (45.5%)	0.469
Hypertension, *n* (%)	21 (84.0%)	29 (87.9%)	0.715
Permanent pacemaker, *n* (%)	1 (4.0%)	6 (18.2%)	0.127
PAD, n (%)	5 (20.0%)	8 (24.2%)	0.760
Underlying kidney disease			
Diabetic nephropathy, *n* (%)	7 (28.0%)	10 (30.3%)	0.849
Nephrosclerosis, *n* (%)	0 (0.0%)	9 (27.3%)	0.007
Chronic glomerulonephritis, *n* (%)	16 (64.0%)	6 (18.2%)	< 0.001
Focal glomerulosclerosis, *n* (%)	1 (4.0%)	2 (6.0%)	1.0
Others, *n* (%)	1 (4.0%)	6 (18.2%)	0.300
Systolic BP (mmHg)	145 [132–171]	147 [112–161]	0.255
Diastolic BP (mmHg)	74 [64–83]	72 [60–77]	0.262
Hemoglobin (g/dL)	11.1 [10.7–11.7]	10.9 [10.4–11.8]	0.494
Hemoglobin A1c (%)	5.6 [5.2–5.9]	5.3 [5.0–5.9]	0.370
Serum albumin (g/dL)	3.4 [3.2–3.5]	3.2 [3.0–3.4]	0.110
Serum Ca (mg/dL)	8.8 [8.4–8.9]	8.7 [8.3–9.1]	0.771
Serum phosphate (mg/dL)	5.3 [4.5–6.3]	4.9 [4.0–5.4]	0.090
Intact PTH (pg/mL)	220 [163–316]	190 [106–253]	0.695
BNP (pg/mL)	538 [271–753]	773 [319–1218]	0.412
Cardiac parameters			
EuroSCORE II, (%) [IQR]	2.50 [2.00–4.23]	3.20 [2.50–6.00]	0.036
Ejection fraction (%) [IQR]	59.0 [54.0–63.0]	53.0 [38.0–60.0]	0.091
< 30%, *n* (%)	0 (0%)	6 (18.2%)	
30% ≤ < 50%, *n* (%)	5 (20.0%)	10 (30.3%)	0.032
50% ≤ , *n* (%)	20 (80.0%)	17 (51.5%)	
Aortic valve area (cm^2)	0.71 [0.59–0.73]	0.71 [0.64–0.80]	0.358
Mean aortic pressure gradient (mmHg)	42.0 [36.0–56.0]	45.0 [38.0–48.0]	0.931

SAVR surgical aortic valve replacement, *TAVI* transcatheter aortic valve replacement, *BMI* body mass index, *PAD* peripheral artery disease, *IQR* interquartile range, *BP* blood pressure

in patients treated with TAVI (Additional file 1: Table S2). The prescription of intermittent dialysis needed to be altered with substantial reductions in Qb, membrane area and ultrafiltration rate in the SAVR group, whereas modest or no changes in these parameters were noted in the TAVI group.

Prior to SAVR or TAVI operation, intradialytic hypotension was observed in 1 patient in the SAVR group and 2 patients in the TAVI group (Fig. 1A). During the postoperative period, the number of the patients with an episode of intradialytic hypotension was increased in the SAVR group (from 1 to 8 cases, $p=0.023$), whereas no increase was seen in the TAVI group ($p=1.0$). Subgroup analysis showed that the patients aged 75 or older had higher incidence of intradialytic hypotension among the SAVR-treated patients (odds ratio = 15.75 [95% CI 2.30–107.93], Fig. 1B).

Comparison of postoperative complications and outcomes

Table 2 shows the incidence of adverse events in SAVR- and TAVI-treated patients. Incidence of stroke tended to be higher in the SAVR group during the 1-year observational period ($p=0.075$). De novo placement of permanent pacemakers was conducted in only 1 case following the SAVR implementation. Other parameters, including all-cause mortality, bleeding episodes, device failure and hospital re-admission, did not differ between these two groups.

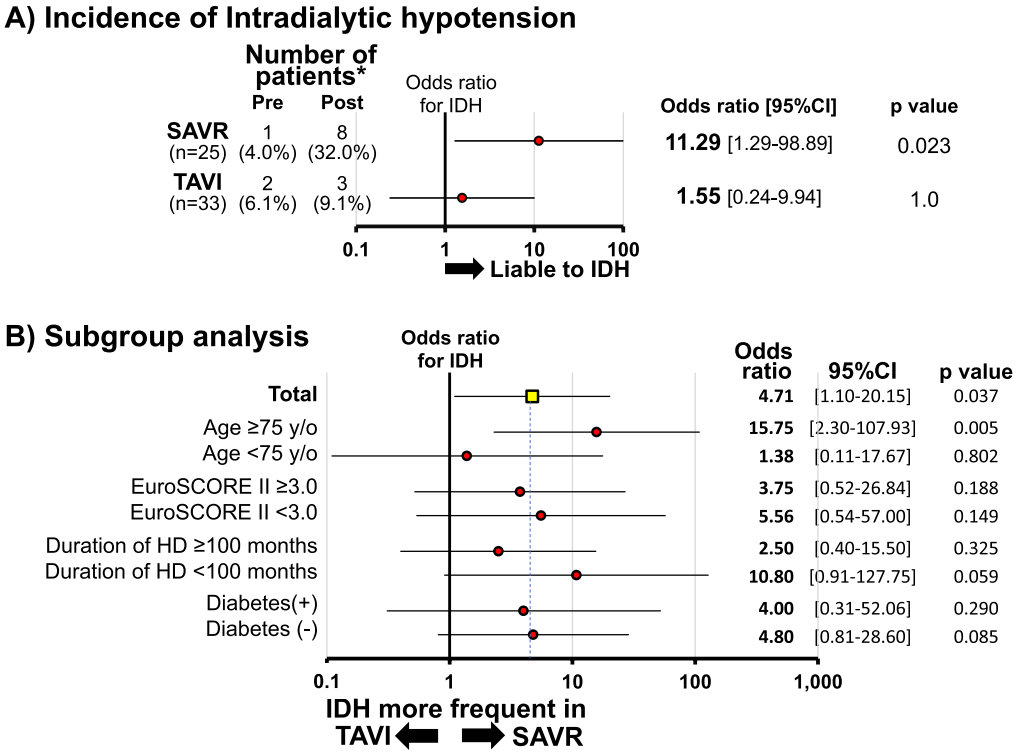

Fig. 1 Incidence of intradialytic hypotension and factors affecting its occurrence during postoperative periods. SAVR; surgical aortic valve replacement, TAVI; transcatheter aortic valve implantation. IDH; intradialytic hypotension, HD; hemodialysis

Table 2 Adverse events

Types of events, *n* (%)	≤ 30 days			One year		
	SAVR	TAVI	*p* value	SAVR	TAVI	*p* value
All-cause mortality	0 (0.0%)	0 (0.0%)	–	2 (8.0%)	3 (9.1%)	1.0
Bleeding episodes	1 (4.0%)	1 (3.0%)	1.0	3 (12.0%)	1 (3.0%)	0.305
Stroke	1 (4.0%)	0 (0.0%)	0.431	3 (12.0%)	0 (0.0%)	0.075
De novo permanent pacemaker implantation	1 (4.0%)	0 (0.0%)	0.431	1 (4.0%)	0 (0.0%)	0.431
New onset of vascular complications	0 (0.0%)	1 (3.0%)	1.0	0 (0.0%)	1 (3.0%)	1.0
Device failure	0 (0.0%)	3 (9.1%)	0.251	3 (12.0%)	3 (9.1%)	1.0
Re-admission	1 (4.0%)	3 (9.1%)	0.627	10 (40.0%)	11 (33.3%)	0.520

SAVR surgical aortic valve replacement, *TAVI* transcatheter aortic valve replacement

Kaplan–Meier analyses showed that the 1-year survival rates did not differ between the SAVR and the TAVI group ($p=0.413$, Fig. 2A). Likewise, nearly identical probabilities of composite events were seen in these two groups ($p=0.716$, Fig. 2B). Subgroup analyses showed that among the population with no diabetes, the patients treated with SAVR tended to have more composite events than those with TAVI (odds ratio; 3.34 [95% CI 0.80–13.94], $p=0.098$, Fig. 2C). Other parameters, including age, EuroSCORE II, and the duration of dialysis therapy, did not have different impacts on the incidence of composite events. Moderate paravalvular regurgitation was seen in 2 cases among the TAVI group but was not observed in the SAVR group ($p=0.501$).

Because there existed significant differences in baseline characteristics between the SAVR and the TAVI group (i.e., age, duration of dialysis therapy, and EuroSCORE II, Table 1), these groups were re-analyzed after propensity score matching. A logistic regression based on these three parameters was used to generate propensity scores

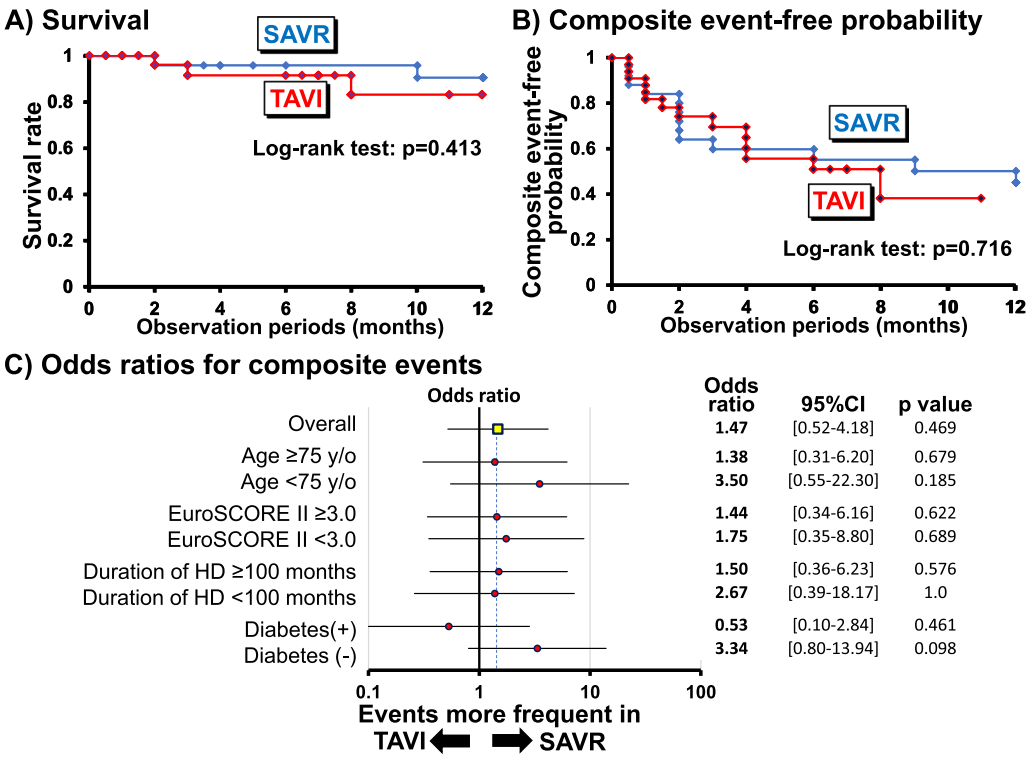

Fig. 2 Probabilities of survival/freedom from composite events and subgroup analyses for composite events. SAVR; surgical aortic valve replacement, TAVI; transcatheter aortic valve implantation, HD; hemodialysis. Composite events include mortality, stroke, bleeding episodes, vascular complications, and re-admission

for SAVR or TAVI. This matching model allocated 11 subjects to each group and showed no difference in age, duration of dialysis therapy or EuroSCORE II between these two groups (Additional file 1: Figure S1). Under these renewed settings, the incidence of various events did not differ between the SAVR and the TAVI group (all-cause mortality; 2 vs. 1, bleeding episodes; 1 vs. 0, stroke; 1 vs. 0, new permanent pacemaker implantation; 0 vs. 0, device failure; 2 vs. 0, re-admission; 4 vs. 2, for SAVR and TAVI, respectively). Kaplan–Meier analysis showed no difference in the composite event-free probability between these two groups ($p=0.816$).

Discussion

Aortic valve calcification is commonly observed in hemodialysis patients and frequently involves the stenosis of the aortic orifice (i.e., AS) as the most frequent valvular heart disease [1, 2]. Several studies show that dialysis patients with AS have higher mortality and major complications than non-dialysis patients [13]. Traditionally, SAVR was the exclusive way to treat AS in dialysis patients but might instead result in unfavorable outcomes associated with the cardiac surgery. Alternatively, TAVI has been introduced to the treatment of severe AS and is implemented even in hemodialysis patients with multiple cardiovascular risk factors [8, 9, 13–17]. In Japan, however, the treatment with TAVI in dialysis patients has only very recently been covered by healthcare insurance system in 2021. Moreover, there have been reported no studies comparing the impact of SAVR and TAVI on the short- or long-term outcomes in hemodialysis patients with severe AS in Japan.

Comparison between SAVR and TAVI during 30-day postoperative period

Many studies evaluated the impact of TAVI on the postoperative mortality and adverse events in hemodialysis patients with AS and have shown that TAVI constituted an effective alternative tool for the treatment of severe AS [8, 9, 14–19]. Thus, better 30-day or in-hospital survival rates with TAVI were reported, compared with SAVR in hemodialysis patients though new permanent pacemaker implantation was more prevalent among the patients with TAVI [9, 18, 19]. In the present study, no mortality was found in either SAVR or TAVI group during the 30-day postoperative period (Table 2). Furthermore, the incidence of adverse events did not differ between the SAVR and TAVI group. Alternatively, 32.0% of the patients with SAVR experienced episodes of intradialytic hypotension despite the implementation of

several preventive measures, including reductions in Qb, membrane area and ultrafiltration rate, whereas nearly stable dialysis sessions were obtained in the TAVI group (Fig. 1A, Additional file 1: Table S2). Furthermore, length of hospital stay, generally used as a proxy of efficient hospital management [20], was curtailed in the TAVI group [9, 13], which could result in less total cost of hospitalization [18]. In concert, these findings lend support to the premise that TAVI confers more favorable results than SAVR at least during the short-term postoperative period.

Of note, the present study showed that the patients treated with SAVR, particularly among the group aged 75 or older, were associated with markedly higher incidence of intradialytic hypotension than those with TAVI (Fig. 1B) despite no differences in cardiac function, ANP levels [21] or blood pressure between the SAVR and the TAVI group (Additional file 1: Tables S1, 2). It has been reported that intradialytic hypotension is more likely to occur among elderly patients [22] and is associated with the circulatory stress of hemodynamics, including myocardial stunning and brain ischemia [23]. Furthermore, several guidelines for the management of AS recommend the implementation of TAVI for elderly patients; ESC/EACTS guidelines propose that TAVI should be considered for patients aged 75 or older [24]. The Japanese guidelines for the management of valvular heart disease (JCS/JSCS/JATS/JSVS 2020 Guidelines) also recommend TAVI for elderly patients because of the lack of the data on long-term durability of the bioprosthetic valve [10]. It is reasonably posited therefore that patients aged 75 or older favor TAVI rather than SAVR, irrespective of the implementation of hemodialysis therapy.

Comparison between SAVR and TAVI during one-year postoperative period

One-year survival rate and the incidence of adverse events (bleeding episodes, new permanent pacemaker implantation and re-admission) were nearly the same between the TAVI and the SAVR group (Fig. 2, Table 2). Farber et al. [9] have also demonstrated that the 1-year mortality in hemodialysis patients with TAVI is the same as in those with SAVR. Recently, using the United State Renal Data System, however, Ogami et al. [19] have shown that TAVI is associated with higher 3-year mortality than SAVR though TAVI has lower in-hospital mortality. In concert, although TAVI confers favorable effects on short-term survival, more substantial evidence needs to be accumulated to clarify whether TAVI offers long-term benefits to dialysis patients with severe AS.

Among dialysis patients with severe AS, a worldwide trend shows that the population with SAVR is relatively younger and at lower risk than that with TAVI [9, 14]. The present study shows that the age and EuroSCORE II are higher in the TAVI group than in the SAVR group while the duration of dialysis therapy is shorter (Table 1). We therefore adopted a propensity score model, which yielded 11 matched pairs but no differences in these parameters and demonstrated nearly similar composite event-free probabilities between the TAVI and the SAVR group ($p=0.816$, Additional file 1: Figure S1). A couple of studies also showed that TAVI was equivalent to SAVR in 1-year survival rate among propensity score-matched dialysis patients [9, 14]. Obviously, a larger population and longer-term evaluation would establish the role of TAVI in dialysis patients with severe AS.

Implementation of TAVI in hemodialysis patients in Japan

Although TAVI has been used worldwide as a first-line strategy for the treatment of severe AS, particularly in elderly patients, its clinical application to dialysis patients has not been established fully in Japan where a large number of elderly patients undergo dialysis for a lengthy period [3]. Indeed, dialysis patients with severe AS possess multiple high-risk factors for cardiac surgery [13, 25, 26] and teleologically favor less aggressive modalities for the treatment of AS. An early 1-year study evaluating the efficacy and safety of TAVI in Japanese dialysis patients showed that TAVI was a potent and safe tool for the treatment of severe AS in patients who were inoperable or at too high risk for conventional SAVR [15]. The authors also reported that the 3-year mortality and the major cardiovascular event-free probability were relatively poorer compared with those in non-dialysis patients [27]. In the present study, we showed that both survival rates and composite event-free probabilities in the TAVI group were nearly the same as those in the SAVR group over a 1-year period (Fig. 2). Whereas TAVI is demonstrated to offer 5-year clinical benefit in non-dialysis patients [28], the mid-term or long-term impact remains undetermined in Japanese hemodialysis patients. Furthermore, the durability of bioprosthetic valve over a 10-year or longer period is unestablished [10, 29], and the sustained exposure to the deranged internal milieu in dialysis patients, including mineral and bone disorders, may facilitate the development of aortic valve dysfunction [27, 30]. Hence, the role of TAVI in dialysis patients warrants further evaluation.

Conclusions

As improved longevity of dialysis patients, aortic valve calcification and the subsequent symptomatic severe AS are observed more frequently. In addition to the conventional surgical strategy, TAVI offers an alternative approach in treating severe AS in these patients, particularly in Japan where the patient population is

getting older and the duration of dialysis period is becoming longer. More extended studies will elucidate the role of TAVI in the treatment option of severe AS among dialysis patients.

Abbreviations

AS	Aortic valve stenosis
SAVR	Surgical aortic valve replacement
TAVI	Transcatheter aortic valve implantation
CRRT	Continuous renal replacement therapy
IQR	Interquartile range

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41100-023-00501-3.

Additional file 1: Table S1. Changes in aortic valve and hemodynamic parameters before and after operation. **Table S2**. Changes in blood pressure and dialysis-associated parameters before and after operation. **Figure S1**. Composite event-free probability after propensity score matching.

Acknowledgements
Not applicable.

Author contributions
MS, KE, KK, SI, and TS designed the study. YH, AM, KT, TH, MK, KY, TI, YS, JI, KO, and HW collected the data. MS, KH, SI and TS were responsible for data curation and analyzed the data. MS, KH and TS wrote the manuscript. All authors read and approved the final manuscript.

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee at which the studies were conducted (IRB approval number 728) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was registered in UMIN (ID: UMIN000046157).

Consent for publication
Written informed consent was waived because of the retrospective observational study design. Opt-out information was offered; available in the following URL: https://tokyobay-mc.jp/patient-right/).

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Department of Nephrology, Endocrinology and Diabetes, Tokyo Bay Urayasu Ichikawa Medical Center, 3-4-32 Todaijima, Urayasu, Chiba 279-0001, Japan. [2]Department of Emergency and Critical Care Medicine, St Marianna University School of Medicine, Kawasaki, Japan. [3]Department of Medical Engineering, Tokyo Bay Urayasu Ichikawa Medical Center, Urayasu, Japan. [4]Department of Cardiovascular Surgery, Tokyo Bay Urayasu Ichikawa Medical Center, Urayasu, Japan. [5]Department of Cardiology, Tokyo Bay Urayasu Ichikawa Medical Center, Urayasu, Japan.

Received: 30 April 2023 Accepted: 10 September 2023
Published online: 19 September 2023

References

1. London GM, Pannier B, Marchais SJ, Guerin AP. Calcification of the aortic valve in the dialyzed patient. J Am Soc Nephrol. 2000;11:778–83.
2. Varma R, Aronow WS, McClung JA, Garrick R, Vistainer PF, Weiss MB, et al. Prevalence of valve calcium and association of valve calcium with coronary artery disease, atherosclerotic vascular disease, and all-cause mortality in 137 patients undergoing hemodialysis for chronic renal failure. Am J Cardiol. 2005;95:742–3.
3. Kimata N, Tsuchiya K, Akiba T, Nitta K. Differences in the characteristics of dialysis patients in Japan compared with those in other countries. Blood Purif. 2015;40:275–9.
4. Braun J, Oldendorf M, Moshage W, Heidler R, Zeitler E, Lyft FC. Electron beam computed tomography in the evaluation of cardiac calcification in chronic dialysis patients. Am J Kidney Dis. 1996;27:394–401.
5. Herzog CA, Ma JZ, Collins AJ. Long-term survival of dialysis patients in the United States with prosthetic heart valves: should ACC/AHA practice guidelines on valve selection be modified? Circulation. 2002;105:1336–41.
6. Cribier A, Eltchaninoff H, Bash A, Borenstein N, Tron C, Bauer F, et al. Percutaneous transcatheter implantation of an aortic valve prosthesis for calcified aortic stenosis: first human case description. Circulation. 2002;106:3006–8.
7. Smith CR, Leon MB, Mack MJ, Miller C, Moses JW, Svensson LG, et al. Transcatheter versus surgical aortic-valve replacement in high-risk patients. N Engl J Med. 2011;364:2187–98.
8. Kuno T, Takagi H, Ando T, Ueyama H, Fujisaki T, Kodaira M, et al. Short- and long-term outcomes in dialysis patients undergoing transcatheter aortic valve implantation: a systematic review and meta-analysis. Can J Cardiol. 2020;36:1754–63.
9. Farber G, Bleiziffer S, Doenst T, Bon D, Boning A, Weiler H, et al. Transcatheter or surgical aortic valve implantation in chronic dialysis patients: a German Aortic Registry analysis. Clin Res Cardiol. 2021;110:357–67.
10. Izumi C, Eishi K, Ashihara K, Arita T, Otsuji Y, Kunihara T, et al. JCS/JSCS/JATS/JSVS 2020 guidelines on the management of valvular heart disease. Circ J. 2020;84:2037–119.
11. K/DOQI Workgroup. K/DOQI clinical practice guidelines for cardiovascular disease in dialysis patients. Am J Kidney Dis. 2005;45(4):S1–153.
12. Nashef SAM, Roques F, Sharples LD, Nilsson J, Smith C, Goldstone AR, Lockowandt U. EuroSCORE II. Eur J Cardiothorac Surg. 2012;41:734–44.
13. Kawase Y, Taniguchi T, Morimoto T, Kadota K, Iwasaki K, Kuwayama A, et al. Severe aortic stenosis in dialysis patients. J Am Heart Assoc. 2017;6:e004961.
14. Kobrin DM, McCarthy FH, Herrmann HC, Anwaruddin S, Kobrin S, Szeto WY, et al. Transcatheter and surgical aortic valve replacement in dialysis patients: a propensity-matched comparison. Ann Thorac Surg. 2015;100:1230–7.
15. Maeda K, Kuratani T, Torikai K, Ichibori Y, Nakatani K, Onishi T, et al. Early outcomes in Japanese dialysis patients treated with transcatheter aortic valve implantation. Circ J. 2015;79:2713–9.
16. Dumonteil N, van der Boon RMA, Tchetche D, Chieffo A, Dumonteil N, van der Boon RMA, et al. Impact of preoperative chronic kidney disease on short- and long-term outcomes after transcatheter aortic valve implantation: a Pooled-RotterdAm-Milano-Toulouse in Collaboration Plus (PRAGMATIC-Plus) initiative substudy. Am Heart J. 2013;165:752–60.
17. Gupta T, Goel K, Kolte D, Khera S, Villablanca PA, Aronow WS, et al. Association of chronic kidney disease with in-hospital outcomes of transcatheter aortic valve replacement. JACC Cardiovasc Interv. 2017;10:2050–60.
18. Alqahtani F, Aljohani S, Boobes K, Maor E, Sherieh A, Rihal CS, et al. Outcomes of transcatheter and surgical aortic valve replacement in patients on maintenance dialysis. Am J Med. 2017;130(1464):e1-1464.e11.
19. Ogami T, Kurlansky P, Takayama H, Ning Y, Zimmermann E, Zhu RC, et al. Three-year survival of transcatheter versus surgical aortic valve replacement in dialysis. Catheter Cardiovasc Interv. 2022;99:1206–13.

20. Borghans I, Kleefstra SM, Kool RB, Westert GP. Is the length of stay in hospital correlated with patient satisfaction? Int J Qual Health Care. 2012;24:443–51.
21. Suresh M, Farrington K. Natriuretic peptides and the dialysis patient. Semin Dial. 2005;18:409–19.
22. Halle MP, Hilaire D, Francois K, Denis T, Hermine F, Gloria AE. Intradialtic hypotension and associated factors among patients on maintenance hemodialysis: a single-center study in Cameroon. Saudi J Kidney Dis Transpl. 2020;31:215–23.
23. Chou JA, Kalantar-Zadeh K, Mathew AT. A brief review of intradialytic hypotension with afocus on survival. Sem Dial. 2017;30:473–80.
24. Vahanian A, Beyersdorf F, Praz F, Milojevic M, Baldus S, Bauersachs J, et al. 2021 ESC/EACTS guidelines for the management of valvular heart disease. Eur Heart J. 2022;43:561–632.
25. Yamauchi T, Yamamoto H, Miyata H, Kobayashi J, Masai T, Motomura N. Surgical aortic valve replacement for aortic stenosis in dialysis patients. Circ J. 2020;84:1271–8.
26. Kuroda Y, Marui A, Arai Y, Nagasawa A, Tsumaru S, Arakaki R, et al. Impact of dialysis in patients undergoing bioprosthetic aortic valve replacement. Interact Cardiovasc Thorac Surg. 2021;33:348–53.
27. Maeda K, Kuratani T, Mizote I, Shimamura K, Ichibori Y, Onishi T, et al. Midterm outcomes of transcatheter aortic valve replacement in dialysis patients with aortic valve stenosis. Circ J. 2019;83:1600–6.
28. Sawa Y, Takayama M, Goto T, Takanashi S, Komiya T, Tobaru T, et al. Five-year outcomes of the first pivotal clinical trial of balloon-expandable transcatheter aortic valve replacement in Japan (PREVAIL JAPAN). Circ J. 2017;81:1102–7.
29. Kataruka A, Otto CM. Valve durability after transcatheter aortic valve implantation. J Thorac Dis. 2018;10(Suppl 30):S3629–36.
30. Masuyama S, Mizui M, Maeda K, Shimamura K, Sakaguchi Y, Morita M, et al. Preoperative hypomagnesemia as a possible predictive factor for postoperative increase of transvalvular pressure gradient in hemodialysis patients treated with transcatheter aortic valve implantation. Ren Fail. 2022;44:1084–90.

Publisher's Note