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Article

Invasive Versus Echocardiographic Transvalvular Pressure Gradients After Transcatheter Aortic Valve Implantation: A Long-Term Retrospective Cohort

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Abstract

Background: Evidence regarding the reliability of transthoracic echocardiography (TTE) in assessing valvular gradients immediately following transcatheter aortic valve implantation (TAVI) remains conflicting. Thus, this study aimed to compare post-procedural TTE and invasive mean aortic valve (AV) pressure gradients immediately after TAVI. **Methods**: This was a retrospective, single-institution cohort study of consecutive TAVIs between 2012 and 2023. Immediate post-procedural mean AV pressure gradients were measured invasively via pigtail catheter and non-invasively via TTE. The Spearman coefficient was used to assess the correlation between TTE and invasive gradients. Multivariable Cox proportional-hazards regression was performed for long-term survival. **Results**: A total of 1589 patients underwent TAVI with available TTE and invasive pressure gradients. A total of 49.2% received self-expanding valves (SEVs), and 50.8% received balloon-expanding valves (BEVs); 7.2% underwent valve-in-valve (ViV); 17.6% received a small valve (Evolut $\leq$26 mm, Sapien $\leq$23 mm, and Portico/Navitor $\leq$25 mm). For the entire cohort, the TTE and invasive mean gradients showed a moderate correlation (Spearman $\rho = 0.401$), with a median absolute difference of 2.2 [1.0–4.0] mmHg. The SEV gradients were more strongly correlated than the BEV gradients ($\rho = 0.447$ vs. 0.345). Similarly, the small valve gradients were more strongly correlated than the large valve gradients ($\rho = 0.455$ vs. 0.375), while the ViV gradients were more strongly correlated than the native TAVI gradients ($\rho = 0.575$ vs. 0.357). A total of 1.6% of the patients had a difference >10 mmHg between the invasive and TTE gradients. In the multivariable Cox regression, a >10 mmHg discordance was not significantly associated with an increased hazard of death after TAVI ($p = 0.326$). **Conclusions**: Following TAVI, we observed a moderate correlation between TTE and invasive measurements of mean AV pressure gradients, with only modest discordance noted between measurement modalities.

Keywords: invasive AV gradient; TTE; transvalvular AV gradient; TAVI

1. Introduction

Transcatheter aortic valve implantation (TAVI) has been used increasingly in patients with severe aortic stenosis (AS) [1–3]. In the outpatient setting, transthoracic echocardiography (TTE) is the predominant tool used to assess transvalvular gradients [4]. Given its reliability in measuring gradients across calcified valves, TTE has also been applied to the evaluation of valvular function immediately following valve implantation, acting in conjunction with invasive catheterization as a metric of procedural success [5]. However, even after accounting for factors such as pressure recovery and sinotubular junction (STJ) dimensions, some reports suggest that TTE may misjudge valvular gradients across surgical prostheses due to various valve and aortic properties [6]. Though prior studies suggest that TTE may overestimate transvalvular pressure gradients after TAVI, evidence regarding the accuracy of TTE for assessment of valvular gradients in comparison to invasive catheter measurements remains lacking [7,8]. This study aims to compare post-procedural echocardiographic and invasive mean pressure gradients immediately after TAVI, while also identifying predictors and clinical outcomes associated with discordance between these two measurement modalities.

2. Methods

2.1 Patient Population and Study Design

This was an observational study using a prospectively maintained database of TAVI procedures performed at a single institution from 2012 to 2023. Definitions and terminology were consistent with the Society of Thoracic Surgeons (STS)–American College of Cardiology (ACC) Transcatheter Valve Therapy (TVT) Registry. All patients undergoing TAVI with both invasive and echocardiographic post-procedural mean aortic valve pressure gradients were included in the study. Mean valvular gradient measurements were collected in the immediate post-procedural setting after deployment of the transcatheter heart valve. Echocardiographic gradients were measured according to current recommendations from the American Society of Echocardiography [9]. Invasive gradients were obtained from simultaneous left ventricular (LV) and aortic pressures measured via pigtail catheters. This study was approved by the Institutional Review Board of the University of Pittsburgh on 4/17/2019 (STUDY18120143), with written consent waived.

This study aimed to assess the correlation between post-procedural TTE and invasive pigtail catheter mean aortic valve pressure gradients in patients undergoing TAVI. The correlation between the invasive and the TTE pressure gradient *before* TAVI was not assessed in this study. In severe AS, TTE is the gold standard for quantifying stenosis severity because of the simplified Bernoulli equation, which assumes laminar flow at a single level of stenosis and treats flow acceleration and viscous forces as negligible. However, these assumptions may not be true for *non-restrictive* transcatheter heart valves. For this reason, invasive pressure gradients are unlikely to significantly diverge from TTE pressure gradients when the valve is severely stenotic, while they are more likely to diverge when the valve is non-restrictive [10]. By implication, correlating TTE and invasive pressure gradients before TAVI is unlikely to be related to correlations after TAVI.

The primary outcome was the correlation between TTE and invasive mean pressure gradient measurements after TAVI. Secondarily, this study sought to determine risk factors for discordance between TTE and invasive pigtail gradients $>$10 mmHg, measured as the *raw difference* between each modality (i.e., TTE pressure gradient minus invasive pressure gradient). This is consistent with prior studies, where $>$10 mmHg has defined clinically significant discordance [7,8]. Moreover, short-term and long-term clinical outcomes were determined for patients with a TTE-invasive discordance $>$10 mmHg. A Cox proportional-hazards model was built for survival to assess the potential relationship between discordance and the long-term hazard of death. The proportional-hazards assumption was tested by Schoenfeld Residuals. All follow-up data were obtained from a clinical warehouse that contains long-term survival data for patients undergoing cardiac operations at the University of Pittsburgh Medical Center. All patients had longitudinal follow-up at 1-month, 6-months, 1-year, and yearly thereafter. Survival status was obtained via chart review of these follow-up appointments as well as patient phone calls, all of which were verified with the Social Security Death Index at the time of this study. All time-to-event data were right-censored. For all analyses, missing data were handled via single imputation by group median if less than 15% of the total cohort was missing.

2.2 Invasive Gradient Acquisition

Immediately after valve deployment, LV and aortic pressures were recorded simultaneously. LV pressure was obtained retrograde with a pigtail positioned as apically as feasible in the LV, while aortic pressure was obtained in the proximal ascending aorta via a second pigtail through contralateral access. All transducers were flushed and zeroed to atmospheric pressure. Waveforms were checked for dampening prior to acquisition. The mean transvalvular gradient was calculated from the difference between LV and aortic pressures integrated over systole, which were averaged across three consecutive beats at end-expiration.

2.3 Statistical Methods

Continuous variables were presented as mean ± standard deviation for normally distributed data or median and interquartile range for nonnormally distributed data. Categorical data were reported by frequency and percentage. Normally distributed continuous variables were analysed by the Student t-test, whereas nonnormally distributed continuous variables were analysed with the nonparametric Mann-Whitney U test. A χ^2 or Fisher exact test was used to compare categorical variables between groups.

Spearman's coefficient was used to assess the correlation between TTE and invasive gradients (where coefficient values from 0.90 to 1.0 indicate very strong correlation; 0.70 to 0.89 strong correlation; 0.40 to 0.69 moderate correlation; and $<$0.40 weak correlation). Logistic regression was used to determine risk factors for TTE-invasive discordance $>$10 mmHg, while multivariable Cox proportional-hazards regression was performed for long-term survival. All statistical analyses were performed with SAS/STAT version 15.2 software (SAS Institute, Cary, NC, USA). All tests were 2-sided with an α level of 0.05 designated to indicate statistical significance.

3. Results

3.1 Baseline Demographic and Clinical Variables

A total of 1589 patients underwent TAVI with available TTE and invasive pressure gradients. Baseline characteristics are reported in Table 1. In this cohort, 782 (49.2%) of the implanted valves were self-expanding valves (SEV) and 807 (50.8%) were balloon-expanding valves (BEV). Additionally, 1474 (92.8%) procedures involved TAVI in native valves, while 115 (7.2%) were valve-in-valve (ViV) procedures. Transcatheter heart valves were additionally stratified by size, with small valves defined as Evolut (Medtronic, Minneapolis, MN, USA) valves ≤26 mm, Sapien (Edwards Lifesciences, Irvine, CA, USA) valves ≤23 mm, and Navitor/Portico (Abbott Vascular, Santa Clara, CA, USA) valves ≤25 mm. While 1309 (82.4%) patients had a large transcatheter heart valve implanted, 280 (17.6%) patients had a small valve implanted. Based upon consensus, recent randomized controlled trials have defined the small aortic annulus as a mean annular

Table 1. Baseline characteristics of the total cohort.

Variable	Total TAVI Cohort (n = 1589)
Age (years)	82.0 [77.0–87.0]
Sex: Women	750 (47.2%)
Race: Caucasian	1235 (77.7%)
Body Mass Index (BMI) (kg/m^2)	27.8 [24.2–32.3]
STS Predicted Risk of Mortality (%)	4.4 [2.8–7.1]
Creatinine (mg/dL)	1.1 [0.9–1.4]
Diabetes mellitus	598 (37.6%)
Cerebrovascular disease	96 (6.0%)
Peripheral vascular disease	414 (26.1%)
Hypertension	1381 (86.9%)
Prior aortic valve replacement	155 (9.8%)
History of heart failure	353 (22.2%)
History of myocardial infarction	377 (23.7%)
Atrial fibrillation	602 (37.9%)
Operative Variables	
Variable	Total TAVI Cohort (n = 1589)
Valve design	
Balloon-expanding (BEV)	807 (50.8%)
Self-expanding (SEV)	782 (49.2%)
Valve size	
Large valve*	1309 (82.4%)
Small valve*	280 (17.6%)
Valve-in-valve (ViV)	115 (7.2%)

* Small valves were defined as Evolut valves ≤26 mm, Sapien valves ≤23 mm, and Portico valves ≤25 mm. Large valves were subsequently defined as those with larger dimensions.

Table 2A. Comparing invasive and TTE mean gradients for the entire cohort.

Variable	Total Cohort (n = 1589)
Invasive mean gradient (mmHg)	6.0 [4.0–9.0]
TTE mean gradient (mmHg)	6.0 [4.0–8.0]
TTE-Invasive Discordance (mmHg)	2.2 [1.0–4.0]
Spearman correlation coefficient between TTE and invasive gradients (ρ)	0.401 (0.360–0.440)

diameter <23 mm or an annular area ≤430 mm^2 [11,12]. Evolut ≤26 mm, Sapien ≤23 mm, and Navitor/Portico ≤25 mm valves fit into small aortic annuli according to these definitions, while larger aortic annuli can only accommodate larger sizes of the commercially available valves. As such, this study's definition of small and large valve implants is based upon previous scientific literature, rather than industry designation.

3.2 Total Cohort and Subgroup Analysis

For the entire cohort, TTE and invasive mean gradients correlated moderately well (Spearman $\rho = 0.401$, $p < 0.001$, Fig. 1, Table 2A), with a median absolute difference of 2.2 [1.0–4.0] mmHg between measurement modalities. Summary statistics of post-implantation gradients in TAVI subgroups are listed in Tables 2A,2B,2C,2D. Invasive and TTE gradients were more strongly correlated in SEVs than BEVs (Spearman $\rho = 0.447$ vs. 0.345, respectively, Fig. 2, Table 2B). Similarly, TTE and invasive measurements were better associated in small valves compared to large valves (Spearman $\rho = 0.455$ vs. 0.375, respectively, Fig. 3, Table 2C), while ViV TAVI pressure gradients were better correlated than native TAVI gradients (Spearman $\rho = 0.575$ vs. 0.357, respectively, Fig. 4, Table 2D). Figs. 1,2,3,4 are scatter plots of TTE versus invasive pressure gradients, and the curves in each figure depict a linear regression that models the relationship between TTE and invasive measurements.

3.3 Agreement Analysis (Bland-Altman)

To assess agreement between TTE and invasive pressure gradients, we constructed a Bland-Altman plot. The bias (i.e., mean difference between TTE and invasive pressure gradients) was –0.31 mmHg (SD 3.88), with 95% limits of agreement of –7.92 to 7.30 mmHg (**Supplementary**

Table 2B. Comparing invasive and TTE mean gradients for the balloon-expanding vs. the self-expanding subgroups.

Variable	Balloon-expanding valves (n = 807)	Self-expanding valves (n = 782)	*p*-value
Invasive mean gradient (mmHg)	6.0 [4.0–8.0]	6.0 [4.0–9.0]	0.665
TTE mean gradient (mmHg)	6.0 [4.5–8.0]	6.0 [4.0–8.0]	0.936
TTE-Invasive Discordance (mmHg)	2.0 [1.0–4.0]	3.0 [1.0–4.0]	0.028
Spearman correlation coefficient between TTE and invasive gradients (ρ)	0.345 (0.283–0.404)	0.447 (0.390–0.504)	N/A

Table 2C. Comparing invasive and TTE mean gradients for the large vs. the small valve subgroups.

Variable	Large valve (n = 1309)	Small valve (n = 280)	*p*-value
Invasive mean gradient (mmHg)	6.0 [4.0–9.0]	7.0 [5.0–10.0]	<0.001
TTE mean gradient (mmHg)	6.0 [4.0–8.0]	8.0 [5.0–10.0]	<0.001
TTE-Invasive Discordance (mmHg)	2.5 [1.0–4.0]	2.0 [1.0–4.0]	0.099
Spearman correlation coefficient between TTE and invasive gradients (ρ)	0.375 (0.327–0.421)	0.455 (0.358–0.544)	N/A

Table 2D. Comparing invasive and TTE mean gradients for the native vs. the valve-in-valve subgroups.

Variable	Native valve (n = 1474)	Valve-in-valve (n = 115)	*p*-value
Invasive mean gradient (mmHg)	6.0 [4.0–8.0]	10.0 [6.0–15.0]	<0.001
TTE mean gradient (mmHg)	6.0 [4.0–8.0]	10.0 [7.0–13.0]	<0.001
Discordance (mmHg)	2.0 [1.0–4.0]	3.0 [1.0– 5.0]	0.075
Spearman correlation coefficient between TTE and invasive gradients (ρ)	0.357 (0.312–0.401)	0.575 (0.438–0.690)	N/A

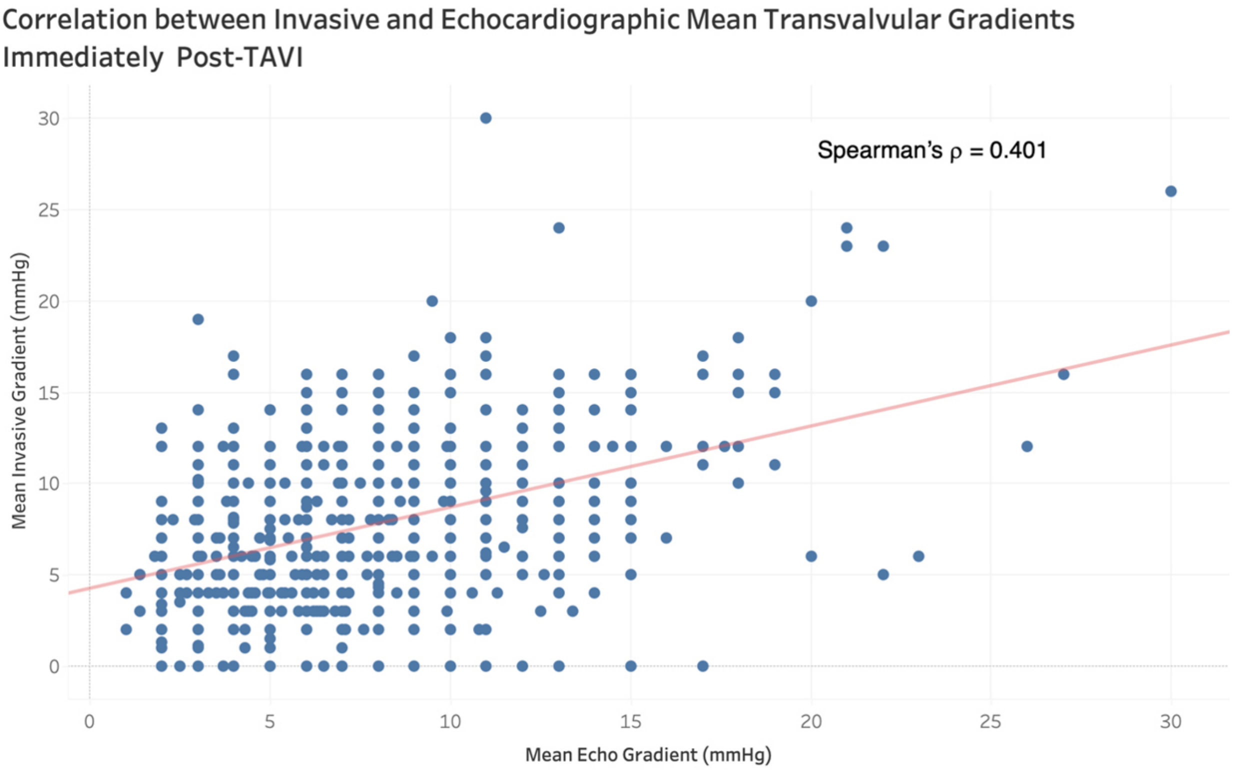

Fig. 1. Correlation between invasive and echocardiographic mean transvalvular aortic gradients immediately post-TAVI.

Fig. 1). This near-zero bias indicated no systematic difference between each modality of measuring pressure gradients. 95% of pairs differed by less than 8 mmHg, and visual inspection of the Bland-Altman plot showed no proportional bias across the measurement range.

Fig. 2. Correlation between post-TAVI invasive and echocardiographic mean gradients in balloon- vs. self-expanding valve designs.

3.4 Discordance Analysis

The difference between the TTE and invasive pressure gradient was calculated and called the "TTE-invasive discordance". The TTE-invasive discordance was compared to the TTE gradient to determine if the TTE-invasive discordance changed as the TTE gradient increased. Correlation between TTE-invasive discordance and TTE mean gradients was weak (Spearman $\rho = 0.107$, $p < 0.001$).

Twenty-five patients (1.6%) had a TTE-invasive discordance that exceeded 10 mmHg. Patients with a TTE-invasive discordance $>$10 mmHg had significantly higher TTE gradients compared to those with a TTE-invasive dis-

Fig. 3. Correlation between post-TAVI invasive and echocardiographic mean gradients in large vs. small valve implantation.

cordance ≤10 mmHg (12.0 mmHg vs. 6.0 mmHg, $p < 0.001$). There were no differences in most immediate post-TAVI outcomes in patients with a TTE-invasive discordance >10 mmHg versus patients with a TTE-invasive discordance ≤10 mmHg, including in-hospital mortality, permanent pacemakers, renal failure, and stroke ($p > 0.05$, Table 3). However, patients with TTE-invasive discordance >10 mmHg had more blood product transfusions (12.0% vs 3.8%, $p = 0.038$) and more major vascular complications (4.0% vs 0.2%, $p < 0.001$). On univariable logistic regression, risk factors for a TTE-invasive discordance >10 mmHg included age, ViV TAVI ($p < 0.001$), and a small valve TAVI ($p = 0.005$), but not SEVs vs. BEVs ($p = 0.281$) (Table 4).

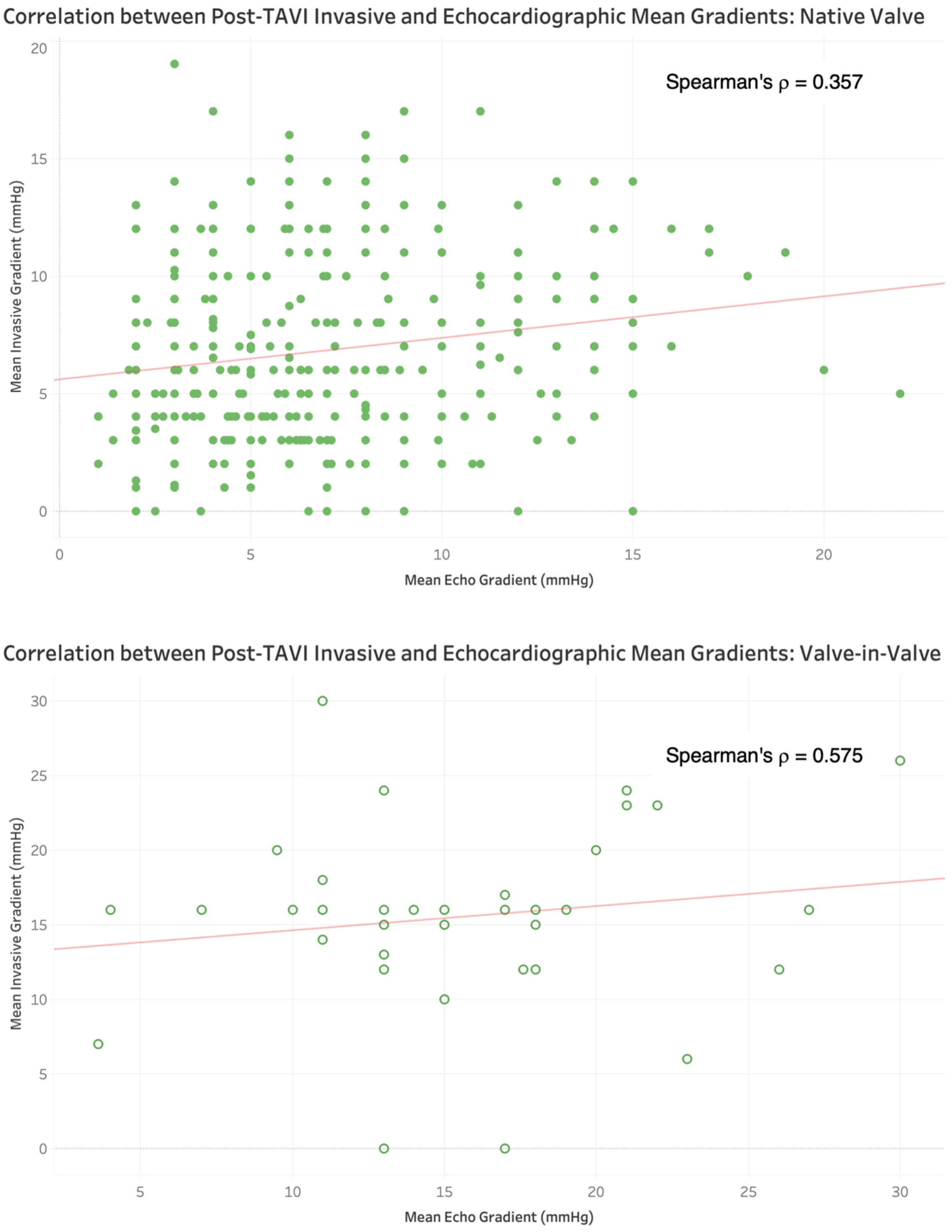

Fig. 4. Correlation between post-TAVI invasive and echocardiographic mean gradients in native vs. valve-in-valve implantations.

Median [IQR] follow-up for the entire cohort was 3.3 [2.1–4.9] years and there were a total 505 (31.8%) deaths. On multivariable Cox regression, a TTE-invasive discordance >10 mmHg was not significantly associated with an increased hazard of death after TAVI (HR: 1.37; 95% CI: 0.73–2.54; p = 0.326, Table 5). Variables that were found to be significantly associated with death included diabetes, atrial fibrillation, and pre-procedure creatinine.

To determine if the raw pressure gradients measured by either modality were separately more predictive of survival, another Cox model was built, with the post-procedural TTE and invasive pressure gradients being treated as *independent* variables for predicting death. For this model, the same covariates listed in Table 5 were utilized. Neither the TTE pressure gradient (HR: 1.02 [per 1 unit increase in mmHg], 95% CI: 0.90–1.16, p = 0.750) nor

Table 3. Postoperative clinical outcomes in TAVI patients with TTE-invasive discordance.

Variable	Discordance <10 mmHg (n = 1564)	Discordance >10 mmHg (n = 25)	*p*-value
In-hospital mortality	6 (0.4%)	0 (0.0%)	0.756
Permanent pacemaker placement	163 (10.4%)	2 (8.0%)	0.910
Renal failure requiring dialysis	3 (0.2%)	0 (0.0%)	0.827
Stroke	42 (2.7%)	0 (0.0%)	0.406
Blood product transfusion	60 (3.8%)	3 (12.0%)	0.038
Major vascular complications	3 (0.2%)	1 (4.0%)	<0.001

Table 4. Univariate logistic regression for risk of TTE-invasive discordance >10 mmHg in TAVI cohort.

Effect	Odds ratio	95% confidence interval	*p*-value
Race: Caucasian	0.50	0.22–1.15	0.103
Sex: Female	1.43	0.64–3.17	0.377
Cerebrovascular disease	0.41	0.06–3.06	0.385
Prior aortic valve replacement	7.75	3.45–17.39	<0.001
Hypertension	0.79	0.27–2.32	0.664
Diabetes mellitus	1.81	0.82–4.00	0.141
Atrial fibrillation	1.52	0.69–3.36	0.297
History of heart failure	0.47	0.14–1.59	0.226
Valve-in-valve TAVI	11.03	4.89–24.90	<0.001
Balloon-expanding	0.64	0.29–1.44	0.281
Small valve	3.20	1.42–7.19	0.005
Age (years)	0.93	0.89–0.97	0.001
Body mass index (BMI) (kg/m^2)	1.02	1.00–1.04	0.071
Creatinine (mg/dL)	1.22	0.96–1.53	0.099

Table 5. Multivariable cox proportional hazards regression for mortality after TAVI.

Variable	Hazard ratio	95% confidence interval	*p* value
Discordance >10 mmHg	1.37	0.73–2.54	0.326
Valve-in-valve (ref: native TAVI)	1.02	0.54–1.94	0.946
Balloon-expanding valve (ref: self-expanding valve)	0.99	0.77–1.26	0.912
Race: Caucasian	1.20	0.97–1.48	0.097
Sex: female	0.94	0.74–1.20	0.622
History of heart failure	1.72	0.99–2.97	0.053
Cerebrovascular disease	1.15	0.84–1.57	0.383
Prior aortic valve replacement	0.95	0.58–1.55	0.836
Peripheral vascular disease	1.00	0.81–1.24	1.000
Hypertension	1.22	0.93–1.60	0.150
Diabetes mellitus	1.37	1.04–1.53	0.016
Atrial fibrillation	1.30	1.08–1.57	0.006
History of heart failure	0.79	0.52–1.19	0.259
Age (years)	1.00	0.98–1.01	0.401
Body mass index (BMI) (kg/m^2)	1.00	0.99–1.01	0.326
Creatinine (mg/dL)	1.21	1.08–1.36	0.001
Small valve (ref: large valve)	1.09	0.77–1.55	0.628

the invasive pressure gradient (HR: 1.10 [per 1 unit increase in mmHg], 95% CI: 0.99–1.22, p = 0.080) were independently associated with mortality.

4. Discussion

In this study, we present a single-center analysis of concordance between post-TAVI TTE and invasively measured prosthetic AV pressure gradients. Moderate correlation was seen between TTE and invasive measurement modalities immediately post-TAVI. Moreover, the median discordance between TTE and invasive measurements was modest (2.2 mmHg). Out of all subgroups analysed, ViV, SEVs, and small-valve TAVIs had the strongest correlation between TTE and invasive measurements, relative to native TAVI, BEV, and large-valve TAVI. TTE–invasive discordance >10 mmHg was relatively rare amongst TAVI procedures, and risk factors associated with a TTE–invasive discordance >10 mmHg were age, ViV TAVI, and a small valve TAVI. However, patients with a discordance >10 mmHg did not have a higher hazard of death compared to patients with a discordance $\leq$10 mmHg. By implication, TTE may reliably quantify transvalvular pressure gradients after TAVI, and the small difference between TTE and invasive pigtail catheter measurements may not have significant clinical impact on outcomes after TAVI in the short-term or long-term.

The use of echocardiography for measurement of mean valvular gradients and subsequent aortic valve function is longstanding. Earliest reports date back to 1980 when echocardiography was first used by Hatle *et al.* [13] in conjunction with Bernoulli's equation to derive pressure gradients across stenotic aortic valves. Since then, understanding of pressure differences across the aortic valve has broadened to incorporate the idea of pressure recovery, with modification of Bernoulli's equation to account for structural cardiac measurements, such as LVOT diameter and STJ diameter [14]. As such, in the preoperative setting, TTE is regarded to be the most important diagnostic tool for AS [4,15]. Stenosed aortic valves allow for TTE to be an accurate measurement tool due to minimal contributions of certain unmeasurable parameters, such as viscous forces, that are treated as negligible in the modified Bernoulli's equation [10]. However, *after implantation*, several studies have questioned the application of TTE to evaluate transvalvular pressure gradients. Because TAVI relieves the stenosis, there may be overestimation of the post-TAVI transvalvular pressure gradient by TTE when compared to invasive hemodynamic assessment [6,16,17]. It is argued that, while the increased aortic velocity across a severely stenotic aortic valve is primarily due to convective acceleration, this may not be true for non-restrictive prosthetic valves, where flow acceleration and viscous forces may play a larger role.

Similar to the current study, previous analyses have also been performed in patients undergoing TAVI. A series of studies by Abbas *et al.* [7,8] have highlighted high levels of discordance between echocardiographic and invasive measurements of pressure gradients after prosthetic valve implantation. Additional reports have examined variance in echocardiographic data for different TAVI valve shapes, specifically observing high Doppler gradient measurements in smaller BEVs [18,19]. In an attempt to understand flow patterns after TAVI, a recent study by Johnson *et al.* [20] observed higher post-TAVI valve resistances (mean transvalvular pressure loss over transvalvular flows) in SEVs vs. BEVs, further contributing to the notion that the frame and skirt dimensions of transcatheter valves may variably impact gradient assessment by TTE versus invasive hemodynamics.

In contrast to previous reports suggesting a weak correlation between measurement modalities, the results of our current study demonstrate a moderate correlation (total cohort ρ = 0.401) between TTE and invasive transvalvular gradients immediately post-TAVI [8] and the discordance between TTE and invasive measurement was modest: 2.2 mmHg for all-comers. Our results suggest that TTE with Doppler may be a more reliable measurement modality for prosthetic transvalvular pressure gradients after TAVI than prior data suggest. By implication, while the theoretical concerns about the modified Bernoulli equation and pressure recovery in a non-restrictive prosthetic valve are reasonable, they may be overstated. As such, these findings may provide continued support for the follow-up TTE assessment recommendations outlined in the Valve Academic Research Consortium-3 guidelines.

Limitations

This study has several important limitations. First, the retrospective observational design of the study may introduce considerable selection bias. Gradient data were measured and collected by a single operator, thereby introducing a potential source of measurement bias. Moreover, TTE gradients were acquired immediately following TAVI, with patients in a supine position. This may have resulted in improper capturing of peak aortic velocities, potentially leading to underestimation of TTE mean gradients. Finally, this study's data are from a single centre, which may limit the generalizability of the findings to other institutions with different experiences with TAVI.

Invasive and TTE pressure gradients were obtained in close temporal succession after valve deployment, but not simultaneously. Thus, interval changes in several parameters — such as blood pressure, heart rate/rhythm, preload/afterload, respiration, and level of sedation — may have introduced variability between modalities. Additionally, this is a single-center retrospective study, presenting inherent limitations for generalizability and leaving room for residual or unmeasured confounding despite multivariable adjustment.

5. Conclusions

After TAVI, transvalvular mean pressure gradients measured via TTE presented a moderate correlation with invasive measurements, with a modestly higher TTE gradient compared to the invasive gradient. This finding differs from prior reports which suggest that invasive and TTE gradients present a poor correlation after TAVI.

Availability of Data and Materials

Data to support the findings of this study are available on reasonable requests from the corresponding author.

Author Contributions

JAB, EA, MPS, AMP, SY, NA, DK, CT, AM, YW, FWT, DSG and IS contributed to the design, data collection, analysis, interpretation, and writing. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was carried out in accordance with the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the University of Pittsburgh (Protocol No. 18120143). Consent was waived because this study involved secondary analysis of existing patient data, which was derived from a prospectively maintained database in a deidentified fashion.

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Conflict of Interest

IS receives institutional research support from Abbott, Atricure, Artivion, Edwards Lifesciences, Medtronic, and Terumo Aortic. None of these are related to this manuscript.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/HSF50776.

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