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ORIGINAL RESEARCH

Contemporary Valvular Mechanisms of Aortic Regurgitation in Tricuspid Aortic Valves: Importance in Repair Versus Replacement Strategy

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BACKGROUND: This study was performed to determine cusp causes of aortic regurgitation in patients with tricuspid aortic valves without significant aortic dilatation and define cusp pathologies amenable to surgical repair (aortic valve repair [AVr]) versus aortic valve replacement.

METHODS AND RESULTS: We retrospectively reviewed surgical reports of consecutive adults with tricuspid aortic valves undergoing surgery for clinically significant aortic regurgitation within a prospective registry from January 2005 to September 2019. Valvular mechanisms were determined by systematic in vivo intraoperative quantification methods. Of 516 patients, 287 (56%) underwent repair (AVr; mean±SD age, 59.9±12.4 years; 81% men) and 229 (44%) underwent replacement (aortic valve replacement; mean±SD age, 62.8±13.8 years [P=0.01 compared to AVr]; 67% men). A single valvular mechanism was present in 454 patients (88%), with cusp prolapse (46%), retraction (24%), and perforation (18%) being the most common. Prolapse involved the right cusp in 86% of cases and was more frequent in men (P<0.001). Two-dimensional transesophageal echocardiography accuracy for predicting mechanisms was 73% to 82% for the right cusp, 55% to 61% for the noncoronary cusp, and 0% for the left-coronary cusp. Cusp prolapse, younger age, and larger patient size were associated with successful AVr (all P<0.03), whereas retraction, perforation, older age, and concomitant mitral repair were associated with aortic valve replacement (all P<0.03).

CONCLUSIONS: Right cusp prolapse is the most frequent single valvular mechanism in patients with tricuspid aortic valve aortic regurgitation, followed by cusp retraction and perforation. The accuracy of 2-dimensional transesophageal echocardiography is limited for left and noncoronary cusp mechanistic assessment. Prolapse is associated with successful AVr, whereas retraction and perforation are associated with aortic valve replacement. With systematic intraoperative quantification methods and current surgical techniques, more than half of tricuspid aortic valve aortic regurgitation cases may be successfully repaired.

Key Words: aortic regurgitation ■ tricuspid aortic valve ■ valvular pathology

See Editorial by Helou and Collier.

Aortic regurgitation (AR) is the third most frequent heart valve dysfunction.[1] It may be related to congenital anomalies, but most individuals develop regurgitation with normal anatomy (ie, tricuspid aortic valve [TAV]). Ultimately, clinically significant aortic regurgitation (ie, moderate-severe or greater) requires surgical therapy, and for decades aortic valve replacement (AVR) has been the standard of care. AVR, however, is associated with valve-related morbidity and mortality.[2–4] In the past decade, aortic valve repair has

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CLINICAL PERSPECTIVE

What Is New?

- The cause of aortic regurgitation in tricuspid aortic valves remains idiopathic in >40% of cases. Systematic intraoperative quantification methods yield information aiding surgical treatment and identify repair candidates in more than half of tricuspid aortic valve aortic regurgitation cases.
- As an in vivo assessment of valvular mechanisms underlying tricuspid aortic valve aortic regurgitation, the quantification of geometric height and effective height was performed, allowing for evaluation of the functional anatomy.

What Are the Clinical Implications?

- This is important because cusp prolapse is a good substrate for repair, and its correction is facilitated by use of quantitative control.

Nonstandard Abbreviations and Acronyms

2D	2-dimensional
AR	aortic regurgitation
AVr	aortic valve repair
AVR	aortic valve replacement
eH	effective height
gH	geometric height
IOTEE	intraoperative transesophageal echocardiography
TAV	tricuspid aortic valve

been increasingly used as an alternative with less morbidity and possibly improved survival.[5,6] Repair aims at restoring normal aortic valve form and thus function, which depends on cusp size and configuration while suspended within the aortic root. In repair, it is of primary importance to precisely define the mechanism of AR to (1) select suitable substrates for repair and (2) develop an adequate reconstructive strategy.

In the absence of aortic dilatation, valvular (cusp) pathology is primarily responsible for AR. Although the valvular mechanisms of AR in bicuspid aortic valves are relatively clear,[7,8] less is known about the valvular causes of AR in TAV when aortopathy is not prominent. Some pathology studies have analyzed the findings of excised TAVs.[9,10] The results of such studies are limited because the functional anatomy cannot be assessed while suspended within the root. Pathology and echocardiography findings can be combined[11] to improve the sensitivity of the analysis by adding qualitative information suggesting prolapse (free cusp edge below the annular plane and eccentric AR jet by echocardiography) or cusp retraction (shortening of a cusp and pathologic scarring). In such a study of 206 patients with TAV, the cause of AR in TAVs remained idiopathic in >40% of cases,[11] the most common TAV mechanisms being root dilatation and suspected cusp prolapse or retraction.

Alternatively, the valve may be analyzed at the time of surgery, traditionally as qualitative inspection only. To improve reliability and reproducibility of surgical assessment, we have instituted the measurement of objective cusp parameters: geometric cusp height[12] and effective cusp height[13] (Figure 1). Geometric height serves as an indicator of the amount of cusp tissue (ie, cusp length), allowing for quantitative diagnosis of cusp retraction. The measurement of effective cusp height (height of the free margin above the annular plane) facilitates detection and quantification of prolapse (Figure 1). Using such parameters in addition to surgical inspection, intraoperative assessment has become a systematic in vivo anatomic assessment, allowing for precise determination of AR mechanisms.

We have systematically documented all anatomic details of TAV requiring surgery as part of a prospective surgical AR registry. The main purpose of our study was to analyze valvular causes (ie, cusp causes) of AR in a large patient cohort with TAV referred for aortic valve surgery in the absence of significant aortic dilatation. In addition, we evaluated the accuracy of 2-dimensional intraoperative transesophageal echocardiography (2D IOTEE) and analyzed anatomic predictors of successful aortic valve repair (AVr) versus AVR.

METHODS

The investigation was approved by the regional ethics committee (Ethikkommission der Ärztekammer des Saarlandes, 117/21); patient consent was waived for the analysis and publication in anonymized manner. Data are available on request.

Patients

Between January 2005 and September 2019, we retrospectively identified 1054 consecutive patients referred for surgery (Saarland University Medical Center) involving treatment of AR in the presence of a TAV. For consistency of analysis, operations were included with participation of the senior author (H.J.S.). We excluded 535 for the presence of ascending aortic or root aneurysm (root diameter ≥45 mm) or aortic dissection as predominant pathologies (Table S1) as well as pediatric patients (n=3). The remaining 516 underwent valve surgery for AR. All had TAV and clinically significant AR

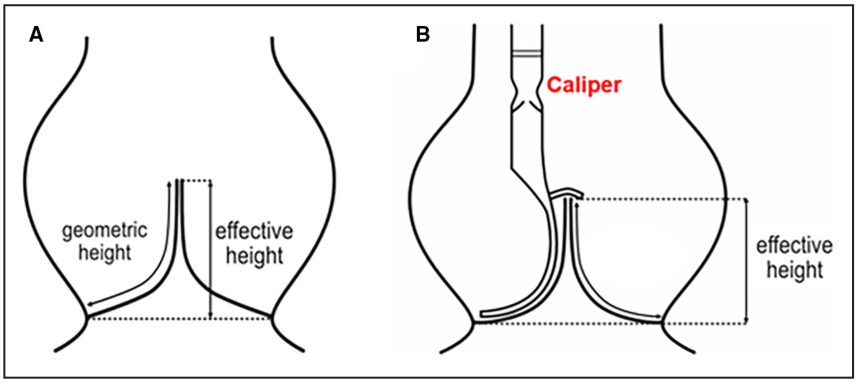

Figure 1. Measurement of geometric and effective height.
A, Schematic drawing of the aortic valve with depiction of geometric and effective height.
B, Effective height can be measured intraoperatively with a specific caliper.

caused by valvular pathology as the primary indication for surgery; AR was quantified according to current guidelines,[14] and was relevant in all. These patients constituted the study cohort.

All surgical reports were reviewed to determine cusp causes of AR. In addition to the description of aortic valve morphology, the geometry of the valve had been assessed intraoperatively by measuring effective height (eH) and geometric height (gH; Figure 1). If the operative findings were equivocal and the valve had been replaced, pathologic findings were also taken into consideration.

In all instances, the aorta was opened by a horizontal incision or transected. To diagnose cusp retraction, gH (Figure 1) was measured with the root stretched (Figure 2A and 2B) and defined as a gH of <18 mm[12] and/or macroscopic signs of retraction (eg, thickening of cusp tissue or local shrinkage). Prolapse was established by measuring eH,[13] using a special caliper (MSS-1; Fehling Instruments,

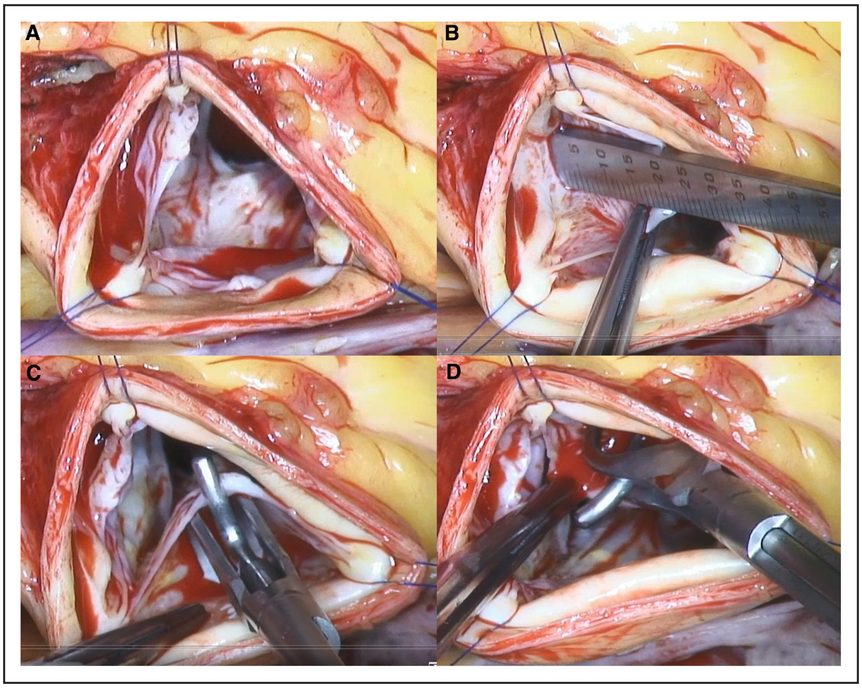

Figure 2. Intraoperative measurements.
A, For reproducible assessment of cusp geometry, the aortic root is stretched using stay sutures. **B**, Geometric cusp height is measured from the nadir to the free margin. **C**, Effective cusp height (eH) is determined on the noncoronary cusp with a caliper, in this case showing an eH of 9 mm. **D**, In the presence of cusp prolapse, eH is abnormally low. The caliper marks an eH of 9 mm, but the free cusp margin is much lower, in this case at an eH of 2 mm.

Karlstein, Germany; Figures 1B and 2C). An effective height of <9 mm or <35% of the geometric height[13,15] was defined as prolapse (Figure 2D). Specific valve pathologies were recorded, such as fenestrations, postendocarditic perforations, commissural retraction, or calcification if more than limited periannular plaques. The reports of the 2D IOTEEs were reviewed to determine the correlation between echocardiographic and intraoperative analysis. Repair techniques were adapted in 2004 with the introduction of eH and gH measurement, and in 2009 by the introduction of the suture annuloplasty. During the study period, the cusp repair concepts remained unchanged.

Patients were treated by either valve repair (AVr; n=287) or valve replacement (AVR; n=229), depending on valve morphology and patient characteristics. The decision was made by the operating surgeon based on the described anatomic/pathologic assessments, and treatment allocation was not randomized.

Statistical Analysis

Continuous variables are reported as mean±SD or median (interquartile range). Normal distribution of variables was assessed using the Shapiro-Wilk test. Differences were analyzed using the independent-samples *t* test or Mann-Whitney *U* test. Correlations were assessed using the Pearson correlation coefficient. For ordinal and nominal variables, absolute and relative frequencies are reported and were compared using χ^2 test or Fisher exact test. A 2-sided $P<0.05$ was considered statistically significant for all analyses. Stepwise logistic regression was performed using forward selection algorithm, and the selection of explanatory variables was based on univariable hypothesis tests and clinical reasoning. Data were statistically analyzed using Microsoft Office Excel (Microsoft Corp, Redmond, WA) and JASP, version 0.14.1 (University of Amsterdam, the Netherlands).

Patient and Public Involvement

Patients were not involved in the research process of this study.

RESULTS

Baseline clinical data are shown in the Table 1. Most patients (n=474; 92%) were aged >40 years (Figure S1) and male (75%). Relevant cardiovascular comorbidities were present in 223 patients (43%; Table 1). Patients with AVR were more frequently female and smaller, and they had a higher prevalence of diabetes and renal dysfunction (Table 1).

Valvular Mechanisms

In 454 patients (88%), a single pathologic mechanism of AR was identified; in 62 patients (12%), 2 mechanisms were identified (Figure 3). Prolapse was the most frequent single mechanism (n=237; 45.9%), followed by retraction (n=125; 24.2%) and cusp perforation or destruction in 92 (17.8%), generally attributable to active or healed endocarditis. In 2 instances, perforations were iatrogenic after mitral valve surgery. Cusp calcification (n=45; 8.6%) was associated with retraction in most cases (n=39). Prolapse and retraction were found in 50 cases (9.7%; Figure 3). In patients undergoing AVr, the most common mechanism of AR was prolapse, whereas retraction and cusp perforation or destruction were common in the replacement group (Figure 4B).

1. Prolapse was seen in 294 patients (57%) at a mean±SD age of 61.5±12 years (range, 21–84 years; median, 62 years). Prolapse was more frequent in men (253/387; 65.4%) than women (41/129; 31.8%; $P<0.001$). Fenestrations were involved in 84 (28.6%) instances in the mechanism of prolapse, also more frequently in men (76/253; 30%) than women (8/41;19.5%; $P<0.001$).

Prolapse was observed in 1 isolated cusp in 219 instances (74.5% of all prolapses), with the right cusp being affected most frequently (n=181; 83.1%), followed by the noncoronary cusp (n=24; 10.3%; Figure 4A). The left cusp was prolapsing in only 14 instances. Two cusps were affected by prolapse in 66 cases (22%), most frequently involving the right and noncoronary cusps (n=44). All 3 cusps were prolapsing in 11 cases (3.5%; Figure 4A). 2D IOTEE identified prolapse found intraoperatively in 73% on the right cusp, 61% on the noncoronary cusp, and none of the left cusp.

2. Retraction was found in 180 patients (mean±SD age, 62.1±14.1 years; range, 23–84 years; median, 65 years); it was more common in female patients (female: 64.3% [n=83]; male: 25.1% [n=97]; $P<0.001$). Retraction was observed in 1 cusp in 49 instances (27.3%), and the right cusp was affected more frequently (n=20), followed by the noncoronary cusp (n=18; Figure 4A) and the left cusp in 11 instances. Two cusps were affected by retraction in 50 cases (29%), most frequently involving the right and left cusps (n=31). In most cases, all 3 cusps were retracted (n=77; 45%). Compared with intraoperative findings, retraction was diagnosed by 2-D IOTEE in 82% on the right cusp, 55% on the noncoronary cusp, and none of the left cusp.

Compared with individuals with isolated prolapse, those with isolated retraction were shorter (168±9

Table. Patient Characteristics

Characteristic	All patients (n=516)	Repair (n=287)	Replacement (n=229)	*P* value
Age, mean±SD, y	61.2±13.1	59.9±12.4	62.8±13.8	0.01
Male sex, n (%)	387 (75.0)	233 (81.2)	154 (67.2)	<0.001
Height, mean±SD, cm	173±9	175±9	172±9	<0.001
Weight, median (IQR), kg	80 (68–94)	82 (68–94)	78 (68–94)	0.003
BSA, mean±SD, m^2	1.97±0.23	2.00±0.23	1.93±0.24	0.002
Creatinine level, median (IQR), mg/dL	1.0 (0.76–1.23)	1.0 (0.76–1.23)	1.0 (0.76–1.23)	0.07
Dyslipidemia, n (%)	247 (48)	161 (44)	108 (53)	0.27
Arterial hypertension, n (%)	431 (84)	238 (83)	193 (84)	0.14
Diabetes, n (%)	52 (10)	12 (4)	40 (17)	0.002
Insulin-dependent, n (%)	18 (3.5)	5 (1.7)	13 (5.7)	
Smoking, n (%)				0.64
Current smoker	33 (6.4)	16 (5.6)	17 (7.4)	
Former smoker	67 (13.0)	36 (12.5)	31 (13.5)	
Never smoker	416 (80.6)	235 (81.9)	181 (79.0)	
Renal function normal, n (%)	435 (84.3)	259 (90.2)	176 (76.9)	0.006
Chronic renal dysfunction, n (%)	59 (11.4)	25 (8.7)	34 (18.8)	
On dialysis, n (%)	12 (2.3)	3 (1.0)	9 (3.9)	
Coronary artery disease, n (%)	107 (20.7)	55 (19.2)	52 (22.7)	0.32
Concomitant surgery, n (%)				
Mitral valve surgery	131 (25.4)	74 (25.8)	57 (24.9)	0.82
Tricuspid valve surgery	95 (18.4)	52 (18.1)	43 (18.8)	0.85
CABG	108 (20.9)	54 (18.8)	54 (23.6)	0.19

Clinical characteristics of all patients with tricuspid aortic valve and aortic regurgitation, in addition differentiated by the type of treatment (repair vs replacement). BSA indicates body surface area; CABG, coronary artery bypass grafting; and IQR, interquartile range.

versus 176±8 cm; *P*<0.001) and there were fewer men (47.7% versus 89.3%; *P*<0.001). Repair was performed less frequently (17.7% versus 94.7%; *P*<0.001; Figure 4B). There were no differences between the 2 subgroups on age, renal function, hyperlipidemia, hypertension, or prevalence of coronary artery disease. The repair rate in all patients with prolapse was higher than in all patients with retraction (84.4% versus 22.2%; *P*<0.001; Figure 4B).

3. Defects attributable to endocarditis were found in 104 patients (20.2%). It was active in 84 patients (16.3%) and healed in 20 patients (3.9%). In 2 of these cases, regurgitation was solely attributable to cusp retraction. In the remaining 102 cases, the mechanism was cusp perforation or destruction, combined with prolapse in 7 and retraction in 4 cases. Patients with endocarditis were younger than patients without endocarditis

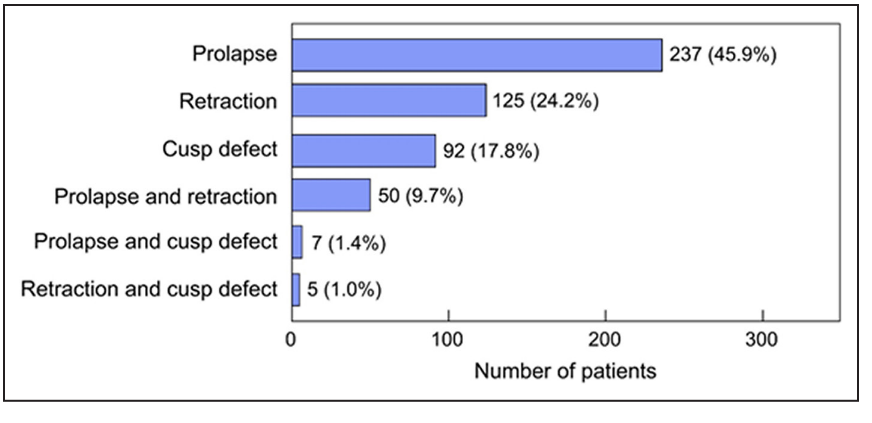

Figure 3. Valvular mechanisms of severe tricuspid aortic valve regurgitation.

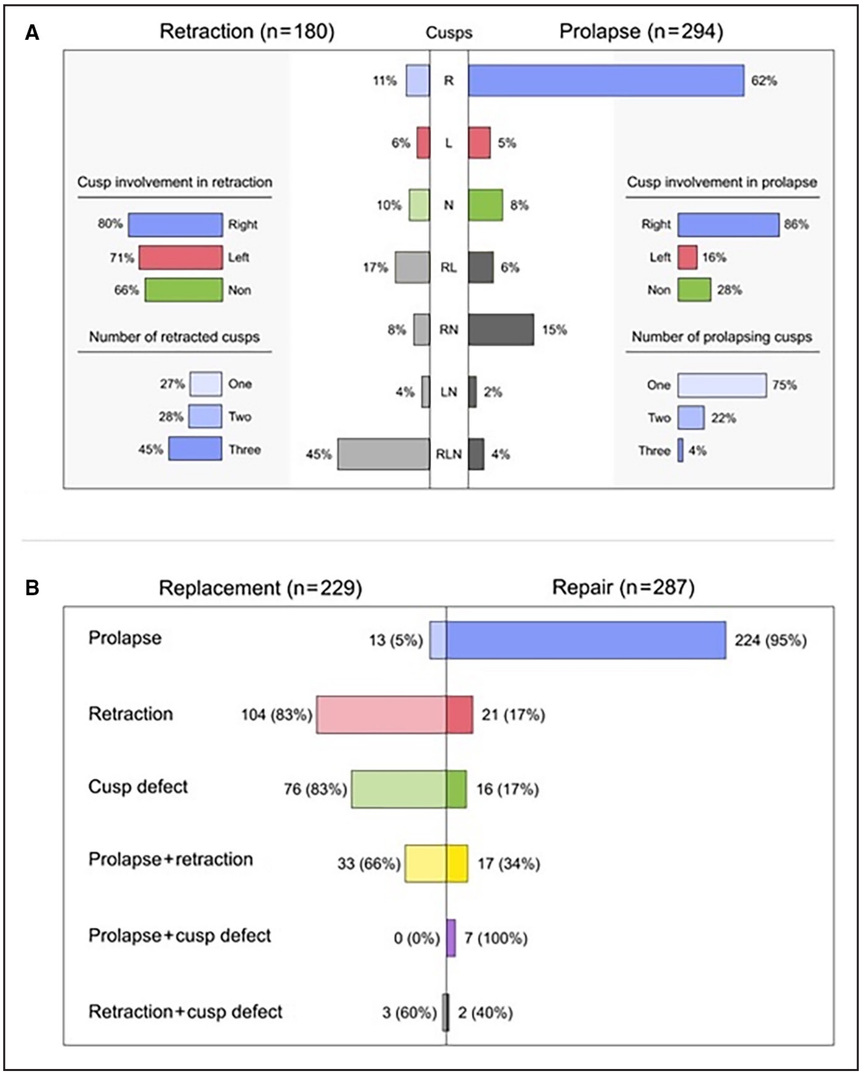

Figure 4. Occurrence of retraction and prolapse.
A, Single and multiple cusp involvement in retraction and prolapse and number of affected cusps. In patients with prolapse, the right cusp (R) was usually prolapsing, whereas in patients with retraction, all 3 cusps were most commonly affected. **B**, Single and combined mechanisms of aortic regurgitation in patients who had aortic valve replacement or aortic valve repair. Percentages refer to mechanisms of aortic regurgitation. Successful repair was possible in 95% of patients with isolated cusp prolapse, whereas aortic valve replacement was more common in patients with retraction (83%) or cusp defects (83%). L, left cusp; N, noncoronary cusp.

(endocarditis: 58.0±14.7 years; no endocarditis: 62.0±12.5 years; *P*=0.005). There was no difference in prevalence between men and women (*P*=0.8). Perforations or destruction of the cusps involved 1 cusp in most cases (n=74; 71%), and 2 (n=26; 25%) or 3 cusps (n=4; 4%) less frequently. All cusps were affected with similar frequency. Right cusp involvement was diagnosed by intraoperative 2-D IOTEE in 86%, noncoronary cusp destruction in 67%, and left cusp in 1 instance.

4. Cusp calcification was absent in patients aged <40 years, and its prevalence increased with the age of the patients. Calcification was equally distributed between male and female patients (male: 35 [9%]; female: 10 [7.8%]; *P*=0.65).

Rare pathologies included 2 iatrogenic cusp perforations as a consequence of mitral valve surgery, 1 case of retracted cusps in Takayasu arteritis, 1 case of retracted cusps in active rheumatic heart valve disease, and 1 case of commissural dissection.

Variability of gH in Patients With Prolapse or Retraction

To assess the normal distribution of gH, a subanalysis was performed in the cusps without retraction or prolapse (564 cusps in 312 patients). Geometric height varied between 18 and 25 mm (20.4±1.2 mm). It was higher in men (20.6±1.2 mm) than women (19.4±0.9 mm; P<0.001), it correlated with body surface area (BSA) (r=0.17; P=0.004), and it decreased with age (r=−0.19; P=0.002; Figure S2A). The ratio eH/gH was similar in men and women (0.45±0.04 versus 0.45±0.04; P=0.73; Figure S2B). This ratio was not influenced by age or BSA (Figure S2C).

In patients with retraction, the mean gH of the 3 cusps varied between 12 and 20 mm (16.5±1.6 mm). The gH of the smallest cusps ranged from 10 to 17 mm (15.0±1.6 mm). There was no correlation between gH and patient age or BSA in cusp retraction, suggesting no confounding with age or size when adjudicating retraction to smaller cusps.

Repair Results and Reasons for AVR

Of the patients with cusp prolapse, 84% were repaired, whereas of the retracted cusps, only 22% appeared repairable. Most repairs showed a good result with AR that was mild or less, and only 23.3% (67) patients had AR greater than mild during postoperative echocardiography. The proportion of repair with AR greater than mild at hospital discharge was lower after prolapse repair (14%) compared with retraction (47%; P<0.001).

By univariate analysis, patients with AR greater than mild had lower BSA (P<0.001), lower height (P=0.002), lower weight (P<0.001), lower mean gH (P=0.001), lower minimal gH (P<0.001), lower mean eH (P=0.01), more retraction (P=0.02), fewer fenestrations (P=0.03), and more concomitant mitral surgery (P=0.03). By stepwise logistic regression, AR greater than mild was associated with lower BSA (odds ratio [OR], 0.18 [95% CI, 0.04–0.81]; P=0.03), lower minimum gH (OR, 0.83 [95% CI, 0.70–0.98]; P=0.03), lower mean eH (OR, 0.67 [95% CI, 0.52–0.87]; P=0.002), and presence of concomitant mitral surgery (OR, 2.25 [95% CI, 1.19–4.25]; P=0.01).

Several factors were identified as reasons for AVR (Table S2; Figure 4B). Cusp retraction was the most frequent, followed by cusp perforation or destruction attributable to endocarditis, cusp calcification, and, rarely, multiple and large fenestrations.

Patients with AVr were younger than those with AVR (AVR: 62.8±13.8 years; AVr: 59.9±12.4 years; P=0.01). In most patients (n=183; 79.9%), the decision to replace the valve was based on a single anatomic criterion; in 46 cases (20.1%), ≥2 criteria were present. Retraction of at least 1 cusp was the most common (n=140; 61.1%); it was more frequent in women (female: 79% [59]; male: 53% [81]; P<0.001). The proportion of patients with ≥2 reasons for replacement increased with patient age. Similarly, the proportion of replaced aortic valves increased in patients aged >70 years (Figure S3).

DISCUSSION

Our study presents a comprehensive assessment of valvular mechanisms underlying TAV-AR for the first time in a large consecutive patient cohort referred for surgical correction, by systematic intraoperative quantification methods. This assessment is unique in that the quantification of gH and eH was performed in vivo, allowing comprehensive evaluation of the functional anatomy of the 3 coronary cusps suspended within the root. Our principal findings are as following: (1) A single valvular mechanism was present in most patients (88%), most commonly cusp prolapse (46%), followed by retraction (24%) and perforation (18%). (2) The right-coronary cusp was involved in most (86%) prolapse cases, more frequently in men. (3) The accuracy of 2D IOTEE for predicting AR mechanisms was limited for noncoronary (55%–61%) and left-coronary cusp (<5%) assessments. (4) Cusp prolapse and larger patient and cusp size were independently associated with successful AVr (all P<0.03), whereas retraction (small cusp), smaller patient, endocarditic lesions, and older age were associated with AVR (all P<0.03). (5) In aortic cusps without retraction or prolapse, geometric cusp height was dependent on sex and body size, whereas the ratio of effective height/geometric height was identical regardless of sex or body size. (6) With implementation of systematic intraoperative quantification methods and current surgical techniques, more than half of TAV-AR cases were successfully repaired.

Importance of Prolapse

The diagnosis of prolapse has relied on echocardiographic criteria, commonly more qualitative than quantitative.[11,16,17] The current investigation is novel in that an in vivo quantitative parameter was used (eH) for prolapse diagnosis. This is important for clinical practice because cusp prolapse is a good substrate for repair,[18] and its correction is facilitated by use of quantitative control. The right cusp was most frequently affected, similar to the findings in other series.[11,18] The reasons for this are unclear, but we propose that the right cusp is supported mainly by septal myocardium, whereas the 2 others are part of the central skeleton of the heart, and thus have more support.

In almost 30% of prolapses, fenestrations with elongated or torn marginal strands led to the distortion of the valve. These fenestrations have been attributed to hypertension,[16] which is not supported by the current analysis. Instead, they are congenital formations in the cusp coaptation zone and have been found with myxomatous cusp degeneration.[17,19] Fenestrations are, however, a possible locus minoris resistentiae in the pericommissural area; failure of the marginal strand attributable to the high stress[20] will result in prolapse.

Interestingly, we could not identify a fenestration by 2D IOTEE in any instance. Although it has been suggested that the echocardiographic findings of partial prolapse are suggestive of fenestrations,[21] we could not confirm this.

Importance of Retraction

The second most frequent finding in the current study was cusp retraction: in most cases, in all 3 cusps, and less frequently, in only 1 or 2 cusps. Patients with retraction were more frequently female and smaller, but we could not identify other clinical association differences between the prolapse and retraction patients. On the basis of the definition of retraction as a geometric height of <18 mm,[12] a bias may have been introduced that led to the diagnosis in smaller individuals who have smaller valves. Although an indexed cutoff may be more appropriate, more data will be needed to investigate the ideal value. However, our current cutoff of 18 mm appears as reasonable, because AVr results in valves with a gH ≥18 mm were excellent. On the basis of the suboptimal durability in another series,[21,22] most retracted valves were replaced. If repaired, we detected a higher proportion of residual AR greater than mild, indicating that with current techniques this is not an ideal substrate for repair.

The current study is unique in that in all patients a mechanism of AR could be clearly identified by systematic intraoperative assessment. This is attributable to the individual assessment of all 3 cusps and quantification of the 2 most important pathologies, prolapse and retraction, by geometric measurements (ie, gH and eH). In addition, we could confirm previous data indicating that gH and eH follow a constant relationship in normal aortic valves[12,13,15] (Figure S2).

2D IOTEE Is Significantly Limited

The information obtained by 2D IOTEE in our analysis differed between the 3 cusps and was imprecise for the noncoronary and almost nonexistent for the left cusp. It allowed for a definition of the mechanism of regurgitation in only 65%, similar to the published series.[11] One reason for the limited accuracy may be the fact that the interpreting echocardiographer relied on qualitative interpretation of the visual impression. Most important, the limited sensitivity of echocardiography can be explained by the limitations of 2D transesophageal echocardiography, in which the midesophageal long-axis plane allows orthogonal visualization of the right cusp. This is less reproducible for the noncoronary cusp, which accompanies the right in the long-axis view but not fully orthogonal, whereas the left cusp is usually in a blind spot. Three-dimensional transesophageal echocardiography (multiplanar reconstruction) can be expected to markedly improve the diagnostic yield of echocardiography[23] for the 3 cusps, and should be the standard of care for these patients.

The finding of concomitant mitral valve surgery related to suboptimal AVr results is interesting and requires further study; we propose that anatomic continuum between the aortic and mitral valves (intervalvular fibrosa) being altered by mitral intervention causes disarray within the fragile balance of the TAV coaptation. Finally, in most cases with endocarditic cusp defects, replacement was chosen, particularly in the presence of active endocarditis and large cusp defects. This was based on previous findings of repair failure in the first few years when a large pericardial patch was necessary to close an endocarditic defect.[24] Additionally, most valves with cusp retraction were replaced because of the expected reduced durability.[21,22]

Limitations

The main limitation of this study is its observational design. Although data of consecutive procedures were obtained prospectively, the analysis was done retrospectively, and treatment allocation was not randomized. Furthermore, a highly experienced surgeon made the choice between surgical treatment options. Despite these limitations, this analysis represents the first available study reporting cusp mechanisms of aortic regurgitation in tricuspid aortic valves using systematic in vivo quantification, and represents the knowledge base for all future mechanistic and TAV repair analyses.

CONCLUSIONS

By way of systematic intraoperative quantification methods, we found that right cusp prolapse is the most frequent single valvular mechanism in patients with TAV-AR, followed by cusp retraction and perforation. The accuracy of 2D IOTEE was limited for left and noncoronary cusp mechanistic assessment. Prolapse was associated with successful AVr, whereas retraction and perforation were associated with AVR. With systematic intraoperative quantification methods and current surgical techniques, more than half of TAV-AR cases may be successfully repaired.

ARTICLE INFORMATION

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Supplemental Material

Tables S1–S2
Figures S1–S3

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