THE USE OF TRANSESOPHAGEAL ECHOCARDIOGRAPHY TO PREDICT SURGICAL COMPLEXITY SCORING SYSTEM FOR DEGENERATIVE MITRAL VALVE REPAIR

Himani V. Bhatt[1], Lauren Lisann-Goldman[2], Elvera L. Baron[3], Benjamin S. Salter[1], Hung-Mo Lin[4], Shinobu Itagaki[5], Anelechi C. Anyanwu[5], David Adams[5], Gregory W. Fischer[6], and Ahmed El-Eshmawi[5]

[1]Icahn School of Medicine at Mount Sinai Department of Anesthesiology Perioperative and Pain Medicine
[2]NYU Langone Hospital - Long Island
[3]Case Western Reserve University School of Medicine
[4]Yale University Department of Anesthesiology
[5]Icahn School of Medicine at Mount Sinai Department of Cardiovascular Surgery
[6]Memorial Sloan Kettering Cancer Center Department of Anesthesiology and Critical Care Medicine

March 13, 2023

Abstract

Background: For severe mitral valve (MV) degenerative disease, repair is recommended. Prediction of repair complexity and referral to centers of excellence can increase rates of successful repair. This study sought to demonstrate that TEE is a feasible imaging modality to predict the surgical MV complexity score previously developed by Anyanwu et al. **Methods:** Two hundred TEE examinations of patients who underwent MV repair ($2009 - 2011$) were retrospectively reviewed and scored by two cardiac anesthesiologists. TEE scores were compared to surgical complexity scores of same subset of patients. Kappa values were reported for the agreement of TEE and surgical scores. McNemar's tests were used to test the homogeneity of the marginal probabilities of different scoring categories. **Results:** TEE scores were slightly lower (2[1,3]) than surgical scores (3[1,4]). Agreement was 66% between the scoring methods, with a moderate kappa (0.46). Using surgical scores as the gold standard, 70%, 71% and 46% of simple, intermediate and complex surgical scores, respectively, were correctly scored by TEE. P1, P2, P3, and A2 prolapse were easiest to identify with TEE and had the highest agreement with surgical scoring (P1 agreement 79% with kappa 0.55, P2 96% (kappa 0.8), P3 77% (kappa 0.51), A2 88% (kappa 0.6)). The lowest agreement between the two scores occurred with A1 prolapse (kappa 0.05) and posteromedial commissure prolapse (kappa 0.14) (Figure 3). In the presence of significant disagreement, TEE scores were more likely to be of higher complexity than surgical. McNemar's test was significant for prolapse of P1 (p=0.005), A1 (p=0.025), A2 (p=0.041), and the posteromedial commissure (p<.0001).

Introduction and Background

Mitral valve repair (MVr) is recommended for severe mitral valve (MV) regurgitation due to degenerative leaflet prolapse. However, despite extensive evidence of the superiority of valve repair over valve replacement, repair rates remain highly variable among different centers. Factors contributing to replacement rather than repair include surgeon experience, hospital case volume, and the complexity of valvular pathology. Referring patients to centers with surgical experience and expertise in mitral valve repair may help increase overall repair rates.

1

A MV disease scoring system was previously developed by Anyanwu et al. to measure valve complexity and difficulty of surgical repair. The scoring system divides degenerative mitral valve prolapse into 3 strata—simple, intermediate, and complex—based on the expected complexity of repair. The scoring system seemed to be directly correlated to the surgical complexity . Importantly, echo-guided repair, including 3D echocardiography, has separately been shown be associated with higher repair rates as well as excellent long-term results.

Transesophageal echocardiography has not yet been investigated as a means for stratifying mitral degenerative disease or predicting the complexity of mitral surgical repair. All components of the previously derived surgical score can be evaluated using preoperative echocardiography. We hypothesize that pre-bypass TEE prior to skin incision by experienced cardiac anesthesiologists can corroborate the previously published surgical mitral valve complexity score and therefore potentially improve early prediction and stratification of mitral valve disease surgical complexity.

Methods

Study Population

After IRB approval and waiver of consent, two cardiac anesthesiologists reviewed and graded pre-bypass TEE images from patients who underwent elective mitral valve repair for MV prolapse due to degenerative mitral valve disease at Mount Sinai Medical Center from June 2009 through December 2011. Patients who had prolapse due to other etiologies (e.g. rheumatic disease or endocarditis) were excluded, as were patients who had degenerative disease but did not have valve prolapse as a principal mechanism of regurgitation. Additional exclusion criteria were as follows: patients with concomitant pulmonic or aortic valvular pathology, emergent surgery, poor TEE image quality, and exams without all standard MV images. A comprehensive TEE was performed intraoperatively on each patient prior to cardiopulmonary bypass (CPB) as the standard of care in our center. Two hundred TEE examinations (the same cohort of patients from the prior surgical score study[1]) were rated by two independent cardiac anesthesiologists board certified in advanced echocardiography.

Surgical Score

The complexity score was developed using a consensus approach via direct examination of the arrested open heart, and was calculated as described by Anyanwu et al. (Table 1)

Echocardiographic (TEE) Measurements

Mitral valve images from the intraoperative, pre-bypass TEE of 200 patients were retrospectively reviewed (Figure 1), and each patient's mitral valve was scored using the same anatomic variables from the surgical complexity score (Table 1). All images were 2D TEE images, given that the study population consisted of patients undergoing surgery from 2009 to 2011, before the updated ASE guidelines were released in 2013, which newly incorporated 3D imaging. Fifty of the 200 TEE exams were analyzed by both echocardiographer/cardiac anesthesiologists to determine inter-rater reliability.

Statistical Analysis

Descriptive statistics (mean (SD), median [interquartile range], and %(N), as appropriate), were presented for MV complexity scores, patient demographics, and comorbidities. Kappa values were reported for the agreement of TEE scores and surgical scores. McNemar's tests were used to test the homogeneity of the marginal probabilities of different scoring categories. All statistical analyses were performed using SAS, version 9.4.

Results

A total of 200 patients with a surgical score underwent pre-bypass TEE scoring. Sixty-seven patients (34%) were surgically scored in the simple group, 92 patients (46%) in the intermediate group, and 41 patients

(21%) in the complex group. Echocardiographically, 64 patients (32%) were scores in the simple group, 102 patients (51%) in the intermediate group and 34 patients (17%) in the complex group.

Overall, transesophageal echo scores were slightly lower (2[1,3]) than surgical scores (3[1,4]). The within-subject difference between TEE and surgical score was 0 [-1, 1]); p=0.759). Overall, agreement was 66% between the scoring methods, with a moderate kappa statistic (0.46). Considering the surgical scores as the "gold standard," 70%, 71% and 46% of the simple, intermediate, and complex surgical scores were correctly evaluated by TEE, respectively (Table 2, Figure 2). Furthermore, when the simple and intermediate groups were combined to determine non-complex vs complex scores, the kappa was 0.36; sensitivity of the complex score was 0.46 and specificity was 0.91.

Amongst the various culprit lesions, posterior leaflet dysfunction and A2 prolapse were easiest to identify with TEE and had the highest agreement with surgical scoring. Agreement between TEE and surgical scoring for P1 prolapse was 79% (kappa 0.55), for P2 was 96% (kappa 0.8), for P3 was 77% (kappa 0.51), and for A2 was 88% (kappa 0.6). Mitral annular calcification (MAC) (92%, kappa 0.56) and any leaflet restriction (96%, kappa 0.41) had moderate agreement between the TEE and surgical scores. The lowest agreement occurred in the setting of A1 prolapse (kappa 0.05) and prolapse of the posteromedial commissure (kappa 0.14) (Figure 3). When significant disagreement was present, the TEE scores were more likely to rate the valve with a higher complexity compared to the surgical scores. McNemar's test was significant for P1 prolapse (p=0.005), A1 prolapse (p=0.025), A2 (p=0.041), and posteromedial commissure prolapse (p<.0001).

Inter-Rater Agreement and TEE-Surgical Agreement

When comparing scores between clinicians, one of the cardiac anesthesiologists (rater 1) had a higher degree of agreement with surgical scores (kappa 0.53) relative to the other (rater 2) (kappa 0.39). For mitral valves surgically rated as "complex," agreement between surgical and TEE scores occurred 63% of the time for rater 1 compared to 31% of the time for rater 2. Inter-clinician agreement for intermediate and complex lesions was 88% and 67%, respectively, and overall agreement was moderate between the two cardiac anesthesiologists (kappa 0.62).

Discussion

The current American Heart Association/American College of Cardiology Guidelines recommend mitral valve repair as the treatment of choice for degenerative MR. Both pre- and intra-operative echocardiography are critical to guiding surgical management in the operating room. Echocardiography enables evaluation of the of the entire MV apparatus including the leaflets, annulus and chordae tendineae, the severity and mechanism of regurgitation, and any additional cardiac pathology that increases surgical risk. Transthoracic echocardiography, as a low cost and minimally invasive diagnostic imaging modality, provides the data needed for clinical decision-making in most patients with chronic primary MR. When TTE images are inadequate, TEE is recommended. The severity of MR can be estimated using multiple echocardiographic parameters such as color doppler, effective regurgitant orifice area, vena contracta width, and pulmonary blood flow.

Outcomes, including postoperative morbidity/mortality and freedom from recurrent moderate/severe MR, after mitral valve repair have been demonstrated to be superior when performed by surgeons with extensive experience at high volume centers. These findings are consistent with guidelines recently published by The American College of Cardiology/ American Heart Association as well as the European Society of Cardiology[9,10]. The MV complexity score has demonstrated to have a direct correlation with the difficulty of surgical repair and the length of cardiopulmonary bypass time, both of which have implications for postoperative outcomes. The current analysis suggests the feasibility of using TEE-derived MV complexity scores to preoperatively stratify degenerative MV repair complexity. This correlation should permit expedient and cost-effective referral of appropriate candidates for MV repair to centers of excellence. The authors accordingly claim that TEE is a practical and useful imaging modality for stratification of MV complexity with the potential to improve mitral valve disease outcomes.

Strengths, Limitations and Future Studies

The strength of this study is the relatively large number of patients (n=200) who underwent surgical intervention in a single timeframe at a single center dedicated to the care of complex, degenerative MV disease. Further, the TEE examinations were performed on the same subset of patients included in the internally validated and published surgical score study by Anyanwu et al. Additionally, the examinations were rated by two independent, board-certified cardiac anesthesiologists with a subset of examinations evaluated by both clinicians.

The retrospective nature of our study is one of its limitations. This study used a surgical scoring system published previously by Anyanwu et al. as the standard of comparison for MV repair complexity stratification. The scoring system in that study was extrapolated retrospectively from surgical notes, rather than generated in real-time based on intraoperative anatomic inspection. Also, the echocardiographic scores included in this cohort are from this older study and were also generated from retrospective review of previously performed echocardiography examinations. However, we chose to use the previously studied and published cohort to allow for better comparison with the same patients.

Importantly, the echocardiographic studies in the current report were performed using TEE imaging technology that has since been updated. Contemporary images obtained using newer echocardiography machines and updated software packages are of better quality, with greater temporal and spatial resolution, better three-dimensional capacity and improved post-processing capabilities. Accordingly, better image quality is likely to further improve the agreement between surgical and echocardiographic scores. Indeed, a prior investigation of echo-guided mitral valve repair by Drake et al. demonstrated that 3D echo images of the mitral valve were more highly concordant with intraoperative surgical findings, further supporting that improved echo technology (which in recent years has seen more noticeable improvements in 3D than 2D imaging), will further improve agreement between surgical and echocardiographic scores.

Training, education, and dissemination of a standardized scoring system is also likely to improve the agreement between TEE and surgical scores, demonstrated by the higher level of agreement between surgical scores and the scores given by the more experienced rater. Though further analysis is required to assess inter-clinician reliability on a larger scale, targeted training and education can standardize image acquisition and reduce variability amongst echocardiographers. Additionally, the current study used a retrospective analysis consisting of images acquired by one clinician then interpreted by another. Future studies applying the scoring system can intentionally focus on acquiring specific images for subsequent interpretation. Importantly, prospective studies are needed to validate the use of TEE in predicting intra-operative surgical complexity scores. Once validated, assessment of the clinical impact of the scoring system can be carried out, ultimately in terms of its ability to improve clinical outcomes, patient education and patient satisfaction.

Conclusion

We found the echocardiographic mitral valve complexity score to be *moderately correlated* with the previously published surgical complexity score. This moderate correlation demonstrates that TEE is a feasible imaging modality to predict the surgical mitral valve complexity score; importantly, with minimal additional risk, given that preoperative TEE is already common practice prior to scheduling MV surgery. Using preoperative TEE to determine the MV complexity score can allow for early stratification, rather than awaiting intraoperative evaluation on the open, cross-clamped heart during cardiopulmonary bypass. Accordingly, by potentially decreasing surgical time and allowing for referral of patients with complex degenerative MV disease to surgeons and hospitals with extensive experience in MV repair, preoperative complexity scoring has the potential to improve patient experience and postoperative outcomes.

Acknowledgment

References

Figure and Table Legends

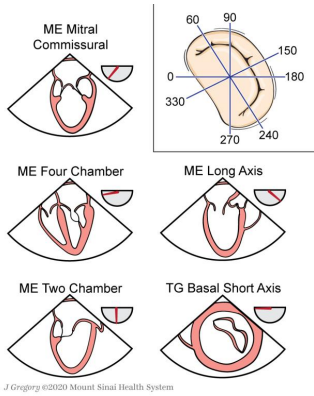**Table 1. Mitral valve complexity score calculation, adapted from Anyanwu et al., 2016.**

Total complexity score = sum of individual scores. Complexity strata: Simple = 1; Intermediate = 2 - 4; Complex [?]5.
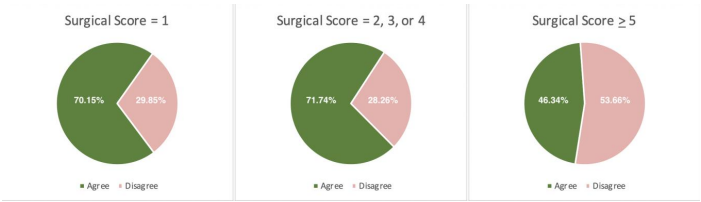
Table 2: Agreement between TEE and Surgical Scores. Agreement was greater between surgical and TEE complexity scores when surgical complexity score was simple (1) or intermediate $(2 - 4)$, versus complex (>5).
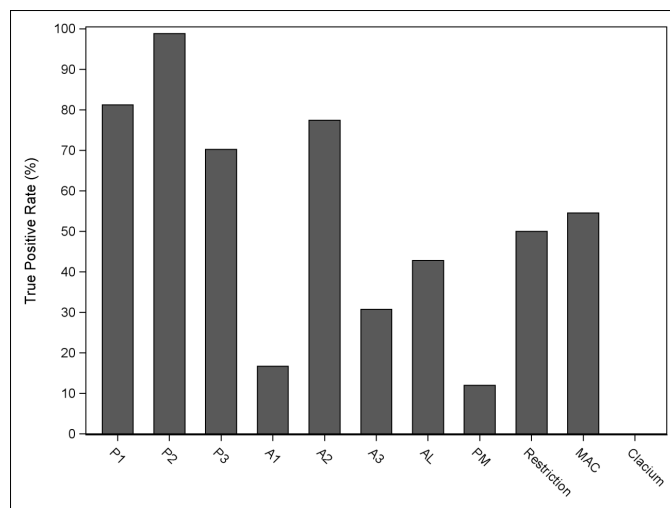
Figure 1: Standard 2D mitral valve transesophageal echocardiographic views. Schematic echocardiographic cross sections of the mitral valve as described in the American Society of Echocardiography and Society of Cardiovascular Anesthesiologists guidelines for performing comprehensive intraoperative transesophageal echocardiographic examinations. Adapted from Shanewise et al., 1999.

Figure 2: Percentage of agreement between surgical and TEE scores by surgical complexity score. Greater agreement between surgical and TEE scores is demonstrated for simple (surgical score = 1) and intermediate (surgical score = 2, 3, or 4) complexity mitral valve lesions.

Figure 3: Agreement between surgical and TEE score for each anatomical segment. Greatest agreement between surgical and TEE complexity score is demonstrated for P1, P2, P3 and A2 prolapse.

ME Mitral
Commissural

60 90
150
0 180
330
270 240

ME Four Chamber

ME Long Axis

ME Two Chamber

TG Basal Short Axis

J Gregory ©2020 Mount Sinai Health System

Surgical Score = 1

70.15%   29.85%

■ Agree   ♦ Disagree

Surgical Score = 2, 3, or 4

71.74%   28.26%

■ Agree   ♦ Disagree

Surgical Score ≥ 5

46.34%   53.66%

■ Agree   ♦ Disagree

Hosted file

MV Scoring Table 1.docx available at https://authorea.com/users/595261/articles/629405-the-use-of-transesophageal-echocardiography-to-predict-surgical-complexity-scoring-system-for-degenerative-mitral-valve-repair

Hosted file

MV Scoring Table 2.docx available at https://authorea.com/users/595261/articles/629405-the-use-of-transesophageal-echocardiography-to-predict-surgical-complexity-scoring-system-for-degenerative-mitral-valve-repair