160. Machine Learning-Derived Echocardiographic Phenotypes Predict Clinical Outcome and Success Repair of Tricuspid Annuloplasty

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Body

Background: Persistent undertreatment of tricuspid regurgitation (TR) reflects uncertainties with its quantification and management. Morphological and functional components of TR, which may account for the success of tricuspid valve intervention, have not been evaluated. This study sought to identify echocardiographic phenotypes in TR and assess their association with outcomes after tricuspid annuloplasty (TA).

Methods: Morphomic and functional network profiling were performed in patients undergoing TA between 2012 and 2019. Principal component (PC) analysis with varimax rotation was used to condense echocardiographic data into PCs, from which clusters were derived using K-means clustering. Clusters and PCs were correlated with clinical outcomes (composite of heart failure hospitalization and all-cause mortality) and residual TR, adjusted for comorbidities, medications, and EuroSCORE II.

Results: Morphomic and functional data from 290 patients (age 63±9 years, 63% female) were profiled and subsequently condensed into PCs. PC 1 described high loadings of tricuspid valve and right atrial morphology; PC 2 described high loadings of right ventricular morphology; PC 3 described high loadings of left ventricular topology. Based on these components, two clusters representing "small" (Cluster 1; n=253) and "large right atria and ventricle" (Cluster 2; n=37) phenotypes were derived (Table, Figure A).

Compared with Cluster 1, Cluster 2 was associated with a higher risk of adverse outcomes (adjusted hazard ratio 2.04; 95% Confidence Interval [CI] 1.17-3.56; P=0.012) (Figure B). Nonetheless, TR remained associated with adverse outcomes after adjusting for the clusters (adjusted hazard ratio 1.005; 95% CI 1.001-1.009; P=0.030). Cluster 2 was also associated with an increased risk of residual TR (Odds Ratio 2.31; 95% CI 1.06-5.00; P=0.034) after TA.

Conclusion: Amongst the two distinct phenotypes of TR, a "large right atria and ventricle" is associated with worse clinical outcomes and a lower chance of repair success. Such association cannot be purely attributed to cardiac morphology alone, supporting other complementary tricuspid valve features in driving poor postoperative outcomes.

Table

	Cluster 1 (n=253)	Cluster 2 (n=37)	P values
Demographics, Symptomatic Status, and Anthropometric Characteristics			
Age, years	64.0 ± 9.5	61.9 ± 6.5	0.203
Male	94 (37.2)	13 (35.1)	0.956
Body mass index, kg/m²	22.74 (4.47)	22.26 (5.17)	0.557
NYHA functional class III/IV	106 (41.9)	13 (35.1)	0.547
Cardiovascular risk factors and comorbidities			
Hypertension	60 (23.7)	4 (10.8)	0.12
Diabetes Mellitus	52 (20.6)	6 (16.2)	0.692
Dyslipidemia	54 (21.3)	2 (5.4)	0.038
Atrial fibrillation	208 (82.2)	32 (86.5)	0.682
Heart failure	147 (58.1)	17 (45.9)	0.224
Smoking	36 (14.2)	4 (10.8)	0.758
Stroke	36 (14.2)	15 (40.5)	<0.001
Chronic rheumatic heart disease	174 (68.8)	30 (81.1)	0.181
Medications			
ACEI/ARB	118 (46.6)	11 (29.7)	0.079
Beta blockers	105 (41.5)	11 (29.7)	0.236
Calcium channel blockers	51 (20.2)	4 (10.8)	0.258
Diuretics	49 (19.4)	19 (51.4)	<0.001
Laboratory measurements			
Hemoglobin, g/dL	12.36 (2.03)	11.08 (1.66)	<0.001
Creatinine, μmol/L	7.42 (2.81)	7.98 (3.58)	0.276
Urea, mmol/L	88.05 (27.36)	95.70 (43.10)	0.146
eGFR, mL/min/1.73m²	69.71 (20.45)	74.65 (26.80)	0.189
Valvular surgery risk-scoring systems			
EuroSCORE II	4.91 (5.82)	6.80 (4.99)	0.062
STS Score	3.02 (2.71)	4.71 (3.79)	0.001
Surgical Details			
MVR	164 (64.8)	19 (51.4)	0.16
MV Repair	67 (26.5)	0 (0.0)	0.001
AVR	91 (36.0)	15 (40.5)	0.721
CABG	20 (7.9)	2 (5.4)	0.838
LV, LA, and left-sided valvular disease			
≥ Moderate MR	152 (60.1)	7 (18.9)	<0.001
≥ Moderate MS	134 (53.0)	19 (51.4)	0.994
≥ Moderate AR	48 (19.0)	4 (10.8)	0.327
≥ Moderate AS	69 (27.3)	16 (43.2)	0.072
LVEDV, mL	99.88 (40.69)	78.27 (30.63)	0.002
LVESV, mL	42.34 (22.30)	32.32 (15.77)	0.009
LVEF, %	58.48 (8.83)	58.68 (8.61)	0.899
LA area, mm²	36.27 (17.50)	53.54 (24.90)	<0.001
RV and RA			
RV basal diameter, cm²	4.62 (1.36)	5.09 (1.17)	0.052
RV mid-cavity diameter, cm²	3.74 (1.19)	4.25 (1.00)	0.014
RV longitudinal diameter, cm²	5.13 (1.22)	6.18 (1.16)	<0.001
RV end-diastolic area, cm²	16.11 (5.59)	24.70 (7.37)	<0.001
RV end-systolic area, cm²	8.71 (3.65)	13.39 (4.32)	<0.001
RV sphericity index	4.19 (1.07)	5.37 (0.94)	<0.001
TAPSE, mm	16.48 (3.06)	14.68 (2.30)	0.001
RV global longitudinal strain, %	-16.37 (5.49)	-12.96 (5.06)	<0.001
RA area, mm²	21.78 (8.09)	53.80 (23.20)	<0.001
PASP, mmHg	48.80 (12.55)	43.84 (10.49)	0.023
Tricuspid Valve			
TR severity			<0.001
Moderate TR	140 (55.3)	1 (2.7)	
Severe TR	113 (44.7)	36 (97.3)	
EROA, mm²	43.74 (24.72)	151.79 (115.42)	<0.001
RVol, mL/beat	43.97 (23.66)	117.23 (70.99)	<0.001
Leaflet tenting height, cm	0.60 (0.15)	0.87 (0.18)	<0.001
Leaflet tenting area, cm²	0.97 (0.44)	1.77 (0.70)	<0.001
IVC diameter	2.13 (0.50)	3.05 (0.71)	<0.001
Right atrial pressure	8.55 (4.52)	15.95 (3.95)	<0.001

Abbreviations: ACEI, angiotensin-converting enzyme inhibitors; ARB, angiotensin II receptor blockers; AS, aortic stenosis; AVR, aortic valve replacement; CABG, coronary artery bypass graft; CRHD, chronic rheumatic heart disease; eGFR, estimated glomerular filtration rate; EROA, effective regurgitant orifice area; EuroSCORE II, European System for Cardiac Operative Risk Evaluation II; LV, left ventricle; LA, left atrium; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; LVESV, left ventricular end-systolic volume; MR, mitral regurgitation; MS, mitral stenosis; MV Repair, mitral valve repair; NYHA, New York Heart Association; PASP, pulmonary artery systolic pressure; RA, right atrium; RV, right ventricle; RVol, regurgitant volume; STS score, Society of Thoracic Surgeons Predicted Risk of Mortality Score; TAPSE, tricuspid annular plane systolic excursion; TR, tricuspid regurgitation.

Figure
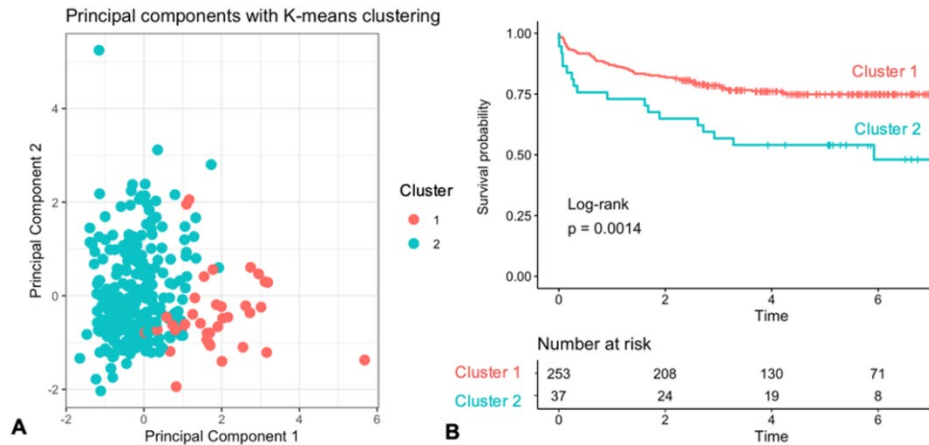
Clinical Implications: better understand the morphological and functional components of tricuspid regurgitation and their implications on the successful repair and clinical outcomes of tricuspid annuloplasty.