

1 **Title Page**

2 **“Trying to Straighten a Leaning Measurement: Corrected EROA PISA in Tricuspid**
3 **Regurgitation”**

4 *Moving Beyond Geometric Assumptions—Refining Quantification of Tricuspid Regurgitation*

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14 Conflicts of Interest: Nothing to Disclose.

15 No new data were generated or analysed in support of this research.

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17 *Editorial to:*

18 **A novel method of proximal isovelocitv surface area correction for quantitative**
19 **assessment of tricuspid regurgitation severity**

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1 For many years, tricuspid regurgitation (TR) has been regarded as a “forgotten” valve disease.
2 Its prognostic relevance is now well recognized, and TR is increasingly becoming a target for
3 transcatheter therapies.

4 Quantification of TR remains challenging. Despite the growing acknowledgment of its
5 clinical impact, TR is still frequently underestimated because available quantitative methods
6 have not kept pace with the anatomical and hemodynamic complexity of the tricuspid valve.
7 The proximal isovelocity surface area (PISA) method—based on conservation of mass¹—
8 remains the primary recommended quantitative tool, yet its limitations are well established.

9 As flow converges toward a small regurgitant orifice, the isovelocity shells deviate from
10 hemispheric geometry (the “angle assumption”), leading to underestimation. Functional TR is
11 also temporally dynamic, making results dependent on timing of PISA radius measurement.
12 Moreover, the regurgitant orifice is often non-planar and irregularly shaped (not circular; the
13 “shape assumption”), reflecting the multi-scalloped structure of the tricuspid valve. Finally,
14 low right-sided flow rates reduce the gradient between aliasing and peak TR velocities (the
15 “flow assumption”), further contributing to systematic underestimation.¹

16 The study by Tat *et al.*² provides timely insights into these limitations. By correcting PISA-
17 derived EROA for three major sources of error—flow rate, leaflet angle, and orifice ellipticity
18 (**Figure 1**)—the authors propose a method better aligned with tricuspid anatomy.

19 In 100 patients with \geq mild TR, conventional 2D PISA-derived EROA (EROA_{PISA}, with the
20 radius averaged during the entire systolic period; 0.62 ± 0.47 cm²) was substantially lower
21 than Doppler volumetric EROA (EROA_{DOPPLER}; 1.40 ± 1.11 cm²) and 3D-VCA (averaged
22 during the entire systolic period; 1.66 ± 1.18 cm²), confirming the systematic nature of PISA
23 underestimation. Both EROA_{PISA} and EROA_{CORRECTED} correlated strongly with EROA_{DOPPLER}
24 and 3D-VCA; however, correlation does not mitigate the inherent bias of an underestimating
25 measurement.

26 After correction for flow, leaflet angle, and ellipticity, EROA_{CORRECTED} showed improved
27 agreement with EROA_{DOPPLER} (1.31 ± 1.19 cm²; no significant difference) (**Figure 2A**) and
28 reclassified 24 of 43 patients from mild/moderate to severe TR. Removal of left-sided
29 geometric assumptions renders PISA more coherent with right-sided anatomy.

30 Previous studies similarly demonstrate that EROA_{PISA} underestimates severity, especially in
31 functional TR.^{3,4}

32 However, the three quantitative techniques evaluated—EROA_{PISA}, EROA_{DOPPLER}, and 3D-
33 VCA—each have limitations. EROA_{PISA} systematically underestimates TR; EROA_{DOPPLER} is
34 technically demanding, with 2D annular area modestly underestimating the true 3D area; 3D-
35 VCA may overestimate EROA due to non-planar orifice geometry.

36 Regarding reference standards, EROA_{DOPPLER} and 3D-VCA_{TEE} showed highest agreement;
37 however, feasibility was limited for 3D-VCA (61% by TTE; 67% by TEE) compared with
38 EROA_{DOPPLER} (91%); while EROA_{PISA} was feasible in all patients.

3 Prognostic implications

4 An important strength of the study is the prognostic validation of $EROA_{CORRECTED}$ (**Figure**
5 **2B-C**). A threshold ≥ 0.75 cm² independently predicted mortality and morbidity, comparable
6 to $EROA_{DOPPLER}$ and 3D-VCA. This reinforces the association between quantitatively robust
7 TR measures and adverse outcomes.⁵

8 However, this threshold exceeds guideline recommendations for severe TR ($EROA_{PISA} \geq 0.40$
9 cm²) and differs from prior findings ($EROA_{CORRECTED} > 0.46$ cm²).⁴ ROC analysis in the
10 present study identified an even lower cut-off (0.38 cm²), with high sensitivity but limited
11 specificity.

12 Even uncorrected $EROA_{PISA}$ values of ~ 0.25 – 0.30 cm² were associated with adverse events
13 (AUC 0.72), suggesting that the current guideline-based threshold of 0.40 cm² may be
14 insufficiently sensitive.⁶

15 Misclassification has growing clinical implications: underestimation may delay referral,
16 whereas overestimation may prompt unnecessary intervention.

18 Integration of advanced imaging

19 3D echocardiography and CMR have reshaped the assessment of right-sided valves. 3D
20 Doppler enables direct VCA planimetry and 3D-PISA, improving accuracy across etiologies;
21 CMR provides assumption-free quantification of regurgitant volume and fraction and is
22 emerging as a potential reference standard.⁷

23 PISA remains widely used in clinical practice; therefore, a corrected approach represents a
24 pragmatic step toward improved accuracy while maintaining workflow feasibility.

26 Implications for practice

27 The evidence supports:

- 28 1. **Recalibration of severe TR thresholds** using outcome-based data. Uncorrected PISA
29 cut-offs are likely too low; thresholds aligned with $EROA_{CORRECTED}$, $EROA_{DOPPLER}$, 3D-VCA,
30 and CMR may offer improved risk discrimination.⁵
- 31 2. **Integration of quantitative TR assessment into structured reporting**, in accordance
32 with recent ASE/EACVI recommendations.⁸ Routine use of $EROA_{CORRECTED}$, 3D-VCA, and
33 CMR (when available) should be encouraged.

1 These steps would advance TR evaluation from semi-quantitative impressions toward
2 standardized, multimodal, outcome-validated classification.

3 A broader question remains: what defines prognostic TR? Uniform thresholds may
4 oversimplify a heterogeneous condition influenced by right ventricular structure, function,
5 and RV–PA coupling. A staging approach, rather than merely a grading of TR only, may
6 therefore provide more robust prognostic information.

7 While grading remains essential for procedural decision-making, overreliance on a single
8 parameter is unwise in a field moving toward integrated staging systems.

10 Future directions: the role of artificial intelligence

11 Emerging AI approaches can directly assess regurgitant jets, derive flow features, and
12 integrate structural and functional parameters into unified risk scores.⁹ In such models,
13 $EROA_{CORRECTED}$ will likely become one component rather than a standalone determinant.

15 Study limitations

16 The sample size was modest, and one-third of screened patients were excluded due to
17 incomplete quantitative data, introducing potential selection bias. The study population
18 consisted of patients referred for intervention, further limiting generalizability. Low event
19 rates restrict the strength of prognostic conclusions. Future work should validate findings
20 against CMR, automated 3D-PISA, 3D-VCA, and 3D volumetric Doppler. Differences
21 between atrial, ventricular and primary TR may also warrant investigation.

22 The correction factors may be particularly valuable in moderate TR or in anatomies predictive
23 of PISA underestimation (low TR velocities, significant leaflet tethering, elliptical orifices),
24 though such patients represented less than half of the cohort.

26 Conclusion

27 **In summary, correcting $EROA_{PISA}$ for flow, leaflet angle, and orifice shape represents a**
28 **practical and clinically meaningful refinement that improves alignment with advanced**
29 **imaging, enhances prognostic accuracy, and moves TR quantification toward a more**
30 **standardized and outcome-driven framework** consistent with the evolving landscape of
31 valvular heart disease.

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1 **Figure legends**

2 **Figure 1 (modified by Tat et al). $EROA_{CORRECTED}$: Correcting proximal isovelocity**
3 **surface area assumptions.**

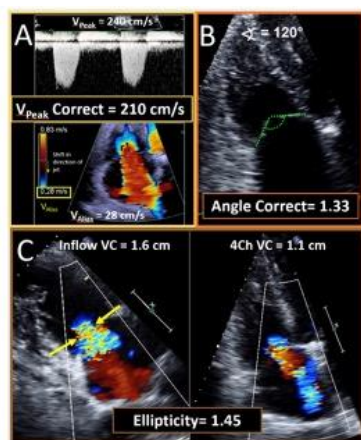
4 Three assumptions of the proximal is velocity surface area (PISA) method for calculating
5 the effective regurgitant orifice area (EROA) require correction for the flow and anatomic
6 characteristics of patients with secondary TR: A) flow rate correction, B) leaflet tenting
7 angle, measured as the angle subtended by the valve leaflets at end- systole on the
8 apical four-chamber view, and C) orifice ellipticity, measured as the ratio of the
9 maximum and minimum vena contracta (VC) diameters. Using all three correction
10 factors, $EROA_{CORRECTED}$ is represented by the formula in the right panel.

11

12 **Figure 2. Correlation of TR quantitative measures and prognostic validation.**

13 A. Only $EROA_{CORRECTED}$ resulted in similar quantitation of regurgitant orifice size compared
14 to quantitative Doppler ($EROA_{DOPPLER}$) or 3D-VCA (by transthoracic [TTE] or
15 transesophageal echo [TEE]). B-C. Multivariate and ROC curve analysis show a
16 significant association with different cut offs between all quantitative measures of
17 regurgitant orifice area with the composite outcome of all-cause mortality, heart failure
18 hospitalization, and either surgical or transcatheter tricuspid valve intervention.

19



$$EROA_{CORRECTED} = \underbrace{\frac{2\pi r^2 \times V_{alias}}{V_{peak} - V_{alias}}}_{\text{Flow Correction}} \times \underbrace{\frac{360 - \alpha}{180}}_{\text{Angle Correction}} \times \underbrace{\frac{VC_{max}}{VC_{min}}}_{\text{Shape Correction}}$$

Figure 1
53x23 mm (x DPI)

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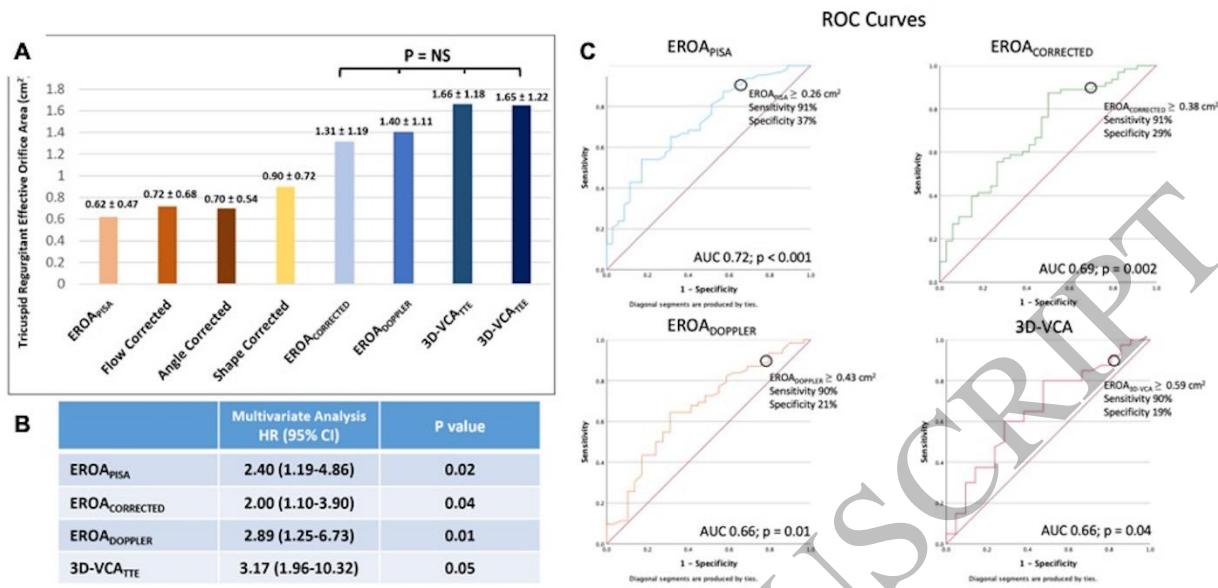


Figure 2
165x78 mm (x DPI)

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