FULL LENGTH ARTICLE

# Radius of proximal isovelocity surface area in the assessment of rheumatic mitral stenosis: Connecting flow to anatomy and hemodynamics

Alaa Mabrouk Salem Omar [a,*], Mohamed Ahmed Abdel-Rahman [b], Hala Raslan [a], Osama Rifaie [b]

[a] Department of Internal Medicine, Medical Division, National Research Centre, Dokki, Cairo
[b] Department of Cardiology, Ain Shams University, Abbasiya, Cairo

[a,b] Egypt

*Background:* Echocardiographic assessment of left atrial pressure (LAP) in mitral stenosis (MS) is controversial. We sought to examine the role of the radius of the proximal isovelocity surface area (PISA-r) in the assessment of the hemodynamic status of MS after fixing the aliasing velocity (Val).

*Methods and results:* We studied 42 candidates of balloon mitral valvuloplasty (BMV), for whom pre-BMV echocardiography was done and LAP invasively measured before dilatation. PISA-r was calculated after fixing aliasing velocity to 33 cm/s. In addition, the ratio IVRT/Te′–E was also measured, where IVRT was isovolumic relaxation time, and Te′–E was the time difference between the onset of mitral flow E-wave and mitral annular early diastolic velocity. IVRT/Te′–E and PISA-r showed a strong correlation with LAP (r = −0.715 and −0.637, all $p < 0.001$) and with right-sided pressures. In addition, PISA-r correlated with mitral valve area by planimetry method (MVA) and with left ventricular outflow tract stroke volume (r = 0.66 and 0.71, all $p < 0.001$). Receiver operator characteristic curve (ROC-curve) showed that PISA-r was not inferior to IVRT/Te′–E in differentiating LAP ⩾25 from <25 mmHg.

*Conclusion:* Provided that Val is set to a constant of 33 cm/s, PISA-r can assess the hemodynamic status of MS, and seems a simple alternative to the tedious IVRT/Te′–E for estimation of LAP.



*Keywords:* Mitral stenosis, Mitral valve area, Left atrial pressure, Proximal isovelocity surface area

*Disclosure:* Authors have nothing to disclose with regard to commercial support.

Received 8 February 2015; accepted 3 March 2015.
Available online 12 March 2015

* Corresponding author at: Department of Internal Medicine, Medical Division, National Research Centre, El Buhouth St., Dokki, Cairo 12311, Egypt. Tel.: +20 2 33371362; fax: +20 2 33370931.
E-mail address: alaahoda2001@gmail.com (A.M.S. Omar).

P.O. Box 2925 Riyadh – 11461KSA
Tel: +966 1 2520088 ext 40151
Fax: +966 1 2520718
Email: sha@sha.org.sa
URL: www.sha.org.sa



Peer review under responsibility of King Saud University.
URL: www.ksu.edu.sa
http://dx.doi.org/10.1016/j.jsha.2015.03.001

Production and hosting by Elsevier

## Introduction

Symptoms of mitral stenosis (MS) are believed to be due to the building up of pressures behind the stenosed valve leading to increased left atrial pressure (LAP) and pulmonary pressures [1]. Changes in LAP are not only dependent on the anatomic severity of MS but also on various other factors such as mitral valve resistance, left atrial size and compliance [2–5].

Echocardiographic assessment of LAP in MS is difficult as most echocardiographic determinants of LAP become inaccurate [3]. Reportedly, the time interval variable IVRT/Te′–E can estimate LAP in MS, where IVRT is isovolumic relaxation time (IVRT) and Te′–E is the time difference between the upstroke of the tissue Doppler early mitral annular velocity and the Doppler early mitral inflow velocity [6].

Proximal isovelocity surface area (PISA) is an application of the continuity equation that reportedly can assess mitral valve area (MVA) using the following equation:

$$\text{MVA} = \text{PISA-flow}/\text{Vmax}$$

PISA flow in this equation can be calculated using the equation:

$$\text{PISA-flow} = \text{PISA surface area} \times \text{aliasing velocity} \times \text{angle correction}$$

That is, $\text{PISA-flow} = 2\pi \times \text{PISA-r}^2 \times \text{Val} \times \alpha/180$, where PISA-r is the radius of the PISA cap in centimeters, Val is the aliasing velocity in cm/s, and $\alpha$ is the angle between mitral valve leaflets in degrees [7–12]. Several simplifications of the PISA equation have been suggested [13–16]. We have recently suggested that fixing $\alpha$ to 100 degrees and Val to 33 cm/s would not affect the accuracy of PISA and would leave only one parameter, PISA-r, apparently the most important in the PISA flow equation [17], allowing for a chance to study the effects of MS on the size of the PISA cap, determined by the PISA-r.

Accordingly, we sought to study the value of PISA-r in the echocardiographic assessments of patients with MS, after fixing the Val to 33 cm/s.

**Abbreviations**

| | |
|---|---|
| MS | mitral stenosis |
| BMV | Balloon mitral valvuloplasty |
| MVA | mitral valve area by planimetry method |
| PISA-r | radius of proximal isovelocity surface area cap |
| PG | pressure gradient |
| LAVmax | maximal left atrial volume |
| LAVmin | minimal left atrial volume |
| Cn | net atrio-ventricular compliance |
| IVRT | isovolumic relaxation time |
| Te′–E | time difference between the onset of mitral annular e′ and mitral flow E-wave |
| DFT | diastolic filling time |
| LAP | left atrial pressure |
| mPAP | mean pulmonary artery pressure |
| RVSP | right ventricular systolic pressure |
| Cath. PG | invasively measured LA-LV mean pressure gradient |
| Af | atrial fibrillation |
| TDI | tissue Doppler imaging |
| ΔP | pressure gradient |

## Methods

### Study population

In the period between August 2013 and June 2014, we recruited 45 consecutive rheumatic MS patients referred to our echocardiography laboratory for pre-balloon mitral valvuloplasty (BMV) assessment. The study protocol was approved by the research committee of our institution, and all patients gave informed consent consistent with this protocol. Three patients (7%) were excluded from all subsequent analyses because of suboptimal images from poor echocardiographic windows. Accordingly, the patient study group consisted of 42 patients.

### *Invasive measurements*

Fluoroscopically verified cardiac pressures, particularly left atrial pressure (LAP), pulmonary artery pressure (mPAP), and systolic right ventricular pressure (sRVP), and mean LA-LV pressure gradient (Cath.PG) was measured before balloon inflations during BMV. Pressures were obtained at end expiration with the zero-level set at the mid-axillary line and representing the average of five cardiac cycles.

### *Echocardiography*

Echocardiographic examinations were done immediately before BMV. All echocardiographic studies were acquired with a commercially available echocardiography system using a 2.5 MHz multi-frequency phased array transducer (Vivid 5 or 7; GE Vingmed Ultrasound AS, Horten, Norway). The LV ejection fraction was assessed using the biplane Simpson's method by manual tracing of the digital images. Maximum and minimum left atrial volume (LAVmax, LAVmin) were assessed using the biplane area length method. Left atrial stroke volume (LA-SV) was calculated as the difference between LAVmax and LAVmin.