The pulmonary capillary wedge pressure accurately reflects both normal and elevated left atrial pressure

Anikó I. Nagy, MD, PhD,[a] Ashwin Venkateshvaran, MSc,[b,c] Pravat Kumar Dash, MD,[c] Banajit Barooah, MD,[c] Béla Merkely, MD, PhD,[a] Reidar Winter, MD, PhD,[b,d] and Aristomenis Manouras, MD, PhD[b,d] *Budapest, Hungary; Stockholm, Sweden; and Bangalore, India*

Background Pulmonary capillary wedge pressure (PCWP) is routinely used as an indirect measure of the left atrial pressure (LAP), although the accuracy of this estimate, especially under pathological hemodynamic conditions, remains controversial.

Objectives The aim of this prospective study was to investigate the reliability of PCWP for the evaluation of LAP under different hemodynamic conditions.

Methods Simultaneous left and right heart catheterization data of 117 patients with pure mitral stenosis, obtained before and immediately after percutaneous mitral comissurotomy, were analyzed.

Results A strong correlation and agreement between PCWP and LAP measurements was demonstrated (correlation coefficient = 0.97, mean bias ± CI, 0.3 ± −3.7 to 4.2 mm Hg). Comparison of measurements performed within a 5-minute interval and those performed simultaneously revealed that simultaneous pressure acquisition yielded better agreement between the 2 methods (bias ± CI, 1.82 ± 1.98 mm Hg). In contrast to previous observations, the discrepancy between the 2 measures did not increase with elevated PCWP. Multiple regression analysis failed to identify hemodynamic confounders of the discrepancy between the 2 pressures. The ability of PCWP to distinguish between normal and elevated LAP (cutoff set at 12 and 15 mm Hg, respectively), as tested by receiver operating characteristics analysis, demonstrated a remarkably high diagnostic accuracy (area under the curve: 0.989 and 0.996, respectively).

Conclusions Although the described limits of agreement may not allow the interchangeability of PCWP and LAP, especially at lower pressure ranges, our data support the clinical use of PCWP as a robust and accurate estimate of LAP. (Am Heart J 2014;0:1-8.)

In common clinical practice, pulmonary capillary wedge pressure (PCWP) is used as an equivalent of left atrial pressure (LAP). However, regarding the accuracy of this estimate, controversy has existed over the past 65 years.

Description of the first PCWP measurements in human dates back to 1949.[1] The accuracy of PCWP as a reflection of LAP under different conditions has subsequently been investigated, and numerous early studies performed in small groups of patients questioned the interchangeability of the 2 approaches.[2-11]

From the [a]Heart and Vascular Centre, Semmelweis University, Budapest, Hungary, [b]School for Technology and Health, Royal Institute of Technology, Stockholm, Sweden, [c]Sri Sathya Sai Institute of Higher Medical Sciences, Bangalore, India, and [d]Department of Cardiology, Karolinska University Hospital, Stockholm, Sweden.

Submitted October 7, 2013; accepted January 30, 2014.

Reprint requests: Anikó I Nagy, MD PhD, Heart and Vascular Centre, Semmelweis University, 9. Gaál József St, 1122 Budapest, Hungary.

http://dx.doi.org/10.1016/j.ahj.2014.01.012
0002-8703/

The single large-scale study that investigated the agreement between PCWP and LAP, using direct LAP measurement through transseptal puncture, was published in 1973.[12] Waltson and coworkers reported the comparison of left and right heart catheterization data collected retrospectively for 13 years from a diverse population of 700 subjects, including healthy individuals as well as patients with ischemic heart disease and a variety of valvular lesions. Results from this study confirmed a good correlation and agreement between PCWP and LAP at reference ranges of mean PCWP (≤15 mm Hg). However, at higher wedge pressures, the prediction of LAP by PCWP was subject to considerable error. In fact, in case of wedge pressures greater than 15 mm Hg, the discrepancy between mean LAP and PCWP varied by roughly 15 mm Hg, increasing further at pressures greater than 20 mm Hg.

Both for the LA and PCWP measurements, the zero level was set at the midthoracic line. However, that the tip of the 2 catheters (wedge balloon and LA) could not by any means be certainly located at the same level due to obvious anatomical reasons, a minor discrepancy regarding the absolute pressure values cannot be excluded. Nonetheless, we believe that in this case, the error that might have been introduced would be random.

Considering the significant proportion of patients with elevated wedge pressures among those undergoing right heart catheterization, the reported observation renders the predictive ability of PCWP for LAP assessment, thus its diagnostic use, highly unreliable. Despite the demonstrated lack of concordance between the 2 measures at high pressures, PCWP is extensively used in everyday clinical practice in place of LAP for diagnostics as well as for hemodynamic monitoring.

On the background of the aforementioned, the present prospective study was designed to examine the agreement between PCWP and LAP and to elucidate possible physiological or methodological factors that may influence the concordance between the 2 measures.

Methods

Study population

One hundred seventeen consecutive patients with symptomatic mitral stenosis (MS) in sinus rhythm who underwent percutaneous transvenous mitral commissurotomy (PTMC) in the Sri Sathya Sai Institute between January and June 2012 were enrolled prospectively. Subjects were excluded from the study if they had significant aortic disease, more than mild (grade > 1) mitral regurgitation, associated ischemic heart disease, systemic hypertension, or diabetes mellitus. The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the Sri Sathya Sai Institution's ethics committee. All subjects provided written informed consent. Importantly, all measurements were performed in conscious patients without the use of anesthetics. Patient characteristics are summarized in Table.

Cardiac catheterization

Simultaneous right and left heart catheterization data were obtained during the PTMC procedure, before and after balloon inflation. Right heart catheterization was performed through femoral vein access using a 6F wedge catheter (Arrow Balloon Wedge-Pressure Catheters; Teleflex, Limerick, Ireland) connected to a pressure transducer (Philips 1290 Series, Andover, MA). Right atrial mean pressure, right ventricular systolic pressure (RVSP), pulmonary artery systolic and mean pressure, and PCWP were measured under fluoroscopic guidance. Concurrently, a 6F pigtail catheter was advanced through the aorta into the left ventricle (LV) to measure the LV end-diastolic and end-systolic pressures before and after balloon inflation. Interatrial septal puncture was performed with an 8F Mullins sheath, dilator, and a Brockenbrough needle. The LA pressure was measured directly through the Mullins sheath used during valvuloplasty. Two transducers were used, one as connected to the pigtail that was passed to the LV. The other dome measured the LA pressure. Both the transducers were zeroed before pressure measurements were commenced. In all cases, sequential LAP measurements were taken within 5 minutes after PCWP measurements. In 51 cases, in addition to the sequential pressure measurements, simultaneous, beat-to-beat, LAP and PCWP tracings were also recorded. All the various pressure tracings were recorded after careful calibration, during a period of 10 seconds, and subsequently stored in dedicated software (WITT Series III; Witt Biomedical Corp, Melbourne, FL) for offline analysis. The mean pressure values for all recordings were considered. The zero-pressure level was set at the midthoracic line for both transducers. No manifold was used during the pressure measurements.

Table. Demographic and echocardiographic characteristics of the study population

Parameter	Before PTCM	After PTCM
Age (y)	32 ± 9	
Female	84 (67%)	
BSA (m^2)	1.4 ± 0.2	
HR (beats/min)	75 ± 14	79 ± 15
SBP (mm Hg)	108.5 ± 10.3	
DBP (mm Hg)	70 ± 7.3	
EF (%)	64.3 ± 9.2	63.9 ± 9.3
EF < 55%	9 (7%)	
MVA (cm^2)	0.9 ± 0.2	
LVESP (mm Hg)	134.8 ± 17	131.4 ± 18
LVEDP (mm Hg)	12.6 ± 4	16.1 ± 4.9
RVSP (mm Hg)	62.5 ± 25	50.9 ± 18.6
Mean RAP (mm Hg)	6.1 ± 3.9	6 ± 3.9
Mean PCWP (mm Hg)	25.8 ± 7.3	19.2 ± 7.1
Mean LAP (mm Hg)	26.5 ± 7.1	18.5 ± 6.5
CO (L/min)	3.6 ± 1.1	4.5 ± 1.3
PVR (Wood Units)	4.4 ± 4.7	3.5 ± 3.9
SVR (Wood Units)	27.7 ± 94	22 ± 9.5

Abbreviations: *BSA*, body surface area; *SBP*, systolic blood pressure; *DBP*, diastolic blood pressure; *MVA*, mitral valve area; *LVESP*, left ventricular systolic pressure; *LVEDP*, left ventricular end-diastolic pressure; *RVSP*, right ventricular systolic pressure; *RAP*, right atrial pressure.

Mitral valvuloplasty was performed using a 24- to 28-mm Accura balloon catheter (Vascular Concepts, Essex, UK) using standard technique. After the PTMC, pressure recordings were repeated in all patients. Cardiac output (CO) and vascular resistance were measured before and after PTMC. Cardiac output was calculated using the estimated Fick's method. Systemic vascular resistance (SVR) and pulmonary vascular resistance (PVR) were derived from mean arterial and atrial pressures using standard formulae.

Echocardiographic data

All patients underwent standard transthoracic echocardiogram using a GE Vivid E9 system (GE Ultrasound, Horten, Norway) and a 2.5-MHz matrix array transducer. Recordings were analyzed according to the recommendations of the American Society of Echocardiography.[13] Images were digitally stored and analyzed offline using dedicated software (EchoPac PC; GE Ultrasound, Waukesha, Wisconsin).

Statistical analysis

Statistical analysis was performed using SPSS version 20.0 for Windows (IBM Inc, Chicago, IL). Data are expressed as mean ± SD. Correlations between variables were determined using the Pearson 2-tailed correlation test. Significance of bias was tested by 1-sample t test. Multiple regression analysis was used to