

**PRESSURE-VOLUME MEASUREMENTS BY
CONDUCTANCE CATHETER METHOD IN RIGHT
VENTRICULAR STUDIES**

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RIGHT VENTRICULAR STUDIES

Measurement of right ventricular volume is difficult because of the intricate shape of the chamber, often described as a 3-dimensional crescent, with an outflow tract almost the same length as the distance from tricuspid valve to apex. Heavy trabeculation of the endocardial wall further complicates description of the RV shape in terms of a model. The conductance catheter partially overcomes these difficulties in that it does not require assumptions about the cross section of the chamber. In practice, however, it is all but impossible to apply the electric field along the entire length of the RV: especially the outflow tract is hardly accessible unless the catheter is applied retrogradely through the pulmonary valve.

Method studies.

Over the past 5 years, attempts have been made to investigate the reliability of the conductance catheter in assessing (changes in) relative and/or absolute RV volume (1, 2, 3, 4, 5, 6, 7). Woodard's group found that actual volume may be measured correctly by conductance catheter in post-mortem RV's of dogs, and good correlation between CC-obtained and EM-flowprobe-obtained stroke volume in vivo (1). In a later study these investigators advocated the access route via a femoral vein as optimal, using a catheter without pigtail (2). Solda et al used the same methods for checking accuracy in vitro and in vivo as Woodard, but using rabbits and found comparable good correlations (3). Dean et al investigated a mock-up model of the RV and found excellent correlations between actual and measured volumes, and reported on specific effects of temperature and geometry (4). Stamato et al investigated the method in pigs in vivo, employing thermodilution and EM flowmetry on the pulmonary artery to check accuracy of stroke volume (changes) and found very good agreement. They also obtained P-V loops of the RV. White et al were the first to check the methodology in human hearts, using post-mortem casts and, again, reported excellent agreement (6). Finally, Nicolosi et al studied the CC method as well as two RV dimensions obtained by ultrasonic crystals and compared both methods against SV obtained by EM-flowprobe as gold standard. He also found good correlations for the CC method, both during control and altered inotropism (7). A common finding of most of the above studies was that the slope of the relation between the CC-obtained (stroke) volume and the independent method was often much less than one and tended to differ substantially between individual animals. This necessitates the use of an independent, accurate method to obtain the proper calibration if so required, e.g. a carefully performed thermodilution measurement.

Basic studies

All of which show RV pressure-volume loops including the end-systolic P-V relationship (ESPVR), were performed by several groups recently (7, 8, 9, 10, 11, 12). Park et al studied ESPVR's and 'force-velocity relationships' of the RV in response to the ischemia caused by left heart bypass (LHB) in dogs, both with normal hearts (8) and failing hearts (11). They found that the resulting decrease in RV performance was related to the assist ratio of LHB, depending upon the RV afterload. Somewhat at variance with these findings, Kitano et al found that LHB did not change the slope of the RV ESPVR and that LHB improved the compliance of the RV (also obtained from the P-V loops) because of afterload unloading

(10). Dickstein et al studied ESPVR of the RV in pigs, during control and inotropic

interventions, brought about by dobutamine and esmolol and found that the changes in the relation were qualitatively similar to those observed in the left ventricle (9). Similar findings were reported by Nicolosi et al who changed RV performance by administration of calcium and pentobarbital (7). Finally, Pinsky et al were the first to publish left and right ventricular P-V loops simultaneously obtained using two conductance catheters and two Sigma-5 instruments (tuned at different frequencies to prevent cross-talk), in rabbits. They measured ESPVR's and end-diastolic P-V relationships (EDPVR) in both ventricles, enabling them to assess LV-RV interaction in response to partial aortic and pulmonary artery occlusions and inferior vena caval occlusion. Their findings should be of great value in the understanding of ventricular interdependence.

A few studies were published regarding the influence of changes in RV characteristics (hypertrophy, pulmonary valve stenosis etcetera) on changes in left ventricular performance, measured with P-V loops using conductance volumetry (13, 14, 15). However, in these studies RV performance per se was not measured, although all of them discussed the intriguing question of LV-RV interaction.

Studies in patients

Studies in patients have been concerned mostly with the problem of detecting changes in RV volume in order to obtain optimal pacing settings (16, 17, 18, 19, 20, 21). With the exception of Maloney et al, who used 8 electrodes (21) all studies were performed with just 4 electrodes, an approach which only enables to measure relative changes in one RV cross-sectional area. Boheim et al were the first to employ this concept for RV volume assessment to adjust pacemaker frequency (16). The publications from the same group by Schaldach et al saved the same purpose, with the aim to establish closed loop pacing (19, 20). Measuring RV conductance was used by the group of Khoury and Maloney for antitachycardia system control (17, 21). Snoeck et al employed RV conductance to record atrial flutter waves (18). An exception to the pacing studies is the publication by McKay et al who were the first to apply the conductance catheter in the RV of patients, showing relative stroke volumes and changes in it by the Valsalva maneuver (22). Like Maloney et al, these investigators employed 8 electrodes on the conductance catheter, i.e. the same configuration as originally employed for LV measurements by Baan's group in 1981.

The continuous recording of RV performance immediately following cardiac surgery, especially in infants operated for congenital heart disease, seems to be of great importance. Based on the majority of the above studies, the conductance catheter appears to be an ideal method to acquire these data postoperatively in the OR or intensive surgical care unit.

References.

- [1] Woodard JC, Bertram CD, Gow BS. Right ventricular volumetry by catheter measurement of conductance. *PACE*. 1987; 10: 862-870.
- [2] Woodard JC, Bertram CD, Gow BS. Detecting right ventricular volume changes using the conductance catheter. *PACE*. 1992; 15: 2283-2294.
- [3] Solda PL, Pantaleo P, Perlini S, Calciati A, Finardi G, Pinsky MR, Bernardi L. Continuous monitoring of right ventricular volume changes using a conductance catheter in the rabbit. *J Appl Physiol*. 1992; 73: 1770-1775.

- [4] Dean DD, Cabreriza SE, Spotnitz HM. Geometry and temperature dependence of conductance ventriculography. *ASAIO J.* 1995; 41: M673-M677.
- [5] Stamato TM, Szwarc RS, Benson LN. Measurement of right ventricular volume by conductance catheter in closed-chest pigs. *Am J Physiol (Heart Circ Physiol 38).* 1995; 269: H869-H876.
- [6] White PA, Bishop AJ, Conroy B, Oldershaw PJ, Redington AN. The determination of volume of right ventricular casts using a conductance catheter. *Eur Heart J.* 1995; 16: 1425-1429.
- [7] Nicolosi AC, Hettrick DA, Warltier DC. Assessment of right ventricular function in swine using sonomicrometry and conductance. *Ann Thorac Surg.* 1996; 61: 1381-1387.
- [8] Park CH, Nishimura K, Kitano M, Okamoto Y, Ban T. Right ventricular performance is impaired by full assist of left heart bypass: Analysis of right ventricular performance against change in afterload in heart failure models. *ASAIO J.* 1994; 40: M303-M308.
- [9] Dickstein ML, Yano O, Spotnitz HM, Burkhoff D. Assessment of right ventricular contractile state with the conductance catheter technique in the pig. *Cardiovasc Res.* 1995; 29: 820-826.
- [10] Kitano M, Nishimura K, Hee PC, Okamoto Y, Ban T. Right ventricular function evaluated by volumetric analysis during left heart bypass in a canine model of postischemic cardiac dysfunction. *J Thorac Cardiovasc Surg.* 1995; 109: 796-803.
- [11] Park CH, Nishimura K, Kitano M, Matsuda K, Okamoto Y, Ban T. Analysis of right ventricular function during bypass of the left side of the heart by afterload alterations in both normal and failing hearts. *J Thorac Cardiovasc Surg.* 1996; 111: 1092-1102.
- [12] Pinsky MR, Perlini S, Solda PL, Pantaleo P, Calciati A, Bernardi L. Dynamic right and left ventricular interactions in the rabbit: Simultaneous measurement of ventricular pressure volume loops. *J Crit Care.* 1996; 11: 65-76.
- [13] Del Nido P, Benson LN, Mickle DAG, Kielmanowicz S, Coles JG, Wilson GJ. Impaired left ventricular postischemic function and metabolism in chronic right ventricular hypertrophy-. *Circulation.* 1987; 76: V168-V173.
- [14] Appleyard RF, Glantz SA. Pulmonary model to predict the effects of series ventricular interaction. *Circ Res.* 1990; 67: 1225-1237.
- [15] Witsenburg M, Van der Velde ET, Klautz RJM, Hess J, Baan J. Acute effects of pulmonary balloon valvuloplasty and pacing on left ventricular performance in children with moderate pulmonary valve stenosis, analysed by systolic and diastolic pressure-volume relationships. *Eur Heart J.* 1994; 15: 83-88.
- [16] Boheim G, Schaldach M. [Frequenzadaptation eines kunstlichen Herzschrittmachers uber einen Volumenregelkreis] I(in German). *Biomed Technik.* 1988; 33: 100-105.
- [17] Khoury D, McAlister H, Wilkoff B, Simmons T, Rudy Y, McCowan R, Morant V, Castle L, Maloney J. Continuous right ventricular volume assessment by catheter measurement of impedance for antitachycardia system control. *PACE.* 1989; 12: 1918-1926.
- [18] Snoeck J, Berkhof M, Vrints C, Hitter E, Decoster H, Cools F. Recording of atrial flutter waves by intraventricular impedance. *Proc North Sea Conf Biomed Eng.* 1990; ?
- [19] Schaldach M. Automatic adjustment of pacing parameters based on intracardiac impedance measurements. *PACE.* 1990; 13: 1702-1710.
- [20] Schaldach M, Ebner E, Hutten H, Von Knorre GH, Niederlag W, Rentsch W, Volkmann H, Weber D, Wunderlich E. Right ventricular conductance to establish closed-loop pacing. *Eur Heart J.* 1992; 13: 104-112.
- [21] Maloney J, Khoury D, Simmons T, Wilkoff B, Morant V, Trohman R, Castle L. Effect of atrioventricular synchrony on stroke volume during ventricular tachycardia in man. *Am Heart J.* 1992; 123: 1561-1568.
- [22] McKay RG, Spears JR, Aroesty JM, Baim DS, Royal HD, Heller GV *et al.* Instantaneous measurement of left and right ventricular stroke volume and pressure-volume relationships with an impedance catheter. *Circulation.* 1984; 69:

703-710.