Title: COMPARISON OF DIRECT AND INDIRECT ARTERIAL PRESSURE MEASUREMENTS DURING CARDIAC SURGERY

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Introduction: The relationship between direct and indirect measurements of blood pressure (BP) is controversial.[1,2] This study compares simultaneous measurements of four indirect BP methods with direct brachial arterial pressure and includes the full range of hemodynamic measurements provided by a Swan-Ganz catheter.

Methods. After obtaining informed consent we studied 40 adult patients undergoing cardiac surgery (34 CABG, 6 valve replacements). Measurements included brachial (B) direct arterial pressure, Riva-Rocci auscultatory (A) (Mean = diastolic + (systolic-diastolic/3), diastolic = higher of Korotkoff sound disappearance or muffling) automated oscillometric (D) (Dinamapp™) "return-to-flow" occlusion (O), and systolic flicker (F) indirect arterial pressures; pulmonary artery (PA) pulmonary artery occluded (PAO), right atrial (RA) pressures, duplicate thermodilution cardiac outputs (C.O.), and heart rate (HR). Derived measurements included systemic vascular resistance (SVR), stroke volume, and cardiac index. All pressure measurement techniques were calibrated to a mercury standard. Cuffs and cuff bladder sizes were selected according to American Heart Association guidelines. We measured direct arterial pressure using a 2 inch teflon 20 gauge catheter attached to a Gould P50 transducer via 2 stopcocks and 30 inches of high-pressure tubing recorded on a Hewlett Packard (HP) thermal recorder. HP8805C amplifiers derived mean arterial pressure from the area under the arterial wave form. Dynamic response was determined before and during surgery by the fast flush technique at a recorder speed of 100 mm/sec (mean resonant frequency 20 Hz, mean damping coefficient 0.27).[3] All measurements were made by the same individual at eight intervals: pre-induction, post-induction, chest open; and 5, 10, 20, 30, and 60 minutes after cardiopulmonary bypass (CPB); all BP measurements were completed within 60 seconds. Statistical analysis was by simple linear regression, 2-tailed T-test, and by multivariate analysis of covariance where appropriate. This study was evaluated and approved in advance by our Committee for Human Research.

Results. Because analysis of covariance showed that time did not significantly influence the relationship between indirect and direct measurement techniques, the data for all time periods was pooled (Table 1). Mean difference represents the average difference (e.g., B-A) between techniques. The range represents the extremes of differences observed. Among systolic pressures SF was highest and SA was lowest. SD was closest to direct brachial arterial (SB). Indirect diastolic (DD, DA) and mean (MD, MA) pressures were higher than analogous direct arterial pressures (DB, MB). Techniques significantly different ($p<.05$) from brachial arterial included SA, SO, DD, and DA. Statistical analysis indicates that neither SVR nor HR accounts for the difference between direct arterial pressure and SA, DD, and DA.

Discussion. Indirect and direct techniques for measuring blood pressure often differ widely, as demonstrated by the ranges reported in Table 1. The mean differences show the average relationship between measurement techniques to be: (1) SF>SD = SB>SO>SA, (2) DB<DA = DO, (3) MB<MA<MD), but these reflect a large series of measurements. The clinician should be interested in the wide scatter between direct and indirect BP measurements, which was observed despite consistent single-observer technique using scrupulously calibrated instruments. This resembles Bruner's experience, although he used different instrumentation for oscillometric measurements.[1] Indirectly measured mean and diastolic pressures usually exceed directly measured ones. Automated oscillometric systolic BP most closely approximated direct arterial systolic pressure. In this study, systemic vascular resistance did not account for the differences in techniques.

Table 1
Comparison with brachial arterial pressure

Technique	Mean diff. (mmHg)	S.D. (mmHg)	Range low	Range high	R	P
SD	0	13	-45	+59	.74	>.05
SA	9	13	-23	+65	.74	<.001
SO	7	13	-35	+55	.72	<.05
SF	-5	15	-43	+55	.68	>.05
DD	-9	9	-39	+30	.65	<.001
DA	-8	9	-49	+36	.64	<.001
MD	-5	10	-36	+32	.70	>.05
MA	-3	10	-30	+48	.72	>.05

Abbreviations: SD - systolic Dinamapp™ oscillometric, SA - systolic auscultatory (Riva-Rocci), SO - systolic occlusion, SF - systolic flicker, DD - diastolic Dinamapp oscillometric, DA - diastolic ausculatory, MD - mean oscillometric, MA - mean auscultatory, S.D. - standard deviation, R - correlation coefficient with simple linear regression, P - significance of difference compared to brachial using two-tailed T-test.

References

1. Bruner JMR, Krenis LJ, Kunsman JM, et al.: Comparison of direct and indirect methods of measuring arterial blood pressure, Medical Instrumentation 15: 11-21, 97-101, and 182-189, 1981.
2. Van Bergen FH, Weatherhead S, Treloar AE, et al.: Comparison of indirect and direct methods of measuring arterial blood pressure, Circulation 10: 481-490, 1954.
3. Gardner RM: Direct blood pressure measurement dynamic response requirements, Anesthesiology 54: 227-236, 1981.