Title : OPTIMAL FILLING PRESSURES FOLLOWING CARDIOPULMONARY BYPASS

Authors : D.T. Mangano, Ph.D., M.D., D.C. Van Dyke, M.D., R.J. Ellis, M.D.

Affiliation: Departments of Anesthesia, Nuclear Medicine and Surgery
University of California, San Francisco, CA 94143

Introduction: Previous studies have demonstrated that in patients with acute myocardial infarction, maximum ventricular output (stroke work, stroke volume) is achieved at abnormally elevated filling pressures. The relationship between ventricular output and filling pressures has not been studied in detail following cardiopulmonary bypass. Nevertheless, it is often recommended that patients be maintained at elevated filling pressures after bypass in an attempt to maximize cardiac output. Furthermore, the price of maximizing cardiac output, in terms of myocardial efficiency and oxygen demand, has not been well documented. We have studied these relationships in the following investigation.

Methods: Fifteen men admitted for coronary artery surgery were studied (with informed consent and approval by the Human Research Committee, UCSF). Preoperative ejection fractions ranged from .39 to .82 (normal being .66±.06). Anesthesia consisted of morphine sulfate (1.5 to 3 mg/kg I.V.) and diazepam (0.25 to 0.50 mg/kg I.V.). Ventilation (with 100 percent oxygen) was controlled. Intraoperative ejection fraction was determined with a co-axial cardiac scintillation probe. Following cardiopulmonary bypass, the aortic and vena cava cannulae were removed, and the sternum was temporarily re-approximated. Surgery was stopped, and a five minute period of hemodynamic stability was established. After control measurements were made, 1500 ml of whole blood was transfused into a peripheral vein over thirty minutes. Hemodynamic measurements were repeated after 500 ml, 1000 ml, 1250 ml, and 1500 ml were transfused.

Results: Transfusion of 1500 ml of blood (Table) increased end-diastolic volume index (EDVI) and pulmonary wedge pressure (PCW) with associated increases in cardiac, stroke volume, and stroke work indices (CI, SVI, SWI). However, ejection fraction (EF) decreased, end-systolic volume index (ESVI) increased, and estimated left ventricular wall tension (T) increased. The relationships between EF, CI, EDVI and PCW at the five transfusion levels are shown in the Figure. Left ventricular function curves (such as SVI versus EDVI), constructed for each patient, began to flatten when PCW increased above 7 mmHg (corresponding to EDVI above 70 ml/M^2).

Discussion: Following cardiopulmonary bypass, volume loading increases ventricular output with the maximum increases occurring over 'normal' rather than abnormally elevated values of PCW (EDVI). The decreases in EF and increases in ESVI are suggestive of worsening myocardial function, and the increase in wall tension is indicative of increasing myocardial oxygen consumption. Thus, in these patients, volume loading above a PCW of 7 mm Hg not only becomes progressively less effective in increasing cardiac output, but also causes detrimental effects on the heart. This study suggests that the "optimum" filling pressure following cardiopulmonary bypass is the lowest filling pressure commensurate with adequate tissue perfusion.

HEMODYNAMIC CHANGES FOLLOWING VOLUME TRANSFUSION

	CONTROL	AFTER 1500 ml TRANSFUSION
END-DIASTOLIC VOLUME INDEX (ml/M^2)	41 (±3)	88 (±6)
PULMONARY WEDGE PRESSURE (mmHg)	2.3 (±.6)	7.6 (±.9)
ARTERIAL PRESSURE (mmHg)	88 (±4) 52 (±2)	113 (±7) 60 (±4)
HEART RATE (bpm)	88 (±5)	83 (±4)**
SYSTEMIC VASCULAR RESISTANCE (dyne sec/cm^5)	1258 (±11)	1024 (±8)
CARDIAC INDEX (liter/min/M^2)	2.1 (±.1)	3.6 (±.1)
STROKE VOLUME INDEX (ml/M^2)	28 (±2)	42 (±2)
STROKE WORK INDEX (gm sec/M^2)	20 (±1)	38 (±4)
EJECTION FRACTION	.70 (±.04)	.49 (±.04)
END-SYSTOLIC VOLUME INDEX (ml/M^2)	13 (±2)	47 (±5)
ESTIMATED WALL TENSION (dynes/cm)*	227 (±11)	371 (±25)

*TENSION = (MEAN SYSTOLIC BLOOD PRESSURE) X $(3EDV/4\pi)^{1/3}$
VALUES ARE MEAN ± STANDARD ERROR
**ALL CHANGES WERE SIGNIFICANT (P<.05) WITH EXCEPTION OF HEART RATE.