TITLE: MYOCARDIAL ADAPTATION DURING EXTREME HEMODILUTION IN HUMANS

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Normovolemic hemodilution is commonly employed during cardiac surgery to conserve blood and reduce risks associated with blood transfusions. Tissue oxygen demands during hemodilution are usually met by physiologic compensatory responses. These responses include increases in cardiac output (CI), stroke volume, organ blood flow, and tissue oxygen extraction. The coronary vascular bed unlike other organ beds can increase O_2 extraction minimally since basal VO_2 is maximal even at rest. In addition, cardiovascular adjustments occurring during hemodilution further increase oxygen demands of the heart. This study was designed to evaluate cardiovascular compensation, myocardial metabolism, and safe limits of extreme hemodilution in anesthetized patients during cardiac surgery.

Seven patients undergoing coronary artery bypass surgery (CABG) with ejection fraction > 50% were studied. Autologous blood was withdrawn through the aortic cannula to hemodilute the patient to a Hct of 15%. CABG was conducted in a standard fashion and the patient weaned from CPB and warmed to 37°C. Hemodynamic data, coronary blood flow, and myocardial metabolic data were collected at Hct of 15%. Patients were then transfused to Hct 20% and 25% and data collection repeated. No inotropes were employed during data collection.

VARIABLES	BASELINE BEFORE CPB	DIL #1	DIL #2	DIL #3
Hgb	12.4±.3	5.8±.4*	7.5±.4*†	9.6±.4*†‡
MAP	94±.1	43± 3*	73± 1	66±5
CI	2.3± 1	4.0±0.3*	4.2±.1*	3.6±.2*
PVO	43.6±.7	44.7±2.3	49 ±2.5†	41.7±2.9†
CSF(ml/min)		168±10	191±8†	182±12
LACT EXT(%)		19.6±1.2	23.8±1.8	21.8±2.2
MVO		6.9±1.3	11.2±1.7†	12.3±1.4†
LVO D			13.5±.9	20.9±1.2

23.7±1.4

Mean ± SE

p<.05 compared to Baseline *, DIL #1 †, DIL #2 ‡

In our patients, as left ventricular oxygen delivery (LVO_2D) increased, coronary sinus flow (CSF) and myocardial oxygen consumption (MVO_2) increased. However, despite reduction in MVO_2 and CSF at greatest dilution (DIL #1) there was no evidence of anaerobic metabolism as indicted by lactate extraction at all degrees of dilution. The PVO_2 at the most dilute situation in our patients was 45 torr. This is similar to the anemic hypoxia model of Cain et al.[1] We have demonstrated that after coronary bypass the human heart tolerates hemodilution well. There is no evidence of myocardial ischemia even during hemodilution to Hct of 15%. The model used in this study may not be appropriate to conditions of hemodilution in other settings.

1. J Appl Physiol 1977; 42:225

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TITLE: GAS EXCHANGE DURING EXTREME HEMODILUTION IN HUMANS

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Compensatory cardiovascular adjustments i.e. increases in cardiac index (CI), stroke volume and reduction in SVR occur during hemodilution to meet tissue oxygen demands. Previous studies have shown directionally similar changes in QS/QT when cardiac output is manipulated. Thus, cardiovascular adjustments occurring during hemodilution have the potential to worsen gas exchange function of the lung. This study was designed to examine cardiovascular compensation and gas exchange during extreme hemodilution.

Seven patients undergoing coronary artery bypass surgery (CABG) with ejection fraction > 50% were studied. Autologous blood was withdrawn through the aortic cannula in sufficient amounts to hemodilute the patient to a Hct of 15%. CABG was conducted in a standard fashion and each patient was weaned from CPB and warmed to 37°C. Hemodynamic and gas exchange data were collected at a Hct of 15%. Patients were then transfused to Hct 20% and 25% and data collection repeated. No inotropes were employed during data collection.

VARIABLES	BASELINE BEFORE BYPASS	DIL #1	DIL #2	DIL #3
Hgb	12.4 ± .3	5.8 ± .3*	7.5 ± .4*†	9.6 ± .4*†‡
CI	2.3 ± .1	4.0 ± .3*	4.2 ± .4*	3.6 ± .2*
PvO_2	43 ±·2	45 ± 2	49 ± 3†	52 ± 3†
PaO_2	416 ± 13	306 ± 35*	338 ± 36	349 ± 36
DO_2I	391 ± 1	351 ± 37	465 ± 55†	498 ± 40*†
VO_2I	99 ± 3	101 ± 10	104 ± 12	100 ± 14
ER (%)	26 ± 2	29 ± 1	22 ± 1†	20 ± 2*†‡
QS/QT	8 ± 1	26 ± 4*	22 ± 4*†	23 ± 3*†

Mean ± SE

p<.05 compared to Baseline *, DIL #1 †, DIL #2‡

Hemodilution increased CI and QS/QT compared to baseline. However, changes in CI among dilution groups were not significant. VO_2I remained constant while ER increased with greatest dilution (DIL #1). PaO_2 decreased with hemodilution (DIL #1) and then increased with transfusion (DIL #2 and #3). Our data are contrary to previous experimental studies where PaO_2 increased progressively during hemodilution in the presence of fixed anatomic shunt or injured lungs. Our data suggest that during hemodilution tissue autoregulation of VO_2I and utilization is not impaired. However, gas exchange function as measured by QS/QT is impaired. What component of gas exchange impairment is due to lung injury caused by CPB or hemodilution per se cannot be discerned from this data.