Oxygen Extraction Rate As A Tool To Control The Effect Of Hemodilution During Cardiopulmonary Bypass

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Citation

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Abstract

INTRODUCTION

Despite recent advances in blood conservation techniques, up to 30% to 80% of patients undergoing open heart operations require allogeneic blood transfusions [1]. The following methods of reducing allogeneic blood transfusions are well known: autologous blood donation, isovolemic hemodilution, hemodilution at the beginning and during extracorporeal circulation (ECC), hemofiltration and ultrafiltration to increase hemoconcentration, cell saver autotransfusion, reinfusion of blood from drainages, pharmacological influence on hemostasis, use of coated perfusion systems in extracorporeal perfusion, use of centrifugal pumps in extracorporeal perfusion, etc.

A prospective, randomized study was performed to test the effect of withdrawing blood during ECC by the perfusionist while controlling the oxygen extraction rate. The aim was to evaluate if a withdrawal of blood (400 ml) is tolerable concerning the O2-extraction rate since a crucial upper limit of 22% - 30% during ECC has been postulated [2].

METHODS

40 male patients (62–78 years, mean age 69 years) undergoing CABG-procedures were randomized to either withdrawal of 400 ml blood from the cardiotomy reservoir with simultaneous substitution of cristalloid solutions 10 minutes after cross-clamping of the aorta (group I, n= 20) or performance of coronary artery bypass with standard ECC technique (group II, control group, n = 20). In both groups the oxygen extraction rate was measured.

In group I 400 ml of blood were temporarely stored in biopack-bags (Biotrans(r), Holland) during the ECC – with simultaneous substitution of cristalloid solutions – and controlled retransfusion during the rewarming or the post-bypass period was performed if the extraction rate increased up to more than 25%.

In the control group (group II) CABG surgery was performed without hemodilution using standard ECC technique.

The oxygen extraction rate was calculated with the following formula [3] using a conventional software program (Excel(r), Microsoft(r), USA):

- (1,39 x Hb) x art. saturation + (PaO2 x 0,003) = ml O2 / 100 ml blood = CaO2
- (1,39 x Hb) x ven. saturation + (PvO2 x 0,003) = ml O2 / 100 ml blood = CvO2
- CaO2 x CO x 10 = DO2
- CaO2 - CvO2 = avDO2 (O2 / 100ml blood)
- avDO2 x CO x 10 = VO2
- VO2 / DO2 = oxygen extraction rate in %

Abbreviations:

- PaO2 = arterial O2 pressure (mm Hg) CaO2 = arterial oxygen concentration
- PvO2 = venous O2 pressure (mm Hg) CvO2 = venous oxygen concentration
- DO2 = capacity of oxygen transport CO = cardiac output
- avDO2 = arterio-venous difference in oxygen concentration
- VO2 = oxygen consumption / min

Points of measurement in both groups:

- Point I: at 30°C blood temperature (at cross-clamping of the aorta)
- Point II: at 30°C blood temperature (10 min after withdrawal of 400 ml blood from the cardiotomy reservoir
- Point III: regaining 37°C blood temperature and after the end of the cross clamping period

STATISTICS

The hematocrit and the oxygen extraction rate were calculated by analysis of variance (ANOVA) with repeated measurements. In each group the oxygen extraction at different points of measurement was calculated with the student T-test.

RESULTS

A significant difference (p<0,05) was seen regarding the oxygen extraction rate at point II between both groups. (Fig. 1, 2). In group I a significant difference (p: 0,02) was evident between points I and II (Fig. 1). No significant difference was seen regarding the hematocrit between any points in any of the two groups (Fig. 1, 2).

In 15% of the patients (n = 3) the withdrawn blood had to be retransfused to the cardiotomy reservoir due to extraction rate values more than 25%. In 85% the stored biopack bags could be handed over for further use.

Figure 1

Figure 1

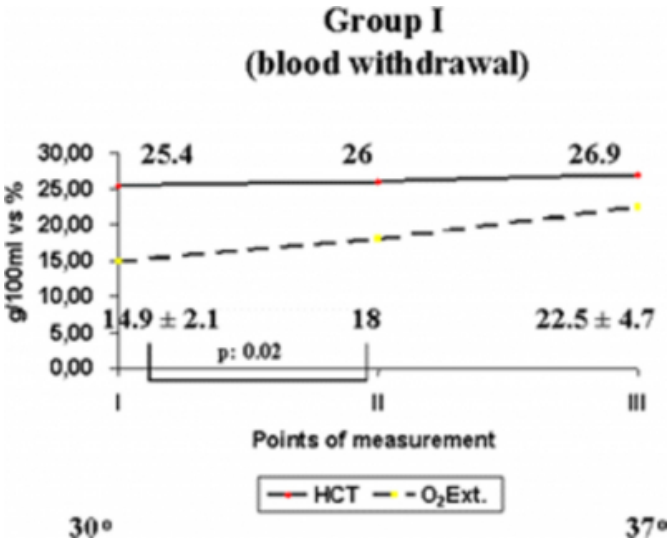

Figure 2

Figure 2

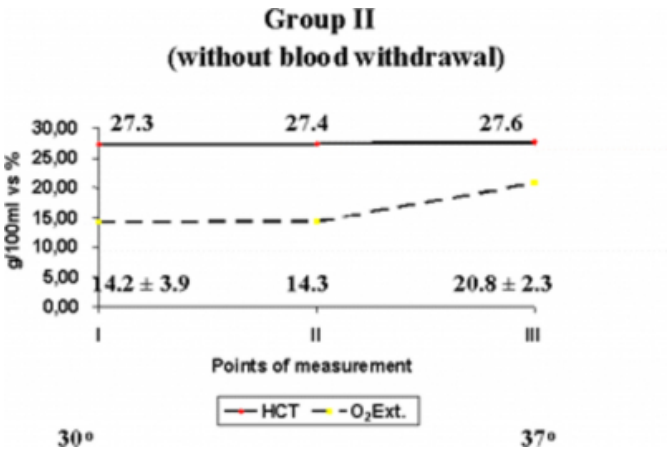

Fig. 1 and 2: all the values at points I, II and III are mean values ± standard deviation. Abbreviations: HCT = hematocrit in g/100 ml, O2Ext = O2-extraction in %

DISCUSSION

The preoperative autologous blood donation [4] is considered to be the safest and best method and should be applied in elective cardiac surgery. However, there are several contraindications as in patients with unstable angina, left main stenosis, heart failure in stage of decompensation, in aortic and mitral valve stenosis of higher degree (III – IV), in the case of a hemoglobin concentration less than 11 g/dl, in defects in hemostasis and in hemophilia or in congenital and aquired erythrocytal defects. Additionally, the costs for storage must not be left out of consideration.

Isovolemic hemodilution reflects one of the major methods in reducing blood transfusions 4. However, the simultaneous volume exchange with high-molecular or cristalloid solutions decreases the hematocrit and has several wellknown disadvantages like reduction of vital substances in the plasma, promotion of defects of hemostasis, increasing the perioperative risk of infection (immunosuppressive effect) or increasing the accumulation of extracellular/interstitial fluid (capillary leak syndrome).

Additionally, the equation of Fox [5] should be kept in mind that in case of low hematocrit levels a further increase of an already high blood flow will only lead to minimal changes in systemic oxygen consumption. Experimentally, at hematocrit values less than 17% - 20% an increase of cardiac output cannot maintain adequate oxygen distribution, as shown in healthy canine hearts [6]. The fact that a crucial lower limit of the hematocrit level exists is wellknown,

however, the O2-extraction rate is the limiting factor to control hemodilution.

Our method of measuring the oxygen extraction rate after withdrawing blood from the cardiotomy reservoir after initiation of ECC seems to be a good tool to provide information concerning the current O2–consumption during ECC. The disadvantage is that the method can only be applied in about 85% of the patients.

Limitations of the study are that there was no long term evaluation of the morbidity at the intensive care unit (ICU) and that we cannot present results with isovolemic hemodilution. Additionally, measurements of lactate parameters after arrival at the ICU were not considered.

In conclusion, a priming free of allogeneic blood, a low volume in priming and an additional blood withdrawal during ECC with hemodilution while controlling the oxygen extraction rate might reduce the need for allogeneic blood transfusions during open heart operations.

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