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Original Article

Impact of Peripherally Established Cardiopulmonary Bypass on Regional and Systemic Blood Lactate Levels

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Background: **To investigate blood lactate levels during and after peripherally established cardiopulmonary bypass (CPB).**

Methods: **In 86 patients (41 males, mean age 13.8 ± 7.2), CPB was established via femoral vein and artery cannulation for thoracoscopic closure of atrial ($n = 54$) or ventricular septal defect ($n = 32$). Arterial and venous blood lactate levels were measured from the cannulated limb during CPB, and from systemic circulation after CPB.**

Results: **The mean duration of CPB and cannulation of a lower extremity were 50.0 ± 10.5 min and 76.0 ± 18.5 min, respectively. The mean arterial lactate level measured from the systemic circulation remained unchanged during CPB ($P > 0.05$). In patients with CPB for 3 h or more, mean arterial lactate in the cannulated limb were higher than the baseline values (3.3 ± 0.5 vs 0.8 ± 0.2 mmol/L, $P < 0.05$). In patients with more than 2 h of CPB, mean venous lactate levels in the cannulated limb were also higher than the baseline values (3.4 ± 0.2 vs 1.1 ± 0.3 mmol/L, $P < 0.05$). Within 6 h after CPB, systemic arterial (3.0 ± 0.2 vs 0.8 ± 0.1 mmol/L, $P < 0.01$) and venous lactate levels (6.5 ± 0.2 vs 1.0 ± 0.1 mmol/L, $P < 0.01$) were higher than the pre-CPB values.**

Conclusions: **Peripherally established CPB was associated with an arterial and venous lactate elevation in local and systemic circulation. The duration of CPB and lower limb cannulation appears to be related to the lactate elevation.**

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Keywords. Congenital cardiac defect; Lactate; Cannulation; Cardiopulmonary bypass

Introduction

During cardiac surgery with cardiopulmonary bypass (CPB) in adult patients, an increase in blood lactate or hyperlactataemia can be detected in 10–20% of the patients [1–3]. Elevation of serum lactate (>3 mmol/L), or hyperlactataemia found during CPB is associated with postoperative morbidity and mortality [1,2]. The metabolic mechanisms of hyperlactataemia during and after cardiac operations are not totally clear, but systemic tissue hypoxia has been postulated as the main contributing factor [4–7]. The majority of the previous studies about the impact of CPB on hyperlactataemia were based on CPB that was established via a standard median sternotomy, aortic root cannulation, and single or double atrial cannulation for venous return [2,3,6,7]. In recent years, as the applications of totally thoracoscopic cardiac surgeries are gathering pace, more CPBs are established peripherally via cannulations through femoral vein and femoral artery [8–12]. Femoral artery cannulations involve temporary obstruction of arterial blood supply to the cannulated limb which may cause ischaemia and metabolic disturbances contributing to hyperlactataemia during CPB. However, there has been limited information about the blood lactate levels in patients undergoing peripherally established CPB. The purpose of the present study was to investigate the venous and arterial lactate levels during and after CPB in a group of patients who received totally thoracoscopic closure of atrial or ventricular septal defect using femoral vein and artery cannulations for CPB.

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Table 1. *Baseline Characteristics of the Patients.*

Variables	Adults Group ($n=41$)	Paediatrics Group ($n=45$)	P Value
Age	25.6 ± 6.3	12.7 ± 4.3	NS
Female n (%)	29 (71)	31 (69)	NS
Cardiac defects n (%)			
VSD	19 (46.3)	19 (42.2)	NS
ASD	21 (51.2)	25 (55.6)	NS
VSD + ASD	1 (2.4)	1 (2.2)	NS
NYHA classes n (%)			
I	31 (75.6)	44 (97.8)	0.002
II	10 (24.4)	1 (2.4)	0.002
III or IV	0	0	NS
Liver function			
AST (0–40 IU/L)	28.1 ± 3.6	28.3 ± 3.6	NS
ALT (0–40 IU/L)	27.9 ± 4.1	28.0 ± 3.7	NS
Renal function			
BUN (2.9–8.2 mmol/L)	4.5 ± 0.8	4.4 ± 0.7	NS
Cr (62–115 mmol/L)	82.5 ± 3.5	79.6 ± 5.6	NS
Lactate (0.5–2.2 mmol/L)	0.9 ± 0.3	0.8 ± 0.1	NS
CI (2.5–4.0 L/min/m^2)	3.2 ± 0.8	3.1 ± 0.7	NS
CPB pressure (mmHg)	60.8 ± 5.6	51.3 ± 3.5	NS

NYHA, New York Heart Association; ASD and VSD, atrial and ventricular septal defect; BUN, blood urea; Cr, creatinine; CI, cardiac index; CPB, cardiopulmonary bypass; NS, no statistically significant difference.

Patients and Methods

Patient Selection

This study was approved by our institutional review board. Written informed consent was obtained from all participants or their parents before the study. Between June 2009 and April 2011, 86 patients undergoing thoracoscopic closure of atrial ($n=54$) or ventricular septal defects ($n=32$) in our department were selected for this study. There were 41 males and 45 females with a mean age of 13.8 ± 7.2 years (range 3–47). There were 41 adults and 45 children (Table 1). None of the patients were given cardiovascular medications, such as diuretics, digoxin, vasodilators, aspirin, warfarin, beta-blockers or amiodarone, before the operation. None of the patients had diabetes or hypertension before the surgery.

Surgical Techniques for CPB

CPB was established peripherally using previously reported open methods in patients undergoing totally thoracoscopic closure of congenital heart defects [11,12]. In brief, under general anaesthesia, a single or double-lumen endotracheal tube was placed to allow for single-lung or double lung ventilation. Patients were positioned in supine position with right side of the body elevated to 15–20°. After systemic heparinisation, a Carpentier double-lumen catheter (16F/20F, 20F/24F, 24F/29F, or 30F/33F, Medtronic, MN, USA, or Kangxin, MU, China) was inserted through the right femoral vein into the inferior and superior vena cava. The size of the catheter was determined by patient's age, body weight and estimated blood vessel sizes. Bypass circuit was completed by positioning a catheter (7F, 12F, 14F, or 21F, Medtronic, MN, USA, or Kangxin, MU, China) in the abdominal aorta through right femoral artery. The site of femoral artery cannulation was at the proximal side of the deep and superficial femoral artery bifurcation. Cannulation at this site often leads to complete obstruction of the femoral flow to the distal part of the limb. A "Cooley" clamp was applied to the cannulated femoral artery to completely stop the arterial blood flow to the right lower limb. Core body temperature, which was constantly measured from patient's nose, was reduced to 32 °C and an aortic crossclamp was positioned on the ascending aorta under the direct view of thoracoscopy. Cardiac arrest was achieved by injecting cold cardioplegic solution to the aortic root before closure of atrial or ventricular septal defect. Once the surgical repair of defects was complete, patients were re-warmed and CPB stopped, and cannulations in the right femoral vein and artery were withdrawn to resume blood supply to the right lower limb.

Measurements of Lactate, Oxygen and Carbon Dioxide

Blood lactate, oxygen and carbon dioxide were measured in two different settings. During CPB, they were measured from the blood in the cannulated right lower limb to assess the impact of blood flow obstruction on the metabolism of the lower limb. After CPB, lactate, oxygen and carbon dioxide were measured in the systemic circulation to assess the impact of blood flow obstruction and reperfusion in the right lower limb on systemic metabolism. Therefore, during CPB, blood samples were taken from the right dosalis pedis artery and the right saphenous vein at a site distal to the right femoral vein cannulation. Blood samples were taken before CPB and 1 h, 2 h, 3 h and 4 h following initiation of CPB. For post-CPB measurements, venous and arterial blood samples were taken from a vein in the forearm and radial artery, respectively, at 1 h, 2 h and 6 h after the restoration of the blood flow in the right femoral vein and the right femoral artery. All blood samples were heparinised and analysed with an automated GEM PREMIER 3000 blood gas analyser (IL Instrument Lab, MA, USA). Arterial or venous partial pressure of oxygen (P_{aO_2}, P_{vO_2}), carbon dioxide (P_{aCO_2}, P_{vCO_2}), blood pH and lactate were measured.