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ORIGINAL ARTICLE

The Effect of Optimising Cerebral Tissue Oxygen Saturation on Markers of Neurological Injury during Coronary Artery Bypass Graft Surgery

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Background Surgical revascularisation of the coronary arteries is a cornerstone of cardiothoracic surgery. Advanced age and the incidence of preoperative co-morbidity in patients presenting for coronary artery bypass graft surgery increases the potential for stroke and other perioperative outcomes. It is hypothesised that by using interventions during cardiac surgery to improve cerebral oxygenation, the risk of patients enduring adverse neurological outcomes would be reduced.

Methods Forty patients (mean age 55.3, standard deviation 9.74 and range from 39 to 72 years) undergoing on-pump coronary artery bypass graft surgery were recruited at Inkosi Albert Luthuli Central Hospital, South Africa. Patients were randomised into a control group ($n = 20$) and interventional group ($n = 20$). Intraoperative regional cerebral oxygen saturation (rSO_2) monitoring with active display and Murkin treatment intervention protocol was administered for the interventional group. Arterial blood samples for the measurement of serum S100B were taken pre and postoperatively. An enzyme immunoassay (ELISA) was used for the quantitative and comparative measurement of human S100B concentrations for both groups. A prioritised intraoperative management protocol to maintain rSO_2 values above 75% of the baseline threshold during cardiopulmonary bypass was followed.

Results There was a highly significant difference in the change in S100B concentrations post surgery between the interventional (37.3 picograms per millilitre) and control groups (139.3 pg/ml). The control group showed a significantly higher increase in S100B concentration over time than the intervention group ($p < 0.001$). There was a significant difference in cerebral desaturation time ($p < 0.001$) between the groups. The mean desaturation time for the control group was 63.85 min as compared to 24.7 min in the interventional group. Cerebral desaturation occurred predominantly during aortic cross clamping, distal anastomosis of coronary arteries and aortic cross clamp release. Predictors of cerebral oxygen desaturation included, partial pressure

Abbreviations: CABG, coronary artery bypass graft surgery; S100B, serum S100beta protein; MAP, mean arterial pressure; $PcvCO_2$, partial pressure of carbon dioxide; HR, heart rate; HCT, haematocrit; SpO_2, patient oxygen saturation; NIRS, near infrared spectroscopy; rSO_2, regional cerebral oxygen saturation; rSO_2R, right cerebral oxygen saturation; rSO_2L, left cerebral oxygen saturation; $ScvO_2$, central venous oxygen saturation

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of carbon dioxide (pCO_2), temperature, pump flow rate (LMP), mean arterial pressure (MAP), haematocrit, heart rate (HR) and patient oxygen saturation (SpO_2).

Conclusion Monitoring brain oxygen saturation during on-pump CABG together with an effective treatment protocol to deal with cerebral desaturation must be advocated.

Keywords Cerebral tissue oxygen saturation (rSO_2) • Serum S100beta protein (S100B) • Coronary artery bypass graft surgery (CABG) • Near infrared spectroscopy (NIRS) • Murkin protocol

Introduction

Inadequate oxygen supply is thought to play a vital role in the aetiology of brain injury detected in patients post coronary artery bypass graft surgery [1]. Monitoring of cerebral oxygenation can be used as a useful tool in the detection of hypoxic conditions associated with adverse neurological sequelae [2]. Serum S100B protein has been used as a biochemical marker in the detection of brain injury during cardiac surgery. Elevated levels serve as an indicator of brain cell damage and adverse neurological outcomes [3,4]. Near infrared spectroscopy (NIRS) can be employed as a non invasive monitor which measures real time cerebral oxygenation during cardiac surgery. The principal goal for the application of NIRS monitoring is to detect and hence optimise factors that affect cerebral oxygen supply [5]. The aim of the study was to maintain cerebral tissue oxygen saturation during cardiopulmonary bypass above 75% of the baseline level by implementation of the Murkin interventional protocol [1]. The analysis of S100B which is a marker of neurological injury and optimisation of regional cerebral oxygen saturation would allow for the formulation of specific intervention strategies which could be implemented by cardiovascular perfusionists during on-pump coronary artery bypass graft surgery as a preventive clinical measure further reducing the risk of neurological injury.

Materials and Methods

After ethical committee approval and informed consent, 40 patients undergoing elective on-pump coronary artery bypass graft surgery were enrolled in the study. Patients were randomised into a control group ($n = 20$) and interventional group ($n = 20$) using a sealed envelope system. In the interventional group, intraoperative regional cerebral oxygen saturation (rSO_2) monitoring was performed with active display and administration of the Murkin treatment interventional protocol [1]. In the control group, regional cerebral oxygen saturation monitoring was not visible to the cardiovascular perfusionist operating the heart lung machine during cardiopulmonary bypass (Blinded).

Inclusion Criteria

Age over 18 yrs, scheduled for elective on-pump coronary artery bypass graft surgery and a preoperative haematocrit greater than 36% (haemoglobin >12 g/dl).

Exclusion Criteria

Exclusion criteria were: pregnancy, history of stroke or persistent neurological residue, history of transient ischaemic attack (TIA), unilateral stenosis of carotid artery greater than 70%, bilateral stenosis of carotid artery greater than 50%, combined cardiac procedure, i.e. CABG plus heart valve replacement, left ventricular ejection fraction less than 40%, left main stem stenosis more than 70%, symptomatic chronic pulmonary disease requiring long term medication, renal insufficiency or anuric renal failure or creatinine above 1.5 mg/dl, HIV positive patients, patients in AF (atrial fibrillation), patients presenting with left ventricular thrombosis preoperatively, presence of aortic artheroma detected pre, intra or post operatively.

All patients received general anaesthesia using a standard technique, intravenous induction with propofol 2 mg/kg, and paralysis with pancuronium or rocuronium. Maintenance was with isoflurane and ventilation was adjusted to maintain normocarbia, as assessed by continuous end-tidal CO2 monitoring and intermittent arterial blood gas analysis. Fentanyl was used for analgesia. A central venous line and arterial line was inserted for all patients as is routinely done for all cardiac patients.

Preoperative data collection included:

- Age
- Gender
- Body mass index
- Height
- Weight
- Calculated flow rate (cardiac index)
- Type II diabetes mellitus (Non insulin)
- Type I diabetes mellitus (Insulin)
- Baseline rSO_2 (Cerebral oxygen saturation)
- Baseline blood gas
- Activated clotting time (ACT)
- Heart rate
- Mean arterial pressure
- Temperature

Cerebral Monitoring

Cerebral monitoring constituted the use of Near-infrared spectroscopy (NIRS), a Somanetics INVOS model 5100c cerebral/somanetic oximeter (Covidien [Pty Ltd], Midrand South Africa) was employed to measure cerebral oxygen delivery and consumption [5].

Serum S100B Protein Sampling and Analysis

Arterial blood samples were taken from the arterial line preoperatively and postoperatively to determine levels of