Assessment of Splanchnic Perfusion During Cardiopulmonary Bypass by Continuous Gastric Tonometry and Transesophageal Echocardiography

Thesis submitted in partial fulfillment for MD degree in Anesthesiology

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2009

(بسم الله الرحمٰن الرحيم)

" قالوا سبحانك لا علم لنا إلا ما علمتنا إنك أنت العليم الحكيم"

صدق الله العظيم
[سورة فصلت الآية 53]

Acknowledgement

I express my great sense of gratitude to Prof. Dr. Fawzia Mohamed Abu El-Fetouh, Professor of Anesthesia, Faculty of Medicine, Cairo University; for her supervision of this thesis. Her advice, help, encouragement, and sincere guidance throughout this work and her careful revision of the manuscript are appreciated.

I am indebted to Dr. Ahmed Ehsan El-Agati, Assistant professor of Anesthesia, Faculty of Medicine, Cairo University; for his great help and dedication of his valuable time for this work to become complete. His encouragement and support are greatly acknowledged.

I sincerely thank Dr. Osama M. Asaad Kheder, Lecturer of Anesthesia, Faculty of Medicine, Cairo University; for his great help, valuable advice, and keen supervision that helped to bring this work to light.

I would like to express my deep thanks for my family for their continuous encouragement and warm feelings that helped me to finish this work.

Abstract

Objective: Abdominal complications after cardiac surgery while relatively uncommon are associated with a significant mortality. Perioperative splanchnic ischemia appears to be an important cause of these complications. The aim of this study was to evaluate the effects of normothermic cardiopulmonary bypass on global and regional splanchnic blood flow using TEE and continuous gastric tonometry during CABG surgery.

Design: Single-arm prospective observational study.

Setting: Cairo University hospital cardiothoracic operative theater.

Participants: Twenty patients of both sexes undergoing elective on-pump CABG were included in the study.

Methods: Superior mesenteric artery blood flow was measured with duplex ultrasound using TEE probe, while gastric mucosal perfusion was assessed using continuous gastric tonometry (Pg-aCO_2 gap) simultaneously during CABG surgery under normothermic CPB (>35°C). Measurements were made six times: T1 (after induction of anesthesia), T2 (after initiation of CPB), T3 (30 min after initiation of CPB), T4 (60 min after initiation of CPB), T5 (5 min after weaning from CPB), T6 (end of surgery).

Results: Superior mesenteric artery blood flow showed a highly significant decrease from baseline value (p value < 0.01) after initiation of CPB (T2) till its end (T4) and increased shortly after bypass then decreased again significantly below baseline (p value = 0.04) at the end of surgery (T6). While Pg-aCO_2 gap showed a highly significant increase from baseline value (p value < 0.01) 30 minutes after CPB initiation (T3) then 5 minutes after weaning from CPB (T5) and at the end of surgery (T6), however no correlation was found between both variables.

Conclusion: Normothermic cardiopulmonary bypass is associated with significant splanchnic ischemia that can not be explained by decreased global splanchnic blood flow. TEE allows intraoperative assessment of blood flow to splanchnic viscera.

Keywords: Superior mesenteric artery, gastric tonometry, splanchnic ischemia, normothermic CPB.

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Abbreviations

- **CaI:** The arterial concentration of indocyanine green.
- **CABG:** Coronary artery bypass graft.
- **ChvI:** Hepatic venous concentration of indocyanine green.
- **CI:** Cardiac index.
- **CO:** Cardiac output.
- **CPB:** Cardiopulmonary bypass.
- **CVP:** Central venous pressure.
- **eNOS:** Endothelial nitric oxide synthase.
- **FDA:** Food and drug administration.
- **GIT:** Gastrointestinal tract.
- **GSH:** Reduced glutathione.
- **H_2O_2:** Hydrogen peroxide.
- **HABR:** Hepatic arterial buffer response.
- **HR:** Heart rate.
- **ICG:** Indocyanine green.
- **ICU:** Intensive care unit.
- **iNOS:** Inducible nitric oxide synthase.
- **I/R:** Ischemia/reperfusion.
- **i-FABP:** Intestinal fatty acid binding protein.
- **LBP:** Lipopolysaccharide-binding protein.
- **LDH:** Lactate dehydrogenase.
- **LDF:** Laser Doppler flowmetry.
- **LPS:** Lipopolysaccharide.
- **MAP:** Mean arterial pressure.
- **MOF:** Multi organ failure.

- **MPO:** Myeloperoxidase.
- **NOS:** Nitric oxide synthase.
- **nNOS:** Neural nitric oxide synthase.
- **$O_2^{\cdot-}$:** Superoxide radical.
- **OER:** Oxygen extraction ratio.
- **$HO^{\cdot}$:** Hydroxyl radical.
- **$ONOO^-$:** Peroxynitrite.
- **PaO_2:** Arterial O_2 tension.
- **$PaCO_2$:** Arterial CO_2 tension.
- **$PeCO_2$:** End tidal CO_2 tension.
- **$PgCO_2$:** Gastric intramucosal carbon dioxide tension.
- **$Pg\text{-}aCO_2$:** $PgCO_2$ - $PaCO_2$.
- **$Pg\text{-}eCO_2$:** $PgCO_2$ - $PeCO_2$.
- **pHi:** Gastric intramucosal pH.
- **PMNs:** Polymorphonuclear neutrophils.
- **ROS:** Reactive oxygen species.
- **SBF:** Splanchnic blood flow.
- **SIRS:** Systemic inflammatory response syndrome.
- **SMA:** Superior mesenteric artery.
- **SMABF:** Superior mesenteric artery blood flow.
- **SMABF/CO:** SMABF percentage of CO.
- **SMA-d:** Superior mesenteric artery diameter.
- **SOD:** Superoxide dismutase.
- **SVR:** Systemic vascular resistance.
- **TAMV:** Time averaged mean velocity.
- **TNF:** Tumor necrosis factor.
- **VTI:** Velocity time integral.

- **XD:** Xanthine dehydrogenase.
- **XO:** Xanthine oxidase.

Introduction and aim of work

The splanchnic region participates in the regulation of circulating blood volume and systemic blood pressure. Major reduction of splanchnic blood flow can be vital in defending brain and heart perfusion in acute hypovolemia, but prolonged hypoperfusion of the splanchnic region will inevitably lead to hypoxic tissue injury and release of inflammatory mediators, which have a major impact on both systemic and regional blood flow and tissue functions. (**Hessel, 2004)**

Splanchnic hypoperfusion is a common finding in patients undergoing cardiopulmonary bypass (CPB). Although overt injury of the intra-abdominal organs after cardiac surgery is relatively uncommon, they are associated with a high mortality. Splanchnic ischemia prior to, during, and especially postoperatively appears to be an important cause of these complications. In addition, splanchnic ischemia is hypothesized to be one cause of the systemic inflammatory response syndrome and multiorgan failure that may follow cardiac surgery through damage of the mucosal barrier, allowing gut translocation of endotoxin stimulating the inflammatory response to cardiac surgery. (**Hessel, 2004) (Warltier, 2002)**

Assessment of hepatic and splanchnic perfusion is of scientific and clinical interest. Several techniques are available for determination of splanchnic blood flow (SBF), but some are not suitable for human studies. Techniques using indicators including (sulfobromophthalein, galactose, D-sorbitol or ethanol) have been used but are not sufficiently accurate because of extensive extrahepatic uptake. The indicator dilution technique using constant-rate infusion of the dye indocyanine green (ICG) has evolved as a gold standard, but it requires hepatic vein catheterization for the determination of hepatic ICG extraction. **(Gårdeba, et al, 2002)**

Gastric tonometry determines the perfusion status of the gastric mucosa by measuring local carbon dioxide tension ($PgCO_2$), originally tonometry was performed by installing a small volume saline sample into a silicon balloon in the tip catheter of a special nasogastric catheter, several practical problems were encountered with such technique, the most recent development, automated air tonometry, has solved these problems. The monitor automatically fills the catheter with 4 ml of room air, CO_2 diffuses from the mucosa into the lumen of the stomach and then into the silicone balloon of the tonometer. The balloon gas is drawn after equilibration with gastric mucosa and measured with an infrared sensor. The measured PCO_2 reflects gastric intramucosal CO_2. Gastric mucosal CO_2 and the CO_2 gap (difference between gastric mucosal CO_2 and arterial CO_2) have been shown to reflect gastric mucosal perfusion . (**Uusaro, et al, 2000)**

Duplex ultrasound provides a noninvasive and accurate assessment of blood flow. Visualization of major abdominal arteries and main hepatic veins by transesophageal echocardiography (TEE) has been reported, allowing intraoperative assessment of splanchnic hemodynamics. However, the impact of TEE-measured splanchnic blood flow on mucosal perfusion is still ill-defined and under investigated. (**Fiore, et al, 2006) (Meierhenrich, et al, 2001)**

The aim of work

To measure splanchnic blood flow during CPB employing transesophageal echocardiography Doppler–measured superior mesenteric artery blood flow (SMABF), and to study gastric tonometry data simultaneously in the same patients; to assess the impact of splanchnic as well as systemic hemodynamic changes on gastric mucosal perfusion during on-pump CABG procedure.