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LOW CARDIAC OUTPUT SYNDROME (LCOS) AT SEPARATION FROM CARDIOPULMONARY BYPASS (CPB): OUR EXPERIENCE AT QUEEN ALIA HEART INSTITUTE, AMMAN JORDAN

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ABSTRACT

Objective: To determine the perioperative risk factors that are associated with increased likelihood of low cardiac output syndrome at separation from cardiopulmonary bypass.

Methodology: This retrospective cross sectional study included patients who presented for cardiac surgical procedures due to different cardiac pathologies at Queen Alia Heart Institute between December 2013 and June 2014. Data was collected in a special form and included patient's particulars. Patients were divided into two groups according to age: Group 1 up to 60 years of age and Group 2 more than 61 years. Also patients were divided into two groups according to CPB time: Group A with less than 2 hours and Group B of more than two hours. EUROSCORE (European system for cardiac operative risk evaluation) value was calculated.

Results: A total of 108 patients were included with mean age of 58.3 years of both genders. Average EUROSCORE of study sample was 1.35. Inotropic support was used in 40 patients with 31% of females developed LCOS, ($p = 0.6$) and 44 patients had preoperative left ventricular impairment with 35 of them needed inotropic support (79.5%). About 63 patients were < 60 years old ($p=0.03$). Urgent cases had higher incidence of LCOS ($p=0.05$). About 30 patients had chronic respiratory disease (53.3%) ($p=0.03$). Hypertensive patients were 79 patients, (43%) ($p=0.033$). The average EUROSCORE for patients who developed LCOS was higher than study population (2 vs. 1.35) ($p=0.05$)

Conclusion: LCOS was associated more often with preoperative left ventricular dysfunction, old age, urgent surgery, preoperative chronic respiratory disease and hypertension. EUROSCORE can help predict LCOS and the likelihood for the need of inotropes.

Key Words: Low Cardiac Output Syndrome, EUROSCORE

INTRODUCTION

The low cardiac output syndrome (or low output syndrome) is a serious clinical situation of inadequate tissue perfusion due to myocardial dysfunction that often occurs at termination of cardiopulmonary bypass (CPB) or shortly thereafter. It is usually transient and reversible, but persistent LCOS is associated with high incidence of morbidity and mortality, increased duration of postoperative mechanical ventilation, prolonged intensive care unit and hospital stay. Several definitions are available for the LCOS; it can be defined as the need of inotropic support or intra-aortic balloon pump to maintain a systolic blood pressure (SBP) above 90 mm Hg and cardiac index (CI) more than 2.1 l/min/m^2, It can also be defined as inability to wean the patient off CPB despite maximal inotropic support or evidence of end-organ dysfunction (e.g. low urine output of less than 0.5 ml/kg/hour).

The incidence of low cardiac output syndrome varies widely in literature, being almost between 10 to 45%.[1] Risk factors that are associated with LCOS include preoperative ventricular dysfunction, old age and urgent (or emergent) surgery.

Possible causes of the perioperative LCOS are myocardial injury resulting in myocardial ischemia or infarction, poor myocardial preservation, reperfusion injury and/or inadequate cardiac surgical repair or revascularization. The condition of nonpermanent post-ischemic myocardial dysfunction without myocardial necrosis in the presence of normal flow is called myocardial stunning.[2]

Despite advances in surgical and anaesthetic technique, a large proportion of patients undergoing cardiac surgery (up to 95%) still suffer from ventricular dysfunction (at least transient) which improves gradually in less than 24 hours postoperatively in most patients. In low-risk patients, postoperative ventricular dysfunction occurs to a comparable level after on-pump and off-pump surgery, but in patients with severe preoperative ventricular dysfunction (the high-risk patient), off-pump surgery causes less myocardial injury.[3]

The risk profile of the cardiac surgical patients has increased significantly over the last years due to older age at presentation for surgery combined with increasing co-morbidities. This emphasizes the importance of meticulous cardiac protection in order to avoid postoperative myocardial dysfunction and failure especially in patients with preoperative ventricular dysfunction.

The immediate period following CPB is often marked by hemodynamic instability; as patients emerging from CPB have hemodilution, altered potassium levels, hypocalcaemia and hypomagnesaemia. Factors that determine the cardiac output (preload, afterload, contractility, heart rate and rhythm) and the presence of residual lesions (e.g. residual ventricular septal defect (VSD), residual outflow obstruction or incomplete revascularization) are usually investigated and managed accordingly with inotropes, vasodilators, inodilators and intra-aortic balloon counter-pulsation). As normal blood pressure does preclude a LCOS, several clinical and biochemical investigations are recommended. The choice of the appropriate inotropic agent for a given patient is of paramount importance and is usually guided by the systemic and pulmonary vascular resistances, myocardial performance (contractility), central venous pressure, systemic blood pressure and urine output.

METHODOLOGY

This study is a single centre retrospective cross sectional study of adult cardiac surgical patients undergoing coronary artery bypass grafting, heart valve repair (or replacement) or combined surgeries (coronary and valve surgery) at Queen Alia Heart Institute in Jordan in the period from December 2013 to June 2014.

Inclusion criteria for this study were: adult patients (age above 18 years), coronary artery bypass grafting, single or multiple heart valve replacement surgeries, combined (coronary and valve) procedures, utilization of cardiopulmonary bypass and aortic cross clamping. Exclusion criteria were paediatric cases, off-pump coronary arteries bypass grafting (OPCABG), surgery for repair of an atrial septal defect, aortic arch replacement surgeries, and preoperative cardiac arrest.

Data for each patient was collected in a special proforma designed for the purpose of this study, then transferred to computer and statistically analysed using SPSS version 16. Patients were compared for the development of LCOS according to:

1) Pre-operative factors: age (less than 60 years or more than 60 years), gender, body mass index, co-morbidities, preoperative ventricular dysfunction and either the surgery was elective or urgent.

2) Intra-operative factors: duration of cardiopulmonary bypass (less than 2 hours versus more than 2 hours), aortic cross clamp time (less than 1 hour versus more than 1 hour), level of hypothermia used during CPB (mild- 36-33° C, moderate 33-30° C and severe hypothermia if less than 30° C) and type of procedure.

LV impairment was defined by either an echocardiographic assessment or visual estimation of the left ventricular segmental motion by the left heart catheterization or both.

Respiratory disease was considered for any patient who is being followed or treated by the pulmonology team.

RESULTS

A total of 108 patients were included with ages ranging from 19 to 80 years (average 58.5 years), and around 42% of the patients were above 60 years. Male patients were 92 (85%), while females were 16 (15%). The incidence of LCOS was 37% (40 patients).

The prevalence of hypertension among this study population was 73%, diabetes 55%, chronic respiratory disease 28% and pre-operative ventricular dysfunction 41%. The average body mass index for the study population was around 29 kg/m^2, with an incidence of obesity of 25%. Patients' EUROSCORE values ranged from 0.5 to 5.3 (average of 1.4 for the study sample). Patients who had LCOS had an average EUROSCORE of 1.99. (Tables 1 and 2).

Factors that had statistically significant influence on development of LCOS were age above 60 years (p =0.031), hypertension (p=0.033), pre-operative ventricular dysfunction (p =0.001), respiratory disease (p =0.03) and urgency of surgery (p=0.05). Although higher incidence of LCOS was seen among diabetic patients (44.1%) as compared to non-diabetic patients (28.6%), the association between diabetes and LCOS was not statistically significant (p=0.097).

The average CPB duration was 87 (±26) minutes. The CPB duration was less than 2 hours in 92 patients (85%), and more than 2 hours in 16 patients (15%). The average aortic cross clamp time was 48.6 (±21) minutes. The aortic cross clamp time was more than 1 hour in 45 patients (41.7%), and more than 1 hour in 63 patients (58.3%). The mean temperature during CPB was 33.4 (±1.4) ° C. Moderate hypothermia was utilised most frequently (37%), and severe hypothermia least frequently (6.5%). Coronary arteries bypass grafting was the most common procedure performed (91 patients, (84.3%)), and left internal mammary artery was utilised in 65 patients (60%).

Patients who had a CPB duration of more than 2 hours had higher incidence of LCOS (38%) than those who had a CPB duration of less than two hours (31%), but the influence of CPB duration was not statistically significant (p=0.6). The only factor that was significant for development of LCOS was the aortic cross clamp time (p=0.031). Patients who had an aortic cross clamp time of more than 1 hour had an incidence of LCOS of 50%, while those who had an aortic clamp time of less than 1 hour had an incidence of 28.6%.

Table 1: Patients Characteristics and Perioperative Variables

Variable	n (%)
Total number of patients	108 (100%)
Female	16 (14.8 %)
Male	92 (85.2 %)
Hypertension	79 (73.1%)
Diabetes Mellitus	59 (24.1%)
Respiratory Disease	30 (14.8%)
Smoking	53 (49%)
CABG surgery	91 (84.25%)
Harvest of internal mammary artery	65 (60.2%)
Urgent surgery	7 (6.5%)
Low cardiac output syndrome	40 (37%)
Inotropic support	40 (37%)
Intra-aortic balloon pump	10 (9.3%)
Reopening (resternotomy)	6 (5.6%)

DISCUSSION

Identification of patients who are likely to develop LCOS is the initial step of management. Preoperative ventricular dysfunction, urgent surgery, old age and serious co-morbidities, are predictors of weaning difficulty from CPB and usually raises the level of our preparation to avoid, treat and manage LCOS. Intraoperatively, the complexity of the procedure, durations of CPB and aortic clamp time (ischemia time), incomplete revascularization due to poor status of the coronary targets and the need of inotropes are also predictors of difficult weaning from CPB and impending LCOS. The next step is prevention of LCOS by meticulous myocardial preservation which consists of anaesthetic, surgical and perfusional techniques, all concerned to preserve the balance between myocardial oxygen and nutritional demand and delivery.

In our hospital, the use of pulmonary artery catheter (Swan-Ganz) has declined dramatically and is rarely used due to its serious complication profile.Although treatment of CPB is generally accomplished by inotropic support, there is no perfect inotrope. An easy and efficacious method of determining the aetiology of LCOS is by calculation of

Table 2: Patients Characteristics and Perioperative Variables

Variable	Mean ± SD
Age(years)	58.3±11.5
BMI (kg/m ^{2})	29 ± 4.6
Operation time(minutes)	250 ±46
CPB time (minutes)	87±26
Hypothermia (° Celsius)	33.44 ±1.4
AXC time (minutes)	48.6±21
Post operative blood loss (ml)	414±328

Table 3: Pre-Operative Factors Affecting Development of LCOS

Preoperative factors		Number of patients (%)	Number of patients who developed LCOS, (% of population)	Incidence of LCOS among category (%)	P-Value
Gender	Male	92 (85.2%)	35 (32.4%)	38%	0.604
	Female	16 (14.8%)	5 (4.6%)	31.25%	
Age	Above 60 years	45 (41.7%)	22 (20.4%)	48.9%	0.031
	Below 60 years	63 (58.3%)	18 (16.7%)	28.6%	
Hypertension	Yes	79 (73.1%)	34 (31.5%)	43%	0.033
	No	29 (26.9%)	6 (5.6%)	20.7%	
Diabetes Mellitus	Yes	59 (54.6%)	26 (24.1%)	44.1%	0.097
	No	49 (45.4%)	14 (13%)	28.6%	
LV dysfunction	Yes	44 (40.7%)	35 (32.4%)	79.5%	0.001
	No	64 (59.3%)	5 (4.6%)	7.8%	
Respiratory illness	Yes	30 (27.8%)	16 (14.8%)	53.3%	0.03
	No	78 (72.2%)	24 (22.2%)	30.8%	
Body Mass Index (kg/m ^{2})	Normal	20 (18.5%)	9 (8.4%)	45%	0.352
	Overweight	61 (56.5%)	19 (17.6%)	31.1%	
	Obese	27 (25%)	12 (11.1%)	44.4%	
Urgency of procedure	Elective	101 (93.5%)	35 (32.4%)	34.7%	0.05
	Urgent	7 (6.5%)	5 (4.6%)	71.4%	

LCOS: Low cardiac output syndrome

systemic vascular resistance (SVR) by substituting the CPB flow rate for the cardiac output in the equation: SVR = MAP-CVP/CO X 80.

In an euvolemic patient, low SVR necessitates a drug with alpha adrenergic properties, while a high SVR may necessitates a vasodilator and a normal or acceptable SVR will address a contractile dysfunction where a drug with beta adrenergic properties is preferred.

Inotropes are upgraded (number of drugs and dosage increase) according to various parameters which are closely titrated.[6] These parameters are as follows.

i. Clinical: Significant tachycardia, peripheral vasoconstriction.

ii. Biochemical: Deranged SvO_2, $SaO_2 - SvO_2$ difference, lactates, anion gap.

iii. Hemodynamic: Persistent LaP surges, increased CVP.

iv. Echo: Worsening systemic ventricular function, significant pulmonary hypertension with or without RV systolic dysfunction, significant RV diastolic dysfunction.

Epinephrine is the inotrope used in our unit. It is also used for resuscitation and occasionally, in low dose, for severe systolic dysfunction. Doses of epinephrine greater than 0.2 mc/kg/min are associated with significantly increased afterload and are generally avoided.[8]

Table 4: Intraoperative Factors Affecting Development of LCOS

Intraoperative factors		Number of patients, (%)	Number of patients who developed LCOS, (% of population)	Incidence of LCOS among category (%)	P-value
Cardiopulmonary bypass time	Less or equal to 2 hours	92 (85.2%)	35 (32.4%)	38%	0.604
	More than 2 hours	16 (14.8%)	5 (4.6%)	31.3%	
Aortic clamp time	Less or equal to 1 hour	45 (41.7%)	22 (20.4%)	48.9%	0.031
	More than 1 hour	63(58.3%)	18 (16.7%)	28.6%	
Level of hypothermia used during cardiopulmonary bypass (CPB)	Normothermic CPB	29 (26.9%)	14 (13%)	48.3%	0.4
	Mild hypothermia	32 (29.6%)	8 (7.4%)	25%	
	Moderate hypothermia	40 (37%)	15 (13.9%)	37.5%	
	Severe hypothermia	7 (6.5%)	3 (2.8%)	42.9%	
Type of procedure	CABG	91 (84.3%)	31 (28.7%)	34%	0.204
	One valve repair	8 (7.4%)	3 (2.8%)	37.5%	
	More than one valve	4 (3.7%)	2 (1.9%)	50%	
	CABG and valve(s) repair	5 (4.6%)	4 (3.7%)	80%	

LCOS: Low cardiac output syndrome

Norepinephrine is the vasopressor used for right ventricular dysfunction especially when associated with significant peripheral vasodilatation, in vasodilatory shock and in postoperative residual dynamic left ventricular outflow tract obstructions.[6] We have no experience with the use of vasopressin.

Aggressive afterload reduction is our mainstay of management in severe systolic ventricular dysfunction. This practice is based on the observation that afterload reduction is associated with a proportionally greater increase in cardiac output in severe ventricular dysfunction as compared to mild or moderate ventricular dysfunction.[2] Afterload reduction has been shown to be particularly useful to augment stroke volume and overall cardiac output in children hearts as well as in those with poor myocardial contractility.

Afterload reduction in the postoperative period is achieved with:

1. Phenoxybenzamine-commenced intraoperatively and continued postoperatively-the main problem being its long half-life (>24 h) occasionally causing protracted and severe systemic hypotension.

2. Sodium nitroprusside is easier to titrate and is a gentler vasodilator due to its short half-life and rapidity of action. Sodium nitroprusside is used for afterload reduction due to its favorable qualities and low cost.

3. Milrinone: In any of the above situations if there is worsening lactic acidosis, increasing $SaO_2 - SvO_2$ gradient, increasing peripheral vasoconstriction (exclude occult hypovolemia) or other features of LCOS-(clinical, biochemical, hemodynamic, echo) or significant systemic ventricular dysfunction then the policy is to upgrade to milrinone.

4) Nitroglycerine is used primarily for its venodilator properties following Coronary artery bypass surgeries, valvuloplasty or valve replacement and as a pulmonary and coronary vasodilator (coronary spasm). Nitroglycerine is also used for preload optimization whenever the central venous pressures are elevated.[8] The need for increased use of IABP during cardiac surgery in the recent years has been reported by many groups.[5,9] This is mainly due to the fact that the patient population has changed and now includes older patients with multi-vessel disease and more impaired ventricles. On the other hand, there is a lower threshold for IABP use due to improve technology and lower rate of complications.[5]

CONCLUSION

LCOS was associated more often with preoperative left ventricular dysfunction, old age, urgent surgery, preoperative chronic respiratory disease and hypertension. EUROSCORE can help predict LCOS and the likelihood for the need of inotropes, and which inotropes to start and when to start them, not forgetting the need for intra aortic balloon pumps.

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