Study of predictors of low cardiac output syndrome after cardiac valve surgery

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Summary:

Objective: Low cardiac output syndrome (LCOS) is defined as a decrease in cardiac index (CI) <2.0L/min/m2 and systolic blood pressure <90mmHg, accompanied by signs of a tissue hypoperfusion (cool peripheries, clammy skin, altered mental status, reduced urine output, elevated serum lactate levels) and the need for medication or mechanical circulatory support to improve hemodynamics [4,7]. LCOS is one of the serious complications after open cardiac surgery with a rate of 2-14% depending on the patient and the risk of death increases 12-25 times [3]. Besides modern equipment, early detection and timely treatment reduce mortality as well as increase myocardial recovery. LCOS prognostic factors play an important role. The aim of this study is to identify the prognostic signs of LCOS after valvular surgery.

Subjects and methods: A cross-sectional descriptive study on patients undergoing valvular heart surgery at the Cardiovascular Anesthesiology Department - Cardiovascular Center - Hue Central Hospital from February 2022 to July 2022. LCOS is the dependent variable and the independent variable was divided into three groups before surgery, during surgery and after surgery. The data were processed by software R4.2.2. Using univariate logistic regression to identify independent prognostic factors.

Results: A study on 60 patients after heart valve surgery showed that: LCOS after heart valve surgery has a rate of 28.3% with an average time of 5.88 hours after surgery. Through univariate logistic regression analysis, the results found independent prognostic factors including: EF <=40% at preoperative time points (OR=12.9, 95%CI 1.73 – 26.5), EF 0h (OR) =2.3, 95%CI 2.4-8.9), EF 4h (OR=2.9, 95%CI 1.9-6.7), EF 24h (OR=1.9, 95%CI 1.5-9.5), lactate at 0h postoperative time (OR=1.81, 95%CI 1.25-2.8), 4h (OR=1.41, 95%CI 1.13-1.85), 8h (OR=1.38, 95%CI 1.14-1.73), 12h (OR=1.35, 95%CI 1.11-1.72), creatinine at 24 h after surgery (OR=1.02, 95%CI 1.01-1.04), time to extracorporeal circulation (OR=1.02, 95%CI 1.02-1.04), time to clamp aorta (OR=1.2, 95%CI 1.1-1.2).

Conclusion: Low cardiac output syndrome is one of the serious complications after heart valve surgery, early detection and timely treatment reduce the risk of death for patients. The study showed that many factors before, during and after surgery are independent prognostic factors for LCOS after surgery.

***Keywords**: Low cardiac output syndrome, valvular surgery, open heart surgery.*

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1. Background

Low cardiac output syndrome (LCOS) is a serious complication and high risk of death following open cardiac surgeries. The cause of decreased cardiac output after surgery is transient myocardial dysfunction, with a variety of clinical manifestations and symptoms of organ hypoperfusion (cool peripheries, clammy skin, oliguria, altered mental status, increased blood lactate levels…) and hypotension with systolic blood pressure <90mmHg [7,11]. Without early detection and timely treatment, the patient will progress to more severe complications as irreversible myocardial dysfunction, multi-organ failure and possibly death. In order to reduce complications due to tissue hypoperfusion, the primary goal of treatment is to provide adequate oxygen and nutrition to the tissue with the use of medicines as well as mechanical support devices.

Besides using the mechanical support devices, early detection of low cardiac output syndrome is very important which might contributes to reducing mortality. Many authors have studied and proposed independent prognostic factors for LCOS after open cardiac surgeries. In 2005, Manjula D. studied on aortic valve surgery patients and found that independent prognostic factors were preoperative heart failure, preoperative renal failure, emergency surgery, and prior stroke or small left ventricular size [9]. In 2010, one studied on patients with mitral valve surgery showed similar results: emergency surgeries, preoperative renal failure are independent predictors of LCOS [10]. When studying on patients undergoing coronary bypass surgeries, WenJun Ding also found independent prognostic factors for LCOS as age > 60 years, EF <40%, emergency surgeries, or coronary artery bypass graft using extracorporeal circulation. To find out patient characteristics as well as independent prognostic factors for LCOS after cardiac valve surgeries, we study on prognostic factors of low cardiac output syndrome after valvular surgery with two goals: Determine the charateristics of patients after cardiac valve surgery and analyze the relationship between the prognostic factors and low cardiac output syndrome after cardiac valve surgeries.

2. Methods

A cross-sectional descriptive study, patient over 16 years old admitted to the Cardiovascular Anesthesiology Department - Cardiovascular Center - Hue Central Hospital for cardiac valve surgeries. The exclusion criteria was: patients who did not agree to participate in the study, patients with coronary artery bypass graft surgery, patients with heart valve diseases due to myocardial infarction.

Eligible patients we included in the study. We recorded medical history, do preoperative laboratory tests. When the patients entered surgery, we observed the extracorporeal circulation time, aortic clamping time duration, and the course of surgery were monitored. The patients after resuscitation were monitored for laboratory tests and echocardiography. The variables in the study are divided into dependent variables (LCOS) and independent variables:

Dependent variables:

The diagnostic criteria for low cardiac output syndrome (LCOS) after cardiac valve surgery [12]:

- Need for mechanical circulatory support with intra-aortic balloon pump, left ventricular assist device, or extracorporeal membrane oxygenation during or after surgery, and/or
- Hemodynamic instability requiring continued pharmacologic support with ≥2 inotropic medications (dobutamine, adrenaline, dopamine, milrinon) on postoperative day 1 after surgery.

Independent variables:

The independent variables performed in this study were divided into three groups as preoperative factors, intraoperative factors and postoperative factors.

- Before surgery: Patient age was divided into two groups under 60 years old and ≥ 60 years old [12], gender (male and female), severe mitral stenosis, heart rate (sinus and atrial fibrillation), preoperative EF (> 40%, ≤40%) [1] , LVDD (Left ventricular diameter diastolic), LVDS (Left ventricular diameter systolic), hemoglobin, creatinin, SGOT, SGPT.
- In surgery: Type of surgery (emergency and elective), number of surgical valves, mitral valve surgery, time of extracorporeal circulation, crossclamp time.
- After surgery: EF at 0h, 4h, 24h after surgery, lactate at 0h, 4h, 8h, 12h after surgery. SGOT, SGPT, creatinine at 0h and 24h after surgery.

Statistical analysis:

Statistical analysis was done with R4.2.2 software. Qualitative variables were expressed as frequency table, quantitative variable were expressed as means ± standard deviations. T-test was used to compare two means and $\chi 2$ test was used to compared two proportions. Using univariable logistic regression analysis to find independent prognostic factors for LCOS.

3. Results

A cross-sectional descriptive study on 60 patients undergoing valvular heart surgery at the Cardiovascular Anesthesiology Department - Cardiovascular Center - Hue Central Hospital from February 2022 to July 2022. Statistical analysis was done with R4.2.2 software, the results are as follows:

3.1. General characteristics

Some characteristics of the patients and factors related to LCOS treatment are presented in Table 1. In this study, the proportion of men (63.3%) was higher than that of women (36.7%), patients with age <60 years old and ≥60 years old accounted for 76.7% and 23.3%, respectively. Low cardiac output syndrome after cardiac valve surgery accounted for 28.3%, and the time of LCOS occurrence was 5.88 hours in average. Among patients with LCOS after cardiac valve surgery, 58.8% of patients responded to medical treatment and 41.2% of patients needed mechanical support IABP (Intra-Aortic balloon pump).

Talble 1. General characteristics

Characteristics		**N**	**%**
Sex	**Male**	38	63.3%
	Female	22	36.7%
Age	**< 60 tuổi**	36	76.7%
	≥60 tuổi	14	23.3%
LCOS	**Yes**	17	28.3%
	No	43	71.7%
Time of LCOS		5.88±2.06 (h)	
IABP	**Yes**	7	41.2%
	No	10	58.8%
Inotropes – Vasoconstrictor	**No**	17	28.3%
	Dobutamin	24	40%
	Adrenalin	2	3.3%
	Noradrenalin	0	0%
	Dobu + Adre	10	16.7%
	Dobu + Adre + Nor	7	11.7%

3.2. Clinical and laboratory characteristics

Clinical and laboratory characteristics of patients with cardiac valve surgery were divided into three groups: before surgery, during surgery and after surgery. The preoperative patient characteristics are presented in Table 2. The table shows the non-significant difference in age, sex, history of mitral stenosis, preoperative heart rate or hemoglobin, SGOT, SGPT and serum creatinine concentration between the two groups of LCOS and Non-LCOS patients. Patients with EF ≤40% before surgery had a significant higher rate of LCOS than whom with EF >40%, ($p < 0.05$). Left ventricular size in diastolic (LVDD 50.2±9.32) and systolic (LVDS 34.6±7.68) of LCOS patients smaller than left ventricular size in diastolic (LVDS 42.3±9.48) and systlic (LVDD 56.9±9.27) of Non-LCOS patients, the difference was statistically significant ($p<0.05$).

Table 2. Characteristics before surgery

Characteristic		**Non-LCOS**	**LCOS**	**P-Value**
Age	**< 60**	35 (81.4%)	11 (64.7%)	0.299
	≥ 60	8 (18.6%)	6 (35.3%)	
Sex	**Male**	16 (37.2%)	6 (35.3%)	1
	Female	27 (62.8%)	11 (64.7%)	
Severe mitral stenosis	**No**	30 (69.8%)	10 (58.8%)	0.613
	Yes	13 (30.2%)	7 (41.2%)	
Preoperative heart rhythm	**Sinus rhythm**	28 (65.1%)	7 (41.2%)	0.16
	Atrial fibrilation	15 (34.9%)	10(58.8%)	
Preoperative EF	**>40%**	42 (97.7%)	13 (76.5%)	**0.038**
	≤40%	1 (2.3%)	4 (23.5%)	
LVDD		56.9±9.27	50.2±9.32	**0.021**
LVDS		42.3±9.48	34.6±7.68	**0.008**
Preoperative Hb		13.0±1.84	12.3±1.45	0.142
Preoperative Creatinin		87.2±23.2	98.7±33.8	0.21
Preoperative SGOT		34.3±18.3	44.2±41.6	0.356
Preoperative SGPT		40.9±34.7	36.4±28.4	0.608

When studying the patient characteristics during surgery, the results are presented in Table 3. Among the studied variables, only the time of extracorporeal circulation and crossclamp time are statistically significant difference between the two groups of LCOS and Non-LCOS patients. The extracorporeal time of the LCOS group (151±74.5) was higher than the Non-LCOS group (108±26.8), crossclamp time of LCOS group (87.4±26.9) was higher than the Non-LCOS group (76.7±26.4).

Table 3: Characteristics intraoperative

Characteristic		**Non-LCOS**	**LCOS**	**P-Value**
Type of surgery	**Elective**	42 (97.7%)	15 (88.2%)	0.393
	Emergency	1 (2.3%)	2 (11.8%)	
Mitral surgery	**No**	8 (18.6%)	4 (23.5%)	0.943
	Yes	35 (81.4%)	13 (76.5%)	
Number of surgical valves	**1 valve**	32 (74.4%)	13 (76.5%)	1
	2 valve	11 (25.6%)	4 (23.5%)	
Time of extracorporeal circulation		108±26.8	151±74.5	**0.031**
Crossclamp time		76.7±26.4	87.4±26.9	**0.017**

When studying the postoperative characteristics of the patients, the study results were presented in Table 4. Left ventricular systolic function (EF≤ 40%) at three times 0h, 4h and 24h are higher ratio in the LCOS group was statistically significant with P<0.05. Blood lactate levels at 0h, 4h, 8h, and 12h after surgery in the LCOS group were higher statistically significant difference than the Non-LCOS group with P<0.05.

Table 4: Characteristics postoperative

Characteristics		**Non-LCOS**	**LCOS**	**P-Value**
EF 0h	**>40%**	41 (95.3%)	8 (47.1%)	**<0.001**
	≤40%	2 (4.7%)	9 (52.9%)	
EF 4h	**>40%**	41 (95.3%)	7 (41.2%)	**<0.001**
	≤40%	2 (4.7%)	10 (58.8%)	
EF 24h	**>40%**	40 (93.0%)	7 (41.2%)	**<0.001**
	≤40%	3 (7%)	10 (58.8%)	
Lactate 0h		3.07±1.34	4.67±2.03	**0.006**
Lactate 4h		4.14±2.02	6.64±3.51	**0.015**

Lactate 8h	4.91±2.36	8.14±4.13	**0.005**
Lactate 12h	4.71±2.32	7.32±3.88	**0.016**
SGOT 0h	56.1±25.2	142±32.9	0.297
SGPT 0h	30.3±17.3	35.4±29.9	0.511
SGOT 24h	70.4±22.4	222±48.1	0.214
SGPT 24h	35.1±188	59.8±97	0.313
Creatinin 0h	94.3±25.4	107±31.7	0.149
Creatinin 24h	90.4±34.3	122±43.6	**0.0142**

3.3. The dependent prognostic factors

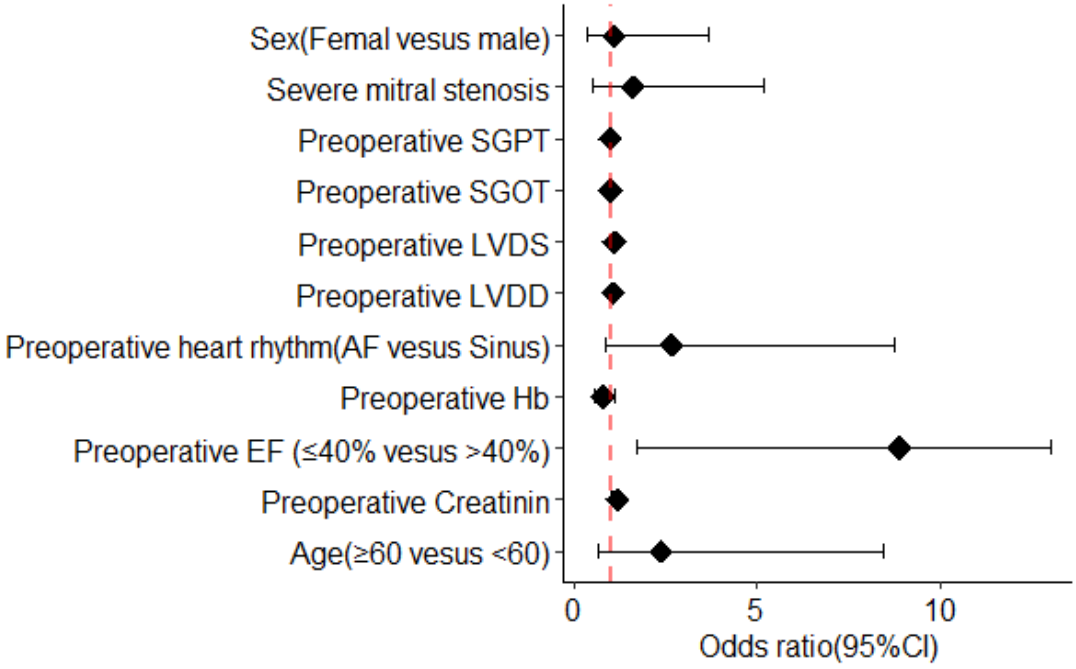

Figure 1: The preoperation prognostic factors

The preoperative prognostic factors were anlyzed by univariable logistic regression method, the results were shown in Figure 1. The diagram shows only preoperative left ventricular systolic function was an independent predictor of postoperative LCOS. EF ≤40% increased the risk of LCOS after surgery with (OR=12.9, 95%CI 1.73 – 26.5)

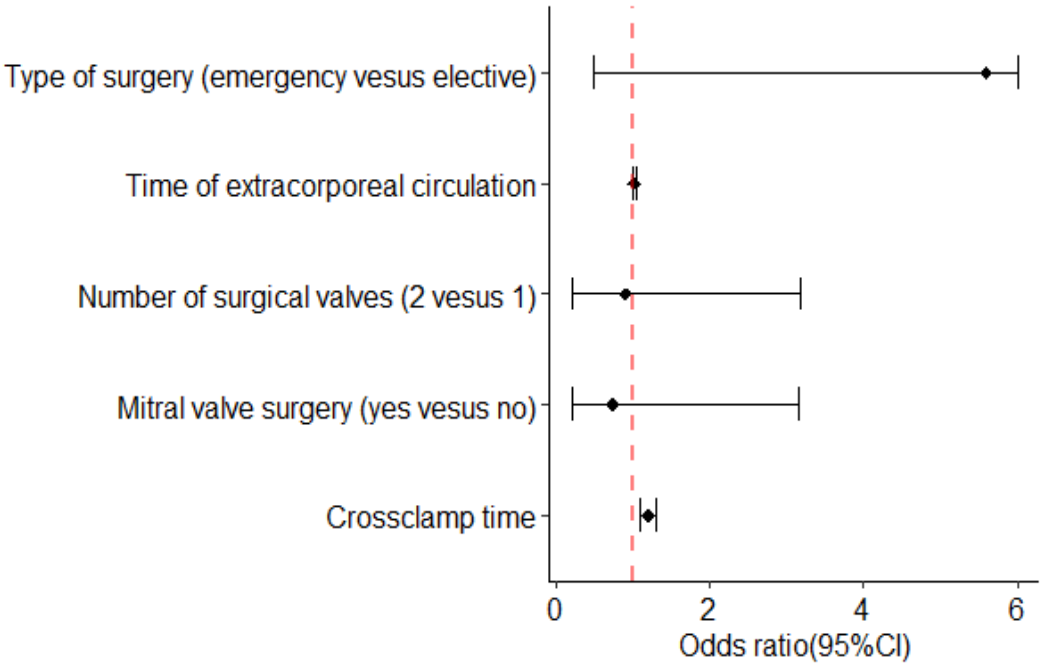

Figure 2: The intraoperation prognostic factors

The intraoperation prognostic factors were analyzed by univariable logistic regression method, the results were shown in Figure 2. The increase of extracorporeal circulation time increased the risk of LCOS (OR=1.02, 95%CI 1.02-1.04). Crossclamp time also gave similar results (OR=1.2, 95%CI 1.1-1.2).

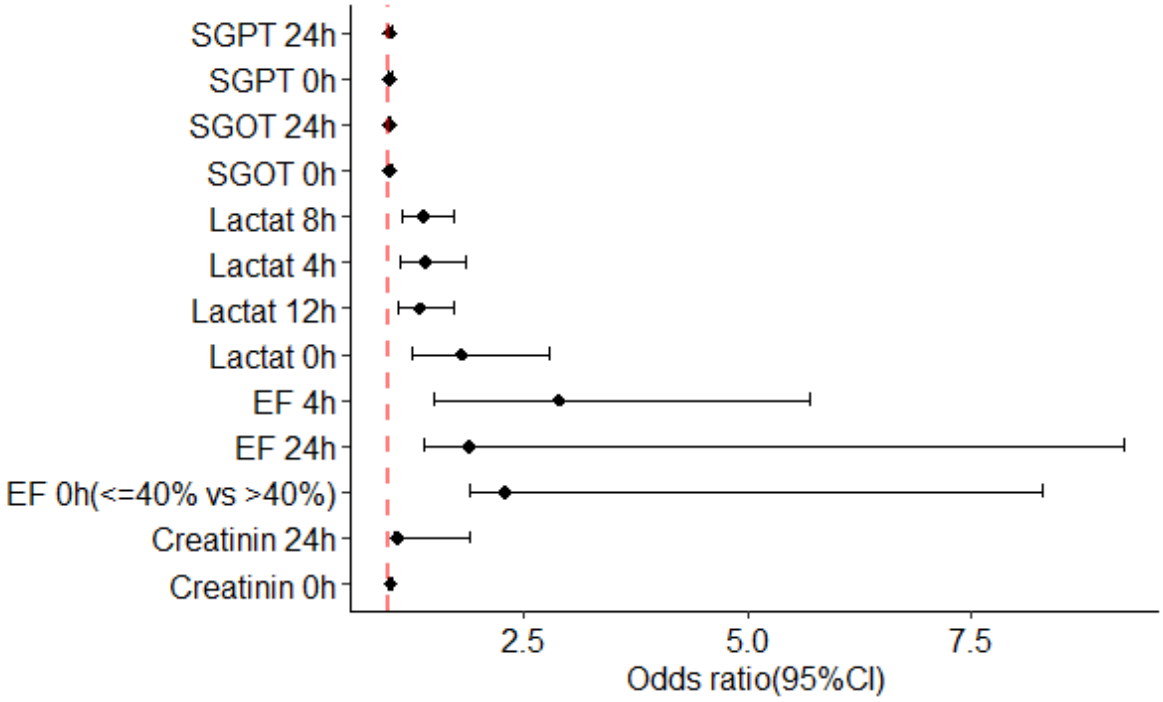

Figure 3: The postoperation prognostic factors

The postoperative laboratory results when analyzing with univariate logistic regression method were presented in Figure 3. The diagram shows the left ventricular systolic function at 0h, 4h and 24h after surgery was an independent prognostic factor for LCOS with EF 0h (OR=2.3, 95%CI 2.4-8.9), EF 4h (OR=2.9, 95%CI 1.9-6.7), EF 24h (OR=1.9, 95%CI 1.5-9.5). Blood lactate level at 0h (OR=1.81, 95%CI 1.25-2.8), 4h (OR=1.41, 95%CI 1.13-1.85), 8h (OR=1.38, 95) %CI 1.14-1.73), 12h (OR=1.35, 95%CI 1.11-1.72) was an independent prognostic factor. Serum creatinine concentration at 24h after surgery is a predictor of LCOS with OR=1.02, 95%CI 1.01-1.04.

4. Discussion

LCOS is an important complication after cardiac valve surgery, contributing to an increased risk of postoperative mortality by 12-25 times [3]. Depending on different studies with different research subjects such as coronary bypass surgeries, mitral valve diseases surgeries, congenital heart disease surgeries, the rate of LCOS after surgery fluctuates between 2-30% [3]. A study on a group of cardiac surgery patients using cardiopulmonary bypass by author Andra E. Duncan and colleagues in 6067 patients showed the rate of LCOS after surgery at 10%[3]. Author Manjula D. Maganti and colleagues conducted a study on 2255 patients with valve surgery, the results for the LCOS rate were 3.9%[9]. In addition, the author also conducted a study on 3039 patients undergoing mitral valve surgery. The results showed that the rate of LCOS was 7% [10]. Another study by author WenJun Ding on 205 patients with coronary artery bypass graft surgery showed that the LCOS rate was 13.5%[12]. In my study, the LCOS rate was 28.3%.

The clinical characeristics of LCOS is due to an imbalance between oxygen distribution and tissue oxygen demand [5]. Therefore, the goal of treatment is to maintain adequate tissue oxygenation with aggressive medical therapy and mechanical support [7]. In my study, among 17 patients diagnosed with LCOS after surgery, 41.2% of patients needed IABP support and 58.8% of patients responded to aggressive medical treatment.

The risk factors play a very important role in early detection and timely treatment of LCOS after surgery. Therefore, many authors have conducted studies to find out the risk factors of LCOS after surgery. In this study, after performing univariate logistic regression, I found out some risks of LCOS after cardiac valve surgeries: Left ventricular systolic function before surgery, left ventricular systolic function at 0h, 4h and 24h after surgery. Blood lactate levels at 0h, 4h, 8h, and 12h after surgery. Extracorporeal circulation time, crossclamp time and serum creatinine concentration at 24 h after surgery.

Left ventricular systolic function was assessed by echocardiography through the EF index. Research shows that EF ≤40% increases the risk of LCOS after surgery. At the time before surgery was OR=12.9, 95%CI 1.73 – 26.5). After surgery at the time points EF 0h OR=2.3, 95%CI 2.4-8.9, EF 4h OR=2.9, 95%CI 1.9-6.7, EF 24h OR=1.9, 95%CI 1.5-9.5, this result also similar to other studies. Author Manjula D. Maganti studied on aortic valve surgery patients and showed that EF <40% increased the risk of LCOS with OR= 3.6, 95%CI 1.9–6.8 [9]. WenJun Ding studied on patients undergoing coronary artery bypass graft surgery, the results were similar with OR = 2.05, 95%CI 1.53-4.54 [12].

This study showed that the duration of extracorporeal circulation and the duration of crossclamp time were predictive factors for LCOS after surgery. The duration of extracorporeal circulation and crossclamp time were longer in patients with LCOS. This result is similar to the result from Manjula D. Maganti, WenJun Ding, Andra E. Duncan when studied on 3039 patients underwent isolated mitral valve surgery with or without coronary bypass surgery, all showed the duration of extracorporeal circulation and crossclamp were the main prognostic factors for LCOS [3,9,10,12].

Acute kidney injury is a complication after open cardiac surgeries and it is also a risk factor of LCOS. In my study and the studies of other authors, it was shown that the post-operative serum creatinine concentration is a predictor of LCOS after surgery [9,10,12].

Low cardiac output syndrome (LCOS) is defined as a decrease in cardiac index (CI) <2.0L/min/m2 and systolic blood pressure <90mmHg, accompanied by signs of tissue hypoperfusion (cool peripheries, clammy skin, altered mental status, oliguria, increased blood lactate levels) and the need to use medicines or mechanical circulatory support to improve patient hemodynamics. For a patient with LCOS, the first presenting symptom is organ hypoperfusion, in which lactate levels are sensitive markers of, so it is a prognostic factor of LCOS. In my study, lactate level at 0h, 4h, 8h and 12h after surgery was an independent predictor of LCOS. The result is similar in the study of the Najib Advani, Ludhmila A Hajjar, Liang Hong when studying lactate levels as the prognosis factor of patients after open cardiac surgeries [2,6,8].

5. Conclusion

Low cardiac output syndrome is a severe complication after open cardiac surgeries. It is accounted for 28.3% in this study. 58.8% of LCOS patients responded to medical treatment and 41.2% of patients needed mechanical support IABP (Intra-Aortic balloon pump).

Using univariate logistic regression analysis, the study found that independent prognostic factors including: EF <=40% before sugery (OR=12.9, 95%CI 1.73 – 26.5), EF 0h (OR=2.3, 95%CI 2.4-8.9), EF 4h (OR=2.9, 95%CI 1.9-6.7), EF 24h (OR=1.9, 95%CI 1.5-9.5), blood lactat level after surgery at 0h (OR=1.81, 95%CI 1.25-2.8), 4h (OR=1.41, 95%CI 1.13-1.85), 8h (OR=1.38, 95%CI 1.14-1.73), 12h (OR=1.35, 95%CI 1.11-1.72), serum creatinin concentration at the time 24h after surgery (OR=1.02, 95%CI 1.01-1.04), the duration of extracorporeal circulation (OR=1.02, 95%CI 1.02-1.04), and the duration of crossclamp time (OR=1.2, 95%CI 1.1-1.2).

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