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Association of hematological and biochemical tests and complications after cardiovascular surgery

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Abstract

Cardiac surgery has postoperative complications of varying severities. Knowing the predictors of such complications can minimize risks and increase patient survival. However, studies address postoperative complications without any standardization of predictors of such complications. The objective of this study was to evaluate the association of hematological and biochemical parameters in the pre- and postoperative period with general clinical complications and those according to organ affected in the postoperative period of cardiac surgery. This is a cross-sectional, retrospective, analytical and documentary study. Inclusion criteria: Elective myocardial revascularization surgeries and/or valve replacements with a cardiopulmonary bypass from January to December 2017, in patients older than 18 years old, survivors until hospital discharge. Incomplete medical records were excluded. Ethical research precepts were followed. 194 patients were included. Preoperative leukocyte alterations increased the chance of postoperative complications by 8.24 times (p=0.039); high mean INR values in the first postoperative period were associated with complications (p=0.036); changes in creatinine (p=0.020) and INR (p=0.002) in the first and second postoperative period were associated with complications, in addition to changes in hemoglobin associated with cardiac complications on the third postoperative day (p≤0.001). There was an association between: leukocyte alteration prior to surgery and total postoperative complications; postoperative hematological and biochemical changes and complications in general and by affected organ. These results can support the development of risk indicators. This also indicates the need to improve monitoring of leukocyte levels, INR, hemoglobin, and creatinine, perceived as predictors of surgical complications.

Keywords: Cardiovascular Surgical Procedures. Clinical Laboratory Techniques. Postoperative Complications.

INTRODUCTION

Contemporary lifestyle habits, associated with increased life expectancy, increase the occurrence of cardiovascular diseases[1]. In Brazil, in 2018, 1,309,774 people were diagnosed with diseases of the circulatory system[2]. Surgery is a therapeutic modality, and some of the most frequently performed procedures are myocardial revascularization (MRS) and the correction of valvular diseases, using the conventional non-pulsatile cardiopulmonary bypass (CPB) technique[3]. However, they cause complex pathophysiological conditions[4], with important organic repercussions, clinical instability, with subsequent manifestations of severe complications in the postoperative period and of different causes[5].

Some studies address postoperative complications[6,7], however, there is no

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standardization regarding predictors of such complications. There is also a lack of studies on hematological and biochemical parameters for predicting surgical outcomes, since some publications use mortality as the main outcome, without considering the importance of other complications[8], regardless of complexity, as well as their association with factors prior to the surgical procedure[6,7,8]. These factors make it possible to establish care according to the predictability of postoperative complications[9,10,11]. Therefore, controversies in relation to studies that address the theme are perceived.

Furthermore, knowing the predictors of complications in patients undergoing cardiac surgery is necessary to reduce risks and improve survival. Among these, hematological and biochemical alterations that have not yet triggered diseases stand out, whose levels are evaluated according to clinical history in the preoperative routine[8], with the intention of obtaining information from the patient prior to the procedure[7].

Due to the accuracy of hematological and biochemical tests, their reproducibility and applicability for clinical monitoring, it is possible to infer that their measurement contributes to the identification of potential complications[9], individually predicting the necessary care needed for the surgical patient, in order to develop preventive strategies[10,11].

Thus, it is assumed that hematological and biochemical alterations, both prior to and in the trans- and postoperative periods, contribute to the manifestation of clinical complications. This study aimed to evaluate the association of hematological and biochemical parameters in the pre- and postoperative period with general clinical complications and those according to organ affected in the postoperative period of cardiac surgery.

METHODS

This is a cross-sectional, retrospective, analytical and documentary study, based on the analysis of data contained in the medical records of patients undergoing cardiac surgery. The study was carried out at a Level IV General Hospital in the Northwest Region of the state of Rio Grande do Sul, Brazil. The Ethics and Research Committee of the Regional University of the Northwest of the State of Rio Grande do Sul – UNIJUÍ, approved this study, according to opinion No. 1.983.681. The study flowchart with the description of the inclusion and exclusion criteria are shown in figure 1.

The variables considered in the patients' profiles were age, sex, and cardiovascular risk factors: systemic arterial hypertension, dyslipidemia, diabetes mellitus, smoking, alcohol consumption, sedentary lifestyle, history of acute myocardial infarction, family history of arterial disease, and surgical history.

The study factors were hematological and biochemical variables measured in different periods, including: preoperative period, collected within 15 days prior to the surgical procedure, in different laboratories according to the patient's choice and in the postoperative periods measured according to evaluation and individual clinical criteria in the immediate postoperative period (IPO), first postoperative day (1PO), second postoperative day (2PO), and third postoperative day (3PO), which are times where there was a higher percentage of examinations. The following variables were analyzed: hematological variables - hematocrit, hemoglobin, leukocytes, platelets, prothrombin time (PT), and international normalization ratio (INR); and the biochemical variable - creatinine. In the

postoperative period, the glucose variable was added, due to the relevance of the measurement. Such exams were categorized according to updated references in results: adequate (normal levels), high (levels above normality standards) and low (levels below normality standards).

The reference parameters of hematological and biochemical tests are presented in Table 1.

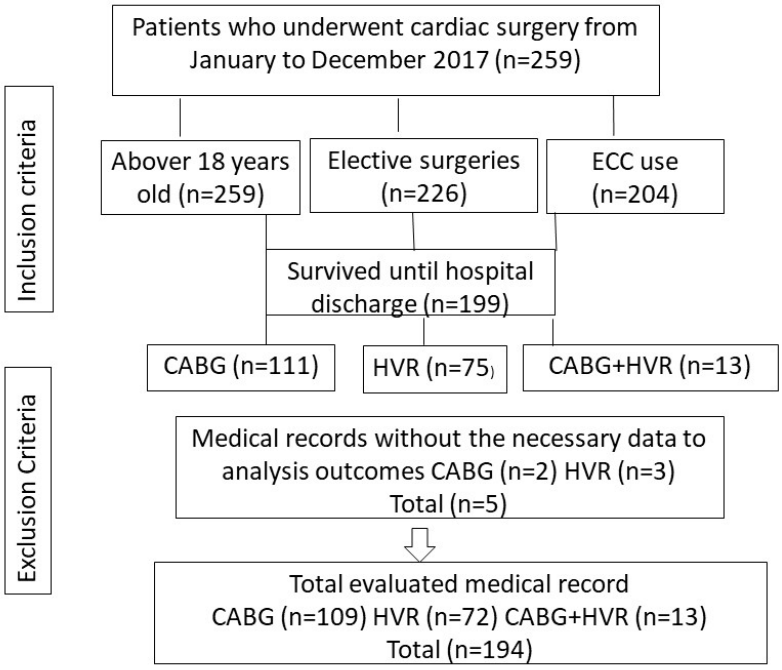

Figure 1 – Flowchart of inclusion and exclusion of the medical records. Ijuí, (RS), Brazil, 2017.
MRS: myocardial revascularization surgery; HVR: heart valve replacement surgery; ECC: extracorporeal circulation

Table 1 – Reference Parameters of Hematological and Biochemical Exams, used to evaluate the results of patient exams. Ijuí, (RS), Brazil, 2017.

Hematological and Biochemical Exams		Reference Parameters
Hematocrit	Men	14 - 18 g/dL proposed by Azevedo[12]
	Women	12 – 16 g/dL proposed by Azevedo[12]
Hemoglobin	Men	40 – 54% proposed by Azevedo[12]
	Women	37 – 47% proposed by Azevedo[12]
Leukocytes		4,000 to 11,000/mm3 proposed by Azevedo[12]
Platelets		150,000 to 450,000/mm3 proposed by Yun *et. al.*[13]
INR		0.8 to 1 proposed by Amaral *et. al.*[14]
Prothrombin time		10 to 15 seconds proposed by Pereira *et. al.*[15]
		Biochemical Variables
Creatinine		0.50 to 1.20 mg/dL proposed by Dusse *et. al.*[16]
Glucose		70 to 100 mg/dL proposed by the American Diabetes Association[17]

Note: g/dL: gram per deciliter; mg/dL: milligrams per deciliter; mm3: cubic millimeter; INR: International Normalized Ratio.

The study outcomes were postoperative clinical complications at the hospital level, subdivided according to the affected organ: cardiac (acute myocardial infarction, low cardiac output, vasoplegic syndrome, cardiac arrhythmias, hypertensive crisis, pericarditis, and cardiac tamponade); respiratory (acute respiratory failure, atelectasis, pneumothorax, pleural effusion, pulmonary embolism, and pneumonia); renal (low urine output and acute kidney failure); neurological (stroke and confusional state); circulatory (continuous bleeding with hemodynamic repercussion); gastrointestinal (upper gastrointestinal bleeding, perforation of gastroduodenal ulcer, mesenteric ischemia, jaundice, and acute cholecystitis); integumentary (operative wound with signs of infection); and thermoregulation (hyperthermia). They were also stratified in a generalized way throughout the postoperative period, regardless of the affected organ, described as general complications, as well as categorized between the IPO and PO3 periods, shown in table 3.

Descriptive statistical procedures were used for data analysis, such as: mean and standard deviation for quantitative variables, and for qualitative variables, absolute and relative frequency were used. Data normality was tested using the Kolmogorov-Smirnov test. To verify the association between two or more qualitative variables, Pearson's chi-squared hypothesis test and Fischer's exact test were used. For quantitative variables, a comparison of means test was used, for parametric and independent samples Student's t-test was used, and to test the homogeneity of variance Levene's test was applied. Odds Ratios (OR) were also calculated to verify the association between hematological and biochemical alterations prior to surgery and the presentation of postoperative complications. For all tests, a 5% level of significance was considered.

RESULTS

There was a predominance of males (71.1%), 31.4% were smokers, and 2.6% were alcoholics. Among the comorbidities, 30.4% had dyslipidemia, 88.7% hypertension, 30.4% diabetes, 41.8% declared themselves to be sedentary, 28.9% have had an acute myocardial infarction, 33.5% have a family history of cardiovascular diseases, and 28.9% had already undergone previous surgeries. The mean age was 62.6±9.9 years, a minimum of 31 years and a maximum of 83 years, and the mean length of stay was 6.12 ±2.80 days.

In this study, an increase in leukocyte values was observed, above the parameters, in tests prior to surgical intervention, thus, increasing the chance of having postoperative complications by 8.24 times, with a statistical significance (p=0.039) (Table 2). The mean number of leukocytes in the preoperative period was 7,226±2,496/mm³, with a minimum of 1700/mm³ and maximum of 18,000/mm³.

Table 2 – Association between hematological and biochemical tests in the preoperative period and general complications in the postoperative period of cardiac surgery (n=194), Ijuí (RS), Brazil, 2017.

		Complications			
		N	Yes (n/%)	No (n/%)	Sig.
Hemoglobin	Adequate		49/51	47/49	0.521
	Altered Higher	178	1/25	3/75	
	Altered Lower		42/53.8	36/46.2	
Hematocrit	Adequate		36/51.4	34/48.6	0.996
	Altered Higher	180	2/50	2/50	
	Altered Lower		55/51.9	51/48.1	
Leukocytes	Adequate		79/49.4	81/50.6	0.039
	Altered Higher	173	9/90	1/10	
	Altered Lower		2/66.7	1/33.3	
Platelets	Adequate		83/51.6	78/48.4	0.809
	Altered Higher	177	2/66.7	1/33.3	
	Altered Lower		6/46.2	7/53.8	
INR	Adequate		58/48.7	61/51.3	0.786
	Altered Higher	164	23/51.1	22/48.9	
	Altered Lower		-	-	
PT	Adequate		54/48.2	58/51.8	0.437
	Altered Higher	130	5/50	5/50	
	Altered Lower		2/25	6/75	
Creatinine	Adequate		16/40	24/60	0.090
	Altered Higher	168	26/56.5	20/43.4	
	Altered Lower		46/56	36/44	

Note: Pearson's Chi-squared test, with significance level ≤0.05%.

When associating the mean of altered hematological and biochemical tests on 1PO with the occurrence of general complications during the postoperative period (Table 3), higher mean values of INR (p= 0.036) were observed among the patients who had complications, of these 80.9% had higher levels of INR.

When associating the means of preoperative hematological levels with 1PO, leukocytes rise from 7.267±2.51/mm³ to 14.769±4.48/mm³ (p≤0.001) and INR from 0.974±0.91 to 1.06±0.18 (p=0.263). Furthermore, a decrease in hemoglobin from 13.07±1.77 g/dL to 10.42±1.50 g/dL (p≤0.001) as well as in hematocrit from 39.530±5.07% to 31.224±4.65% (p≤0.001) was observed.

Table 3 – Association between the mean number of altered hematological and biochemical tests on the 1st PO and general complications in the cardiac postoperative period (n=194), Ijuí (RS), Brazil, 2017.

Altered exams		Complications			
		N	Mean	Standard Deviation	Sig.
Hemoglobin	Yes	93	10.433	1.4999	0.166
	No	93	10.372	1.5517	
Hematocrit	Yes	93	31.289	4.5711	0.561
	No	93	31.082	4.7375	
Leucocytes	Yes	93	15.16559	4.769115	0.189
	No	93	14.32903	3.824679	
Platelets	Yes	93	164.93548	55.958992	0.864
	No	93	163.58065	51.325119	
INR	Yes	91	1.3379	0.36896	0.036
	No	91	1.2367	0.37988	
PT	Yes	58	1.0819	0.22366	0.158
	No	65	1.0383	0.09955	
Creatinine	Yes	42	169.62	58.134	0.910
	No	38	168.34	40.376	

Note: Student's t test, with significance level ≤0.05%.

The analysis between the association of stratified biochemical and hematological tests per day after the surgical procedure with complications up to 3PO (Table 4) showed statistical significance between complications and changes in INR on 1PO (p=0.002) and on 2PO (p≤0.001). 1PO creatinine (p=0.020) was also associated with complications, although only 5.2% of patients had kidney damage and in 66.66% creatinine values were adequate.

Mean creatinine values between the preoperative period and the IPO showed a decline from 1.239±0.268 mg/dL to 1.104±0.447 mg/dL (p≤0.001). Between IPO and 1PO there was an increase from 1.248±0.269 mg/dL to 1.285±0.370 mg/dL (p=0.052).

The INR displayed a different tendency: minimum values were equal between IPO and 1PO (0.88); the mean decreased between the periods from 1.12±0.141 to 1.05±0.170; and maximum values increased from 1.83 to 2.56. Both parameters demonstrated a decrease in all mean values from 2PO onwards.

As for the other biochemical and hematological tests, significant changes were observed, however, without statistical significance. Glucose showed equal mean values in IPO and 1PO, with an increase in minimum and maximum levels. Leukocytes showed higher mean, minimum and maximum values at 1PO compared to IPO. After 2PO, there was a reduction in all mean levels, in both glucose and PT. Moreover, hemoglobin, hematocrit, platelets, and PT showed a decrease in the average, maximum, and minimum values starting from IPO.

Table 4 – Association of hematological and biochemical tests (IPO, 1PO, 2PO, and 3PO) and general complications between IPO and 3PO of cardiac surgery (n=194), Ijuí (RS), Brazil, 2017.

		Complications															
		IPO				IPO				2PO				3PO			
		N	Yes (n/%)	No (n/%)	Sig.	N	Yes (n/%)	No (n/%)	Sig.	N	Yes (n/%)	No (n/%)	Sig.	N	Yes (n/%)	No (n/%)	Sig.
HEMOG	A		17/21.8	28/25	0.855		12/15.4	12/11.1	0.391		0/0	0/0	0.414		1/2.2	2/3.5	0.581
	H	190	1/1.3	1/0.9		186	-	-		174				103	-	-	
	L		60/76.9	83/74.1			66/84.6	96/88.9			72/100	102/100			45/97.8	55/96.5	
HEMAT	A		14/17.9	25/22.3	0.775		2/2.6	4/3.7	0.504		-	-	0.585		1/2.2	1/1.8	0.696
	H	190	1/1.3	1/0.9		186	-	-		176	0/0	1/1		104	-	-	
	L		63/80.8	86/76.8			76/97.4	104/96.3			73/100	102/99			45/97.8	56/98.2	
LEUC	A		22/32.4	31/29.5	0.693		18/23.1	19/17.6	0.355		25/34.2	39/37.9	0.623		31/67.4	40/70.2	0.796
	H	173	46/67.6	74/70.5		186	60/76.9	89/82.4		176	48/65.8	64/62.1		103	15/32.6	17/29.8	
	L		-	-			-	-			-	-			-	-	-
PLAT	A		53/77.9	80/76.2	0.713		54/69.2	69/63.9	0.610		30/41.10	40/38.8	0.679		20/43.48	20/35.11	0.417
	H	173	0/0	1/1		186	5/6.4	11/10.2		176	-	-		103	0/0	1/1.74	
	L		15/22.1	24/22.9			19/24.4	28/25.9			43/58.90	63/61.2			26/56.52	36/63.15	
ISR	A		9/13.8	16/15.7	0.745		9/19.1	25/47.3	0.002		6/19.4	33/61.1	≤0.001		4/25	6/60	0.074
	H	167	56/86.2	86/84.3		111	38/80.9	39/52.7		85	25/80.6	21/38.9		26	12/75	4/40	
	L		-	-			-	-			-	-			-	-	
PT	A		57/89.1	99/96.1	0.073		47/94	74/96.1	0.442		32/100	53/96.4	0.397		15/93.8	10/100	0.615
	H	167	7/10.9	4/3.9		127	3/6	3/3.9		87	0/0	2/3.6		26	1/6.2	0/0	
	L		-	-			-	-			-	-			-	-	
GLICO	A		6/7.9	9/8.3	0.929		3/7.7	0/0	0.111		3/16.7	9/42.9	0.077		2/22.2	6/40	0.279
	H	185	70/92.1	100/91.7		80	36/92.3	41/100		39	15/83.3	12/57.1		19	6/66.7	5/33.3	
	L		-	-			-	-			-	-			1/11.1	4/26.7	
CREAT	A		53/74.6	79/76.3	0.670		29/38.2	59/55.7	0.020		42/59.2	69/69	0.184		23/53.05	36/64.3	0.278
	H	173	18/25.4	23/22.5		182	47/61.8	47/44.3		174	29/40.8	31/31		99	20/46.5	20/35.7	
	L		-	-			-	-			-	-			-	-	

Note: Student's t test and Fisher's exact test, with significance level ≤0.05%.

When associating the changes in hematological and biochemical tests stratified by postoperative day and complications according to the affected organ, there is statistical significance between changes in hemoglobin on IPO with cardiac complications on 3PO (p≤0.001).

Among the most frequent complications in this study, the following stand out: respiratory complications in 36.1% of the patients, of these 54.3% were pleural effusion, 21.4% pleural effusion and atelectasis, and 12.9% atelectasis, followed by cardiac complications in 8.8% of the patients, of which 70.6% had cardiac arrhythmia, 17.6% had low cardiac output, and 5.9% had acute myocardial infarction. Of the total number of cardiac complications, 2.2% occurred on 3PO.

DISCUSSION

Previous studies[7,18] state that the preoperative evaluation predicts risks, which support decision-making regarding the performance of the procedure, stabilization of the clinical picture, or even cancellation of the surgery, if the risk exceeds the benefit. It also ensures adequate postoperative evolution with reduced hospital stay and the need for intensive care.

In this study, hematological and biochemical parameters can be seen with small variations in the normality rate in the preoperative period, a fact that is in line with the assumptions of the literature regarding the careful evaluation prior to the surgical procedure, in order to minimize risks, ensuring safety and therapeutic efficacy.

Leukocyte alterations, especially those above normal levels, were associated with general postoperative complications, as well as greater chances of developing complications. Elevated leukocyte count is considered a cardiovascular risk marker[19], which plays an important role in inflammatory diseases, such as coronary heart disease, as it is related to the intensity of the inflammatory response[20]. This response is the main driving force in the prolongation of the pathological condition in cardiac events[21] by activating innate immune pathways, as well as inflammatory leukocytes to carry out the phagocytotic process in the surgical wound[22].

The rise in the total leukocyte count occurred until the first postoperative day, a fact that may be associated with the inflammatory effects of cardiopulmonary bypass, which include leukocyte activation, especially in the first 24 hours after surgery[23]. The inflammatory response, when exacerbated, can cause several physiological changes in different organs and systems[24].

A study developed with patients undergoing cardiac surgery associated an increase in preoperative total leukocytes with a higher risk of arrhythmias[25]; however, the data are still insufficient to clarify the main mechanisms involved in the elevation of leukocyte counts prior to surgery and its potential as a predictor of postoperative complications, as well as its relationship with the manifestation of general surgical complications.

Patients with complications resulting from the surgical intervention showed higher mean INR values on 1PO, a behavior that was maintained until 2PO. We also verified a mean reduction in INR between IPO and 1PO, with a maximum peak after 24 hours of surgical intervention compared to the preoperative period.

The INR measures changes in the extrinsic pathway of coagulation, indicated for laboratory monitoring in oral anticoagulation therapy; however, it is widely used in other populations due to its reproducibility and low cost[26]. There is no evidence of the resolvability of monitoring INR in cardiac surgery, given the complexity of the surgical procedure[27].

The ability to predict the risk of INR is controversial, however high values may indicate risk of bleeding/hemorrhage[26]. Several studies[28,29] relate changes in the coagulogram to bleeding complications. There are no consistent reports in the literature that assess the association of INR changes with complications in other systems of the human body. In this study, we observed an association between manifesting postoperative complications regardless of the affected organ and increased mean INR values.

General complications in the postoperative period are associated with activation of the hemostatic system during cardiopulmonary bypass, responsible for pro- and anticoagulant activity, which suffer hereditary influences. The levels of clotting proteins determine the susceptibility of surgical complications. In the conventional modality, despite the dilution and hemodepression of static cells and proteins, there

is little effect on the generation of thrombin[30], which is the main agent of blood clotting that acts at multiple points in the hemostatic process[31].

The elevation of this protein after reperfusion may be related to myocardial ischemia-reperfusion injury and impaired hemodynamic recovery. Its basal level normalizes from hours to days after the occurrence of this process[30,32]. When observing the INR values on consecutive postoperative days in our study, a contradictory behavior was observed, with an increase in maximum values up to 1PO and a reduction in mean levels, associated with a decrease in the total number of tests measured.

Creatinine was another altered biochemical variable, which occurred on the 1st PO and was associated with the presence of general complications from IPO to 3PO. In our study, this biochemical parameter showed a reduction in mean values from the preoperative period to IPO, and a subsequent increase on 1PO.

In contrast to our study, the elevation of preoperative baseline creatinine level ≥ 0.4 mg/dL is considered a risk factor for serious complications[33], its increase is estimated around 36 hours after the initial peak, with a subsequent decline[34,35]. However, subclinical changes are also predictors of events that can trigger kidney damage[4]. These data are in line with the findings of this study, since, of the patients who manifested kidney damage, most exhibited adequate parameters.

Among the causes of creatinine alteration, the following stand out: cardiopulmonary bypass; non-pulsatile flow; nephrotoxic effects of drugs used pre-, trans- and postoperatively[33,36]; arterial hyper and hypotension, decompensated congestive and ischemic heart failure; cardiac arrest episodes; hypovolemia; and thromboembolism[36].

In the present study, due to the lack of guidelines that provide guidance on the measurement of hematological and biochemical parameters in cardiac surgery, we evaluated the tests performed by clinical indication for up to 72 hours. Due to the invasiveness of cardiac surgery, such parameters change immediately after the surgical intervention, which then undergo a stabilization process through homeostasis starting from 2PO[23]. On the other hand, the manifestation of clinical complications can extend for a longer period, in order to verify this time range, we associate hematological and biochemical alterations with complications during the postoperative period, as well as a more restricted time from IPO to 3PO, with the intention of verifying possible discrepancies.

Hemoglobin alterations at IPO showed a significant association with cardiac complications on 3PO. There is a relationship described in the literature of changes in this parameter in the preoperative period to the increased risk of postoperative morbidity[8], which indicates the need for a careful assessment of preoperative hemoglobin levels, in order to determine the cancellation of the procedure or follow-up in the periods after intervention. Among the causes of reduced hemoglobin levels after surgery are: bleeding (intra- and postoperatively) and hemodilution caused by cardiopulmonary bypass[37]. Also, the decrease in hemoglobin is related to a parallel increase in inflammatory proteins, especially in acute myocardial infarction, so it is possible to assume an association between a decrease in hemoglobin and the inflammatory response resulting from cardiac surgery[38], observed herein. The decline in this biochemical parameter may be related to low cardiac output syndrome[39], which justifies its significant association with cardiac complications.

Studies[25,40] that evaluated the relationship between changes in hematological parameters and postoperative complications do not clarify the reason for these associations but assume that the altered indices reflect a subclinical chronic inflammatory state.

By relating pre- and postoperative hematological and biochemical tests to the

manifestation of clinical complications in elective and surviving patients, this study contributes to improve the literary gap regarding predictors of postoperative complications. Among the limitations of the study, we highlight that this was a retrospective study, medical records were used, this was unicentric, and there was lack of a standardized description of postoperative complications of cardiac surgery in the literature. Furthermore, there was the lack of a protocol for pre- and postoperative hematological and biochemical tests according to the degree of risk, with an established routine for collection that not only contemplates measurement criteria, but also considers potential drugs and previous diseases interfering in the analyses. Finally, there was a lack of follow-up in the late postoperative period.

CONCLUSION

Among the main findings of this study, the following stand out: 1) association between leukocyte changes prior to surgical intervention and complications; 2) association between mean INR changes and complications; 3) association of altered INR and creatinine tests stratified by day after the surgical procedure and complications from IPO to 3PO; 4) association between changes in hemoglobin and cardiac complications.

This study showed a probable association, with strong evidence, between hematological alterations, both pre- and postoperatively, and biochemical alterations after surgical intervention with the manifestation of complications. The results may support the development of risk indicators for patients of lesser clinical severity undergoing coronary artery bypass graft surgery or valve replacement with a conventional non-pulsatile cardiopulmonary bypass technique.

We suggest improving the monitoring of hematological and biochemical levels, especially of leukocytes, hemoglobin, INR, and creatinine, perceived according to our results as predictors of postoperative complications. However, it is not possible to say that such associations meet the criteria of independent predictors. Therefore, more studies are needed on the subject in order to subsidize evidence, to enable safe and effective care for heart surgery patients.

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All authors have read and agreed with the published version of the manuscript

REFERENCES

1. Mello JM, Oliveira BPKD Muller EV, Grden CRB, Pinheiro FK, Borges WS. Internações por doenças crônicas não transmissíveis do sistema circulatório, sensíveis à atenção primária à saúde. Texto contexto - Enferm. 2017;26(1):1-11.doi: 10.1590/0104-07072017003390015.
2. Brasil. Ministério da Saúde. Departamento de Informática do SUS (DATASUS). Procedimentos Hospitalares do SUS: por local de internação: Brasil. Brasília. Ministério da Saúde; 2018. Disponível em: http://tabnet.datasus.gov.br/cgi/deftohtm.exe?sih/cnv/qiuf.def
3. Dordetto PR, Pinto GC, Camargo RTCS. Pacientes submetidos à cirurgia cardíaca: caracterização sociodemográfica, perfil clínico-epidemiológico e complicações. Revista da Fac. Ciênc. Méd. Sorocaba. 2016;18(3):144-149. doi: 10.5327/Z1984-4840201625868
4.Altınkaya Çavuş M, Gökbulut Bektaş Ş, Demir A. Postoperative renal damage in heart surgery. GKDA Derg. 2019;25(2):126-132. doi:10.5222/GKDAD.2019.29200
5. Hussain, SMA, Amer H. Complications of coronary artery bypass grafting. Int. J. Med. Rev. 2019;6(1):1-5. doi:10.29252/IJMR-060101
6. Goldfarb M, Drudi L, Almohammadi M, Langlois Y, Noiseux N, Perrault L, Piazza N, Afilalo J. Outcome reporting in cardiac surgery trials: systematic review and critical appraisal. J. Am. Heart Association. 2015 Aug 17;4(8): e002204. doi.10.1161/JAHA.115.002204
7. Balci E, Aykut A, Demir A, Sabuncu Ü, Koçulu R, Karadeniz Ü. In-hospital mortality and complications following coronary artery bypass surgery; is it possible to predict with preoperative values? JARSS. 2019;27(1):56-62. doi:10.5222/jarss.2019.32042
8. Aydinli B, Demir A, Ozmen H, Vezir Ö, Ünal U, Özdemir M. Can preoperative HbA1c values in coronary surgery be a predictor of mortality? Turk. J. Anesthesiol Reamin. 2018; 46 (3): 184-190. doi:10.5152/TJAR.2018.46667
9. Biomarcadores em Cardiologia - Parte 1 – Na insuficiência Cardíaca e nas Cardiomiopatias Específicas. Arq. Bras. Cardiol. [Internet]. 2014;103(6):451-459. doi:10.5935/abc.20140184
10. Khan F, Hashmi S, Naeem SS, Fatima B, Hanif H, Khan MZ, Fatimi SH. Perio-perative determinants of prolonged CICU stay after coronary artery bypass graft surgery in elderly at a private tertiary care hospital: A case control study. J Pak Med Assoc. 2016; 66 (10):19-23. Disponível em: https://ecommons.aku.edu/cgi/viewcontent.cgi?article=1121&context=pakistan_fhs_mc_surg_surg
11. Arthur CP, Mejia OA, Osternack D, Nakazone MA, Goncharov M, Lisboa LA, Dallan LA, Pomerantzeff PM, Jatene FB, de Estudo REPLICCAR G. É Necessário Personalizar a Avaliação da Função Renal na Estratificação de Pacientes Submetidos à Cirurgia Cardíaca? Arq Bras Cardiol. 2017;109(4):290-298. doi:10.5935/abc.20170129
12. Azevedo MR. Hematologia Básica: Fisiopatologia e Diagnóstico Laboratorial. 6a ed. Rio de Janeiro: Thieme Revinter; 2019.
13. Yun SH, Sim EH, Goh RY, Park JI, Han JY. Ativação de Plaquetas: os Mecanismos e Potenciais Biomarcadores. Biomed Res. Int. 2016;2016: 1-5. doi:10.1155/2016/9060143
14. Amaral COF, Nascimento FM, Pereira FD, Parizi AGS, Straioto FG, Amaral MSP. Bases para interpretação de exames laboratoriais na prática odontológica. Cient. Ciênc. Biol. Saúde. 2014;16(3):37-229. Disponível em: https://journalhealthscience.pgsskroton.com.br/article/view/459
15. Pereira JPM, Faustino SMM, Rodrigues ÁSN. Análise dos problemas encontrados na execução do coagulograma em laboratórios da cidade de Macapá-Amapá. Ciênc. Equatorial. 2011;1(1):1-8. Disponível em: https://periodicos.unifap.br/index.php/cienciaequatorial/article/viewFile/396/247
16. Dusse LMS, Rios DRA, Sousa LPN Moraes RMMS, Domingueti CP, Gomes KB. Biomarcadores da função renal: do que dispomos atualmente? Rer. bras. anal. clin. 2017;49(1): 41-51. doi:10.21877/2448-3877.201600427
17. Classification and diagnosis of diabetes: standards of medical care in diabetes. Diabetes Care. 2019;42(1):13-28. doi:10.2337/dc19-S002
18. Johansson T, Fritsch G, Flamm M, Hansbauer B, Bachofner N, Mann E, Bock M, Sönnichsen AC. Effectiveness of non-cardiac preoperative testing in non-cardiac elective surgery: systematic review. Br J Anaesth. 2013;110(6):926-939. doi.10.1093/bja/aet071.
19. Bekler A, Erbag G, Sen H, Gazi E, Ozcan S. Predictive value of elevated neutrophil-lymphocyte ratio for left ventricular systolic dysfunction in patients with non ST-elevated acute coronary syndrome. Pak J Med Sci 2015;31(1):159-163. doi:10.12669/pjms.311.59677
20. Wang J, Song J, Wu J, He C, Xu C, Liu Y. Leukocyte count and leukocyte subsets reveal compensatory mechanisms in coronary heart disease. Clin. Chim. Acta 2013; 418: 79-85. doi: 10.1016/j.cca.2012.12.028
21. Cheng B, Chen HC, Chou IW, Tang TW, Hsieh PC. Leveraging early post-injury inflammatory responses to cardiac regeneration. J Biomed Sci. 2017;24(1):7. doi:10.1186/s12929-017-0315-22
22. Bonaventura A, Montecucco F, Dallegri F. Cell recruitment in myocardial ischemia / reperfusion injury. Eur J Clin Invest. 2016;46(6):590-601. doi:10.1111/eci.126333
23. Gabriel EA, Locali RF, Matsuoka PK, Cherbo T, Buffolo E. Cirurgia de revascularização do miocárdio com circulação extracorpórea: características bioquímicas, hormonais e celulares. Braz J Cardiovasc Surg. 2011;26(4):525-531. doi:10.5935/1678-9741.20110041
24. Laffey JG, Boylan JF, Cheng DC. The systemic inflammatory response to cardiac surgery: implications for the anesthesiologist. Anesthesiology. 2002;97(1):215-52. doi:10.1097/00000542-200207000-00030
25. Jour TY, Soleimani AU, Kiabi AUF, Zeydi AU, Mohammad AU. Can white blood cell count be used as a predictor of atrial fibrillation following cardiac surgery? A short literature review. Anadolu Kardiyol Derg. 2014 (2): 216-7. doi:10.5152/

akd.2014.530
26. Weber CF, Görlinger K, Meininger D, Herrmann E, Bingold T, Moritz A, Cohn LH, Zacharowski K. Point-of-care testing: A prospective randomized clinical trial of efficacy in patients with coagulopathic heart surgery. Anesthesiology 2012; 117 (3): 531-547. doi:10.1097/ALN.0b013e318264c644
27. Whiting P, Maiwenn AI, Westwood M, Corro-Ramos I, Ryder S, Armstrong N, Misso k, Ross J, Severens J, Kleijnenet J. Viscoelastic point-of-care testing to assist with the diagnosis, management and monitoring of haemostasis: a systematic review and costeffectiveness analysis. Health Technol. 2015;19(58):1-227. doi:10.3310/hta19580.

28. Elizondo LC, Muguercia H, Díaz I. Acquired coagulopathies in patients admitted to the intensive care unit of hermanos ameijeiras clinical-surgical hospital. Cuban J. Med. 2017; 56:26-38. Disponível em: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0034-75232017000100004&lng=es
29. Lorga Filho, A M et al. Diretrizes brasileiras de antiagregantes plaquetários e anticoagulantes em cardiologia. Arq. Bras. Cardiol. 2013; 101(3): 01-95. doi:10.5935/abc.2013S009.
30. Sniecinski RM, Levy JH. Management of anticoagulation associated with cardiopulmonary bypass. Best Pract Res Clin Anaesthesio. 2015; 29 (2): 189-202. doi:10.1016/j.bpa.2015.03.005.
31. Martini FH, Ober W C, Bartholomew EC, Nath JL. Anatomia e fisiologia humana: uma abordagem visual. 1ª ed. São Paulo: Pearson Education do Brasil, 2014.
32. Lin L, Wang X, Yu Z. Ischemia-reperfusion Injury in the Brain: Mechanisms and Potential Therapeutic Strategies. Biochem Pharmacol (Los Angel). 2016;5(4):213. doi:10.4172/2167-0501.1000213.
33. Santos CA, Barboza OMA, Brandi AC, Husseini BPH, Menin BJC, Santos MA, Fernandes GM, Braile DM. Fatores de risco para mortalidade de pacientes submetidos à revascularização miocárdica Rer. Bras. Cir. Cardiovas. 2014; 29(4): 513-520. doi:10.5935/1678-9741.20140073.
34. Joslin J, Ostermmann M. Care of the critically ill emergency department patient with acute kidney injury. Emerg Med Int. 2012; 2012:760623. doi:10.1155/2012/7606233
35. Gündüz E, Aydoğdu Titiz T. Kardiyak cerrahi ile ilişkili akut böbrek hasarı ve saptanmasında biyomarkerlar, GKDA Derg. 2019;25(2):79-88. doi:10.5222/GKDAD.2019.63497
36. Singbartl K, Kellum JA. AKI in the ICU: definition, epidemiology, risk stratification, and outcomes. Kidney Int. 2012; 81:819-25. doi:10.1038/ki.2011.339
37. Mann DL, Zipes DP, Libby P, Bonow RO. Braunwald: Tratado de Doenças Cardiovasculares. 10ª ed. Rio de Janeiro: Elsevier; 2017. Disponível em: https://eu-ireland-custom-media-prod.s3-eu-west-1.amazonaws.com/Brasil/Downloads/e-sample%20MANN-9788535283174.pdf
38. Wang R, Neuenschwander FC, Nascimento BR. Inflamação pós-Infarto Agudo do Miocárdio: "Médico ou Monstro". Arq. Bras. Cardiol. 2020;115(6):1-2. Disponível em: https://abccardiol.org/wp-content/uploads/articles_xml/0066-782X-abc-115-06-1112/0066-782X-abc-115-06-1112.x44344.pdf
39. Benedetto U, Ng C, Frati G, Biondi-Zoccai G, Vitulli P, Zeinah M, Raja SG. Miniaturized cardiopulmonary bypass versus myocardial revascularization without cardiopulmonary bypass: a meta-analysis of randomized controlled trials. Int. J. Surgery. 2015; 14:96-104. doi:10.1016/j.ijsu.2014.12.021.
40. Fadini GP, Marcuzzo L, Marescotti MC, Kreutzenberg SV, Avogaro U. Elevated white blood cell count is associated with prevalence and development of the metabolic syndrome and its components in the general population. Acta diabetol. 2012; 49(6): 445–51. doi:10.1007/s00592-012-0402-5.

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