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Original Article

Alterations in antioxidant and oxidant status of children after on-pump surgery for cyanotic and acyanotic congenital heart diseases

Firat H. Altin,[1] Hayriye A. Yildirim,[2] Ibrahim C. Tanidir,[3] Okan Yildiz,[1] Meliha Z. Kahraman,[4] Erkut Ozturk,[3] Sinem B. Celebi,[4] Mugisha Kyaruzi,[1] İhsan Bakir[1]

[1]*Department of Pediatric Cardiovascular Surgery;* [2]*Department of Biochemistry;* [3]*Department of Pediatric Cardiology;* [4]*Department of Anesthesiology and Reanimation, Istanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital, Istanbul, Turkey*

Abstract *Objective:* Oxidative stress refers to an imbalance between reactive oxidative species and antioxidants. In this case-controlled, prospective, observational study, we investigated the total oxidant status, total antioxidant status, oxidative stress index, and albumin and C-reactive protein levels of children with cyanotic and acyanotic congenital heart diseases who had undergone on-pump cardiac surgery. *Method:* The study groups consisted of 60 patients with congenital heart disease, who were operated under cardiopulmonary bypass, and a control group of 30 healthy individuals. The patients were classified into two groups. Among them, one was a patient group that consisted of 30 patients with acyanotic congenital heart disease and the other group consisted of 30 patients with cyanotic congenital heart disease. In the patient groups, blood samples were collected before surgery and at one and 24 hours following surgery. In control groups, blood samples were collected once during hospital admission. *Results:* No statistically significant differences were found between the groups in terms of baseline total oxidant status, total antioxidant status, and oxidative stress index values. Regarding the postoperative first-hour and 24-hour total oxidant status and total antioxidant status levels as well as oxidative stress index values, there were no significant differences between the groups, except for an increase in total antioxidant status levels ($p = 0.002$) 24 hours after surgery in cyanotic patients. *Conclusion:* There was no difference between oxidative stress status of cyanotic and acyanotic congenital heart disease patients and healthy individuals. Oxidative stress status of cyanotic and acyanotic patients does not change after cardiac surgery under cardiopulmonary bypass.

Keywords: Antioxidant; oxidant; oxidative stress; cardiopulmonary bypass; cyanotic; acyanotic

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The term "oxidative stress" refers to an imbalance between reactive oxygen species production and antioxidant defences. Cardiopulmonary bypass results in a complex systemic inflammatory response[1] and is known to mediate oxidative stress and contribute to several adverse reactions in the postoperative period.[2] Children are known to tolerate cardiopulmonary bypass less well than adults.[3] There are a few reports in the literature about the oxidative stress status of children after cardiac surgery.[2]

Serum concentrations of each oxidant and endogenous antioxidant species can be measured by individual techniques, but these are complex and costly. Measurement of antioxidants and reactive oxygen species by determining total antioxidant status and total oxidant status, respectively, using colourimetric and automated direct measurement methods, is practical and cost-effective.[4,5] Oxidative

Correspondence to: F. H. Altin, MD, Istanbul Mehmet Akif Ersoy Thoracic And Cardiovascular Surgery Training and Research Hospital, Istasyon Mah.Turgut Ozal Bulvarı No:11 Kucukcekmece, Istanbul 34303, Turkey. Tel: +9 0212 692 20 00; Fax: +9 0212 471 94 94; E-mail: firat3534@yahoo.com

Table 1. Preoperative demographic and anatomic data.

	Control group (n = 30)	Acyanotic group (n = 30)	Cyanotic group (n = 30)	p
Age (months)	30.17 ± 34.1	36.25 ± 29.32	28.99 ± 26.74	0.718
Weight (kg)	12.41 ± 8.8	27.3 ± 43.57	11.51 ± 12.93	0.126
BSA (m^2)	0.54 ± 0.28	0.7 ± 0.42	0.58 ± 0.32	0.414
Gender (M/F)	16/14	17/13	16/14	0.815
Aristotle-B score		5.78 ± 2.14	8.34 ± 1.58	**0.0001**
Aristotle-C score		6.1 ± 2.51	9.31 ± 1.83	**0.0001**
RACHS score		2.05 ± 0.95	2.7 ± 0.66	**0.016**
STS-EACTS MC		1.85 ± 1.09	2.85 ± 0.88	**0.003**

Aristotle-B score = basic Aristotle score; Aristotle-C score = comprehensive Aristotle score; BSA = body surface area; F = Female; kg = kilogram; M = male; m^2 = square metre; RACHS = Risk Adjustment for Congenital Heart Surgery Score; STS-EACTS MC (The Society of Thoracic Surgeons and European Association for Cardiothoracic Surgery mortality categories)
Values are expressed as the mean ± SD

Stress Index is used to evaluate the balance between oxidation and antioxidation.[6]

The aim of this study was to compare the preoperative and early postoperative changes of total antioxidant status levels, total oxidant status levels, and oxidative stress index values of cyanotic and acyanotic congenital heart disease patients, who underwent surgery using on-pump cardiopulmonary bypass, with healthy children.

Patients and methods

Patient characteristics

This case-controlled, prospective, observational study consisted of 60 patients who underwent open-heart surgery for congenital heart defects using cardiopulmonary bypass and 30 demographically matched healthy control subjects at a tertiary cardiac centre between September 2014 and March 2015; two study groups were formed. Among them, one group consisted of 30 patients with acyanotic congenital heart disease, whereas the other group consisted of 30 patients with cyanotic congenital heart disease. The control group consisted of 30 healthy patients who had normal echocardiographic findings. Patients who had had previous open-heart surgery or who had systemic disease, growth retardation, infection, metabolic or genetic disease, or had recently used antioxidants such as vitamin C, vitamin E, n-acetylcysteine, allopurinol, and captopril were excluded from the study. Patient characteristics are shown in Table 1. The study was approved by the institutional ethics committee (approval number: 2014-02) and was conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from the patients' parents.

Surgery and cardiopulmonary bypass

All the patients underwent surgery under general anaesthesia. Surgery was performed through median sternotomy. Cardiopulmonary bypass was performed with a roller pump and by using either Capiox Baby Rx (Terumo Cardiovascular Systems, Ann Arbor, Michigan, United States of America) or Capiox Fx (Terumo Cardiovascular Systems, Ann Arbor, Michigan, United States of America) with an incorporated cardiotomy reservoir. The pump was primed with Ringer's solution, fresh frozen plasma, erythrocyte suspension, 20% mannitol (2 ml/kg), and 8.4% sodium bicarbonate (1 mmol/kg). Anticoagulation was initially achieved by using heparin (300 U/kg), and the activated clotting time values were maintained at >480 seconds during the operations. Cardiopulmonary bypass was established after cannulation of the aorta and caval veins or the right atrium. Nasopharyngeal temperature of 28–34°C was maintained during cardiopulmonary bypass. The blood flow rate through the pump was 2.2–2.6 L/m^2. Moderate haemodilution (haematocrit of 28–34%) was used. Warm blood cardioplegia was utilised every 20 minutes during the cross-clamp period. Conventional or modified ultrafiltration was performed according to the surgeons' preference. In cyanotic patients, controlled reoxygenation strategy was used at the beginning of cardiopulmonary bypass. After discontinuation of cardiopulmonary bypass, heparin was neutralised with an equipotent dose of protamine sulphate.

Blood sample collection

The plasma levels of total oxidant status, total antioxidant status, albumin, and C-reactive protein were estimated in both the groups. Baseline samples were collected into heparinised tubes from a cubital vein approximately 30 minutes before surgery. The one- and 24-hour samples following surgery were obtained from the central venous line. Blood samples were collected in the fasting state in the control group. Serum samples were centrifuged at 1500 *g* for 10 minutes and stored at −80°C until analyses.

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Measurement of total antioxidant status

Total antioxidant status was determined with an automated measurement using a new version of 2,2'-azinobis (3-ethylbenzothiazoline-6-sulphonate)-based colourimetric method (Rel AssayR, Sahinbey, Gaziantep, Turkey) described by Erel.[4] The results are expressed as micromol Trolox equivalent/L. Each individual sample was run in duplicate.

Measurement of total oxidant status

Total oxidant status levels were determined using a method (Rel AssayR) previously described by Erel.[5] The results are expressed as micromolar hydrogen peroxide equivalent per litre (μmol H_2O_2 Eq/L). Each individual sample was run in duplicate.

Calculation of oxidative stress index

Oxidative stress index was calculated using the following formula: [(Total oxidant status, μmol H_2O_2 equivalent/L)/(Total antioxidant status, μmol Trolox equivalent/L) × 100].

C-reactive protein and albumin

C-reactive protein and albumin levels were determined by using an immunoturbidimetric method (Roche Diagnostics GmbH, Mannheim, Germany) with Cobas 6000 C 501 (Roche Diagnostics). Albumin levels were determined by using a colourimetric method (Roche Diagnostics GmbH) with Cobas 6000 C 501 (Roche Diagnostics GmbH).

Data collection

Hospital charts, echocardiographic and cardiac catheterisation data, and the operative reports were reviewed. The Aristotle scores,[7,8] The Society of Thoracic Surgeons and European Association for Cardiothoracic Surgery Mortality Categories[9], and Risk Adjustment for Congenital Heart Surgery Scores of the patients'[10] were calculated. The medical records were reviewed for the postoperative course.

Statistical method

Statistical calculations were performed with Number Cruncher Statistical System 2007 Statistical Software (Utah, United States of America) programme for Windows. Besides standard descriptive statistical calculations (mean, standard deviation, and median), paired one-way variance analysis was carried out to evaluate the time comparisons of the normally distributed variables. The Newman–Keuls test was used to compare the means of multiple subgroups. The paired t-test was used for comparison of the preoperative and postoperative measurements, whereas independent t-test was used to compare the two groups. Friedman's test was used to assess the time comparisons of the abnormally distributed variables, whereas Dunn's multiple comparison test was carried out for subgroup analysis. The Mann–Whitney U test was used for the comparison of two groups, and the χ^2 test was used to compare qualitative data. Relationships among variables were obtained using Pearson's correlation coefficient. Statistical significance level was established at $p < 0.05$. Using the data obtained in our study, power analysis showed 95% confidence interval and 95% power.

Results

The demographic details, the Aristotle scores, The Society of Thoracic Surgeons and European Association for Cardiothoracic Surgery Mortality Categories, and Risk Adjustment for Congenital Heart Surgery Scores of patients and control subjects are shown in Table 1. The groups were similar in terms of age, gender, and body surface area. The diagnoses of congenital heart disease for both cyanotic and acyanotic groups are shown in Table 2. Operative and early postoperative data of the patients are presented in Table 3. It was found that cyanotic patients had significantly longer cardiopulmonary bypass ($p = 0.008$) and cross-clamp times ($p = 0.01$) compared with acyanotic patients. Cyanotic patients had longer ICU ($p = 0.005$) and hospital stay ($p = 0.049$) than acyanotic patients. There was no in-hospital mortality. In the cyanotic group, mechanical ventilator-related pneumonia occurred in three patients and junctional ectopic tachycardia in two patients. Among acyanotic patients, mechanical ventilator-related pneumonia occurred in one patient, pericardial effusion in one patient, and junctional ectopic tachycardia in one patient. Regarding the total number of complications, there was no statistical difference between the groups.

The comparison of oxidative and antioxidative parameters of the cyanotic, acyanotic, and control groups is shown in Table 4. No statistically significant differences were found between the patient groups and the controls in terms of baseline total oxidant status, total antioxidant status levels, and oxidative stress index values. Regarding the postoperative first-hour and 24-hour total oxidant status, total antioxidant status levels, and oxidative stress index values, which are shown in Table 5, there was no significant difference between the groups, except for a significant increase ($p = 0.002$) in the total antioxidant status levels at 24 hours after surgery in the cyanotic patient group. Alterations in

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Table 2. Operative diagnosis.

Acyanotic group	n	Cyanotic group	n
Ventricular septal defect	14	Tetralogy of Fallot	16
Atrial septal defect	10	Single ventricle	8
Arcus aorta hypoplasia + atrial septal defect	1	Total anomalous pulmonary venous connection	2
Arcus aorta hypoplasia + ventricular septal defect	1	Transposition of great arteries	3
Peripheral pulmonary artery stenosis	1	Truncus arteriosus	1
Atrioventricular septal defect	1		
Mitral valve prolapses	1		
Aortic valve insufficiency	1		

Table 3. Operative and early postoperative data.

Variables	Acyanotic group (n = 30)	Cyanotic group (n = 30)	p
CPB time [minutes (mean)]*	95.6 ± 62.99	141.15 ± 37.2	**0.008**
AXC time [minutes (mean)]	58.8 ± 43.5	91.35 ± 24.8	**0.01**
Lenght of ICU stay after surgery [days (mean)]*	2.8 ± 2.65	9.15 ± 17.22	**0.005**
Length of hospital stay after surgery [days, (mean)]*	9.75 ± 4.08	16.9 ± 20.02	**0.049**
MV time [minutes (mean)]*	27.2 ± 38.24	48.68 ± 75.09	0.097
Ultrafiltration [ml (mean)]*	233.33 ± 152.75	185.71 ± 121.5	0.610
Body temperature during CPB [Celcius (mean)]	31.6 ± 3	31.5 ± 2.59	0.911

AXC = aortic cross-clamp; CPB = Cardiopulmonary bypass; ICU = intensive care unit; ml = mililitre; MV = mechanical ventilation
Values are expressed as the mean ± SD
*Mann–Whitney U test

Table 4. Comparisons of oxidative and antioxidative parameters in cyanotic patients, acyanotic patients, and the control group.

	Control group (n = 30)	Acyanotic group (n = 30)	Cyanotic group (n = 30)	p
TAS levels (μmol Trolox equivalent/L)				
Preoperative	1.75 ± 0.27	1.53 ± 0.51	1.54 ± 0.35	0.128
PO 1 hour		1.73 ± 0.75	1.74 ± 0.45	0.986
PO 24 hours		1.77 ± 0.94	1.9 ± 0.41	0.714
TOS levels (μmol H_2O_2 equivalent/L)				
Preoperative	5.38 ± 2.16	6.04 ± 3.05	7.15 ± 4.39	0.246
PO 1 hour		6.94 ± 4	7.8 ± 4.75	0.133
PO 24 hours		6.04 ± 3.05	7.15 ± 4.39	0.246
OSI values [(μmol H_2O_2 equivalent/L)/μmol Trolox equivalent/L) × 100]				
Preoperative	3.22 ± 1.65	3.93 ± 2.72	4.24 ± 2.04	0.154
PO 1 hour		4.47 ± 2.75	4.9 ± 3.3	0.098
PO 24 hours		4.11 ± 2.55	3.8 ± 2.31	0.227

H_2O_2 = Hydrogen peroxide; L = litre; OSI = oxidative stress index; PO = postoperative; TAS = total antioxidant status; TOS = total oxidant status
Values are expressed as the mean ± SD

serum C-reactive protein and albumin levels are also shown in Table 5. C-reactive protein and albumin levels did not correlate with the total oxidant status or total antioxidant status levels.

The total antioxidant status level correlated positively with the cardiopulmonary bypass times at 1 hour ($r = 0.593$, $p = 0.0001$) and at 24 hours ($r = 0.648$, $p = 0.0001$). It correlated positively with the cross-clamp times at 1 hour ($r = 0.489$, $p = 0.002$) and at 24 hours ($r = 0.574$, $p = 0.0001$) after surgery. It did not correlate with the cooling temperatures. The total oxidant status level did not correlate with the cardiopulmonary bypass or cross-clamp times or cooling temperatures.

Discussion

Free radicals can be defined as molecules having an unpaired valence electron in an atomic orbital. Free radicals that are derived from oxygen are usually

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Table 5. Comparisons of oxidative and antioxidative parameters, albumin, and CRP in cyanotic and acyanotic patients.

	Acyantic group (n = 30)	Cyanotic group (n = 30)	p
TAS levels (mmol Trolox equivalent/L)			
Preoperative	1.53 ± 0.51	1.54 ± 0.35	0.948
PO 1 hour	1.73 ± 0.75	1.74 ± 0.45	0.933
PO 24 hours	1.77 ± 0.94	1.9 ± 0.41	0.572
p	0.322	**0.002**	
TOS levels (μmol H_2O_2 equivalent/L)			
Preoperative	6.04 ± 3.05	7.15 ± 4.39	0.657
PO 1 hour	6.94 ± 4	7.8 ± 4.75	0.542
PO 24 hours	6.04 ± 3.05	7.15 ± 4.39	0.362
p	0.413	0.393	
OSI values [(μmol H_2O_2 equivalent/L)/μmol Trolox equivalent/L) × 100]			
Preoperative	3.93 ± 2.72	4.24 ± 2.04	0.691
PO 1 hour	4.47 ± 2.75	4.9 ± 3.3	0.658
PO 24 hours	4.11 ± 2.55	3.8 ± 2.31	0.686
p	0.744	0.449	
CRP (mg/L)			
Preoperative	5.31 ± 10.66	5.11 ± 5.91	0.942
PO 1 hour	59.62 ± 32.64	53.69 ± 32.23	0.566
PO 24 hours	66.48 ± 50.31	75.47 ± 57.22	0.053
p	**0.0001**	**0.0001**	
Albumin (g/dl)			
Preoperative	3.77 ± 0.52	3.79 ± 0.8	0.944
PO 1 hour	3.39 ± 0.64	3.26 ± 0.6	0.529
PO 24 hours	3.33 ± 0.51	3.1 ± 0.4	0.122
p	**0.002**	**0.0001**	

CRP = C-reactive protein; dl = decilitre; g = gram; H_2O_2 = hydrogen peroxide; L = litre; mg = miligram; OSI = oxidative stress index; PO = post-operative; TAS = total antioxidant status; TOS = total oxidant status
Values are expressed as the mean ± SD

called reactive oxygen species such as hydroxyl radical, hydrogen peroxide, and superoxide anion radical.[11] These free radicals can have harmful effects on deoxyribonucleic acid, proteins, carbohydrates, and lipids, such as lipid peroxidation and deoxyribonucleic acid damage.[12] The antioxidant system provides protection for organisms against reactive oxygen species. The antioxidant system consists of antioxidant compounds, which can be enzymatic, such as superoxide dismutase, catalase, glutation peroxide, or non-enzymatic, such as ascorbic acid, glutathione, uric acid, melatonin, tocopherols, and tocotrienols.[11]

Oxidative stress can lead to the oxidation of lipids and proteins and can cause changes to their structure and functions.[11] It has been attributed to the occurrence of cancer, atherosclerosis, reperfusion injury, diabetes, and acute respiratory distress syndrome.[13] The serum concentrations of different oxidant species can be measured in laboratories separately, but these measurements are time-consuming, labour-intensive, and costly as well as require complicated techniques.[4] Owing to this, we preferred to measure the reactive oxygen species level by determining total oxidant status. Although antioxidant compounds can be measured individually, they do not reflect the total antioxidant response. In this study, as previously mentioned, the total antioxidant status was determined by using a colourimetric method. In the present study, total oxidant species and antioxidant response were estimated. Oxidative stress index was calculated to provide an overall view of the oxidant–antioxidant status.

To the best of our knowledge, no other study has compared the oxidative stress status of cyanotic and acyanotic patients after on-pump cardiac surgery and compared them with the healthy population; however, there are a few studies evaluating the alterations in antioxidant stress status of patients after cardiac surgery.[1–3,6] In paediatric cardiac surgery, it is speculated that cardiopulmonary bypass can cause a significant reduction in the plasma antioxidant capacity.[2,3,14] In the study by Pirinccioğlu et al, total antioxidant status levels in a group of patients with congenital heart disease were significantly higher compared with the control group (<0.001), but there was no difference between cyanotic and acyanotic patients.[15] In a case-controlled, cross-sectional study, by Ercan et al, the level of total antioxidant status and total oxidant status was more evident in the cyanotic patient group.[16] In a study that evaluated the

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antioxidant system using total radical antioxidant assay plasma and malondialdehyde inhibition test, there was an impressive depletion in antioxidants in children after surgery.[3] In another study by Atay et al, in congenital heart disease patients, who underwent off-pump and on-pump cardiac surgery, there was a significant increase in the level of total antioxidant status and oxidative stress index in both groups.[2] In the present study, there was no difference in baseline total oxidant status and total antioxidant status levels as well as oxidative stress index values between congenital heart disease patients and controls. There was no significant change in the total oxidant status level in cyanotic and acyanotic patients after surgery, whereas there was a significant increase in the total antioxidant status level in cyanotic patients 24 hours after surgery. Considering the oxidative stress index values in cyanotic and acyanotic patients, there was no significant change and difference in oxidative stress status. The reason for the insignificant difference between cyanotic and acyanotic patients' total antioxidant and total oxidant levels during the preoperative period may be due to their care being undertaken by paediatric cardiologists during the preoperative period, having medical therapy, not having a history of viral or bacterial infection in recent period, and not having congestive heart disease. Moreover, the reason for the insignificant difference between cyanotic and acyanotic patients' postoperative total antioxidant and total oxidant levels may be due to having similar total antioxidant and total oxidant levels in the preoperative period and our CPB management, with controlled oxygenation, cooling and warming periods, and the use of blood cardioplegia.

In the present study, the Aristotle scores,[7,8] The Society of Thoracic Surgeons and European Association for Cardiothoracic Surgery Mortality Categories[9], and Risk Adjustment for Congenital Heart Surgery Scores[10] were higher among the cyanotic patients. The cyanotic patients had prolonged cardiopulmonary bypass times and hospital stay. Prolongation of cardiopulmonary bypass time and longer hospital stay in group 2 were mainly due to longer length of cross-clamp time and longer ICU stay, respectively. There was no correlation between hospital stay, ICU stay, and the total antioxidant status and total oxidant status levels.

There was no major or any other complication observed in both the groups and between the groups. There was no significant increase in the total antioxidant status and total oxidant status levels in both the groups. In cases where there is no significant change in total antioxidant status and total oxidant status levels during the postoperative period in cyanotic and acyanotic patients, we believe that there will be no significant difference in the complications during the postoperative period; however, because of the low rate of complications in this study, further studies are needed for a more detailed evaluation.

In our centre, we use controlled re-oxygenation for cyanotic patients. Controlled re-oxygenation refers to a pump prime that has a partial pressure of oxygen in the arterial blood matched to the patient's preoperative oxygen saturation at the beginning of cardiopulmonary bypass. In acyanotic patients, we use "hyperoxic (standard) cardiopulmonary bypass", which refers to a pump prime that maintains the arterial oxygen saturation at >95% and partial oxygen pressure levels of 150–250 mm Hg at the beginning of cardiopulmonary bypass. Recently, Caputo et al have demonstrated that controlled re-oxygenation cardiopulmonary bypass significantly ($p < 0.05$) decreased the markers of organ damage, inflammation, stress, and oxidative stress.[17] In our study group, there was no significant alteration in the Oxidative Stress Index values of the cyanotic patient group. This may be related to a positive effect of controlled re-oxygenation on oxidative stress. There was no control group for cyanotic patients who did not have controlled oxygenation. This is one of the limitations of the present study. This was because of the cardiopulmonary bypass policy in our centre.

Total antioxidant status levels significantly increased 24 hours after surgery in the cyanotic patient group. This increase may be because of intensive care unit manipulations, heat changes, and use of blood products, because there was no difference in the postoperative 1st-hour total antioxidant status levels. Cardiopulmonary bypass times and cross-clamp times of the cyanotic patients were longer than the cardiopulmonary bypass and cross-clamp times of the acyanotic patients. Longer operation times may have resulted in more blood transfusions, haemolysis, and fever during the early period in the intensive care unit. These differences may have caused the elevation in 1st-day total antioxidant status levels in the cyanotic patients. Therefore, measurement of total antioxidant status and total oxidant status levels immediately after the operation would provide a clearer assessment of the cardiopulmonary bypass influences on cyanotic and acyanotic patients.

C-reactive protein is an acute-phase reactant, which has been shown to increase after surgery.[1,2] In our practice, there is always a significant increase in C-reactive protein levels 1–2 days after surgery. Normalisation of the C-reactive protein levels generally starts after the 3rd postoperative day. Pirincciogl u et al found significantly elevated C-reactive protein levels in patients with cyanotic congenital heart disease compared with acyanotic

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patients and controls.[15] In the present study, no difference was found preoperatively between the patient groups and the controls. In both groups, there was a prompt and significant increase in C-reactive protein levels, as shown in previous studies.[2] There was no correlation between the C-reactive protein levels and the total antioxidant status and total oxidant status levels. Sternotomy is a highly traumatic access that causes a marked inflammatory response even before the institution of cardiopulmonary bypass.[1] Gu et al reported neutrophil preactivation before the institution of cardiopulmonary bypass.[18] In addition, Chello et al mentioned amplification of inflammatory response by surgical stress in patients undergoing off-pump or on-pump surgery.[19] In our opinion, elevations in C-reactive protein levels are related to the surgical stress itself rather than the use of cardiopulmonary bypass.

Albumin is a negative acute-phase reactant and also acts as an antioxidant agent.[20] The antioxidant functions of albumin are related to its multiple ligand-binding capacities and free radical-trapping properties.[21] In this study, the albumin levels in both groups decreased significantly after surgery, but the total antioxidant status levels and albumin levels were not correlated in any group. These changes may be related to the haemodilution effect of cardiopulmonary bypass.

Limitations

The number of patients in whom ultrafiltration was used was low for statistical analysis. Owing to this, the effects of conventional ultrafiltration cannot be interpreted. Another limitation of this study was the use of blood products during cardiopulmonary bypass. We cannot comment on the effects of blood products used during the operations. Another limitation of the study was the lack of control group for cyanotic patients, who did not have controlled oxygenation.

Conclusion

There is no difference between the oxidative stress status of cyanotic and acyanotic congenital heart disease patients and the healthy population. The oxidative stress status of cyanotic and acyanotic patients does not alter after cardiac surgery under cardiopulmonary bypass. Changes in albumin levels may be due to post-cardiopulmonary bypass haemodilution. The increases in C-reactive protein levels may be due to the surgical stress itself. Complying with the controlled reperfusion and warming–cooling time can decrease the effect of inflammatory response.

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Conflicts of Interest

None.

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