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Research Article / Araştırma

Evaluation of the Effect of Low Cardiac Output Syndrome on Intestinal Flow After Arcus Aorta Surgery in Newborns

Yenidoğanlarda Arkus Aorta Cerrahisi Sonrası Düşük Kalp Debisi Sendromu Varlığının İntestinal Akıma Etkisinin Değerlendirilmesi

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ABSTRACT

Objectives: Dynamic changes during arch surgery in newborns may cause ischemia and tissue damage as a result of decreased blood flow in critical organs. In this study, it was aimed to investigate the changes in intestinal blood flow with Doppler ultrasonography (USG) in the presence of low cardiac output in the early period in newborns who had surgical intervention in the aortic arch.

Methods: The study was carried out between August 1, 2021, and August 1, 2022, in newborns younger than 30 days of age at the time of the operation and who had undergone arch reconstruction surgery. The presence of low cardiac output in the cases was determined by low cardiac output syndrome (LCOS) scoring. Initial, 24th and 48th h intestinal flows of the cases with and without LCOS were calculated by Doppler USG. The celiac artery (TC) was used as the measurement site. Peak systolic velocity (PSV), mean systolic velocity (MV), and end-diastolic velocity (EDV) values, resistance index (RI) and pulsatility index (PI) findings of each case were evaluated statistically.

Results: There were 24 cases during the study period. 70% of the cases were male. The median age at the time of surgery was 15 days (IQR 12–18 days) and median weight was 3.2 kg (IQR 2.9–3.4). LCOS was detected in 25% of cases (n=6). Initial median PSV (72 vs. 76 cm/sec), EDV (27 vs. 30 cm/sec), MV (24 vs. 26), RI (0.79 vs. 0.75), and median PI (1.60 vs. 1.75) values of cases with and without LCOS were similar to each other. There was a significant difference between the values of 24th hour median PSV (55 vs. 66 cm/sec), EDV (21 vs. 27 cm/sec), median MV (18 vs.

ÖZ

Amaç: Bu çalışmada, arkus aortaya cerrahi olarak müdahale edilmiş yenidoğanlarda erken dönemde gelişen düşük debi varlığının doppler ultrasonografi ile intestinal kan akımında olan değişikliklerin araştırılması amaçlandı.

Yöntem: Çalışma, 1 Ağustos 2021-1 Ağustos 2022 tarihleri arasında, operasyon sırasındaki yaşı 30 günden küçük ve arkus rekonstrüksiyonu operasyonu yapılmış olan yenidoğanlarda yapıldı. Düşük kalp debisi sendromu gelişen ve gelişmeyen olguların initial, 24. ve 48. saat doppler ultrasonografi ile intestinal akımları hesaplandı. Ölçüm yeri olarak çölyak (TC) arter kullanıldı. Her bir olgunun peak sistolik velosite (PSV), mean sistolik velosite (MV) ve end-diyastolik velosite (EDV) değerleri, direnç indeksi (RI) ve pulsatilite indeksi (PI) bulguları istatistiksel olarak değerlendirildi.

Bulgular: Çalışma döneminde 24 olgu mevcuttu. Olguların %70'i erkekti. Ameliyat sırasındaki median yaş 15 gün (IQR 12 gün-18 gün) ve median ağırlık 3,2 kg (IQR 2,9-3,4) idi. Olguların %25'inde (n=6) LCOS saptandı. LCOS gelişen ve gelişmeyen olguların başlangıç median PSV (72 vs. 76 cm/sn), EDV (27 vs. 30 cm/sn), MV (24 vs. 26), RI (0,79 vs. 0,75) ve median PI (1,60 vs. 1,75) değerleri birbirine benzerdi. LCOS gelişen ve gelişmeyen olguların 24. saat median PSV (55 vs. 66 cm/sn), EDV (21 vs. 27 cm/sn), median MV (18 vs. 24), median RI (0,84 vs. 0,76) ve median PI (1,65 vs. 1,78) değerleri arasında anlamlı fark vardı (p<0,05). LCOS gelişen ve gelişmeyen olguların 48. saat median PSV (75 vs. 80 cm/sn), EDV (30

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ABSTRACT

24), median RI (0.84 vs. 0.76), and median PI (1.65 vs. 1.78) of cases with and without LCOS ($p<0.05$). 48th h median PSV (75 vs. 80 cm/sec), EDV (30 vs. 32 cm/sec), MV (25 vs. 26), median RI (0.80 vs. 0.74), and median PI (1.55 vs. 1.65) values of cases with and without LCOS were similar.

Conclusion: Changes affecting intestinal blood flow were detected in Doppler USG at the 24th h in newborns who developed LCOS after arcus surgery.

Keywords: Arch surgery, doppler USG, intestinal flow, newborn

ÖZ

vs. 32 cm/sn), MV (25 vs. 26), median RI (0,80 vs. 0,74) ve median PI (1,55 vs. 1,65) değerleri birbirine benzerdi.

Sonuç: Yenidoğanlarda arkus cerrahisi sonrasında düşük debi sendromu gelişenlerde 24. saatte doppler ultrasonografide intestinal kan akımını etkileyen değişiklikler saptanmıştır.

Anahtar sözcükler: Arkus cerrahisi, doppler ultrasonografi, intestinal akım, yenidoğan

Introduction

Aortic arch hypoplasia with or without aortic coarctation is a congenital heart anomaly that occurs as a result of developmental disorder of the aortic arch in the embryological period and is characterized by different clinical findings. The anatomical spectrum of cases can range from mild isolated coarctation to severe hypoplasia of the left ventricle.[1–3]

Aortic arch hypoplasia can cause dynamic changes in aortic blood flow that affect critical organ systems. Excessive dissection during aortic arch surgery, cardiopulmonary bypass (CPB), deep hypothermic circulatory arrest and in some cases, and low cardiac output syndrome (LCOS) may increase these effects. All blood flow changes may occur more prominently, especially in newborns.[4]

Ultrasonography (USG) is a diagnostic and research method that allows us to obtain information about the anatomical and mechanical functions of the heart noninvasively with ultrasonic sound waves. In patients with congenital heart disease, hemodynamic changes can be estimated by calculating the flow velocity and volume with Doppler USG. Color flow Doppler and pulsed wave Doppler USG are the most common application modes. Resistance index (RI) and pulsatility index (PI) have become new Doppler-based USG assessments.[5]

There are limited studies in the literature evaluating the effects of aortic arch surgery on intestinal blood flow in newborns.[4–6] In this study, it was aimed to investigate the possible effects of LCOS development after arch aortic surgery on the flow and volume changes measured by Doppler USG in intestinal blood flow.

Methods

This study was conducted between August 1, 2021 and August 1, 2022 and included neonatal patients younger than 30 days at the time of surgery who had undergone isolated aortic arch surgery. Premature cases and cases with hemodynamically important ventricular septal defect or complex pathologies were excluded from the study. Patients with a history of medication affecting arterial blood flow such as dopamine, dobutamine, indomethacin, and caffeine, umbilical catheterization or phototherapy before the surgery were excluded from the study.

The study was planned as a preliminary study in accordance with the Helsinki Declaration and approved by the local ethical committee. We evaluated the diagnosis, demographic features (age, gender, and body weight), echocardiography, surgery, and intensive care data of patients retrospectively. Echocardiographic evaluations were performed using the Philips Affiniti 50 cardiac ultrasound system (Philips Affiniti 50 Cardiac Ultrasound, Bothell, WA, USA) with 9-MHz probe based on the "Guidelines and Standards for Performance of a Pediatric Echocardiogram" of the American Society of Echocardiography.[7] Four chamber view for left ventricle end-diastolic dimension and mitral valve annulus; long axis view for aortic valve annulus and ascending aorta; suprasternal notch view for transverse aorta, distal aortic arch, and isthmus were used for evaluation and measurements.

The diagnosis of aortic arch hypoplasia was made by echocardiography and/or multidetector computed tomography (CT) angiography findings. The patient was diagnosed with aortic arch hypoplasia when only three criteria were fulfilled.[8]

a. Size of the arch in mm was less than the patient's weight in kg+1,
b. Aortic arch diameter z-score was <−2.0,
c. Ratio of the diameter of the transverse arch to the descending aorta is <50%.

Blood flow and flow rates were obtained with Doppler USG. Intestinal flow was evaluated immediately, at 24 and 48 h after the operation. The measurement site for the intestinal region was the celiac artery (CA). The aortic origin of CA was localized on subcostal sagittal sections. To increase the accuracy of the results, at least three real-time measurements in optimal quality were obtained following the cardiac cycle.

Peak systolic velocity (PSV), mean systolic velocity (MV), and end-diastolic velocity (EDV) values were measured for all patients. RI and PI were calculated according to the following formula.

RI=(PSV-EDV)/PSV; PI=(PSV-EDV)/MV[5,9]

After the aortic arch hypoplasia operation, the cases were divided into two groups as those who developed LCOS (Group I) and those who did not developed (Group II) according to the presence of LCOS in the intensive care unit. Modified Ulate's LCOS score was used for LCOS diagnosis.[10] The LCOS score was calculated by assigning one point for each of the following:

1. Tachycardia (>20% above post-induction heart rate in the operating room),
2. Oliguria (<1 mL/kg/hour),
3. Capillary filling time >3 s,
4. 4) Need for volume expansion (on top of maintenance IV fluids) (>30 mL/kg/day),
5. Decreased near-infrared spectroscope (NIRS) measurements (Cerebral and renal NIRS <50% and 75% of arterial saturations, respectively),
6. Elevated arterial lactate levels (>2 mmol/L or >0.75 mmol/L/hour increase),
7. Need for vasoactive-inotropic infusions over 0.5 µg/kg/minute Milrinone.

Each parameter was given 1 point, and the LCOS score was calculated hourly. If the total LCOS score was 3> at any time in the first 24 h, the patient was considered as LCOS.

Statistical Analysis

In the study, the distribution of variables was classified in computer. Descriptive statistics were calculated using Statistical Package for the Social Sciences for Windows version 15 program. Demographic data are reported as median (Interquartiale range [IQR]), number, and percentage. The Wilcoxon test was used for repeated measurements. P<0.05 was considered statistically significant.

Results

There were 24 cases during the study period. The median weight was 3.2 kg (IQR 2.9–3.4 kg) and the median age was 15 days (IQR 12–18 days). Seventeen of the patients were male. LCOS was detected in 25% of cases (n=6). The patient characteristics were given in Table 1.

The sternum was left open in % 29 (n=7) of the patients, and delayed sternal closure was performed within post-operative 72 h. The choice of inotropes, vasodilators, beta-blockers, and ACE inhibitors was based on patient's blood lactate level, cerebral and renal NIRS levels, heart rate, and blood pressures (coronary perfusion pressures >20 mmHg). Milrinone was used in all cases, with a median duration of 3 days (IQR 2–4 days). Furthermore, noradrenaline (median duration 1 days [IQR 0–2]) and adrenaline (median duration 1 day [IQR 0–2]) were used in eight and four cases, respectively.

Table 1. Baseline characteristics of the patients (n=24)

	n	%
Age, day	15 (12–18)	
Weight, kg	3.2 (2.9–3.4)	
Male	17	70
PGE1	10	40
Pre-operative intubation	5	20
Inotropic support	8	33
Echocardiographic findings		
LVEDs, mm	9 (6–12)	
LVEDd, mm	15 (11–20)	
FS (%)	30 (27–35)	
EF (%)	60 (55–65)	
Patent Foramen Ovale	21	90
Patent ductus arteriosus	8	33
Coarctation of the aorta	7	29
Bicuspid aortic valve	8	33
CTA	16	66
Gothic	5	31
Normal	10	62
Crenel	1	7
Z scores (Echo and/or CTA)		
Aortik valv	0.3 (−0.1–0.8)	
Ascending aorta	−0.3 (−0.9-+1)	
Proximal aortic arch	−3 (−4-+1)	
Distal aortic arc	−5 (−6-−2)	
Aortic isthmus	−3.1 (−5-−1)	
Operative data		
CPB (minutes)	140 (110–170)	
X-clamp (minutes)	75 (65–90)	
Antegrade cerebral perfusion	21	88
DHCA	3	12
Curved porcine pericardium	6	25
Autologous pericardium	17	70
Low cardiac output syndrome	6	25

Median (IQR) or n, %. PGE1: Prostaglandin E1; LVEDs: Left ventricular end-systolic dimension; LVEDd: Left ventricular end-diastolic dimension; FS: Fractional shortening; EF: Ejection fraction; CTA: Computed tomography angiography; CPB: Cardiopulmonary bypass; DHCA: Deep hypothermic circulatory arrest.

The 24th h median VIS scores were higher in patients who developed LCOS (p<0.05) (12 [IQR 5–10] vs. 7 [IQR 5–10]). Initial baseline (7 [IQR 5–10] vs. 7 [IQR 5–10]) and 48th hour (7 [IQR 5–10] vs. 5 [IQR 3–7]) median VIS scores were similar. Besides, esmolol in 12 cases, propranolol in seven cases, dexmedetomidine in seven cases, and ACE inhibitors in ten cases were used. The median post-operative days until extubation were 2 days (IQR 1–3); median intensive care unit stay was 8 days (IQR 6–10); and the median hospital stay was 14 days (IQR 12–16).

Acute kidney injury was observed in seven cases. Among them, four cases were in R, 2 cases were in I and one case was in F group according to the pediatric risk, injury, fail-

Table 2. Celiac artery Doppler indices

Parameter	Initial			24 h			48 h		
	LCOS (+)	LCOS (–)	p	LCOS (+)	LCOS (–)	p	LCOS (+)	LCOS (–)	p
PSV cm/sec	72 (70–75)	76 (72–80)	NS	55 (50–60)	66 (60–729	0.01	75 (70–80)	80 (75–85)	NS
EDV cm/sec	27 (24–30)	30 (26–34)	NS	21 (18–24)	27 (24–30)	0.001	30 (27–33)	32 (28–36)	NS
MV cm/sec	24 (22–26)	26 (24–28)	NS	18 (15–20)	24 (20–28)	0.003	25 (20–28)	26 (24–30)	NS
RI	0.79 (0.75–0.82)	0.75 (0.70–0.80)	NS	0.84 (0.80–0.88)	0.76 (0.72–0.8)	0.003	0.80 (0.75–0.8)	0.74 (0.7–0.78)	NS
PI	1.60 (1.55–1.65)	1.75 (1.70–1.80)	NS	1.65 (1.6–1.8)	1.78 (1.75–1.82)	0.001	1.55 (1.5–1.6)	1.65 (1.6–1.7)	NS

LCOS: Low cardiac output syndrome; PSV: Peak systolic velocity; EDV: End-diastolic velocity; MV: Mean systolic velocity; RI: Resistive index; PI: Pulsatility index; SD: standard deviation; NS: Non-statistically.

ure, loss, end-stage renal disease (an acronym for risk of renal dysfunction, injury to the kidney, failure of kidney function, loss of kidney function, and end-stage renal disease, pRIFLE) classification. Peritoneal dialysis was performed in three patients with low cardiac output and acute kidney damage. Different types of arrhythmias were determined in three cases (junctional ectopic tachycardia in two cases and supraventricular tachycardia in one case. Sinus rhythm was restored after amiodarone infusion in one patient with junctional ectopic tachycardia. The other patient did not require treatment. The patient with supraventricular tachyarrhythmia returned to normal sinus rhythm only after adenosine treatment. LCOS was seen in six cases. Transient nutritional intolerance and necrotizing enterocolitis (NEC) (Stage 1) developed in five and one cases, respectively. No surgery was required for the patient with NEC. One case died on the 27th post-operative day due to klebsiella pneumoniae sepsis.

Doppler flow measurements of CA on the initial, post-operative 24th h and 48th h are shown in Table 2.

Initial median PSV (72 vs. 76 cm/sec), EDV (27 vs. 30 cm/sec), MV (24 vs. 26), RI (0.79 vs. 0.75), and median PI (1.60 vs. 1.75) values of the cases with and without LCOS were similar (p>0.05).

There was a significant difference between the 24th h median PSV (55 vs. 66 cm/sec), EDV (21 vs. 27 cm/sec), median MV (18 vs. 24), median RI (0.84 vs. 0.76), and median PI (1.65 vs. 1.78) values of cases with and without LCOS (p<0.05).

48th h median PSV (75 vs. 80 cm/sec), EDV (30 vs. 32 cm/sec), MV (25 vs. 26), median RI (0.80 vs. 0.74), and median PI (1.55 vs. 1.65) values of the cases with and without LCOS were similar (p>0.05).

Discussion

In this study, we investigated possible changes in intestinal flow with Doppler USG in case of LCOS in newborns who had surgical intervention in the aortic arch. We observed that there was a significant increase in RI and PI and a significant decrease in PSV, MV, and EDV values at the 24th h in the patients who developed LCOS in the post-operative period and these changes improved after the 48th h. Our findings showed that LCOS may cause changes in flow and volumes in intestinal tissues.

LCOS is a clinical and biochemical condition in which oxygen is insufficient to meet the metabolic needs of the patient (insufficient transport and distribution) or oxygen consumption is increased. LCOS usually presents with tachycardia, high systemic vascular resistance and oliguria, high lactate level, and metabolic acidosis due to insufficient tissue perfusion. A decrease in cardiac output can be observed in 20–40% of newborns undergoing arch surgery, due to effects such as ischemia-reperfusion injury caused by CPB, systemic inflammatory response syndrome, length of aortic clamping period, poor protection of myocardium, and hypothermia on the 1st post-operative day.[11,12] In the studies of Pérez-Navero et al.[13] LCOS was expressed as 29%. In another newborn study, this rate was expressed as 42%.[11]

In our study, we used the LCOS score created by Ulate et al.[10] with different clinical and laboratory data. Consistent with the studies in the literature, we determined the LCOS rate as 25%.

The blood flow to the intestinal mucosa provides oxygen and nutrient support and protects the mucosa by removing hydrogen ions. Decreased blood flow may cause mucosal ischemia and damage, especially in newborns. Color flow Doppler USG is a portable, quantitative, and noninvasive valuable tool in the evaluation of blood flow in the celiac, superior mesenteric and inferior mesenteric regions.[4,9] Lynch et al.,[14] in their study comparing perfusion flometry and Doppler USG in the intestinal perfusion model they developed, found that USG predicted ischemia with a rate of 86% and perfusion fluorometry with a rate of 95%. In other studies, it has been shown that findings observed in different disease categories such as ulcerative colitis, Crohn's disease, Celiac disease, NEC, and sepsis are correlated with USG.[15–17] McElhinney et al.[16] showed that the incidence of NEC increased 10–100 times in congenital heart disease cases with decreased mesenteric blood flow.

Hashem et al.,[17] in their study on preterm cases, claimed that USG could detect NEC cases early.

Öztürk et al.,[4] in their study in which they evaluated 16 patients who underwent aortic arch surgery, suggested that RI, which was high in the preoperative period, decreased significantly on the 7th post-operative day.

Johnson et al.[18] compared the patients with single ventricular physiology who underwent Blalock taussig (BT) shunt and those who had a conduit repair between the right ventricle and pulmonary artery in terms of mesenteric blood flow. Although the RI index was high in the cases of the BT shunt group, they saw that this situation had no effect on gastrointestinal events.

In our study, we observed that there was a higher increase in the RI value at the 24th h in patients with LCOS compared to those who did not, and this difference disappeared at 48 h.

Limitations

The main limitation of this study is that it was conducted in a single center and retrospectively on a limited number of patients. The second limitation is that the results were not compared with the healthy control group. Another limitation is the lack of evaluation of the compatibility of the findings and the clinic.

Conclusion

The development of LCOS after arch surgery in newborns affects intestinal flow negatively. There is a need for studies involving more cases on the clinical effects of this issue.

Disclosures

Ethics Committee Approval: The study was approved by The Başakşehir Çam and Sakura City Hospital Clinical Research Ethics Committee (Date: 27/04/2022, No: 2022.04.143).

Informed Consent: Written informed consent was obtained from all patients.

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