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Original Article / Özgün Makale

Surgery-related complications and their management in total anomalous pulmonary venous return during intensive care unit stay

Total anormal pulmoner venöz dönüşte yoğun bakım ünitesinde kalış süresince cerrahiyle ilişkili komplikasyonlar ve bunların yönetimi

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ABSTRACT

Background: This study aims to evaluate complications that appear in patients with total anomalous pulmonary venous return (TAPVR) during intensive care period and preoperative and postoperative factors that affect them.

Methods: The study included 31 TAPVR patients (21 males, 10 females; mean age 36 days; range 2 days to 6 months) operated in our clinic between January 2010 and May 2013. Patients with complex cardiac anomaly and single ventricle physiology were excluded. Patients' demographical characteristics, echocardiographic, angiographic and computed tomography angiographic, and any cardiac catheterization findings were evaluated. Duration and timing of operations, postoperative changes and complications such as pulmonary hypertensive crisis, arrhythmia, septicemia, and low cardiac output observed in intensive care unit were reviewed in detail.

Results: Of patients with TAPVR, 58% were supracardiac, 19% were infracardiac, 13% were cardiac, and 10% were mixed type. Pulmonary venous obstruction was present in 10 patients (32%). While pulmonary hypertension crisis developed in eight patients (25%), low cardiac output was detected in six patients (19%). Rhythm problems were observed in 11 patients (35%). Pulmonary venous obstruction was more common in patients with infracardiac drainage TAPVR, low weight and small age ($p<0.05$). Five patients (16%) died during follow-up. Left ventricular hypoplasia, low cardiac output and preoperative asidosis were independent risk factors for mortality ($p<0.05$). Mean duration of follow-up was 15 months (3 months-2 years). During the follow-up, only one patient was reoperated for pulmonary venous obstruction.

Conclusion: The mortality rate of TAPVR may decrease significantly with early diagnosis and effective, advanced, and suitable intensive care unit follow-up.

Keywords: Child; complications; intensive care; surgery; total abnormal pulmonary venous return.

ÖZ

Amaç: Bu çalışmada total anormal pulmoner venöz dönüşlü (TAPVD) hastalarda yoğun bakım döneminde gelişen komplikasyonlar ve bunlara etki eden ameliyat öncesi ve sonrası faktörler değerlendirildi.

Çalışma planı: Çalışmaya Ocak 2010 - Mayıs 2013 tarihleri arasında kliniğimizde ameliyat edilen 31 TAPVD hastası (21 erkek, 10 kız; ort. yaş 36 gün; dağılım 2 gün-6 ay) dahil edildi. Kompleks kardiyak anomalisi ve tek ventrikül fizyolojisi olan hastalar çalışma dışı bırakıldı. Hastaların demografik özellikleri, ekokardiyografik, anjiyografik ve bilgisayarlı tomografi anjiyografik ve varsa kalp kateterizasyonu bulguları değerlendirildi. Ameliyatların süresi ve zamanı, ameliyat sonrası yoğun bakım ünitesinde gözlenen değişiklikler ve pulmoner hipertansif kriz, aritmi, sepsis ve düşük kardiyak debi gibi komplikasyonlar ayrıntılı olarak incelendi.

Bulgular: Total anormal pulmoner venöz dönüşlü hastaların %58'i suprakardiyak, %19'u infrakardiyak, %13'ü kardiyak ve %10'u karışık tipteydi. On hastada (%32) pulmoner venöz tıkanıklık vardı. Sekiz hastada (%25) pulmoner hipertansif kriz gelişirken altı hastada (%19) düşük kardiyak debi saptandı. On bir hastada (%35) ritim sorunları gözlendi. Pulmoner venöz tıkanıklık infrakardiyak drenaj TAPVD'li, düşük kilolu ve küçük yaştaki hastalarda daha yaygındı ($p<0.05$). Takipte beş hasta (%16) kaybedildi. Sol ventrikül hipoplazisi, düşük kardiyak debi ve ameliyat öncesi asidoz mortalite için bağımsız risk faktörleriydi ($p<0.05$). Ortalama takip süresi 15 ay (3 ay-2 yıl) idi. Takipte yalnız bir hasta pulmoner venöz tıkanıklık için yeniden ameliyat edildi.

Sonuç: Erken tanı, etkin, gelişmiş ve uygun yoğun bakım ünitesi takibi ile TAPVD'nin mortalite oranı anlamlı şekilde azalabilir.

Anahtar sözcükler: Çocuk; komplikasyon; yoğun bakım; cerrahi; total anormal pulmoner venöz dönüş.

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Total anomalous pulmonary venous return (TAPVR) is a heart disease in which the pulmonary vein flows enter the systemic veins, right atrium, or coronary sinus instead of the left atrium, and it accounts for less than 1% of all congenital heart pathologies.[1,2] The signs and symptoms of TAPVR vary according to the sufficiency of the interatrial connection and the presence of pulmonary venous obstruction (PVO). The severity of these symptoms range from mild (e.g., a murmur and tachypnea) to severe (e.g., cyanosis, metabolic acidosis, cardiac insufficiency, or low cardiac output).[1,2] Surgery is the definitive treatment, and thanks to early, accurate diagnostic methods, improved surgical techniques, myocardial protection during surgery, and improved postoperative care in the intensive care unit (ICU), the mortality rate has now been reduced to less than 10%.[1-3]

In this study, we aimed to evaluate the early, surgery-related complications and management strategies during ICU stays for patients with TAPVR and investigate the possible effects related to the type of surgery performed and its duration, complaints upon admission, and various test results, including echocardiography.

PATIENTS AND METHODS

This study included 31 pediatric patients (21 males and 10 females; median age 54 days; range 2-180 days) who underwent surgery for TAPVR in our clinic between January 2010 and May 2013. Those with a complex cardiac anomaly or single ventricle physiology were excluded. The patients' complaints upon admission and their demographic characteristics, including age, baseline body weight, and gender were recorded along with their echocardiographic and computed tomography angiography (CTA) findings. In addition, we also noted the type of that was performed as well as its duration along with the cross-clamp time, length of ICU stay, mechanical ventilation duration, the inotropic agents used and inotropic support duration, and the oxygen saturation (OS) and blood gas levels. Furthermore, we also took notice of the patients' near-infrared spectroscopy (NIRS) parameters during the ICU stay and any surgery-related complications, such as a pulmonary hypertensive crisis, arrhythmia, sepsis, or low cardiac output.

Two-dimensional (2D), M-mode, and Doppler echocardiography were performed using standard imaging techniques in accordance with the recommendations of the American Society of Echocardiography (ASE). The Z score that we used was based on the standard parameters of body weight and height, with a score of less than -2 being representative of hypoplasia. We also obtained the informed consent of the parents of the patients for them to be included in the study. Moreover, the study protocol was approved by the ethics committee, and it was conducted in accordance with the principles of the Helsinki Declaration.

Surgical technique

The surgery performed for the supracardiac, cardiac, infracardiac, and mixed TAPVR was consistent with the procedures mentioned in the literature.[1] The vertical vein was left open or ligated at the discretion of the surgeon, and the invasive blood pressure, OS and end-title carbon dioxide ($etCO_2$) levels, NIRS parameters, electrocardiographic (ECG) results, and intraoperative invasive left atrial and pulmonary artery pressure (PAP) were monitored throughout the operation. The inotrope score was calculated as described by Wernovsky et al.[4] to quantify the inotropic support [the sum of all doses corrected based on the inotropic effect = (dopamine + dobutamine x 1) + (milrinone x 15) + (adrenaline x 100)]. Norepinephrine was excluded from this equation.

A pulmonary hypertensive crisis was characterized by the following: a pulmonary artery systolic pressure that exceeded 50% of the systemic systolic arterial pressure, desaturation or reduced saturation, echocardiographic findings of a leftward deviation of the interventricular septum and patent foramen ovale with a right-to-left shunt, acidosis, or hypotension. Arrhythmia was assessed via atrial ECG, 24-hour Holter monitorization, and an adenosine (100 µg/kg) bolus injection in the patients suspected of having this condition as demonstrated on the ECG.

Statistical analysis

Statistical analysis was performed using the SPSS version 11.5 for Windows software program (SPSS Inc., Chicago, IL, USA). The Mann-Whitney U test was used to compare the mean values between the groups, whereas a chi-square and Fisher's exact test were used to compare the rates between the groups. Furthermore, the Wilcoxon test was used to assess dependent repetitive measurements, and multivariate logistic regression analysis was performed to evaluate the possible factors that might have influenced mortality. A p value of <0.05 was considered to be statistically significant.

RESULTS

Eighteen of the patients had supracardiac TAPVR, four had cardiac TAPVR, six had infracardiac TAPVR, and

Table 1. Demographic characteristics of the patients with total anomalous pulmonary venous return

Anatomical type	Supracardiac				Cardiac				Infracardiac				Mixed				*Total*			
	n	%	Median	Min.-max.	n	%	Median	Min.-max.	n	%	Median	Min.-max.	n	%	Median	Min.-max.	n	%	Median	Min.-max.
Patients	18	58			4	13			6	19			3	10			31			
Prenatal diagnosis	–	–	–	–	–															
Postnatal diagnosis	2				–				3				1				6			
Gender																				
Males	14				4				3				–				21			
Females	4				–				3				3				10			
Median age in days			59	7-180			35	26-60			21	2-40			40	21-90			36	2-180
Younger than 30 days	7				–				3				1				11			
Median weight in kgs (min-max)			3.9	3-7			3.5	3-4.5			3.0	2.3-3.5			4.5	3.2-5			3.5	2.3-7
Weight of less than 2.5 kg			–	–			–	–			1	3.1			–	–			1	3.1
Median pulse oximetry saturation			89	60-92			93	78-98			67	45-74			90	87-92			87	45-98
Median time to surgery in days			5	0-20)			8	1-30			3	0-20			3	2-5			4	0-30
Preoperative intubation	1	3.1			–	–			3	9.3			–	–				4	12.4	
Preoperative acidosis	1	3.1			–	–			3	9.3			–	–				4	12.4	
Syndrome	1	3.1			–	–			–	–			1	3.1				2	6.2	
Complaints on admission																				
Murmur	9				1				4				2				16			
Cyanosis	4				3				5				1				13			
Tachypnea	11				1				3				2				17			
No weight gain	3				1				–				1				5			

Min.: Minimum; Max.: Maximum.

three had mixed TAPVR. At the time of diagnosis, the median weight of the patients was 3.5 kg (range 2.3-7 kg), the median oxygen saturation value was 80% (range 45-90%), and the mean time to surgery was four days (range 0-30 days). The demographic characteristics of the patients as well as their complaints upon admission and preoperative clinical findings are shown in Table 1.

A detailed echocardiographic examination was performed on all of the patients, but three-dimensional (3D) CT images were obtained for just 11 of the study participants. These images allowed for the anatomy of two patients with supracardiac TAPVR and two others with mixed TAPVR to be viewed more widely. Moreover, mixed TAPVR was confirmed via these images in one patient who was suspected of having supracardiac TAPVR. Six patients also underwent cardiac catheterization and angiography. The patients' preoperative diagnostic data is presented in Table 2.

The mean cardiopulmonary bypass (CPB) and aortic cross-clamp (ACC) times were 121±58 minutes and 79±42 minutes for the patients with supracardiac TAPVR, 178±201 minutes and 96±129 minutes for those with cardiac TAPVR, 116±23 minutes and 96±129 minutes for those with infracardiac TAPVR, and 179±42 minutes and 103±6 minutes for those with mixed TAPVR, respectively. Furthermore, the duration of surgery was statistically longer in the patients with mixed TAPVR compared with those with other types of this disease (p=0.02).

Ten patients (33%) with an open sternum and three (10%) with temporary pacing were hospitalized in the ICU. Furthermore, dopamine was prescribed for 28 patients for between two and 30 days, milrinone was given to 25 patients for between two and 18 days, adrenaline was used by 13 patients for between one and 12 days, and neuroadrenaline was given to six patients for between one and eight days. The inotrope score was 112±113 for the patients with supracardiac TAPVR, 66±73 for those with cardiac TAPVR, 110±83 for those with infracardiac TAPVR, and 97±72 for those with mixed TAPVR, and we found no statistically significant differences between these scores based on the type of TAPVR that was present (p=0.842).

Oral sildenafil was also given to six patients for between two and 90 days, ilioprost IV was used by 10 patients for between one and 12 days, and inhaled nitric oxide (iNO) was prescribed for six patients for between 16 and 132 hours. In addition, a peritoneal dialysis catheter was inserted in five patients. Moreover, one patient was intubated because of a pneumothorax, and four others underwent extracorporeal membrane

Table 2. Preoperative diagnostic data

Preoperative diagnostic tests	Total anomalous pulmonary venous return type													
	Supracardiac (n=18)			Cardiac (n=4)			Infracardiac (n=6)			Mixed (n=3)			*Total*	
Anatomical type	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	Mean±SD
Echocardiography														
Pulmonary venous obstruction	3	15		–	–		6	100		1	33		10	
Left ventricular hypoplasia	2	11		–	–		3	50		1	33		–	
Left ventricular diameter			13.1±5.5			11.7±2.7			7.9±1.1			10.1±3		12.3±4
Defect			8.0±4.1			6.1±2.4			5±2.3			5.4±2.1		6.3±3.2
Atrial septal defect	13	–		2	–		3	–		3	–		21	
Patent foramen ovale	5	–		2	–		3	–		–	–		10	
Patent ductus arteriosus	4	–		1	–		2	–		–	–		7	
Computed tomography*	7	41		1	25		–	–		3	100		11	
Cardiac catheterization and angiography	5	29		–	–		1	16		–	–		6	

SD: Standard deviation; * Percentages based on the anatomical types of total anomalous pulmonary venous return.

oxygenation (ECMO), a form of advanced life support. Plus, two of the 31 patients who were operated on had severe bleeding which led to hemodynamic instability, but they did not require revision surgery.

Eight patients experienced a pulmonary hypertensive crisis. Five of these were diagnosed with obstructive pulmonary venous return, three had a non-obstructive pathology, and four suffered from left ventricular hypoplasia. The mean time to the onset of the pulmonary hypertensive crisis was 30 hours (range 8-72 hours) for the ICU patients, and three actually had more than one pulmonary hypertensive crisis. For instance, an eight-month old patient had two late pulmonary hypertensive crises at 10 and 28 days postoperatively. The baseline partial pressure of carbon dioxide (pCO_2) values, NIRS parameters, mean PAP (mPAP), mean invasive blood pressure, and OS values at baseline along with these values during the initial pulmonary hypertensive crisis are shown in Figures 1 and 2.

We also found that six patients had low cardiac output. Four of these having PVO while five also had left ventricular hypoplasia. In addition, two of these patients required ECMO life support due to a continuous low cardiac output in spite of receiving intensive inotropic support and peritoneal dialysis.

Based on the clinical findings, 10 patients were suspected of having acute phase reactants. Four patients had bacterial production in the blood samples, including two with *Klebsiella pneumonia*, one with *Pseudomonas aeruginosa*, and another with *Streptococcus epidermis*. Furthermore, three patients had pneumonia, one had necrotizing enterocolitis, and another had mediastinitis. Based on the results of the culture antibiograms, antibiotherapy was initiated, and the infection resolved in nine of 10 patients.

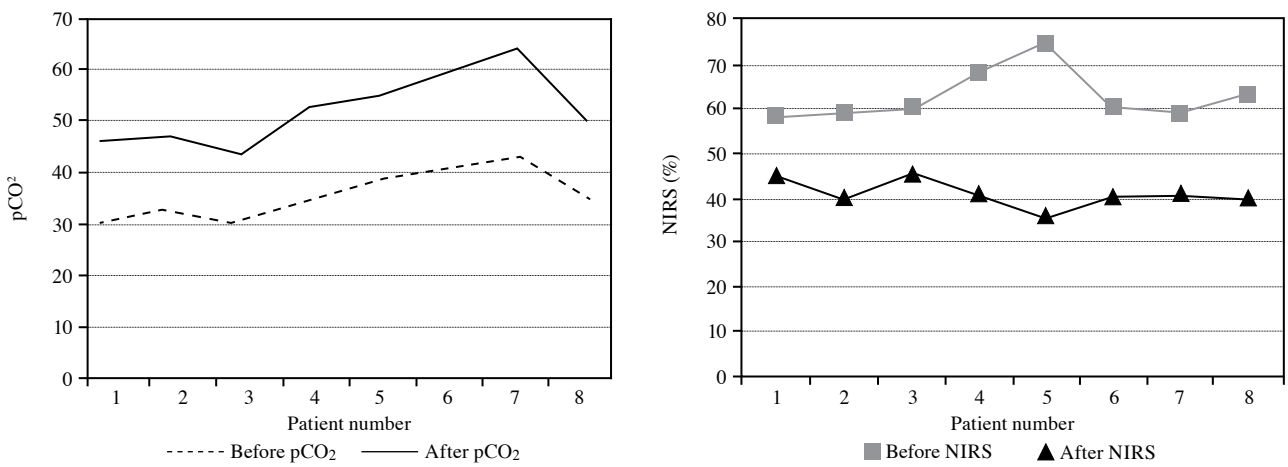

Figure 1. Changes in the baseline near-infrared spectroscopy and partial pressure of carbon dioxide values before and after the pulmonary hypertensive crisis. pCO_2: Partial pressure of carbon dioxide; NIRS: Near-infrared spectroscopy.

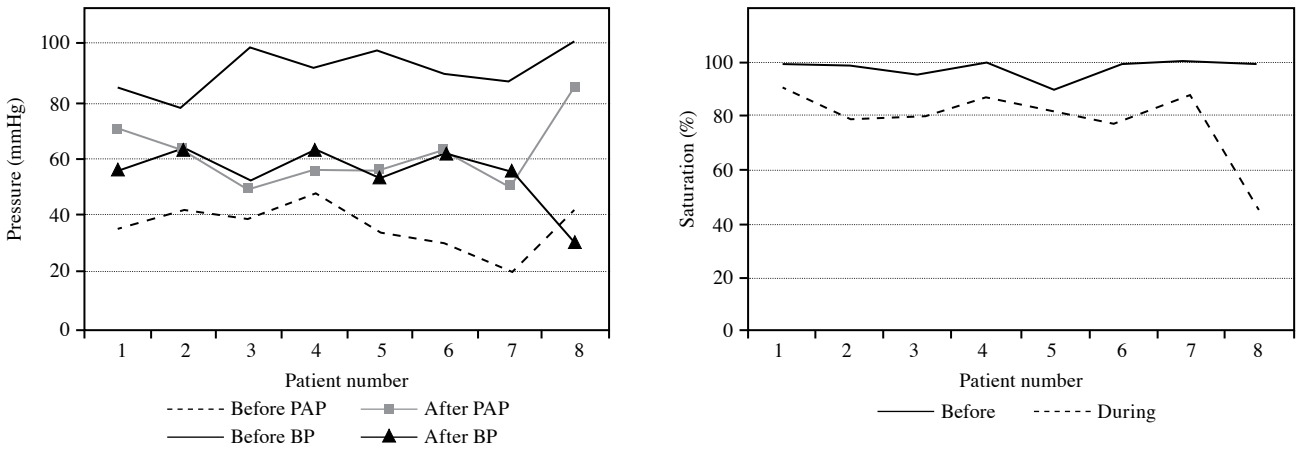

Figure 2. Changes in the baseline oxygen saturation, pulmonary arterial pressure, and blood pressure values before and during the pulmonary hypertensive crisis. No 1,3,8 had the infracardiac type of total anomalous pulmonary venous return while the others had the supracardiac type. Patient number 8 died before the pulmonary hypertensive crisis; The near-infrared spectroscopy parameters along with the oxygen saturation and systemic blood pressure values were statistically significantly reduced during the pulmonary hypertensive crisis, whereas the pulmonary artery pressure and pCO_2 were significantly increased ($p<0.05$ on the Wilcoxon test); PAP: Pulmonary artery pressure; BP: Blood pressure.

In spite of intensive supportive therapy, one patient with necrotizing enterocolitis died due to multiple organ failure. We also determined that none of the patients had chylothorax or a nerve injury. In addition, 17 patients were in normal sinus rhythm, five were in sinus tachycardia, four were in junctional ectopic tachycardia (JET), two were in intra-atrial reentry tachycardia (IART), and one was in supraventricular tachyarrhythmia (SVT). Furthermore, five patients had supraventricular extrasystole (SVE), and three suffered from sinus bradycardia.

The incidence rates of arrhythmia in the early stage of TAPVR are presented in Figure 3. The arrhythmia-related hemodynamic instability was treated, and cold packing was applied to all of the patients with JET. Additionally, three of the JET patients received suppressive therapy with amiodarone while one received overriding pacing + amiodarone. The patients with IART underwent cardioversion and were prescribed anti-arrhythmics, whereas the patients with SVT received adenosine in order to return to normal sinus rhythm. One of five patients with SVT received propafenone, but the others were not prescribed any antiarrhythmics. Moreover, the patients with sinus bradycardia required temporary pacing, and then they returned to normal sinus

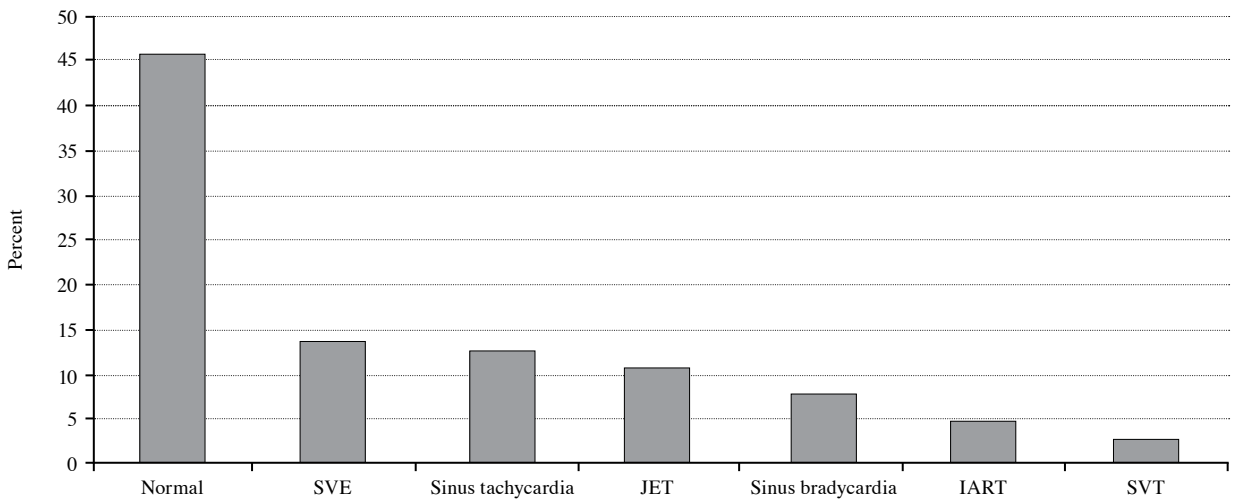

Figure 3. Type and incidence rates of arrhythmias. Percentages based on the total number of patients (Some patients had more than one type of arrhythmia); SVE: Supraventricular extrasystole; JET: Junctional ectopic tachycardia; IART: Intra-atrial reentry tachycardia; SVT: Supraventricular tachyarrhythmia.

Table 3. Postoperative complications by disease type**

Anatomical type	Total anomalous pulmonary venous return type							
	Supracardiac (n=18)		Cardiac (n=4)		Infracardiac (n=6)		Mixed (n=3)	
	n	%	n	%	n	%	n	%
Bleeding	1	6	1	25	1	16	–	–
Low cardiac output syndrome	1	6	1	25	3	50	1	33
Pulmonary hypertensive crisis	5	30	–	–	3	50	–	–
Cardiac arrhythmia*	4	22	2	50	3	50	1	33
Sepsis	6	33	1	25	3	50	–	–
Extubation failure	2	11	–	–	–	–	–	–
Chylothorax	–	–	–	–	–	–	–	–

* Arrhythmias requiring an additional intervention due to hemodynamic instability; ** Percentages based on the anatomical types of total anomalous pulmonary venous return.

rhythm. Two patients underwent tracheostomies due to prolonged intubation and were extubated after this procedure. The postoperative complications according to disease type are summarized in Table 3. The low cardiac output syndrome (LCOS) and pulmonary hypertensive crisis incidence rates were higher in the patients with infracardiac TAPVR ($p<0.05$). The mechanical ventilation, ICU, and hospital stay durations are shown in Table 4, and we found that the patients with supracardiac TAPVR had longer durations in all three categories ($p<0.05$). Unfortunately, five of the patients died during the follow-up period, and the overall characteristics of these patients are shown in Table 5.

Table 4. Duration of mechanical ventilation and intensive care unit and hospital stays

Anatomical type	Mechanical ventilation (hours)	ICU stay (hours)	Hospital stay (hours)
	Mean±SD	Mean±SD	Mean±SD
Supracardiac	239±488	375±609	513±660
Cardiac	53±60	93±99	192±130
Infracardiac	148±173	175±155	316±227
Mixed	89±61	145±82	272±180
Total	179±372	271±468	403±513

ICU: Intensive care unit; SD: Standard deviation.

Table 5. Overall characteristics of exitus patients

Patient number	Gender	Disease type	Age (days)	CPB time (min)	Length of ICU stay (days)	Left ventricular hypoplasia	Cause of death
1*	M	Infracardiac obstructive	14	139	4	Yes	Low cardiac output
2*	F	Infracardiac Obstructive	36	106	8	Yes	Pulmonary hypertensive crisis
3**	F	Cardiac non-obstructive	34	480	1	Yes	Low cardiac output
4	M	Supracardiac non-obstructive	6	114	10	Yes	Sepsis
5*	F	Infracardiac obstructive	2	136	20	Yes	Low cardiac output

CPB: Cardiopulmonary bypass; ICU: Intensive care unit; * Metabolic acidosis in No 1, 2 and 5 before surgery; ** No. 3 had persistent left superior vena cava which was confirmed intraoperatively. The patient was hospitalized in the intensive care unit with extracorporeal membrane oxygenation life support.

Table 6. Effect of pulmonary venous obstruction on the pre-, intra-, and postoperative outcomes

Variable	PVO Negative			PVO Positive			
	n	%	Mean±SD	n	%	Mean±SD	*p*
Anatomical type							
Supracardiac	15			3			0.001
Cardiac	4			–			
Infracardiac	–			6			
Mixed	2			1			
Gender							
Males	5			5			0.222
Females	16			5			
Age			70±50			20±14	0.002
<30 days/total	5/21			6/10			0.106
Weight			4.3±1.2			3.1±0.5	0.008
Preoperative intubation (%)		–			40		0.007
Preoperative acidosis		–			40		0.007
Preoperative saturation			86±7			70±14	0.006
Left ventricular hypoplasia	2			4			0.040
Cardiopulmonary bypass time in minutes			123±95			149±58	0.050
Aortic cross-clamp time in minutes			75±59			91±47	0.179
Duration of mechanical ventilation			206±440			118±143	0.340
Length of intensive care unit stay			323±554			154±126	0.562
Length of hospital stay			457±603			283±188	0.883
Bleeding		10			10		0.999
Extubation failure		10			–		0.899
Low cardiac output syndrome		15			33		0.332
Arrhythmia		35			33		0.981
Postoperative pulmonary hypertension		20			22		0.994
Sepsis		35			33		0.981

PVO: Pulmonary venous obstruction; SD: Standard deviation.

We also analyzed the pre-, intra-, and postoperative data of the PVO and non-PVO patients as confirmed by echocardiography, and the statistical outcomes of the variables are shown in Table 6. The incidence of PVO was higher in the patients with infracardiac TAPVR and in the younger patients with a lower body weight. Additionally, preoperative acidosis, preoperative intubation, and left ventricular hypoplasia were seen more often in the patients with lower preoperative OS values ($p<0.05$).

The statistical analyses of the pre-, intra-, and postoperative risk factors associated with early mortality are given in Table 7. The univariate analysis showed that the possible risk factors included the anatomical type of disease, patient's age, and the presence of preoperative intubation, left ventricular hypoplasia, LCOS, or arrhythmia, whereas the multivariate logistic regression analysis indicated that preoperative intubation [odds ratio (OR): 1.008; confidence interval (CI): 1.003-1.015; p=0.018)], left ventricular hypoplasia (OR: 1.2; CI: 0.9-1.7; p=0.024)], and LCOS (OR: 1.013; CI: 1.006-1.020; p=0.034) were possible risk factors.

The mean patient follow-up time was 15 months (range 3-36 months). Furthermore, two patients had low-grade PVO during the follow-up period, but none required a reoperation.

DISCUSSION

Total anomalous pulmonary venous return is classified into the following four types based on the anatomical sites of the abnormal connection: supracardiac, cardiac, infracardiac, and mixed. Although various incidence rates have been reported in the literature, the most common type is supracardiac while the mixed type is the rarest form.[5] In a study comprised of 377 patients, Karamlou et al.[6] reported that 44% (n=164) had the supracardiac type of TAPVR, 26% (n=98) had the infracardiac type, 21% (n=78) had the cardiac type, and 9% (n=35) had the mixed type of this disease. Three large-scale studies were conducted in Turkey on this topic.[7-9] Ozkara et al.[7] performed

Table 7. Statistical analysis of the risk factors associated with early mortality

	Univariate	Multivariate*	OR	Below 95% CI	Above 95% CI
	p	*p*			
Anatomical type	0.050	NS			
Gender	0.991				
Age	0.063	NS			
<30 days	0.317				
Weight	0.081				
Preoperative intubation	0.008	0.018	1.008	1.003	1.015
Preoperative saturation	0.387				
Left ventricular hypoplasia	0.010	0.024	1.2	0.9	1.7
Pulmonary venous obstruction	0.296				
Cardiopulmonary bypass time	0.162				
Aortic clamping time	0.482				
Vertical vein ligation	0.341				
Closure of atrial septal defect	0.456				
Low cardiac output syndrome	0.001	0.034	1.013	1.006	1.020
Arrhythmia	0.002	NS			
Postoperative pulmonary hypertension	0.675				
Sepsis	0.981				

* Patients with a *p* value of <0.05 as assessed by a univariate analysis also underwent a multivariate logistic regression analysis; OR: Odds ratio; CI: Confidence interval; NS: Not significant.

surgery on 61 patients and found that 44.2% (n=27) had the supracardiac drainage of TAVPR while 39.3% (n=24) had the cardiac drainage, 6.5% (n=4) had the infracardiac drainage, and 9.8% (n=6) had the mixed drainage. In our study, the most common pathology was supracardiac TAPVR, which was identified in 58% (n=18) of the patients. This was followed by the infracardiac type in 19%, the cardiac type in 13%, and the mixed type in 10%, and these percentages were consistent with the data in the literature.

A pulmonary hypertensive crisis is a severe clinical condition with a poor prognosis that is characterized by right ventricular loading that induces right ventricular insufficiency because of pulmonary vein resistance in the early postoperative period following cardiac surgery.[10] Total anomalous pulmonary venous return is one of the leading cardiac defects. It results in pulmonary venous congestion, thereby causing a pulmonary hypertensive crisis. In addition, this type of crisis affects between 20 and 50% of the patients with TAPVR in the postoperative period and is also responsible for the majority of deaths in these same patients.[10-12]

Prevention and management strategies for pulmonary hypertensive crises include intraoperative vertical vein opening, deep sedation, muscle paralysis for 24-48 hours, maintaining the pCO_2 between 30 and 35 mmHg, pharmacological therapy (e.g., sildenafil, phenoxybenzamine, ilioprost, and iNO), the use of a selective pulmonary vasodilator, and ECMO life support.[10-12] Karaci et al.[9] reported that 10% of the patients (n=6) in their study with isolated TAPVR had a pulmonary hypertensive crisis and that in spite of intensive therapy, two of them died. In another study composed of 100 patients, Kelle et al.[12] observed a pulmonary hypertensive crisis in 20 patients, and three of these died as a result of the crisis.

In our study, we observed a significant decrease in the NIRS parameters and OS values during the pulmonary hypertensive crises, but there was a significant increase in the CO_2 values. Although eight of our patients (26%) who underwent surgery developed a pulmonary hypertensive crisis, only one died. This can be attributed to the fact that the operations were performed in a well-equipped facility. Furthermore, cranial NIRS monitoring took place along with the standard monitoring, echocardiography was performed, and iNO therapy was available.

Bove et al.[13] and Hammon et al.[14] reported that the length and function of the left ventricle was considerably reduced in the early postoperative period in selected patients with TAPVR and that this disease was more prominent in patients with preoperative PVO. In turn, this led to lower cardiac output. Saritas et al.[8] found that six of the 40 patients in their study had low cardiac output, and two of these died. In another study by Sagat et al.[15] the authors reported low cardiac output in five of their patients (11%). In our

study, we had six patients with low cardiac output, five of them had an obstructive-type anomalous pulmonary venous return and four of them had left ventricular hypoplasia. Despite intensive inotropic support and ECMO, three of these patients died. As we gain experience regarding ECMO in the clinical practice, we believe that the number of low cardiac output-related deaths, which account for 60% of all mortality associated with TAPVR, can be dramatically reduced.

Early postoperative arrhythmias, which are critical for hemodynamic stability, are seen in 15-20% of all pediatric cardiac surgeries,[16] but these rates may be affected by the surgical technique (open or closed), age of the patient, the presence of a complex intracardiac repair, and the number of patients who receive inotropic support as well as the duration of this support. Hraska et al.[17] reported that 11% of the patients in their study were in JET, 41% were in sinus rhythm, 4% had Wolf-Parkinson-White (WPW) syndrome, 7% were in SVT, and 37% had other arrhythmias. In another study that included patients with obstructive (n=20) and non-obstructive (n=31) pathologies, the authors found that 80% (n=16) of those with obstructive TAPVR and 65% of those with non-obstructive TAPVR had arrhythmias.[15] In our study, we observed JET in 11% of our patients and sinus tachycardia in another 16% (n=5). We also reported IART in two patients (6%).

Pulmonary venous obstruction is crucial for both pre- and postoperative assessment in the ICU. Several studies have shown that patients with preoperative PVO had lower intubation rates, a higher number of postoperative pulmonary hypertensive crises and episodes, and a greater amount of positive inotropic support during their ICU stays.[18] Sagat et al.[15] compared PVO and non-PVO isolated TAPVR patients and found that the PVO patients had longer ICU stays with a higher incidence of ICU complications. However, they reported no significant differences with regard to the duration of surgery and mortality among their patients. We also found no differences between the mortality rates in the PVO patients in our study.

Following TAPVR corrective surgery, the mortality rate in recent years has decreased from 80% to below 10%, with early and accurate diagnoses, new developments in surgical techniques, and effective and improved ICU support being responsible for this dramatic improvement.[1-3] In the study by Karamlou et al.[6] that included 377 TAPVR patients with complex pathologies, they found that the mortality rate had decreased from 50% in the 1960s to 5% in the 1970s. In another single-center study made up of 100 patients, Kelle et al.[12] reported a mortality rate of 5% in patients who underwent biventricular repair. Moreover, Song and Yoon[19] reported a mortality rate of 8.3%. In our study, we reported a mortality rate of 16% in the TAPVR patients in the ICU.

The major factors which affect mortality include the anatomical site of the abnormal connection of the pulmonary vein, the presence of PVO, a poor preoperative clinical and metabolic condition, the age of the patient, the presence of pulmonary hypertension, small left ventricular size, vertical vein ligation during surgery, or the closure of the atrial septal defect (ASD) in patients with TAPVR. Sinzobahamvya et al.[20] determined that the main factor associated with mortality was PVO, which occurs when the pulmonary veins are too narrow. Postoperative progressive and continuing pulmonary hypertension can be explained by the existing intrinsic venous obstruction in the early stage. Bove et al.[13] demonstrated that the mortality rate was significantly higher in patients with infracardiac TAPVR accompanied by metabolic acidosis preoperatively. In addition, Hammon et al.[14] reported that small left cardiac cavities that were inconsistent with the age of the patient might be responsible for low cardiac output postoperatively.

In our study, three of five patients who died had infracardiac TAPVR along with PVO, while all of them had left ventricular hypoplasia. In addition, preoperative intubation due to acidosis, left ventricular hypoplasia, and LCOS were independent risk factors that were directly associated with mortality.

Our study did have a few limitations. First, the sample size was small. Therefore, we recommend further studies be conducted on a larger number of patients to verify our results. In addition, the operations were performed by three surgical teams, and there was a disproportionate volume among the three teams, which might have affected some of our findings. Finally, our follow-up period was relatively short.

Conclusion

Our findings revealed that postoperative complications such as low cardiac output, pulmonary hypertensive crises, and arrhythmia can be prevented by advanced ICU monitorization, especially for patients without the need for mechanical ventilation, those without metabolic acidosis, those with TAPVR who also have left ventricular hypoplasia, and those who have PVO. Furthermore, early and effective treatment with NO drugs or ECMO support to counteract these complications could lead to an improvement in the morbidity and mortality rates of these patients.

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REFERENCES

1. Kirshborn P, Jaggers J, Underleider R. Total anomalous pulmonary venous connection. In: Mavroudis C, editor. Pediatric Cardiac Surgery. 3rd ed. Philadelphia: Mosby; 2003. p. 612-5.
2. Geva T, Van Praagh S. Anomalies of the pulmonary veins. In: Allen HD, Shaddy RE, Driscoll DJ, Feltes TF, editors. Moss and Adams' heart disease in infants, children, and adolescents: including the fetus and young adult. 7th ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2008. p. 761-75.
3. Jonas R. Anomalies of the pulmonary veins. In: Jonas R, editor. Comprehensive surgical management of congenital heart disease. 1st ed. Boston: CRC Press; 2004. p. 400-12.
4. Wernovsky G, Wypij D, Jonas RA, Mayer JE Jr, Hanley FL, Hickey PR, et al. Postoperative course and hemodynamic profile after the arterial switch operation in neonates and infants. A comparison of low-flow cardiopulmonary bypass and circulatory arrest. Circulation 1995;92:2226-35.
5. Seale AN, Uemura H, Webber SA, Partridge J, Roughton M, Ho SY, et al. Total anomalous pulmonary venous connection: morphology and outcome from an international population-based study. Circulation 2010;122:2718-26.
6. Karamlou T, Gurofsky R, Al Sukhni E, Coles JG, Williams WG, Caldarone CA, et al. Factors associated with mortality and reoperation in 377 children with total anomalous pulmonary venous connection. Circulation 2007;115:1591-8.
7. Özkara A, Çetin G, Mert M, Akçevin A, Paker T, Türkoğlu H ve ark. Total anormal pulmoner venöz dönüş ve cerrahi yaklaşımlar: Altmış bir olguda deneyimimiz. Turk Gogus Kalp Dama 2005;13:329-34.
8. Sarıtaş B, Bolat B, Özkan S, Akay T, Vuran C, Özçobanoğlu S ve ark. Total anormal pulmoner venöz dönüş anomalisinin cerrahi tedavisinde açık bırakılan vertikal ven ve/veya atriyal septal defektin etkisi. Turk Gogus Kalp Dama 2008;16:6-10.
9. Karaci AR, Harmandar B, Aydemir NA, Sasmazel A, Balci AY, Saritas T, et al. Early and intermediate term results for surgical correction of total anomalous pulmonary venous connection. J Card Surg 2012;27:376-80.
10. De Wolf D. Clinical practice: pulmonary hypertension in children. Eur J Pediatr 2009;168:515-22.
11. Lindberg L, Olsson AK, Jögi P, Jonmarker C. How common is severe pulmonary hypertension after pediatric cardiac surgery? J Thorac Cardiovasc Surg 2002;123:1155-63.
12. Kelle AM, Backer CL, Gossett JG, Kaushal S, Mavroudis C. Total anomalous pulmonary venous connection: results of surgical repair of 100 patients at a single institution. J Thorac Cardiovasc Surg 2010;139:1387-94.
13. Bove EL, de Leval MR, Taylor JF, Macartney FJ, Szarnicki RJ, Stark J. Infradiaphragmatic total anomalous pulmonary venous drainage: surgical treatment and long-term results. Ann Thorac Surg 1981;31:544-50.
14. Hammon JW Jr, Bender HW Jr, Graham TP Jr, Boucek RJ Jr, Smith CW, Erath HG Jr. Total anomalous pulmonary venous connection in infancy. Ten years' experience including studies of postoperative ventricular function. J Thorac Cardiovasc Surg 1980;80:544-51.
15. Sagat M, Omeje IC, Nosal M, Kantorova A, Valentik P, Poruban R. Long-term results of surgical treatment of total anomalous pulmonary venous drainage in children. Bratisl Lek Listy 2008;109:400-4.
16. Silva JN, Van Hare G. Management of postoperative pediatric cardiac arrhythmias: current state of the art. Curr Treat Options Cardiovasc Med 2009;11:410-6.
17. Hraska V, Sagat M, Sojak V, Kostolny M, Nosal M, Kantorova A, et al. Surgical treatment of total anomalous pulmonary venous return. Bratisl Lek Listy 1999;100:657-61. [Abstract]
18. Michielon G, Di Donato RM, Pasquini L, Giannico S, Brancaccio G, Mazzera E, et al. Total anomalous pulmonary venous connection: long-term appraisal with evolving technical solutions. Eur J Cardiothorac Surg 2002;22:184-91.
19. Song JY, Yoon YS. Long-term clinical study of total anomalous pulmonary venous return. J Korean Pediatr Soc 2000;43:229-35.
20. Sinzobahamvya N, Arenz C, Brecher AM, Blaschczok HC, Urban AE. Early and long-term results for correction of total anomalous pulmonary venous drainage (TAPVD) in neonates and infants. Eur J Cardiothorac Surg 1996;10:433-8.