Some common hemodynamic disorders and risk factors in patients after Blalock- Taussig Shunt in Vietnam National Children's Hospital in 2021

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ABSTRACT

The aims of this study were to describe some common hemodynamic disorders and evaluate some risk factors in patients after Blalock-Taussig Shunt (BTS). It was a cross-sectional study in 70 patients less than 5kg with a closed heart surgery by the simple BTS. Patients' hemodynamic data were collected, some early hemodynamic disorders such as under shunt, over shunt, and capillary leak were described within 48 hours after the BTS, and related factors were recorded. Hemodynamic data were described and compared between complication groups and then some risk factors related to hemodynamic disorders were described. The rate of hemodynamic disorders within 48 hours after the BTS were 94.0%, in which 37.1% were under shunt, 42.9% were overshunt, and 54.3% had capillary leak. Patients with capillary leak after the BTS had higher cardiovascular indexes than those of the others. Neonatal patients and patients who were operated by midline incision had higher risk of capillary leak than the others. BTS patients had a high rate of hemodynamic disorders within 48 hours after the BTS. The neonatal age and the midline incision were risk factors relating to the capillary leak status after the BTS.

Keywords. *Blalock-Taussig Shunt, Capillary leak, Hemodynamic Disorders, Over shunt. Risk factors, Under shunt*

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INTRODUCTION

Congenital Heart Defect is the most common heart abnormality with the rate of 0.8% among live births [1-2]. Appropriately 10-20% of patients with critically congenital heart defects caused collapsed circulation or sudden death in the neonatal stage [3-5]. Most life-threatening congenital heart defects were congenital heart defects depending on Patent Ductus Arteriosus [6-7].

BTS has been performed since 1940, aiming at replacing the role of Patent Ductus Arteriosus [8-9] but the mortality rate after the operation has been high still. The mortality rate of single ventricle has been about 15%, that of two ventricles has been 3-5% [10-11]. A great deal of change in the pulmonary artery resistance in the early stage of infants as well as the change of weight relating to the selection of shunt size and the response of incomplete circulation system led to many hemodynamic disorders after the operation such as pulmonary circulation overload, shunt insufficiency, low heart flow syndrome, and capillary leak [9,12-15].

The study aimed at describing the hemodynamic features of some early hemodynamic disorders in patients after the operation of BTS and determining some

risk factors relating to these hemodynamic disorders.

MATERIALS AND METHODS

Studied subjects

Patients weighing less than < 5kg whose congenital pulmonary circulation depended on patent ductus arteriosus were operated in a closed heart surgery to create a single BTS at The Cardiovascular Center of Vietnam National Children's Hospital.

Exclusion criteria

Patients lacked hemodynamic data after the BST and/or had other fatal congenital heart diseases.

Method

It was a cross-sectional study.

Sample size and sampling process:

All patients with inclusion criteria were collected in the study by convenient method during the study time.

Study time

From 01/06/2016 to 31/07/2021.

Study location

Cardiovascular ressucition unit – Internal Cardiovascular Depart- Cardiovascular Center- Vietnam National Children's Hospital.

Data collection procedures

General data such as age, sex, birthweight, diagnosis, ventilation, and shock before the BTS were gathered by taking medical histories and studying medical records thoroughly. Line incision, type shunt, pulse, CVP, SBP, DBP, MAP, PP, VIS, and UO were recorded during and after the BTS.

Some definitions used in the study: Hemodynamic disorders were defined as patients had to be supported with vasomotor drugs to maintain SBP more than the 5th percentile by age [13]. Criteria for under shunt included SpO_2 < 70% with FiO_2 21%, a need to increase FiO_2 > 60% to ensure SpO_2 > 75%, and the reduction of pulmonary perfusion on X-ray [15]. Criteria for overshunt were SpO_2 > 85% together with FiO_2 21% and increased pulmonary flow on X-ray [15]. Criteria for capillary leak included hypovolemia that needed to be compensated, unstable hemodynamics depending on vasomotor drugs, anasarca, and multimembrane effusion [13].

Necessary data from the studied subjects were collected into an already-designed medical record form.

Data analysis

Data were analysed by SPSS 20.0. Hemodynamic variables were showed as mean ± standard deviation. Means were compared by using independent paired T-test, the differences were statistically significant when p value was less than 0.05. The rate of hemodynamic disorders was calculated as percentages. OR were calculated to describe the relationship of hemodynamic disorders with some risk factors with 95%CI.

Ethical considerations

Study protocol was accepted by Vietnam National Children's Hospital (No 962/BVNTW-VNCSKTE) and approved by Scientific Research Ethics Committee (IRB). The parents or legal guardians of these children gave informed consent after full explanation of the objectives of the study was provided. Each participant in the final sample was identified by assigning a number.

RESULTS

70 patients had enough inclusion criteria for the study. The mean age was 44.3 ± 33.9 days. The mean weight was 3.6 ± 0.6 kg. Common features of studied subjects were presented in table 1.

Table 1. *Common features of studied subject*s

Patient features		Number (n)	Percentage (%)
Age	≤ 28 days	29	41.4
	1 month to 6 months	41	58.6
Gender	Males	46	65.7
	Females	24	34.3
Weight	< 3 kg	7	10
	≥ 3 - < 5 kg	63	90
Diagnosis	Pulmonary atresia/stenosis, ventricular septum defect /Fallot 4	38	54.3
	Pulmonary stenosis/atresia-intact ventricular septum	11	15.7
	Single ventricle with pulmonary atresia or stenosis	21	30
Ventilated before operation	Yes	20	28.6
	No	50	71.4
Shock before operation	Yes	10	14.3
	No	60	85.7
Line incision	Midline	60	85.7
	Lateral	10	14.3
Shunt type	MBTS	62	88.6
	Melbourne	8	11.4
Shunt/weight ratio	< 1 mm/kg	30	42.9
	≥ 1 mm/kg	40	57.1
PDA ligation	Yes	51	72.9
	No	19	27.1

Table 1 shows that neonatal patients represented 41.4%, 54.3% were pulmonary atresia/stenosis with ventricular septum defect or Fallot 4, 88.6% of patients were under MBTS (Modified Blalock-Taussig shunt).

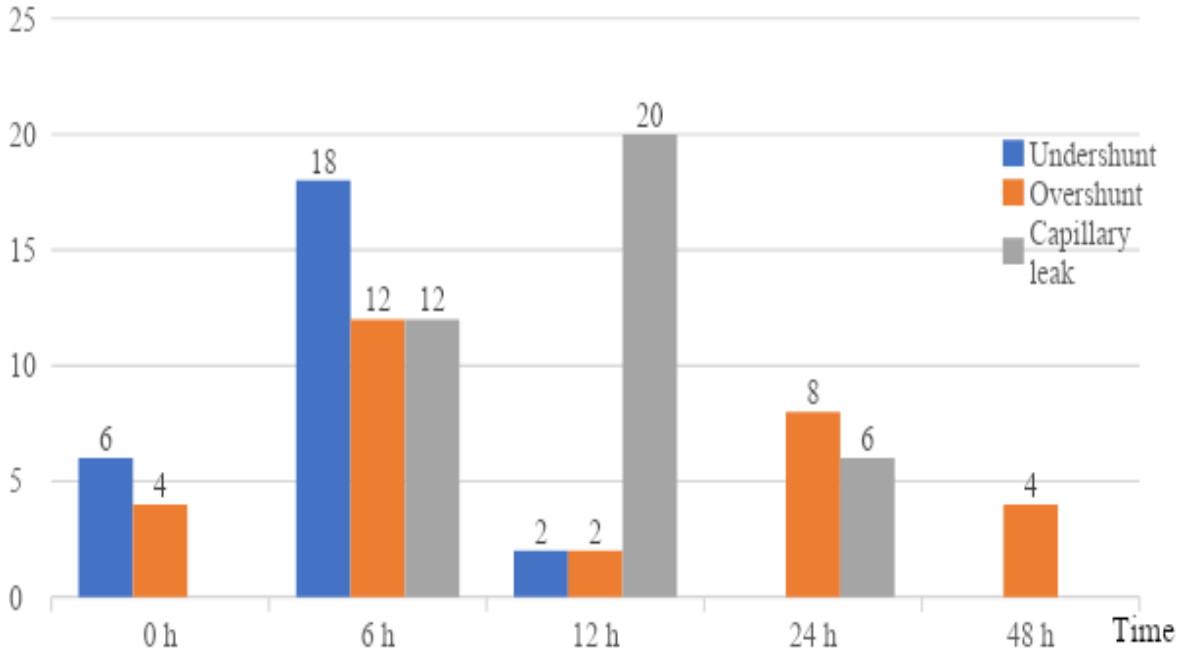

Figure 1. *Early hemodynamic complications after Blalock-Taussig Shunt*

Figure 1 shows that among 70 studied patients, 66 patients (94%) had hemodynamic disorders 48 hours after the operation (requiring vasomotor drugs to maintain systolic blood pressure more than the 5th percentile by age) (these numbers were not displayed in Figure 1)

Table 2. *Hemodynamic differences among under shunt, over shunt, and no complication groups*

Indexes (Mean ± SD)	**No complication (1)**	**Under shunt (2)**	**Over shunt (3)**	**p (1,2)**	**p (1,3)**	**p (2,3)**
Pulse	146.8 ± 21.4	149.8 ± 15.9	145.3 ± 28.8	> 0.05	> 0.05	> 0.05
CVP	9.0 ± 2.3	9.8 ± 2.9	8.5 ± 2.4	> 0.05	> 0.05	> 0.05
SBP	71.2 ± 12.2	76.1 ± 8.4	76.5 ± 15.3	> 0.05	> 0.05	> 0.05
DBP	35.1 ± 6.4	39.1 ± 4,5	31.4 ± 4,4	< 0.05	> 0.05	< 0.05
MAP	49.4 ± 8.3	53.8 ± 4.6	49.0 ± 8.8	< 0.05	> 0.05	< 0.05
PP	36.1 ± 10.5	37.0 ± 10.1	44.7 ± 11.4	> 0.05	< 0.05	< 0.05
UO	3.1 ± 2.9	2.7 ± 2.2	2.7 ± 1.3	> 0.05	> 0.05	> 0.05

Table 2 shows that from comparing hemodynamic disorders, patients with over-shunt syndrome had higher pulse pressure than that in the other two groups ($p < 0.05$).

Table 3. *Hemodynamic differences between capillary leak syndrome and no capillary leak syndrome groups*

Indexes (Mean ± SD)	Capillary leak	No Capillary leak	p
Pulse	140.4 ± 17.0	154.3 ± 31.1	< 0.05
CVP	9.1 ± 2.5	9.3 ± 2.3	> 0.05
SBP	73.8 ± 14.1	70.8 ± 11.8	> 0.05
DBP	36.1 ± 7.1	36.7 ± 6.6	> 0.05
MAP	50.7 ± 9.9	49.9 ± 7.8	> 0.05
PP	37.7 ± 10.2	34.9 ± 9.5	> 0.05
VIS	5.4 ± 4.5	9.4 ± 5.6	< 0.05
UO	4.3 ± 3.1	3.3 ± 2.3	> 0.05

Table 3 shows that patients with capillary leak had faster pulse and higher vasomotor indexes than patients without capillary leak syndrome.

Table 4. *Hemodynamic changes in patients with capillary leak syndrome after the operation*

Indexes (Mean ± SD)	6h	12h	24h	48h
Pulse	149.8 ± 23.2	154.4 ± 31.1	153.4 ± 18.8	135.2 ± 14.6
CVP	9.5 ± 2.0	9.3 ± 2.3	10.0 ± 2.5	9.6 ± 2.1
SBP	72.8 ± 8.8	70.8 ± 11.8	74.9 ± 11.9	78.8 ± 8.4
DBP	36.6 ± 6.9	36.7 ± 6.6	36.0 ± 6.2	36.9 ± 6.6
MAP	50.7 ± 7.0	50.0 ± 7.8	51.1 ± 7.7	53.9 ± 6.7
PP	39.3 ± 10.9	34.9 ± 9.5	39.3 ± 10.9	42.0 ± 9.0
VIS	7.2 ± 6.0	9.4 ± 5.6	11.4 ± 6.4	9.1 ± 7.0
UO	3.3 ± 2.8	3.3 ± 2.4	3.2 ± 2.2	5.4 ± 2.4

Table 4 shows that patients with capillary leak syndrome, hemodynamic disorders had the most severe tendency within 12-24 hours after the operation, with the manifestation of fast pulse and high vasomotor indexes, and gradually stabilized within 48 hours after the operation.

Table 5. *The association between pre-operative, during-operative factors, and post-operative under shunt*

Risk factors		Undershunt n (%)	No Undershunt n (%)	p	OR	95% CI
Age (month)	≤ 1	11 (37.9)	18 (62.1)	1.00	1.06	0.40-2.83
	> 1	15 (36.6)	26 (63.4)			
Weight (kg)	< 3	4 (57.1)	3 (42.9)	0.41	2.49	0.51-12.11
	≥ 3	22 (34.9)	41 (65.1)			
Shunt type	MBTS	23 (37.1)	39 (62.9)	1.00	0.98	0.22-4.50
	Melbourne	3 (37.5)	5 (62.5)			
Shunt/ Weight ratio	< 1	8 (26.7)	22 (73.3)	0.14	0.44	0.16-1.23
	≥ 1	18 (45)	22 (55)			
PDA ligation	Yes	16 (31.4)	35 (68.6)	0.16	0.41	0.14-1.21
	No	10 (52.6)	9 (47.4)			

Table 5 shows that no risk factors were statistically significantly associated with undershunt syndrome after the operation.

Table 6. *The association between pre-operative, during-operative factors, and post-operative over shunt*

Risk factors		Overshunt n (%)	No overshunt n (%)	p	OR	95% CI
Age (month)	≤ 1	13 (44.8)	16 (55.2)	0.81	1.15	0.44-3.00
	> 1	17 (41,5)	24 (58,5)			
Weight (kg)	< 3	3 (42.9)	4 (57.1)	1.00	1,00	0.23-4.85
	≥ 3	27 (42.9)	36 (57.1)			
Shunt type	MBTS	26 (41.9)	36 (58.1)	0.72	0.72	0.17-3.16
	Melbourne	4 (50)	4 (50)			
Shunt/ Weight ratio	< 1	13 (43.3)	17 (56.7)	1.00	1.04	0.40-2.69
	≥ 1	17 (42.5)	23 (57.5)			
PDA ligation	Yes	23 (45.1)	28 (54.9)	0.60	1.41	0.48-4.16
	Không	7 (36.8)	12 (63.2)			

Table 6 shows that no risk factors were statistically significantly associated with over shunt syndrome after the operation.

Table 7. *The association between pre-operative, during-operative factors and post-operative capillary leak*

Risk factors		Capillary leak n (%)	No capillary leaks n (%)	p	OR	95% CI
Age (month)	≤ 1	21 (72.4)	8 (27.6)	0.02	3.71	1.33-10.32
	> 1	17 (41.5)	24 (58.5)			
Weight (kg)	< 3	5 (71.4)	2 (28.6)	0.44	2.27	0.41-12.60
	≥ 3	33 (52.4)	30 (47.6)			
Shock before operation	Yes	6 (60)	4 (40)	0.75	1.31	0.34-5.13
	No	32 (53.3)	28 (46.7)			
Ventilated before operation	Yes	13 (65)	7 (35)	0.30	1.86	0.64-5.43
	No	25 (50)	25 (50)			
Shunt type	MBTS	33 (53.2)	29 (46.8)	0.72	0.68	0.15-3.11
	Melbourne	5 (62.5)	3 (37.5)			
Line incision	Midline	37 (61.7)	23 (38.3)	0.04	14.48	1.72-121.90
	Lateral line	1 (10)	9 (90)			

Table 7 shows that neonatal age and midline incision were 2 risk factors relating to capillary leak syndrome after the BTS. The risk of capillary leak syndrome in neonatal age was 3.71 times higher than that of patients beyond neonatal age. The risk of capillary leak syndrome in patients with the midline incision was 14.48 times higher than that of patients with lateral line incision.

DISCUSSIONS

Hemodynamic disorders after the BTS were defined as the need of vasomotor drug use to maintain the systolic blood pressure more than the 5th percentile regarding age group [13]. In our study, 94% of the patients had hemodynamic disorders after the closed heart surgery for the BTS. Our result was very similar to that of Dirks in 2013 with 89% of the patients requiring vasomotor drugs after the surgery [12].

The undershunt syndrome including an obstructive shunt was a dangerous hemodynamic disorder after the BTS. Among 70 studied patients, 37.1% had a under shunt condition with the manifestation of $FiO_2 \geq 40\%$ to maintain $SpO_2 \geq 75\%$. This hemodynamic condition occurred early within 12 hours after the operation and in particular, 24/36 (66.6%) had this complication 6 hours after the surgery. Among them, 4 patients with an obstructive shunt (5.7%) required the reoperation within 48 hours. In the previous

studies, only the obstructive shunt, a severe manifestation of an undershunt syndrome was reported, which was why our result was higher than that of Dirks (9%) in 2013 and of Nguyen Huu Minh 16.3% [12], [16]. The early detection of undershunt helped patients to be intervened earlier (the increase of vasomotor drug use and anticoagulation medicine), to reduce the risk of the obstructive shunt which required a re-operation.

The overshunt is a frequent hemodynamic complication in patients with BTS. In our study, 42.9% of patients had an overshunt within 48 hours after the surgery with the manifestation of SpO_2 > 85% in room air FiO_2 21%. The rate of overshunt in our study was much higher than that of Nguyen Huu Minh in 2018 (42.9% versus 3.5% respectively) [16].

The capillary leak status after the cardiovascular operation was a complication already described in congenital heart defect patients with cardiopulmonary bypass. Capillary leak is manifested by hypovolemia, diffuse edema, and circulatory collapse requiring vasomotor drug [13]. In our study, 48 hours after the closed heart surgery for the BTS (without Extracorporeal Circulation), 54.3% of the patients had capillary leak with the manifestation of hypovolemia, edema, multimembrane edema, and most cases were detected within 6-12 hours after the surgeries. This rate in our study was significantly higher than that of Boehne in 2016 in patients without extracorporeal circulation (54.3% versus 7.1%), and higher than that of patients with extracorporeal circulation (54.3% versus 38.2%) [13]. The difference between the two studies can be explained by the differences in age, sample size, and other risk factors related to the surgery that were not mentioned in our study and in Boehne's.

According to our results, the neonatal age had two kinds of early hemodynamic complications after the operation (16/29 representing 55,2%) while the group beyond the neonatal age had only one kind of early hemodynamic complication (27/41 representing 65,9%). However, when univariate analysis was done between the age group and each kind of hemodynamic complication, we did not find any significant relationship of the under shunt as well as the over shunt with the age group. Our results were very similar to that of Petrucci in 2011: the age group was not a risk factor of death as well as bad complications after the BTS [10].

When analyzing univariate between the capillary leak status after the BTS and the age group, we found that the neonatal age was significantly statistically associated with the capillary leak status with OR (3.71), 95C% CI (1.33-10.32), and $p<0.05$. Our results differed from that of Boehne in 2016. The author concluded that the neonatal age had a lower risk of systematically inflammatory responses that lead to fewer cases of capillary leak after the BTS [13]. The differences between our study and Boehne in 2016 need to be further studied to explain the physiopathological mechanism.

From the univariate analysis of risk factors during the operation, we found that the midline incision was more likely to be associated with the capillary leak status (OR=14.48, 95%CI: 1.72-121.90, $p<0,05$).

Patent Ductus Arteriosus ligation or not after the BTS is currently still controversial. The study of Petrucci in 2011 showed that the PDA ligation or not after the BTS did not influence the final results [10]. Our study received the same results. The PDA ligation or not was related to the capillary leak status after the BTS.

Limitations

Because the sample size is not big enough, it can influence some important conclusions from the study.

CONCLUSIONS

The hemodynamic disorders within 48 hours after the BTS frequently occurred.

The neonatal age and the midline incision were risk factors relating to the capillary leak after the closed heart surgery.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTION

The authors participated in study design, protocol development and performance, interpretation of data and writing of the manuscript, clinical data collection and data analysis, reading and approving the final manuscript.

DATA AVAILABILITY

The SPSS data used to support the findings of this study are available from the corresponding authors upon request.

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ABBREVIATIONS

CI: Confidence Interval
CVP: Central Venous Pressure
DBP: Diastolic Blood Pressure
FiO2: Fraction of Inspired Oxygen
MAP: Mean Arterial Pressure
OR: Odd ratio
p: p-value
PP: Pulse Pressure
PDA: Patent Ductus Arteriosus
SBP: Systolic Blood Pressure
SpO2: Saturation Peripheral Oxygen
UO: Urine Output
VIS: Vasoactive Inotropic Score

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