Original Article

Effects of protocol-based management on the post-operative outcome after systemic to pulmonary shunt

Sameh R. Ismail [a,*], Muneira M. Almazmi [a], Rajab Khokhar [a], Wedad AlMadani [b], Ali Hadadi [b], Omar Hijazi [a], Mohamed S. Kabbani [a], Ghassan Shaath [a], Mahmoud Elbarbary [a,b,c]

[a] King Abdulaziz Medical City, Riyadh, Saudi Arabia
[b] King Saud Bin Abdulaziz University for Health Sciences, Riyadh, Saudi Arabia
[c] King Abdullah International Medical Research Center, Riyadh, Saudi Arabia

A R T I C L E   I N F O

A B S T R A C T

Objectives: Systemic to pulmonary shunt (commonly known as Modified Blalock–Taussig shunt) is a palliative procedure in cyanotic heart diseases to overcome inadequate blood flow to the lungs. Based on the most recent risk stratification score, the mortality and morbidity of this procedure is still high especially in neonates and over-shunting patients. We developed and implemented protocol-based management in March 2013 to better standardize the management of these patients. The aim of this study is to evaluate the effects of applying this protocol-based management in our center.

Methods: We conducted a retrospective cohort study through chart review analysis.

We included all children who underwent MBTS from January 2000 till December 2015. We compared the early postoperative outcome of patients operated after the protocol-based management implementation (March 2013 till December 2015) (protocol group) with patients operated before implementing the MBTS protocoled management (control group).

Results: 197 patients underwent MBTS from January 2000 till December 2015. Of the 197 patients, 25 patients were in the protocol group and 172 patients were in the control group. There was a significant improvement in the postoperative course and less morbidity after protocoled management implementation as reflected in ventilation time, reintubation rate, inotropic support duration, intensive care unit ICU stay and significantly lower postoperative complications in the protocol group. Mortality of the control group versus protocol group (19.3% VS 8%) with Standardized Mortality Ratio (SMR) dropped from 2.27 before protocoled management to 0.94 after protocoled management (protocol group).

Conclusion: The study suggests that protocoled management of patients with MBTS can improve the postoperative course and early outcome.

1. Introduction

Early complete repair of cyanotic congenital heart diseases has become the preferred treatment option even in the neonatal period due to improved surgical experience, techniques and post-operative intensive care. Palliative shunt operation in cyanotic infants still stands out as a good option when total correction is not possible,[1–3] or in case of lack of experience and resources. In such cases, the Modified Blalock–Taussig shunt (MBTS) appears to be the treatment of choice for infants who have cyanotic congenital heart defects with restricted pulmonary flow.[3] Systemic-to-pulmonary shunt procedures remain the best option in the management of selected neonates and infants with complex cardiac heart defects requiring augmentation of pulmonary blood flow.[4,5] Despite numerous improvements in diagnosis, intensive care and intraoperative management, the overall mortality rate after the MBTS remained high and failed to follow the success of other congenital heart surgeries. Prior reports extending from neo-

nates to even older patients showed a mortality rate up to 16%.[6,7] Based on the STATscore,[8] the systemic to pulmonary shunt (MBTS) has both mortality and morbidity risk category of 4 and has a procedure model based average mortality of 8.5% (7.9–10.0%), potential major complication of 12.4% (11.0–13.9%) with average length of stay of 21.6 days (Interquartile Range IQR 7.0–23.0 days).[9] Several single-institution studies or case series have investigated risk factors for morbidity and mortality after the MBTS[6,7] and have identified age especially neonates, weight, underlying cardiac diagnosis, and shunt obstruction among the risk factors for death. Over-circulation (over-shunting) was also linked to increased mortality after MBTS.[10] Implementing protocoled management may help to tackle factors like over-shunting or under-shunting, helping to balance the systemic to pulmonary circulation that can reflect positively on morbidity, ICU stay and mortality outcome.

1.1. Aim of the study

Our aim in this study is to evaluate the effects of implementing a special protocol on improving the early post-operative outcome, and ICU stay after MBTS.

2. Material and methods

This is a retrospective cohort study through chart review analysis of patients who had MBTS between January 2000 and December 2015. We excluded cases of MBTS as part of hypoplastic left heart syndrome palliation (Norwood procedure). Before 2013 management of patients after MBTS was based on individual preferences, there were no special stepwise approach to deal with those critically ill group of patients, and this was causing a lot of mishaps that was reflected on the outcome of those critically ill patients. We started to apply the protocoled management in March 2013 after ensuring that all team members were aware about it through several teaching sessions. We divided the study population into two groups according to the start of the protocoled management. Protocol group includes all patients operated from March 2013 till December 2015. Control group includes patients operated before the protocoled management between January 2000 and March 2013. We compared both groups in terms of demographic data, mortality, morbidities and early post-operative outcome parameters. We further subdivided the group of patients operated after the protocoled management implementation into a group with systemic to pulmonary over-circulation (over-shunting) and this group was compared to the other non-overshunting patients regarding outcome parameters, morbidity and mortality. Over-shunting was defined as patients having the average saturation of 6 readings in different occasions (within 6 h) more than 85% on room air (FIO2 21%), and the average of 6 readings (within 6 h) of diastolic blood pressure in different occasions less than or equal 35% of the systolic pressure (wide pulse pressure).

2.1. Surgical technique

All our cases were operated through median sternotomy. Cardiopulmonary bypass was needed in 35 cases (18%). Gore-Tex stretch vascular graft size 3.5 or 4 was used to anastomose the brachiocephalic artery to the pulmonary artery branch. Patent ductus arteriosus (PDA) was ligated. In selected cases, based on surgical discretion the PDA was almost occluded using a silastic sling or ligaclips, and the aim is to allow quick rescue in these selected high risk duct-dependent cases if the MBTS gets thrombosed.

2.2. MBTS guidelines

We started to implement the MBTS guidelines in 2013. Before starting, all members of the team including physicians, nurses and respiratory therapists attended teaching sessions about the guidelines. The guidelines involved the anticoagulation and the two common postoperative problems (over-shunting and under-shunting).

(A) **Anticoagulation:** All patients were started on heparin infusion within 2 to 4 h if no bleeding (defined as chest tube drainage less than 2–4 cc/Kg/hour), we start with 15 IU/Kg/hour and titrate till we reach therapeutic level (PTT 60:80 s). Aspirin is usually started after 24 h from surgery. In selected high risk cases such as in heterotaxia patients, enoxaparin is used with aspirin for 4–6 weeks after surgery. This anticoagulation protocol was used in all patients after MBTS even before implementation of the MBTS protocol.

(B) **Over shunting Guidelines:** If the patient fulfills the criteria of over-shunting, the guidelines concentrate on decreasing the systemic vascular resistance (using systemic vasodilators) and avoiding pulmonary vasodilators (oxygen, and alkalosis) (Fig. 1).

Systemic vasodilators:

– We start systemic vasodilators if the patient systolic blood pressure above 75 mmHg and diastolic pressure above 30.
– We initially start with milrinon at a dose of 0.3 mcg/kg/min and titrate up to 1 mcg/kg/min in neonates.
– After reaching milrinon 1 mcg/kg/min (if blood pressure is still maintained) Sodium Nitroprusside can be started at 0.5 mcg/kg/min and titrated up to 5 mcg/kg/min.
– In resistant cases and/or if any contraindication to Nitroprusside, alpha blockers can be used to decrease systemic vascular resistance e.g Phentolamine 5 to 50 mcg/kg/min.
– When patient is more stable and feeding established we replace intravenous vasodilators with oral captopril and or phenoxybenzamine.

(C) **Under shunting Guidelines:** If the patient fulfills the criteria of under-shunting, we must exclude shunt thrombosis by urgent ECHO. If there is thrombosis, surgical revision must be considered. If no thrombosis, then the guidelines aim to increase systemic vascular resistance (using vasopressors), and decrease pulmonary vascular resistance using pulmonary vasodilators (Inhaled Nitric oxide (iNO), oxygen, and alkalosis) (Fig. 2). Inhaled Nitric oxide usually started at 20 PPM (parts per million), in rare cases we may reach up to 40 ppm.

Sildenafil is started when the patient is more stable and feeding established to facilitate weaning the Nitric oxide (starting dose 0.3 mg/kg up to 1 mg/kg every 8 h).

Vasopressors:

– Norepinephrine: we start with 0.05 mcg/kg/min up to 0.5 mcg/kg/min, but rarely we exceed 0.3 mcg/kg/min.
– Vasopressin: We use low dose (5 units in 50 ml Dextrose 5%) infusion as 0.0003 to 0.002 units/kg/min.
– Epinephrine: should be avoided if the patient is having tachycardia 0.05 mcg/kg/min up to 0.5 mcg/kg/min.

3. Statistical analysis

Statistical analysis was performed with SPSS software Statistics 22 (IBM, SPSS, Inc., Chicago, Illinois). Categorical variables are

Patient presented with Over-shunting signs

(Wide pulse pressure – 6 readings within 6 hours of SAT > 85 on room air)

Signs of shock and congested lung

Evaluate Arterial Oxygen Saturation   If (SaO₂) > 85 % on room air

↓

Try to optimize balance of **Qp:Qs**

↓

Decreasing FiO₂ as tolerated to 0.21 even during nebulization or suctioning

↓

Avoid Hyperventilation and keep pH: **7.35 to 7.40**

↓

During ETT suctioning, provide adequate sedation ± paralysis, avoid hyperventilation, avoid hyper-oxygenation, and provide adequate monitoring ensuring that suction should be done fast and avoid aggressive deep suctioning

↓

Consider **PEEP (6-8)** if the lung is severely congested

↓

If the patient is ready for extubation, consider **NIMV, CPAP or HFNC** using blended O₂ (0.21-0.25)

↓

Surgical Revision and/or elimination of additional source of PBF when sever over-shunting affecting tissue perfusion

---

Evaluate Systolic and diastolic BP Blood

↓

SBP > 75 mmHg and DBP > 30

↓

Consider weaning vasoconstrictors, assure adequate sedation, analgesia ± Paralysis

↓

Consider increasing vasodilation but maintain DBP >25

↓

Increase milrinone to a maximum dose of 1 mcg/kg/min

↓

Consider starting Nitroprusside at 0.5 mcg/kg/min (titrate up according to BP). Consider Phentolamine infusion if needed

↓

Follow the patient clinically for signs of low cardiac output (peripheral perfusion, skin temp, urine output, ECG..etc)

↓

Lactic acid and ABG every 4-6 hours avoid early enteral feeding

↓

Measure QP/QS every 4-6 hours to assess response to treatment. Use the following equation if the BT shunt is the only source of pulmonary flow considering that PA Saturation is equal to aorta saturation.
Qp:Qs=[Sat (Ao) − Sat (SVC)] / [Sat (pulm veins)-Sat (PA)]
Estimated Pulmonary veins Saturation=95 (with absence of significant lung pathology)

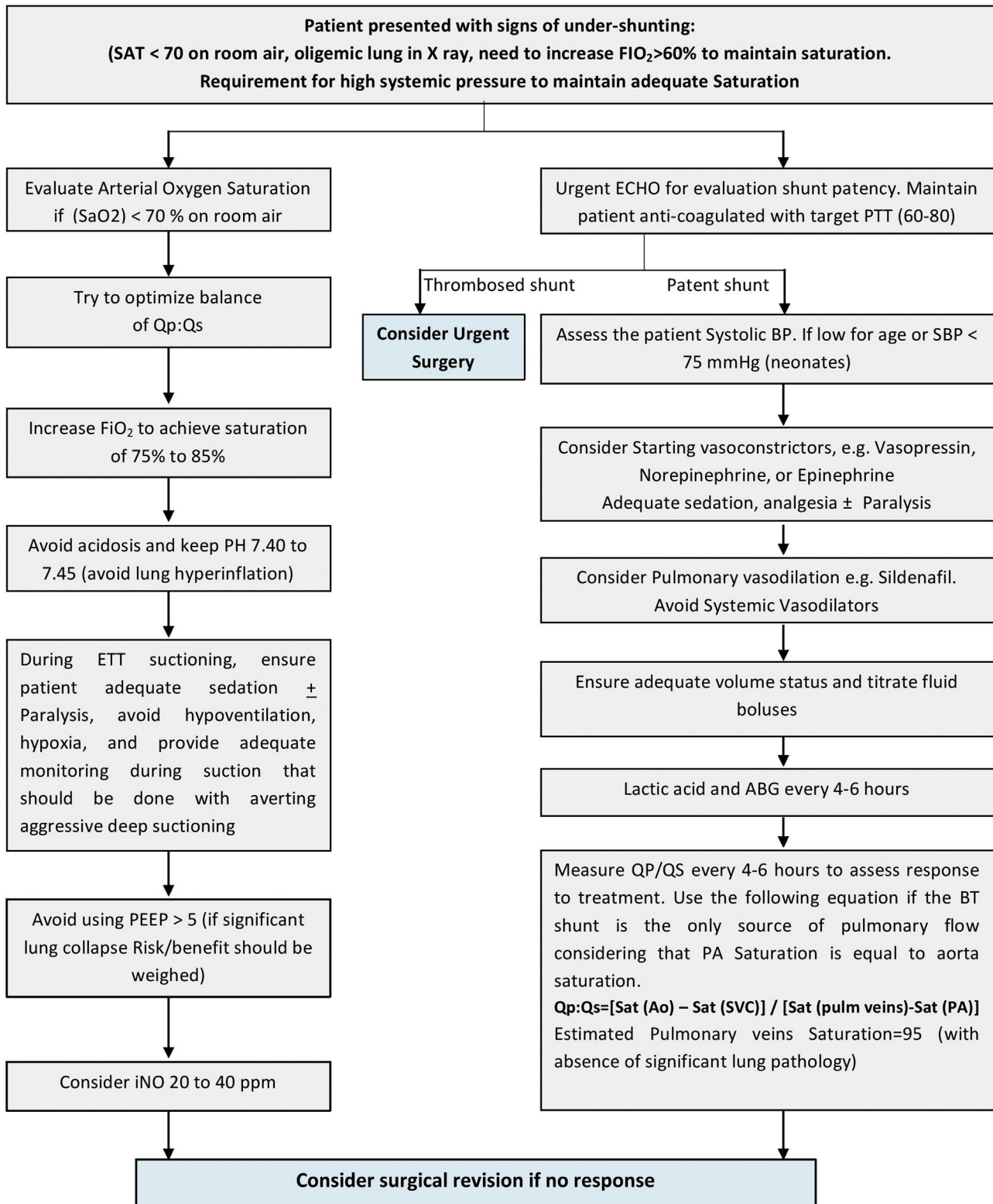**Fig. 1.** Guidelines for Over-shunting patients: (SAT: Saturation, SaO2: arterial Oxygen saturation, QP:QS: pulmonary flow to systemic flow ratio, PH: potential of Hydrogen, ETT: Endo-tracheal tube, PEEP: positive end expiratory pressure, NIMV: Noninvasive mechanical ventilation, CPAP: continuous positive airway pressure, HFNC: High flow nasal cannula, BP: Blood pressure, SBP: systolic blood pressure, DPB: Diastolic blood pressure, mcg: microgram, KG: kilogram, MIN: minute, temp: temperature, ECG: Electrocardiogram, ABG: Arterial blood gas, Qp: pulmonary flow, QS: systemic flow AO: Aorta, SVC: Superior vena cava, pulm: Pulmonary, PA: Pulmonary artery.

expressed as number and percentage, and comparisons are done using chi-square or Fisher exact test.

Continuous variables are presented as mean ± standard deviation. Comparison of continuous variables is consequently analyzed by unpaired *t*-test or Mann-Whitney test. We used the Standardized Mortality Ratio to compare our mortality results in the protocol group and the control group, using the STAT stratification as a bench marking.[8]

Patient presented with signs of under-shunting:
(SAT < 70 on room air, oligemic lung in X ray, need to increase FIO$_2$>60% to maintain saturation. Requirement for high systemic pressure to maintain adequate Saturation

Evaluate Arterial Oxygen Saturation if (SaO2) < 70 % on room air

Try to optimize balance of Qp:Qs

Increase FiO$_2$ to achieve saturation of 75% to 85%

Avoid acidosis and keep PH 7.40 to 7.45 (avoid lung hyperinflation)

During ETT suctioning, ensure patient adequate sedation ± Paralysis, avoid hypoventilation, hypoxia, and provide adequate monitoring during suction that should be done with averting aggressive deep suctioning

Avoid using PEEP > 5 (if significant lung collapse Risk/benefit should be weighed)

Consider iNO 20 to 40 ppm

Urgent ECHO for evaluation shunt patency. Maintain patient anti-coagulated with target PTT (60-80)

Thrombosed shunt

Patent shunt

Consider Urgent Surgery

Assess the patient Systolic BP. If low for age or SBP < 75 mmHg (neonates)

Consider Starting vasoconstrictors, e.g. Vasopressin, Norepinephrine, or Epinephrine
Adequate sedation, analgesia ± Paralysis

Consider Pulmonary vasodilation e.g. Sildenafil. Avoid Systemic Vasodilators

Ensure adequate volume status and titrate fluid boluses

Lactic acid and ABG every 4-6 hours

Measure QP/QS every 4-6 hours to assess response to treatment. Use the following equation if the BT shunt is the only source of pulmonary flow considering that PA Saturation is equal to aorta saturation.
Qp:Qs=[Sat (Ao) – Sat (SVC)] / [Sat (pulm veins)-Sat (PA)]
Estimated Pulmonary veins Saturation=95 (with absence of significant lung pathology)

Consider surgical revision if no response

Fig. 2. Guidelines for Under-shunting patients: (SAT: Saturation, SaO2: arterial Oxygen saturation, Fio2: fraction of inspired oxygen QP:QS: pulmonary flow to systemic flow ratio, PH: potential of Hydrogen, ETT: Endo-tracheal tube, PEEP: positive end expiratory pressure, iNO: inhaled Nitric oxide, PPM: parts per million, ECHO: Echocardiography, BP: Blood pressure, SBP: systolic blood pressure, gm.: gram, dl: deciliter, ABG: Arterial blood gas, Qp: pulmonary flow, QS: systemic flow, AO: Aorta, SVC: Superior vena cava, pulm: Pulmonary, PA: Pulmonary artery.

3.1. Ethics (and consent to participate)

This study was approved on 11th of August 2015 (reference RSS15/044) by the Institutional Review Board (IRB) of King Abdullah International Medical Research Center, and was exempted from consent as it is a retrospective study.

4. Results

There were a total of 197 patients who had MBTS since January 2000 till December 2015 excluding hypoplastic heart syndrome cases. Of the 197, there were 25 patients (64% neonates, 92% single ventricle) after the implementation of the guidelines (protocol group), and 172 patients (60% neonates, 87% single ventricle) before the guidelines implementation (control group) (Table 5). It was observed that although the group of patients after the guidelines implementation was significantly younger and smaller in weight (antagonistic bias), there was a significant improvement in this group regarding the ventilation time, inotropic support requirement, and the reintubation frequency. The ICU stay was significantly shorter in the protocol group (P 0.05), and less incidence of complications after the guidelines implementation (Tables 1 and 2). There was also a trend of higher mortality in the control group (19.3% VS 8.0%) (p 0.26), and using STATstratification as a benchmarking to compare the mortality in both groups Standardized Mortality Ratio (SMR) dropped from 2.27 before protocoled management to 0.94 after protocol management, the risk difference (RD) was 11.3%, relative risk (RR) 0.41, and relative risk ratio (RRR) 59%. While analyzing the mortality cases we discovered that the majority of the mortality in the control group (15 patients) are having pulmonary atresia with intact septum (PA-IVS) (47%) while in the protocol group one of the two mortalities was having (PA-IVS). When we compared patients with over-circulation (over-shunting) with other patients after the guidelines implementation, we documented 14 patients out of the 25 patients studied after the guidelines fulfill the criteria of over-shunting (56%). There was no significant difference in the mortality between the two groups (over-shunting and non-over-shunting) (P = 0.6). There was significantly higher rate of reintubation, chylothorax, a trend for longer hospital stay, ventilation time and inotropic support in the overshunting group (Table. 3). The shunt size was not contributing to the over-shunting physiology as we documented all patients in the over-shunting group had Gore-Tex shunt size 3.5, while nonovershunting group has 4 patients with size 4 Gore-Tex and 8 patients with size 3.5 (P = 0.09) (Table 4). The anticoagulation protocol was used in all patients even before implementation of the MBTS protocol, we documented four patients with shunt thrombosis in the control group (2.3%), while there was one case of shunt thrombosis in the protocol group (4%), but there was no statistically significant difference between both groups. One of the four cases of MBTS thrombosis died early, while in three cases shunt revision was urgently performed, two of them PDA ligation release was done as a bedside rescue procedure before revising the shunt.

5. Discussion

Systemic–pulmonary shunts, especially the Blalock-Taussig shunt (MBTS), are widely used to provide palliation in a number of cyanotic congenital cardiac malformations with single or biventricular physiology.[11,12] The most common malformations in which systemic–pulmonary shunts are used include Tetralogy of Fallot (TOF) especially in neonates, tricuspid atresia and pulmonary atresia with intact ventricular septum and with ventricular septal defect. Most of our patient population who required MBTS in this study were of the single ventricle physiology (87% before 2013 and 92% after 2013). This is a high percentage if we compare it with the results from Baltimore which has only 34% of the patients requiring MBTS of the single ventricle physiology, and Houston group which has 65% with single ventricle physiology.[13,14] This may be related to our tendency to do full repair even at neonatal age and low body weight rather than initial MBTS palliation, and our center's extensive utilization of PDAstenting especially in the recent era, which has been reflected also on the decreased number of patients performing MBTS recently. In spite of overall improvement in results of MBTS,[13] it remains one of the high risk surgeries in pediatric cardiac surgery, mortality reported ranges from up to 16%.[14] We started these MBTS guidelines in 2013 aiming to improve our mortality, ICU stay and morbidity outcome. Our overall postoperative mortality has dropped from 19.3% before the implementation of our MBTS protocol to 8.0% after the protocol and SMR dropped from 2.27 to 0.94. This significant improvement in mortality in our MBTS shunt after applying the protocol occurred despite the fact that the population managed with the protocol were significantly younger and lower in body weight (Table 1), and it is well known that low body weight and younger age are risk factors for mortality after MBTS (antagonistic bias).[10,14] The improvement was not only in the mortality after the protocol, but there was also a significant improvement in the early postoperative course, ICU stay and post-operative morbidities. The optimal shunt size for each patient is still not clearly decided. Odim et al reported on the need for a postoperative shunt size reduction, indicating that overshunting increases mortality rates.[10] Dirks et al. associated bigger shunt size with post-operative mortality, and this may be related to overshunting, leading to diastolic runoff (lower diastolic pressure), which causes decreased coronary and systemic perfusion.[15] In our study, we could not find any associa-

Table 1
Comparison between continuous outcomes before and after the protocol implementation: (SD: Standard deviation, SE: Standard error, sig: significance, CI: Confidence interval, ICU: Intensive care unit).

Variable	Group	Number	Mean	SD	SE	Sig	95% CI	
							Low	Up
Age (days)	Control	172	240.57	828.433	63.167	0.002	79.23	329.9
	Protocol	25	36.00	32.712	6.542			
Weight (Kilogram)	Control	172	4.7310	4.10280	0.31284	0.000	0.631	1.99
	Protocol	25	3.4188	0.73000	0.14600			
Period on inotropes (Hours)	Control	161	116.40	162.620	12.816	0.037	−252.3	−8.17
	A	25	246.64	290.145	58.029			
Length of hospital stay (Days)	Control	172	27.90	27.182	2.073	0.245	−4.67	18.15
	Protocol	25	21.16	25.929	5.186			
ICU stay (Days)	Control	172	14.74	18.63	1.42	0.05	3.80	10.76
	Protocol	25	7.44	5.15	1.03			
Hours of ventilation	Control	172	154.57	230.082	17.544	0.000	108.1	178.5
	Protocol	25	11.20	16.437	3.287			

Table 2
Comparison between categorical outcomes before and after the protocol implementation.

Variable		Groups				P value
		Control		Protocol		
		Count	Column N %	Count	Column N %	
Gender	Male	98	57.0%	19	76.0%	0.083
	Female	74	43.0%	6	24.0%	
Number of re-intubations	0	137	79.7%	20	80.0%	0.000
	1	22	12.8%	3	12.0%	
	2	5	2.9%	2	8.0%	
	3	4	2.3%	0	0.0%	
	4	4	2.3%	0	0.0%	
Death	No	144	80.7%	23	92.0%	0.26
	Yes	28	19.3%	2	8.0%	
Wound infection	No	160	93.0%	22	88.0%	0.413
	Yes	12	7.0%	3	12.0%	
Arrhythmia	No	149	86.6%	24	96.0%	0.323
	Yes	23	13.4%	1	4.0%	
CPR/cardiac arrest	No	146	84.9%	24	96.0%	0.211
	Yes	26	15.1%	1	4.0%	
Chronic renal failure	No	157	91.3%	24	96.0%	0.699
	Yes	15	8.7%	1	4.0%	
Other Complications	No	39	22.7%	16	64.0%	0.000
	Yes	133	77.3%	9	36.0%	

Table 3
Comparison between flow degree and continuous outcomes after the protocol implementation.

	Flow degree	N	Mean	SD	SE	Sig	95% CI	
							Low	Up
Length of stay in days	Non high flow	14	12.64	8.454	2.260	0.108	−43.7	5.02
	High flow	11	32.00	35.914	10.828			
Ventilation invasive	Non high flow	14	7.93	9.417	2.517	0.320	−22.9	8.12
	High flow	11	15.36	22.340	6.736			
Ventilation noninvasive	Non high flow	13	6.46	7.817	2.168	0.388	−22.5	9.09
	High flow	11	13.18	26.248	7.914			
Age	Non high flow	14	45.14	38.10	10.184	0.117	−5.591	47.149
	High flow	11	24.36	20.358	6.138			
Weight	Non high flow	14	3.645	0.849	0.227	0.062	−0.028	1.057
	High flow	11	3.130	0.422	0.127			
Creatinine 1	Non high flow	14	51.29	25.566	6.833	0.415	−10.8	25.44
	High flow	11	44.00	18.265	5.507			
Creatinine 2	Non high flow	14	52.00	27.981	7.478	0.818	−17.19	21.55
	High flow	11	49.82	14.992	4.520			
Inotropes per hour	Non high flow	14	173.714	165.05	44.113	0.207	−435.47	103.99
	High flow	11	339.454	386.91	116.65			
Lactic (mean)	Non high flow	14	2.426	2.156	0.576	0.518	−2.5	1.30
	High flow	11	3.034	2.475	0.746			
	High flow	11	3.5000	0.00000	0.00000			

tion between the shunt size and the incidence of over-shunting or the mortality. When we compared the overshunting patients with other MBTS patients after applying the guidelines, we did not find any difference in the mortality, however, overshunting patients had significantly higher rate of reintubation, chylothorax, a trend for longer hospital stay, ventilation time and inotropic support [Tables 3, and 4]. Cyanotic heart diseases predisposes to higher incidence of thrombosis, that's why anticoagulation is advisable in cases of MBTS especially with the use of Gore-Tex tubes compared to the original Blalock-Taussing Shunt when only native tissues were used. We used heparin followed by aspirin in all cases after MBTS, and in selected high risk patients enoxaparin was used with aspirin for 4:6 weeks after surgery. Mullen et al.,[16] had proved that no benefit of using heparin after MBTS while other studies proved it's benefit in decreasing shunt thrombosis.[17]

In our series the incidence of shunt thrombosis and shunt reintervension was 2.3% and 4% in the control and protocol groups respectively, this was comparable to the report from Bahaaldin et al, who documented (5.7%) incidence of shunt revision.[18]

A higher incidence of MBTS thrombosis was reported by Milwaukee et al. they showed 17% of their cases required shunt revision, one of the important risk factors they discovered was shunt size 3.0 mm, while in our series the smallest shunt size was 3.5 mm. In our series all patients were operated via sternotomy approach. Shauq and colleagues[19] demonstrated increased morbidity related to the sternotomy approach for MBTS, documenting longer duration of ventilator and inotropic support and hospital stay. Using multivariate analysis, sternotomy approach was a risk factor for hospital death. In the early post-operative period in cases with evidence of over shunting Phosphodiesterase-3 inhibitors such as milrinone are "inodilators", which improve systemic oxygen delivery by producing a combination of inotropic and vasodilatory effects. The use of milrinon after MBTS has a number of desirable effects. Peripheral vasodilatation results in afterload reduction, decrease pulmonary to systemic blood flow ratio and improved cardiac output and systemic perfusion.[20] We commonly use systemic arterial vasodilators in over shunting cases to optimize (Qp/Qs ratio), and two main classes of agent are used in the

Table 4
Comparison between flow degree and categorical outcomes after the protocol implementation.

		Flow degree						P value
		Non high flow		High flow		Total		
		N	%	N	%	N	%	
Gender	M	10	71.4%	9	81.8%	19	76%	0.661
	F	4	28.6%	2	18.2%	6	24%	
Year	2013	5	35.7%	1	9.1%	6	24%	0.172
	2014	2	14.3%	5	45.5%	7	28%	
	2015	7	50%	5	45.5%	12	48%	
Re-intubation	0	12	85.7%	8	72.7%	20	80.0%	0.037
	1	0	0.0%	3	27.3%	3	12.0%	
	2	2	14.3%	0	0.0%	2	8.0%	
Transfusion	No	6	42.9%	2	18.2%	8	32.0%	0.234
	Yes	8	57.1%	9	81.8%	17	68.0%	
Inotropes	No	1	7.1%	1	9.1%	2	8.0%	0.859
	Yes	13	92.9%	10	90.9%	23	92.0%	
Chylothorax	No	14	100%	7	63.6%	21	84%	0.026
	Yes	0	0%	4	36.4%	4	16%	
septicemia	No	9	64.3%	7	63.3%	16	64%	1.000
	Yes	5	35.7%	4	36.4%	9	36%	
Complications	0	6	42.9%	5	45.5%	11	44%	0.481
	1	5	35.7%	3	27.3%	8	32%	
	2	3	21.4%	1	9.1%	4	16%	
	3	0	0%	2	18.2%	2	8%	
Shunt size	3.5	8	66.7%	11	100%	19	82.6%	0.093
	4	4	33.3%	0	0%	4	17.4%	

Table 5
Main Diagnosis of the protocol cases and the control cases: (DTGA: Transposition of great arteries, PS: Pulmonary stenosis, AVSD: Atrio-ventricular septal defect, TOF: Tetralogy of Fallout).

Main diagnosis	Protocol group (N: 25)	Control group (N:172)
Pulmonary and/or Tricusped atresia	11	93
Double outlet right ventricle and PS	6	20
Double inlet left ventricle and PS	2	10
DTGA and PS	4	24
AVSD and PS	2	8
AVSD and TOF	0	2
TOF	0	9
Sever PS	0	5
Double outlet left ventricle	0	1

postoperative period. Sodium nitroprusside is a potent arterial vasodilator with a rapid onset and offset of action, and has the potential advantages of a relatively titratable dose dependent effect, and a short half-life.[21] Phenoxybenzamine, an α-adrenergic receptor blocker, was proved to reduce Qp:Qs in a prospective study of 15 patients having MBTS as a part of Norwood procedure.[22] Higher superior vena cava saturation and a narrower arteriovenous oxygen difference were noted, indicating improved systemic oxygen delivery with phenoxybenzamine. In another study, the use of peri-operative phenoxybenzamine was associated with increased survival.[23] In our protocol we used phentolamine as an alternative α-adrenergic receptor blocker as an intravenous infusion early post-operative then replaced with phenoxybenzamine oral after establishing oral feeding. Systemic vasodilators should be used carefully in order to avoid excessive hypotension, which can to an extent be avoided if we maintain an adequate volume status, and establish invasive arterial monitoring.

Inhaled Nitric oxide (iNO) is used in our protocol in patients with under shunting who suffer from hypoxemia and increased oxygen requirement after MBTS, it is tempting to attribute the hypoxemia in such cases to pulmonary vasoconstriction, but obstruction to pulmonary arterial blood flow (e.g., Stenotic or obstructive Blalock–Taussig shunt) should be discriminated from the reactive pulmonary vasoconstriction. ECHO is the best to dif-ferentiate, but until ECHO is done if patient fail to respond to iNO may strongly indicate that there is anatomical obstruction.[24–26]

Mehmet Küçük et al, and other researchers in the field, mentioned clearly in their reports that lack of standardized form of management of this group of critically ill patients may play a major role in increased mortality and morbidity,[27,2] and we were able to prove the benefit of protocol-based management and standardized care on the early postoperative outcome.

6. Conclusion

A protocol-based management of systemic to pulmonary shunts (MBTS) in infants and neonates has improved the early postoperative outcome, morbidities, ICU stay and mortalities. We recommend applying such protocols involving all medical staff dealing with these critical patients after appropriate teaching and orientation.

7. Limitations of the study

The number of the protocol cases is relatively small because of the current era of extensive use of PDA stenting rather than MBTS. We didn't compare the lateral thoracotomy with the median sternotomy approach as all our cases are operated via a median sternotomy. Our study is a retrospective single center experience, so our results need to be verified in a multicenter study to ensure validity and applicability.

Conflicts of interest

I certify that there are no conflicts of interest associated with this manuscript, no funding received for this study, and approval from the Hospital Ethics Committee was obtained.

References

1. Blalock Alfred, Taussig Helen B. The surgical treatment of malformations of the heart in which there is pulmonary stenosis or pulmonary atresia. *JAMA*. 1945;128:189–192.
2. Rana JS, Ahmad KA, Shamim AS, et al.. Blalock-Taussig shunt: experience from the developing world. *Heart Lung Circ*. 2002;11:152–156.
3. Maghur HA, Ben-Musa AA, Salim ME, et al.. The modified Blalock-Taussig shunt: a 6-year experience from a developing country. *Pediatr Cardiol*. 2002;23:49–52.
4. Moulton AL, Brenner JI, Ringel R, et al.. Classic versus modified Blalock-Taussig shunts in neonates and infants. *Circulation*. 1985;72:;II35–:44.
5. Woolf PK, Stephenson LW, Meijboom E, et al.. A comparison of Blalock-Taussig, Waterston, and polytetrafluoroethylene shunts in children less than two weeks of age. *Ann Thorac Surg*. 1984;38:26–30.
6. Kyger 3rd ER, Reul Jr GJ, Sandiford FM, et al.. Surgical palliation of tricuspid atresia. *Circulation*. 1975;52:685–690.
7. Lamberti JJ, Carlisle J, Waldman JD, et al.. Systemic-pulmonary shunts in infants and children. Early and late results. *J Thorac Cardiovasc Surg*. 1984;88:76–81.
8. Jacobs Jeffrey Phillip et al.. Initial application in the EACTS and STS congenital heart surgery databases of an empirically derived methodology of complexity adjustment to evaluate surgical case mix and results. *Eur J Cardiothorac Surg*. 2012;42(5):775–780.
9. Jacobs Marshall L, Jacobs Marshall Lewis, Maruszewski Bohdan, et al.. An empirically based tool for analyzing morbidity associated with operations for congenital heart disease. *J Thorac Cardiovasc Surg*. 2013;145(4). https://doi.org/10.1016/j.jtcvs.2012.06.029.
10. Odim Jonah, Portzky M, Zurakowski D, Wernovsky G, et al.. Sternotomy approach for the modified Blalock-Taussig shunt. *Circulation*. 1995;92:256–261.
11. Harlan BJ, Starr A, Harwin FM. *Systemic–pulmonary shunts In: illustrated handbook of cardiac surgery*. New York, NY: Springer Verlag; 1996. 203–211.
12. Lawless CE, Smith EE, Hallidie-Smith K, et al.. The modified Blalock-Taussig shunt using microporous expanded polytetrafluoroethylene (PTFE). *J Cardiovasc Surg (Torino)*. 1982;23:287–292.
13. Williams JA, Bansal AK, Kim BJ, et al.. Two thousand Blalock-Taussig shunts: a six-decade experience. *Ann Thorac Surg*. 2007;84:2070–2075.
14. Petrucci O, O'Brien SM, Jacobs ML, et al.. Risk factors for mortality and morbidity after the neonatal Blalock-Taussig shunt procedure. *Ann Thorac Surg*. 2011;92:642–651.
15. Dirks V, Prêtre R, KnirschW Modified, et al.. Blalock Taussig shunt: a not-so-simple palliative procedure. *Eur J Cardiothorac Surg*. 2013;44:1096–1102.
16. Mullen JC, Lemermeyer G, Bentley MJ. Modified Blalock-Taussig shunts: to heparinize or not to heparinize? *Can J Cardiol*. 1996;12:645–647.
17. Guzzetta NA, Foster GS, Mruthinti N, et al.. In-hospital shunt occlusion in infants undergoing a modified blalock-taussig shunt. *Ann Thorac Surg*. 2013;96:176–182.
18. Alsoufi Bahaaldin, Gillespie Scott, Kogon Brian, et al.. Results of palliation with an initial modified blalock-taussig shunt in neonates with single ventricle anomalies associated with restrictive pulmonary blood flow. *Ann Thoracic Surg*. 2015;99:1639–1647.
19. Shauq A, Agarwal V, Karunaratne A, et al.. Surgical approaches to the Blalock shunt: does approach matter? *Heart Lung Circ*. 2010;19:460e464.
20. Hoffman TM, Wernovsky G, Atz AM, et al.. Efficacy and safety of milrinone in preventing low cardiac output syndrome in infants and children after corrective surgery for congenital heart disease. *Circulation*. 2003;107:996–1002.
21. Norwood Jr WI. Hypoplastic left heart syndrome. *Ann Thorac Surg*. 1991;52:688–695.
22. Tweddell JS, Hoffman GM, Fedderly RT, et al.. Phenoxybenzamine improves systemic oxygen delivery after the Norwood procedure. *Ann Thorac Surg*. 1999;67:161–168.
23. Tweddell JS, Hoffman GM, Mussatto KA, et al.. Improved survival of patients undergoing palliation of hypoplastic left heart syndrome: lessons learned from 115 consecutive patients. *Circulation*. 2002;106(12 suppl 1):I82–I89.
24. Atz AM, Wessel DL. Inhaled nitric oxide in the neonate with cardiac disease. *Sem Perinatol*. 1997;21:441–455.
25. Adatia I, Atz AM, Jonas RA, Wessel DL. Diagnostic use of inhaled nitric oxide after neonatal cardiac operation. *J Thorac Cardiovasc Surg*. 1996;112:1403–1405.
26. Beghetti M, Morris K, Cox P, Bohn D, Adatia I. Inhaled nitric oxide differentiates pulmonary vasospasm from vascular obstruction after surgery for congenital heart disease. *Intens Care Med*. 1999;25:1126–1130.
27. Küçük Mehmet, Özdemir Rahmi, Karaçelik Mustafa, et al.. Risk factors for thrombosis, overshunting and death in infants after modified blalock-taussig shunt. *Acta Cardiol Sin*. 2016;32.