

Outcomes of Infants Undergoing Modified Blalock-Taussig Shunt Procedures in Oman

A retrospective study

*Samiuddin Shaikh,¹ Khaloud S. Al-Mukhaini,¹ Abdul Hakeem Al-Rawahi,² Omer Al-Dafie¹

ABSTRACT: *Objectives:* A modified Blalock-Taussig (mBT) shunt procedure is a common palliative surgery used to treat infants and children with cyanotic congenital heart disease (CCHD). This study aimed to report the outcomes of infants and children undergoing mBT shunt procedures in Oman. In addition, risk factors associated with early mortality, inter-stage mortality and reintervention were assessed. *Methods:* This retrospective cohort study was conducted from January 2016 to December 2018 at the National Heart Centre, Muscat, Oman. All paediatric patients with CCHD undergoing mBT shunt procedures as a primary palliative procedure during this period were included. Data were retrieved from electronic hospital records. Kaplan-Meier survival curves were used to describe overall survival. *Results:* A total of 50 infants and children were included in this study. The in-hospital mortality and inter-stage mortality rates were 10% and 6.7%, respectively. Preoperative mechanical ventilation (odds ratio [OR] = 3.00, 95% confidence interval [CI]: 1.98–4.76; $P = 0.007$) and cardiopulmonary bypass (OR = 4.09, 95% CI: 2.44–6.85; $P = 0.002$) were significant risk factors for early mortality. In-hospital and interval surgical reintervention rates were 12% and 13.3%, respectively. Following the primary shunt procedure, the median time to second-stage surgery was 15.5 months (range: 5.0–34.0 months). *Conclusion:* The findings of this study support those reported in international research regarding the risks associated with mBT shunt surgeries. In particular, preoperative mechanical ventilation and cardiopulmonary bypass were significant risk factors for early mortality.

Keywords: Pediatrics; Congenital Heart Diseases; Cardiovascular Surgical Procedures; Modified Blalock-Taussig Procedure; Patient Outcome Assessment; Hospital Mortality; Risk Factors; Oman.

ADVANCES IN KNOWLEDGE

- Outcomes following modified Blalock-Taussig (mBT) shunt procedures vary worldwide. To the best of the authors' knowledge, this is the first study to report outcomes following mBT shunt procedures performed in Oman.
- This study identifies various risk factors for mortality following this procedure in the local population.
- These findings provide a baseline for future comparative analysis at both the regional and international level.

APPLICATION TO PATIENT CARE

- Knowledge of likely outcomes following mBT shunt procedures in a local setting will be useful to help the parents of infants and children with cyanotic congenital heart disease make informed treatment choices.
- Moreover, the findings of this study may result in modifications to clinical practice, thereby improving outcomes. In particular, certain high-risk patient categories warrant extra vigilance, such as those requiring preoperative mechanical ventilation or intraoperative cardiopulmonary bypass.

IN OMAN, THE INCIDENCE OF CONGENITAL HEART disease is approximately 7.1 per 1,000 live births; of these, 21.7% are diagnosed with cyanotic congenital heart disease (CCHD).¹ Many infants with CCHD and inadequate pulmonary blood flow require palliative interventions early in life in order to alleviate severe cyanosis.² These include maintaining the patency of the *ductus arteriosus*, either by using a cardiac catheter to percutaneously insert a stent or by surgically creating a systemic-to-pulmonary artery shunt.³

A modified Blalock-Taussig shunt (mBT) is the most common type of systemic-to-pulmonary artery shunt wherein the ipsilateral innominate or subclavian artery is connected to the pulmonary artery using a

prosthetic graft made of polytetrafluoroethylene.³ However, despite considerable improvements in congenital heart surgery in recent years, mBT shunt procedures are still associated with significant morbidity and mortality.^{4–6} For instance, in-hospital mortality rates following mBT shunt procedures range from 7.3–9.8%.^{4,5} Moreover, even after discharge, between 5–13.9% of patients do not survive long enough to undergo the next stage of surgery in the form of a Glenn shunt or total correction procedure.^{5,6}

Various risk factors have been identified as resulting in worse outcomes for patients receiving mBT shunts, including the age and weight of the child at the time of surgery, the size of the shunt, pulmonary atresia with intact ventricular septum

¹Department of Pediatric Intensive Care, Royal Hospital, Muscat, Oman; ²Department of Research, Oman Medical Specialty Board, Muscat, Oman
*Corresponding Author's e-mail: dr.samishaikh@gmail.com

(PAIVS) and preoperative shock or acidosis.^{5,7-9} The immediate postoperative period following insertion of the mBT shunt is when the patient is most vulnerable. According to Petrucci *et al.*, 33% of deaths in neonates undergoing mBT shunt procedures occurred within 24 hours of surgery, with 75% occurring within the first month.¹⁰ Moreover, the procedure can result in complications such as pulmonary overcirculation (30%) and shunt failure including shunt thrombosis or stenosis (8–23%).^{11,12} Risk factors for shunt failure include the use of small shunts or a central shunt, as well as postoperative extracorporeal membrane oxygenation (ECMO) support.^{11,12}

To the best of the authors' knowledge, no established data have yet been reported regarding the outcomes of mBT shunt procedures among paediatric cases in Oman, particularly in terms of morbidity and mortality. As such, this study aimed to determine outcomes of infants with CCHD following mBT shunt procedures in Oman and evaluate risk factors associated with early mortality, inter-stage mortality and reintervention.

Methods

This retrospective cohort study was conducted from January 2016 to December 2018 at the National Heart Centre in Muscat, Oman. This centre receives referrals from all over the country for infants and children with congenital heart diseases who require assessment, surgical intervention or cardiac catheterisation. All neonates and infants who underwent mBT shunt procedures as a primary palliative procedure during the study period were identified using the surgical database. Patients were excluded if they had undergone mBT shunt surgeries as part of a Norwood procedure—i.e. an aortic arch reconstruction plus atrial septectomy and mBT shunt or a right ventricle-to-pulmonary artery conduit, usually performed in cases of hypoplastic left heart syndrome—or to alleviate hypoxia after pulmonary artery banding.

Information regarding the patients' demographic characteristics, underlying anatomical details, surgical notes, postoperative clinical notes, outpatient follow-up visits and outcome data were collected from the surgical database and electronic hospital record system. Patients were classified as duct-dependent if they required an infusion of prostaglandins to ensure *ductus arteriosus* patency and/or if the patent *ductus arteriosus* was the main source of pulmonary blood flow. All patients were followed-up either until they underwent the next stage of surgery—consisting of either a total correction or stage 2 palliation (i.e. a

Glenn procedure)—or for a minimum of one year after the index procedure (i.e. December 2019).

Data were analysed using the Statistical Package for the Social Sciences (SPSS), Version 22.0 (IBM Corp., Armonk, New York, USA). The outcome variables of interest included early mortality, inter-stage mortality and survival to next stage of surgery. Early mortality was defined as mortality occurring within 30 days of the index operation, while inter-stage mortality (i.e. interval mortality) was defined as mortality occurring between 30 days after the index operation and the next surgical stage. Survival to the second stage of surgery was defined as survival from the initial surgery to the next planned surgical intervention. Categorical variables were presented as frequencies and percentages, while continuous variables were presented as medians and interquartile ranges (IQRs). Kaplan-Meier survival curves were used to describe overall survival. Univariate associations were assessed using a Chi-squared test, along with odds ratios (ORs) and 95% confidence intervals (CIs) wherever applicable. A *P* value of <0.050 was considered statistically significant.

Ethical approval for this study was obtained through the institutional ethical approval board of the Royal Hospital as well as the Centre of Studies and Research of the Ministry of Health in Oman (SRC#120/2018 code #9368). The need for patient consent was waived in view of the retrospective nature of the study.

Results

A total of 50 paediatric patients with CCHD underwent mBT shunt procedures as a first palliative surgery during the study period. The primary indication for the procedure was to provide a stable source of pulmonary blood flow sufficient to maintain systemic oxygen saturation (SpO₂) at 75–85%. The median age at surgery was 22.5 days (IQR: 7.2–90.0 days) and the median weight was 3.2 kg (IQR: 2.7–4.2 kg). Over half of the patients (*n* = 26; 52%) were neonates (i.e. ≤28 days old). The underlying diagnosis was either single ventricle (*n* = 25; 50%) or biventricular (*n* = 25; 50%) defects. A total of 20 patients (40%) received preoperative mechanical ventilation. Nine patients (18%) had previously undergone failed attempts at cardiac catheterisation (e.g. ductal stents) prior to the mBT shunt procedure [Table 1].

Among those with single ventricle defects, the majority had PAIVS (*n* = 7; 28%), followed by tricuspid atresia and pulmonary atresia (*n* = 4; 16%), tricuspid atresia and restrictive ventricular septal defect (VSD;

Table 1: Baseline characteristics of infants and children with cyanotic congenital heart disease undergoing modified Blalock-Taussig shunt procedures in Oman (N = 50)

Characteristic	n (%)
Age in days at time of surgery	
≤28	26 (52)
>28	24 (48)
Median (IQR)	22.5 (7.2–90.0)
Gender	
Male	27 (54)
Female	23 (46)
Weight in kg at time of surgery	
<2.5	7 (14)
≥2.5	43 (86)
Median (IQR)	3.2 (2.7–4.2)
Underlying diagnosis	
Single ventricle defect	25 (50)
Biventricular defect	25 (50)
Circulation status	
Duct-dependent	30 (60)
Non-duct-dependent	20 (40)
Preoperative mechanical ventilation	
Yes	20 (40)
No	30 (60)
Preoperative acidosis*	
Yes	9 (18)
No	41 (82)
Unsuccessful preoperative cardiac catheter interventions	
Yes	9 (18)
No	41 (82)

IQR = interquartile range. *Defined by an arterial blood pH value of <7.3.

n = 4; 16%), unbalanced atrioventricular septal defect (AVSD) and hypoplastic right ventricle (n = 2; 8%), pulmonary atresia and double-inlet left ventricle (n = 2; 8%), pulmonary atresia with AVSD and total anomalous pulmonary venous connection (n = 2; 8%) and other defects (n = 4; 16%). For those with biventricular defects, the most common underlying diagnosis was pulmonary atresia and VSD (n = 10; 40%), followed by tetralogy of Fallot (n = 7; 28%), dextro-transposition of the great arteries with VSD and pulmonary stenosis (n = 3; 12%), AVSD and tetralogy of Fallot (n = 2; 8%) and other defects (n = 3; 12%).

Table 2: Surgical details and outcomes of infants and children with cyanotic congenital heart disease undergoing modified Blalock-Taussig shunt procedures in Oman (N = 50)

Variable	n (%)
Surgical approach	
Sternotomy	45 (90)
Thoracotomy	5 (10)
Cardiopulmonary bypass	
Yes	16 (32)
No	34 (68)
Arterial connection	
Innominate/subclavian	35 (70)
Other	15 (30)
Other surgical/non-surgical details	
Median shunt size in mm (range)	4 (3–5)
Mean postoperative SpO ₂ in % ± SD	82.6 ± 6.3
Median duration of postoperative MV in days (range)	2 (0–19)
Median duration of ICU stay in days (range)	6 (1–31)
Median duration of hospital stay in days (range)	13 (1–76)
Median age at second-stage surgery in months (range)	15.5 (5–34)

SpO₂ = oxygen saturation; SD = standard deviation; MV = mechanical ventilation; ICU = intensive care unit.

A sternotomy was the most common approach for the surgery (n = 45; 90%). A total of 16 patients (32%) required cardiopulmonary bypass during the shunt procedure due to haemodynamic instability or for other concomitant procedures. The innominate or subclavian artery was used as the proximal arterial connection in 35 cases (70%). The median shunt size was 4 mm (range: 3–5 mm), with a mean shunt-to-weight ratio of 1.25 in neonates. The median duration of mechanical ventilation, length of stay in intensive care and total length of postoperative hospital stay was two days (range: 0–19 days), six days (range: 1–31 days) and 13 days (range: 1–76 days), respectively [Table 2]. Upon arrival to intensive care, all patients received an infusion of unfractionated heparin and were subsequently transitioned to low-dose aspirin once they could be fed enterally. After the primary shunt procedure, three patients (6%) required ECMO support and six (12%) had to undergo shunt revision during the same hospitalisation period.

A total of five patients died within 30 days of the index operation; subsequently, three of the remaining 45 patients died after discharge but before the second-

Table 3: Outcomes according to diagnosis among infants and children with cyanotic congenital heart disease undergoing modified Blalock-Taussig shunt procedures in Oman (N = 50)

Variable	Type of diagnosis, n (%)		P value
	Single ventricle (n = 25)	Biventricular (n = 25)	
Median age in days at time of surgery (IQR)	13 (4–50)	74 (15–107)	0.020
Median weight in kg at time of surgery (IQR)	3.1 (2.6–3.6)	3.4 (2.9–5.2)	0.271
Early mortality*	4 (16)	1 (4)	0.048
Inter-stage mortality [†]	3 (12)	0 (0)	
Median age at second-stage surgery in months (IQR)	12 (6.8–14)	22 (16–24)	0.019
Reintervention during initial hospitalisation [‡]	2 (8)	4 (16)	0.049
Reintervention during the interval period [§]	2 (8)	9 (36)	

IQR = interquartile range.

*Defined as mortality occurring within 30 days of the index operation. [†]Defined as mortality occurring between 30 days after the index operation and the next surgical stage. [‡]Surgical shunt revision. [§]Surgical shunt revision or catheter intervention.

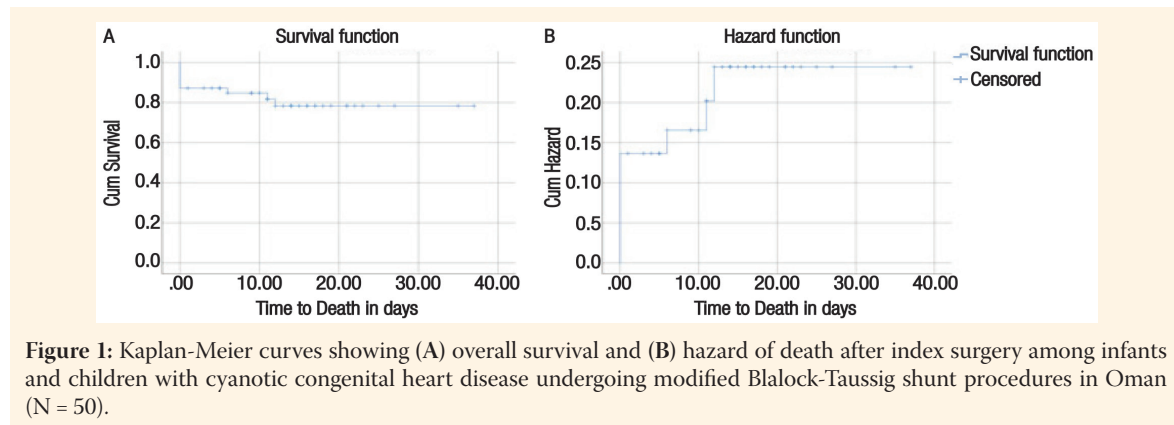


Figure 1: Kaplan-Meier curves showing (A) overall survival and (B) hazard of death after index surgery among infants and children with cyanotic congenital heart disease undergoing modified Blalock-Taussig shunt procedures in Oman (N = 50).

stage surgery, resulting in early mortality and inter-stage mortality rates of 10% and 6.7%, respectively. Of the five early mortalities, four (80%) had single ventricle defects and one (20%) had biventricular defects. The biventricular patient died due to myocardial dysfunction and low cardiac output syndrome on the sixth postoperative day. Among the four early mortalities in the single ventricle group, two (50%) died due to myocardial dysfunction, one (25%) due to septic shock and one (25%) due to preoperative hypoxic-ischaemic encephalopathy and cardiac arrest during an attempt at ductal stenting. All three patients who died during the inter-stage period had single ventricle defects; of these one (33.3%) died due to a chest infection and sepsis, while cause of death could not be determined in the other two patients (66.7%) as they died at home.

During the inter-stage period, in addition to the three patients (6.7%) who died, one patient (2.2%) was labelled as not suitable for further surgeries and three patients (6.7%) were lost to follow-up. The median interval before the second stage of surgery

was 15.5 months (range: 5.0–34.0 months). Overall, 11 patients (24.4%) who survived >30 days from the index operation required reintervention in the form of either surgical shunt revision (n = 6; 54.5%) or catheter interventions (n = 5; 45.5%). Most of these interventions were performed for patients with biventricular defects (n = 9; 81.8%) and those with an underlying diagnosis of pulmonary atresia and VSD (n = 8; 72.7%). Differences in baseline variables and outcomes between the single ventricle and biventricular groups are shown in Table 3.

The majority of in-hospital deaths occurred within the first 10 days of surgery [Figure 1]. According to the univariate analysis, preoperative mechanical ventilation (OR = 3.00, 95% CI: 1.98–4.76; P = 0.007) and intraoperative cardiopulmonary bypass (OR = 4.09, 95% CI: 2.44–6.85; P = 0.002) were the only statistically significant risk factors for in-hospital mortality. While other factors such as prematurity and underlying genetic conditions showed an increased association with in-hospital mortality, these differences were not statistically significant [Table 4].

Table 4: Risk factors associated with early mortality among infants and children with cyanotic congenital heart disease undergoing modified Blalock-Taussig shunt procedures in Oman (N = 50)

Variable	Number of deaths per category	OR (95% CI)	P value
Age (≤ 28 versus > 28 days)	-	0.58 (0.09–3.83)	0.661
Weight (≤ 2.5 versus > 2.5 kg)	-		1.000
Prematurity	3/11	6.94 (0.99–47.61)	0.064
Genetic condition	2/5	9.34 (1.10–76.92)	0.072
Comorbidity	2/13	2.06 (0.30–13.88)	0.595
Single ventricle defect	4/25	4.56 (0.47–43.47)	0.349
Duct dependency	4/30	2.92 (0.30–2.85)	0.636
Preoperative mechanical ventilation	5/20	3.00 (1.98–4.76)	0.007
Unsuccessful preoperative shunt-related procedures	2/9	3.60 (0.50–25.64)	0.216
Non-innominate/subclavian arterial connection	3/15	4.13 (0.61–27.78)	0.152
Cardiopulmonary bypass	5/16	4.09 (2.44–6.85)	0.002
Associated procedure (e.g. PA plasty)	3/12	5.98 (0.87–41.66)	0.080
Postoperative SpO ₂ of $> 85\%$	2/16	1.47 (0.10–4.52)	0.518
Shunt revision during initial hospitalisation	2/6	6.84 (0.66–52.63)	0.103
Shunt size-to-weight ratio of > 1.2	2/21	1.09 (0.17–7.19)	> 0.999

OR = odds ratio; CI = confidence interval; PA = pulmonary artery; SpO₂ = oxygen saturation.

Discussion

In this study, the rate of in-hospital mortality among paediatric CCHD cases following primary mBT shunt procedures was 10%, while the rate of inter-stage mortality was 6.7%. These results are in line with those reported in the literature.^{7,11} Indeed, several studies have indicated a paradoxical rise in mortality following mBT shunt procedures in recent years; for instance, Dorobantu *et al.* observed that overall 30-day

mortality increased from 5.1% between 2000–2006 to 9.8% between 2007–2012, while Bove *et al.* reported a rise in mortality from 7% between 1995–2002 to 11% between 2002–2013.^{5,6}

Brown *et al.* noted that systemic-to-pulmonary artery shunt procedures were the only type of cardiac surgery to demonstrate increased mortality in a large national paediatric population.¹³ A number of factors could explain this disturbing phenomenon. First, it appears that fewer patients with biventricular defects (especially those with tetralogy of Fallot) are offered mBT shunts as a treatment option.^{5,11} Second, palliative shunt surgery may be employed in more complex cases such as those involving underlying univentricular heart defects. Third, it is possible that cardiac catheterisation is used with greater frequency among patients with suitable anatomies, thus resulting in surgical shunt procedures being reserved for those with more complex or challenging anatomies.^{5,11}

Patients with single ventricle defects have a high risk of adverse outcomes following mBT shunt surgeries, including death.^{5–7,11,14} In the current study, all but one of the patients who died within 30 days of the index procedure had single ventricle defects; moreover, the early mortality rate for this group was 16%. Similar findings have been reported in larger cohorts.^{6,7} In a study of 730 patients with mBT shunts, McKenzie *et al.* reported an in-hospital mortality rate of 15% in single ventricle cases versus 3% in biventricular cases.¹⁵ In another study of 1,273 neonatal patients who received mBT shunts, Petrucci *et al.* found rates of discharge mortality to be 5.1%, 7.2% and 15.6% for patients with biventricular defects, single ventricle defects (excluding those with hypoplastic left heart syndrome) and PAIVS, respectively.¹⁰

Similar trends regarding lesion-specific variations in mortality have been described elsewhere. Alsofi *et al.* observed higher mortality following mBT shunt procedures among patients with atrial isomerism and PAIVS in a single ventricle cohort.⁷ In the present study, patients with single ventricle defects had an increased risk of in-hospital mortality, although this association was not statistically significant. It is likely that the higher incidence of concomitant anomalies and underlying genetic syndromes, the complex nature of the cardiac anatomical structures and the coexistence of coronary pathologies serve to make patients with single ventricle defects more vulnerable to adverse outcomes. Moreover, the volume overload imposed on a single ventricle heart by systemic-to-pulmonary artery shunts—including mBT shunts—may predispose these patients to adverse outcomes even in the long term.¹⁶

In the current study, preoperative mechanical ventilation and intraoperative cardiopulmonary bypass were the only statistically significant risk factors for early mortality. Preoperative mechanical ventilation is a known predictor of adverse outcomes following paediatric cardiac surgery.¹⁷ In an analysis of 25,476 paediatric congenital heart surgeries, Jacobs *et al.* found that discharge mortality was significantly higher in patients who were mechanically ventilated preoperatively compared to overall mortality for neonates (15.1% versus 9.88%), infants (11.5% versus 2.91%) and children (14.4% versus 0.92%; $P < 0.001$).¹⁸ Similar observations have been described post-mBT shunt surgery.^{10,14} On the whole, the need for preoperative mechanical ventilation reflects the precarious condition of these infants, which may explain the greater occurrence of adverse outcomes following surgery in such cases. It is also plausible that mechanical ventilation itself contributes to poor outcomes by altering the systemic-to-pulmonary blood flow ratio and increasing the need for sedation and neuromuscular blockade and the risk of pulmonary complications. Therefore, it is advisable to avoid elective intubation in this high-risk population, if possible.^{19,20}

Moreover, performing a cardiopulmonary bypass during an mBT shunt procedure has frequently been associated with mortality, particularly among single ventricle patients.^{7,15} In this context, a cardiopulmonary bypass is generally performed due to preoperative haemodynamic instability or the need for concomitant cardiac surgery. There are several possible explanations for the association between cardiopulmonary bypass and adverse outcomes following mBT shunt procedures including activation of the inflammatory and coagulation cascades, alterations in pulmonary compliance and myocardial dysfunction and the decrease in diastolic pressure.^{7,15} In addition, previous studies have reported other predictors of mortality following mBT shunt procedures among paediatric CCHD cases such as low birth weight, underlying genetic syndromes, duct dependency and higher mBT shunt size-to-weight ratios.⁷ While these factors were not statistically significant predictors of mortality in the present study, it is possible that the small sample size precluded further analysis.

In the immediate postoperative period following mBT shunt procedures, two predominant reasons for increased early morbidity and mortality include the occurrence of shunt blockade (due to kinking or thrombosis) and pulmonary overcirculation (also known as over-shunting).²¹ In the current study, 12% of patients required surgical shunt revision due to shunt blockade during the same hospital admission period, of which one-third later died. In contrast, pulmonary

overcirculation (i.e. maintaining SpO₂ at >85%) was not a significant risk factor for early mortality. This probably reflects an underestimation of the prevalence of this factor, given that the majority of in-hospital deaths were due to myocardial dysfunction and low cardiac output. Over-shunting is one of the major causes of ventricular dysfunction and low cardiac output syndrome after mBT shunt procedures.²¹

Palliative mBT shunt procedures lead to unstable circulation, with patients at high risk of death even after being discharged from hospital. Previous research indicates that the rate of inter-stage mortality after mBT shunt surgeries varies from 3–11%.⁹ In the present study, the inter-stage mortality rate was 6.7%; this finding is in line with other published research, despite being calculated over a longer period of time.¹¹ During the interval period, patients with mBT shunts are at an increased risk of acute adverse events caused by alterations to the systemic-to-pulmonary blood flow or due to acute shunt thrombosis, especially during periods of concomitant illness (e.g. diarrhoea or sepsis). Longer interval periods can also render the shunt inadequate due to neointimal proliferation or somatic growth, mandating reintervention.²²

Cardiac catheterisation using a ductal or right ventricle outflow tract (RVOT) stent has been proposed as an alternative to an mBT shunt.²³ Comparative research has indicated that this alternative strategy is not inferior to mBT shunts in terms of clinical outcomes and is superior in terms of other variables like hospital mortality.^{23–25} However, a sizeable number of cases in which attempts at ductal/RVOT stenting fail have been found to eventually require mBT shunts.²³ While this subgroup of patients were observed to have a higher risk of death in the current study, the small study population precluded further analysis. As such, further research to compare outcomes between ductal stenting and mBT shunt procedures in a local setting might be helpful to guide patient selection.

The overall rate of surgical reintervention in the current study was 24%. While this is similar to the rate reported by Bentham *et al.*, it remains unarguably high.²⁴ Moreover, half of these interventions took place prior to hospital discharge. O'Connor *et al.* reported that 9.7% of 207 patients required reintervention before discharge, whereas Do *et al.* observed the rate of in-hospital shunt failure requiring reintervention to be 7.3% among 9,172 at-risk infants.^{26,27} Prevention of early shunt failure and reintervention is very important as these events entail considerable mortality and morbidity.^{26,27}

Reasons for the high rate of reintervention in the current cohort are not entirely clear and require further evaluation; however, it is worth mentioning

that most reinterventions were performed for biventricular patients with underlying diagnoses of pulmonary atresia and VSD, especially during the interval period. This is understandable considering the complex nature of this lesion, with many surgeons preferring to employ a staged approach with regards to the initial placement of the mBT shunt to allow for the growth of the pulmonary arteries.^{28,29} As pulmonary atresia and VSD was the most common underlying diagnosis in the biventricular group, this could also possibly explain the longer interval period before the second-stage surgery among these patients.

Worldwide, outcomes following mBT shunt procedures are still poor compared to other types of congenital heart surgery.^{5,6,13} However, there nevertheless remains room to improve outcomes of this surgery among infants in Oman. Suggestions to decrease early mortality include improved patient selection with regards to the decision for surgical intervention compared to interventional cardiac catheterisation, the selection of appropriate shunt sizes, optimum anticoagulation to prevent shunt thrombosis and standardised postoperative management.³⁰ Similarly, shorter interval periods, pre-emptive patient management during periods of concomitant illness and greater awareness of risk factors among community healthcare professionals and parents may serve as strategies to improve survival after discharge.

This study was subject to certain limitations. As the study was conducted at a single centre, utilised a retrospective design, involved non-standardised procedures and included a comparably small number of patients, it may have been affected by bias. Thus, the results need to be interpreted in the background of institutional practices and the specific study population. Notwithstanding these limitations, the findings of this study contribute to knowledge regarding the outcomes of palliative mBT shunt procedures in infants with CCHD in Oman. Moreover, these results may serve as a platform for targeted strategies to improve outcomes in this setting.

Conclusion

In the current study, mBT shunt procedures were found to carry an extremely high risk of mortality and reintervention in the treatment of CCHD in a paediatric population. These findings reflect those reported in the existing global literature. In particular, preoperative mechanical ventilation and cardiopulmonary bypass represented significant risk factors for early mortality. Further studies are needed

to compare outcomes between mBT shunt procedures and cardiac catheter interventions in order to guide patient selection in this setting.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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AUTHORS' CONTRIBUTION

SS and KSM conceived and designed the study and drafted the manuscript. SS, KSM and OD collected the data. AHR performed the statistical analysis and interpreted the results. All authors approved the final version of the manuscript.

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