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## Original Article

## Cardiac recovery and outcome of neonates and infants presenting with severe aortic coarctation and depressed cardiac function

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## ABSTRACT

**Objectives:** Coarctation of the aorta represents 5–8% of all congenital heart diseases. Children with severe coarctation of the aorta may present with significant depression of myocardial function. The aim of this study is to identify short and midterm outcomes of neonates and infants with isolated coarctation of the aorta and depressed left ventricular systolic function with regard to recovery of their cardiac function.

**Methods:** All patients with isolated coarctation of the aorta who underwent surgical repair between December 2002 and December 2015 were retrospectively reviewed in a cohort study. The patients were divided into 2 groups: (1) Patients with depressed left ventricle systolic function who were found to have an ejection fraction and fractional shortening less than 55% and 25%, respectively, (2) Patients with coarctation of the aorta and normal left ventricle systolic function (Control Group). We reviewed both groups after surgery and compared them in terms of their cardiac function recovery.

**Results:** 58 patients were included. 25 patients (43%) depressed left ventricle systolic function group, 33 patients (57%) Control Group. There were statistically significant differences in ejection fraction and fractional shortening ( $p < 0.0001$ ) between the two groups before surgery. Follow-up demonstrated improvement and recovery of ventricular function in most of the patients, six months after surgery there was no more statistical difference between the groups in terms of cardiac function.

**Conclusion:** Majority of the patients with isolated coarctation of the aorta and depressed left ventricle systolic function showed improvement of ventricular function within 4 weeks after surgery, except for patients with residual coarctation of the aorta.

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## 1. Introduction

Coarctation of the aorta is a common defect that accounts for 5–8% of all congenital heart defects. In neonates, coarctation of the aorta may present as a patent ductus arteriosus dependent lesion. The obstruction that starts during fetal life leads to myocardial dysfunction and subendocardial ischemia that manifests itself as endocardial fibroelastosis and dilated left ventricle.<sup>1,2</sup>

Neonates with critical coarctation of the aorta usually present with variety of congestive heart failure symptoms, including poor

feeding, tachypnea, tachycardia, and poor urine output. The perfusion to the lower part of the body depends mainly on Persistent Ductus Arteriosus. As the persistent ductus arteriosus starts to close soon after birth, blood flow to the lower body becomes restricted and as a result the neonate may present with a shock-like state which is occasionally misdiagnosed as septic shock.<sup>1</sup> Administration of Prostaglandin E1 to maintain the persistent ductus arteriosus open is a lifesaving treatment to achieve the stage of surgical repair. Due to pressure overload, aortic flow obstruction and acidosis, it is not unusual that patients with critical coarctation of the aorta present with severely depressed cardiac function reflected in low ejection fraction, fractional shortening, increased left ventricular end-diastolic volume, and dilated left ventricle. Compromised cardiac function will deteriorate further unless the aortic flow obstruction is relieved.

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Surgical correction of coarctation of the aorta was first described in 1945 with resection of stenosis and end-to-end anastomosis.<sup>3</sup> Since that time several other procedures have been described and surgical correction is now established as the treatment of choice.<sup>3</sup> There is general agreement about the necessity for urgent operation in coarctation of the aorta associated with heart failure, depressed cardiac function or with severe upper limb hypertension.<sup>4,5</sup> It is unclear, however, how often an infant with isolated coarctation of the aorta may present with depressed function and dilated left ventricle. Further, although correction of coarctation of the aorta has been accomplished with excellent surgical results, in patients with depressed function the period for recovery of cardiac function is not well defined. Furthermore, it is also undetermined how the dilated left ventricle with abnormal ventricular function will progress once the volume loaded left ventricle is unloaded by releasing the obstruction and whether some perioperative factors may have an influence on the recovery period of ventricular function with restoration of normal ventricular ejection and geometry.

The aim of this study is (1) to identify short and midterm outcome of neonates and infants diagnosed with isolated coarctation of the aorta and depressed left ventricular systolic function with regard to recovery of their cardiac function and their overall post-operative course after surgical repair and (2) to compare this group of patients (depressed left ventricle systolic function Group) with other similar patients who have coarctation of the aorta, too, but demonstrate normal ventricular function (Control Group).

## 2. Methods

A retrospective, cohort study of all patients with isolated coarctation of the aorta who underwent a surgical repair between December 2002 and December 2015 in our institute (King Abdulaziz Cardiac Center) was conducted. The study was approved by our research committee and received approval number RC16/147/R from the institutional review board at King Abdullah International Medical Research Center's.

We excluded all the patients with other major cardiac problem, that needed surgical intervention different to repair of the coarctation of the aorta and the patients that did not attend to a regular follow up during the first year post surgery.

The patients were divided into two groups. First group included cases with coarctation of aorta and depressed left ventricular systolic function, labeled as depressed left ventricle systolic function Group, and second group included cases with coarctation of aorta and normal left ventricle systolic function, labeled as Control Group.

Trans-thoracic echocardiography evaluation was done for each patient before and after surgery. Left ventricular dimensions were measured as diameters in end-diastole and end-systole and were labeled in tables and figures as (LVDD and LVSD), respectively. Cardiac function was determined by analyzing 2 specific parameters that include ejection fraction and fractional shortening. We defined depressed left ventricle systolic function by echocardiography when the patient had Ejection Fraction <55% and Fractional Shortening <25%, respectively, and it was correlated with the clinical symptoms of each patient. The guidelines suggest that the normal LVEF is >50%, the echo reports show an Ejection Fraction between 50–55% as a low normal, however recent studies,<sup>6,7</sup> showed that the patients with Ejection Fraction between 50–55% are more likely to develop heart failure and death than the patients with Ejection Fraction >55%, all the patients with isolated coarctation of the aorta with Ejection Fraction <55% were added to the group of depressed left ventricular systolic function. Left ventricle systolic function was assessed before and after surgical repair for

patients in each group and statistical comparison was done within each group pre and post repair and between the two groups. All images were reviewed by at least 2 pediatric cardiologists with focus in cardiac imaging who confirmed the functional results. The follow-up echocardiography after surgery was done during 3 clinic visits within one year (1, 6 and 12 months after surgery). The end to end repair was used in 92% of the patients in the depressed left ventricle systolic function group, and in 96% of the patients in the control group.

Descriptive statistics were used for the analysis of continuous variables to obtain the mean and standard deviation. Unpaired T-test was used for analysis of continuous variables between the two groups. The Chi-square with Yates correction was used for categorical variables comparison.

## 3. Pediatric cardiac intensive care unit methods

Regarding the management of these patient in the ICU, our protocol includes keeping these patients before the surgery on Prostaglandin E1, to keep the ductus arteriosus patent until the time of surgery.

After surgery the patients with depressed ventricular systolic function in general need an inotropic support with or without vasopressor, the most commonly used in our unit are Epinephrine and Milrinone, however some other patients may need to add to their treatment Norepinephrine and/or Vasopressin. Management of patients with normal ventricular systolic function and high blood pressure is mainly sodium nitroprusside, and/or short acting beta blockers infusion (esmolol). Patients with high blood pressure and depressed ventricular function are managed with dilators only such as sodium nitroprusside, phentolamine, and/or hydralazine.

All patients are received after surgery ventilated, weaning of ventilation is individualized according to the patient condition before and after surgery.

Regarding the oral feeding, in our ICU, we keep these patients on Nil Per Oral (NPO) during the first 72 h after surgery considering the high risk of necrotising enterocolitis (NEC) and chylothorax that can be present in these patients. Chest drains are removed after establishing full feeding to rule out chylothorax.

## 4. Results

The total number of patients with coarctation of the aorta who underwent surgery during the study period was 318. There were 58 patients with isolated coarctation of the aorta who fulfilled the inclusion criteria and were included. Twenty-five patients (43%) of all included cases presented with depressed left ventricle systolic function, reflected in low Ejection Fraction and Fractional Shortening (Depressed left ventricle systolic function Group). The remaining 33 patients (57%) with isolated coarctation of the aorta had normal left ventricle systolic function (Control Group). In both groups more male patients were seen (52% in the depressed left ventricle systolic function Group and 64% in the control group, respectively (Table 1). Depressed left ventricle systolic function

**Table 1**  
Comparison of demographic data between DLVSF Group and Control Group.

Variable	DLVSF Group	Control Group	P value
Number of patients	25/58	33/58	
Average age (month)	1.2 ± 1.1	8.2 ± 8.0	0.04
Average weight (kg)	3.4 ± 1.0	6.0 ± 4.0	0.01
Gender (male/female)	13/12	16/9	

DLVSF: Depressed left ventricular systolic function.

was present more in small patients with lower body weight ( $p < 0.01$ ) and younger age ( $p < 0.04$ ) (Table 1). There was no significant difference in the incidence of postoperative complications between both groups (Table 3). There were statistically significant differences regarding left ventricle systolic function parameters (ejection fraction and fractional shortening;  $p < 0.0001$ ) between the two groups on admission before surgery (Figs. 1 and 2, and Table 2). At the time of the discharge, the difference between ejection fraction and fractional shortening was still statistically significant with a p-value of 0.0011 and 0.0016, respectively. Regarding the time of the discharge, there was no significant difference between the groups with a P value of 0.81. In the group with depressed LVSF the mean of days for discharge was  $5.16 \pm 4.20$ , and for the control group the mean of days for discharge was  $5 \pm 6.37$ . Six months after surgery left ventricle systolic function recovered fully to normal in most of the patients; and the difference gradually disappeared and became statistically insignificant (Figs. 1 and 2, and Table 2). There was a statistically significant difference for both diameters in end-diastole and end-systole before surgery and during the first follow up visit one month after

surgery with a p-value of 0.01 (Figs. 3 and 4). In the subsequent visits at 6 and 12 months after surgery, this difference gradually abolished and became insignificant. Most of the patients recovered to normal cardiac function within 4 weeks after the surgery. All the patients (100%) had complete recovery of their cardiac function with normal ejection fraction, fractional shortening and left ventricle dimensions within 6 to 12 months except for two patients who had a delayed recovery with restoration of their function more than 6 month after surgery (Figs. 1 and 2), and Table 2); both patients had post-operative complications and residual lesions. The first case presented with moderate pulmonary hypertension while the second case had low body weight at the time of surgery with mild residual gradient in descending aorta with an estimated peak gradient of 25 mmHg after surgery that improved during follow-up and resolved at the 6 months visit after discharge.

### 5. Discussion

Coarctation of the aorta is a congenital anomaly in which narrowing of the isthmus of aorta or descending aorta restricts the

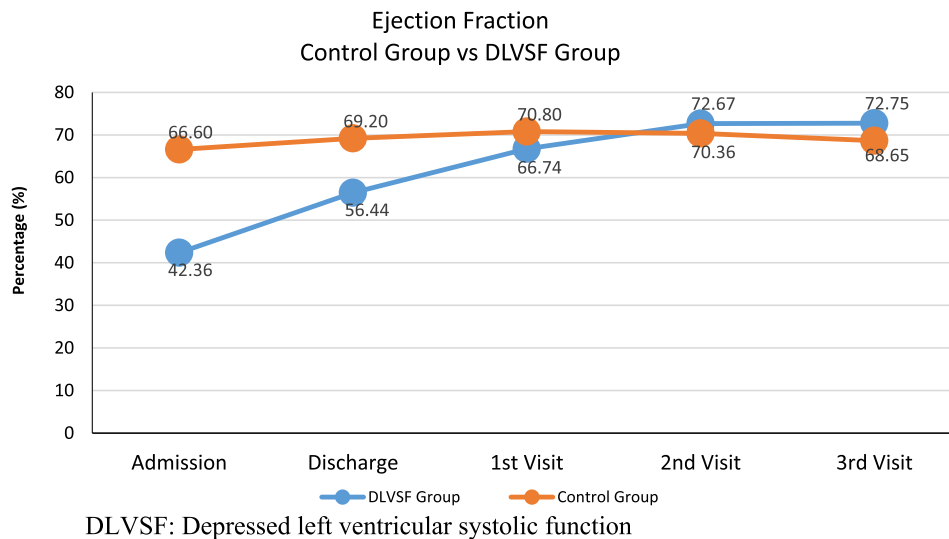


Fig. 1. Distribution of the groups by EF before and after surgery (one year of follow-up).

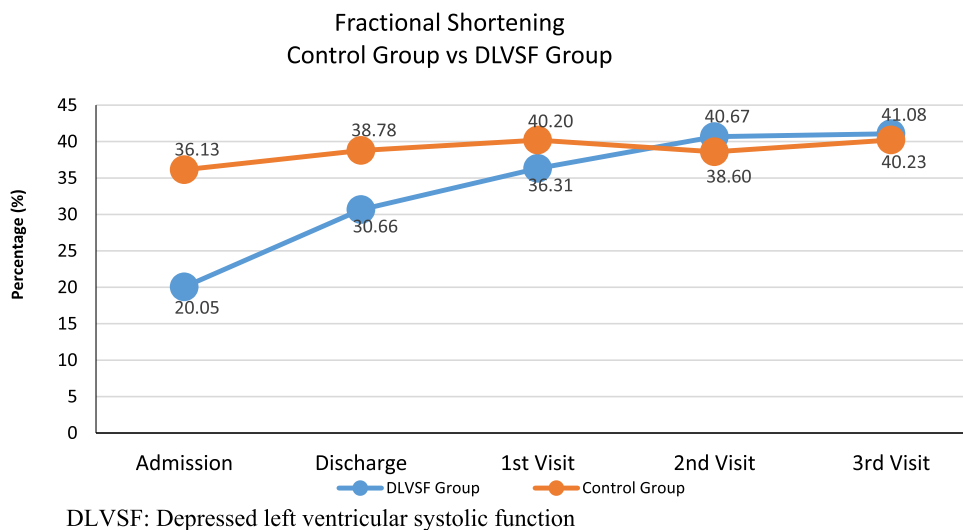


Fig. 2. Distribution of the groups by FS before and after surgery (one year of follow-up).

**Table 2**  
The comparison of EF and FS before and after surgery between DLVSF Group and Control Group (one year follow-up).

Variable		DLVSF N = 25	Control N = 33	P value
Admission	EF	42.3 ± 15.0	67.0 ± 9.0	0.0001
Admission	FS	20.0 ± 8.0	36.1 ± 7.0	0.0001
Discharge	EF	56 ± 20.0	69.2 ± 8.1	0.001
Discharge	FS	31.0 ± 12.0	39.0 ± 7.0	0.01
1st Visit	EF	66 ± 15.0	71.0 ± 11.0	0.15
1st Visit	FS	36.3 ± 10.4	40.2 ± 9.3	0.13
2nd Visit	EF	73.0 ± 10.0	70.4 ± 11.0	0.33
2nd Visit	FS	41.0 ± 7.4	38 ± 7.1	0.33
3rd Visit	EF	73.0 ± 8.0	69.0 ± 6.0	0.02
3rd Visit	FS	41.0 ± 7.0	40.2 ± 5.0	0.67

DLVSF: Depressed left ventricular systolic function, EF: ejection fraction, FS: fractional shortening.

**Table 3**  
Comparison of post-operative complications between DLVSF Group and Control Group.

Variable	DLVSF N = 25	Control N = 33	P value
Infections	4/25 (16%)	7/33 (28%)	0.87
Respiratory	3/25 (12%)	10/33 (36%)	0.18
Arrhythmias	2/25 (8%)	1/33 (4%)	0.06
Pulmonary hypertension	1/25 (4%)	2/33 (6%)	0.09
Neurologic	0	1/33 (4%)	0.37

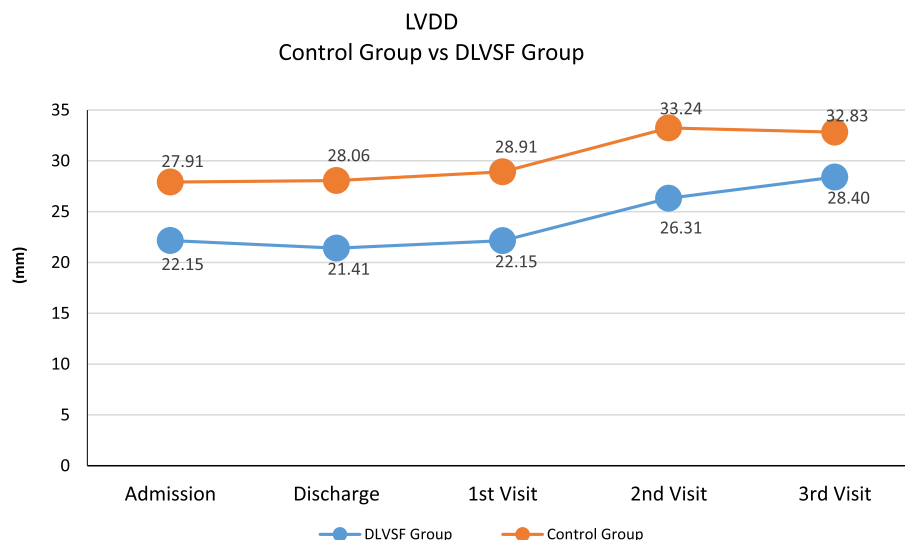
DLVSF: Depressed left ventricular systolic function.

blood flow to the lower part of the body, and as a consequence increases backward pressure on the left ventricle. This increase of the afterload pressure has an impact on left ventricular systolic function and ultimately leads to heart failure and left ventricle dilatation.<sup>5</sup> Patients commonly present with cardiogenic shock due to cardiac dysfunction, however it has been reported that after the removal of the pressure load the ventricular function improves significantly shortly after surgery. Jashari et al. followed and reviewed patients with coarctation of the aorta for a short term

of 8 days post-surgery.<sup>8</sup> They reported 21 patients with isolated coarctation of the aorta, half of them presented with cardiogenic shock. Soon after surgery they could appreciate the improvement in left ventricle systolic function and ejection fraction, but the parameters remained still abnormal. However, in the midterm follow-up (850 days) of these patients they reported total recovery of the left ventricle systolic function in all patients. In our study we have similar results in 25 patients with coarctation of the aorta and depressed left ventricle systolic function; most of them showed improvement in left ventricle systolic function within 4 weeks after surgery and few of them showed recovery to normal function in the midterm (6–12 months) follow-up.

Assaf et al. reported in 2005,<sup>3</sup> 13 neonates who presented with cardiogenic shock and underwent surgical repair, 7 of them had isolated coarctation of the aorta with severely depressed left ventricle systolic function. During post-operative follow-up most of the patients demonstrated an improvement of their cardiac function up to full restoration to normal. The improvement in left ventricle systolic function was observed as early as few days after surgery.

Another study done by Graham and collaborators<sup>9</sup> showed two groups of patients, one with coarctation of the aorta and depressed left ventricle systolic function and another group with coarctation of the aorta and good left ventricle systolic function. They again described improvement of the left ventricle systolic function post-operatively in patients with depressed left ventricle systolic function. Thus they concluded that alterations of the left ventricle systolic function in small infants with symptoms of heart failure are related to the afterload pressure and that these changes do not reflect a permanent impairment as left ventricle systolic function recovers in most of the patients shortly after surgical repair.<sup>10,11</sup> Balderrábano-Saucedo et al. studied 40 children with coarctation of the aorta and compared their left ventricle systolic function and myocardial performance index with healthy children. They reported that not all patients demonstrated a recovery of their cardiac function back to normal after coarctation repair, this was true particularly in certain cases where patients had significant systemic hypertension pre-operatively or when the repair was achieved later >4 years of age. They concluded that long



DLVSF: Depressed left ventricular systolic function, LVDD: Left ventricular end-diastole diameter.

**Fig. 3.** Distribution of the groups by LVDD before and after surgery (one year of follow-up).

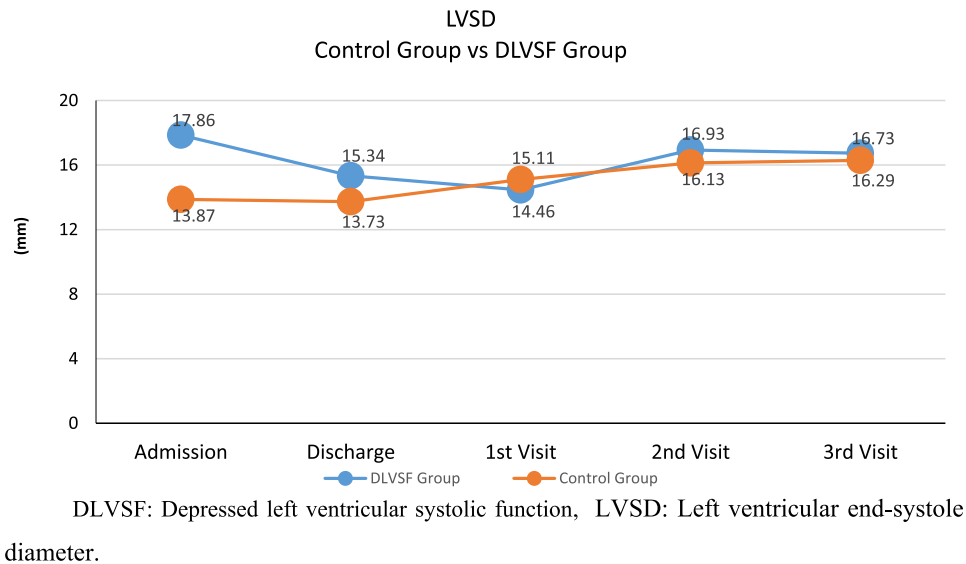


Fig. 4. Distribution of the groups by LVSD before and after surgery (one year of follow-up).

standing afterload may lead to permanent loss of normal geometry and left ventricle systolic function with subsequent impact on long term development of cardiovascular diseases or unfavourable cardiovascular events.<sup>12</sup>

Among all patients with coarctation of the aorta, it was documented that the surgical outcome and the risk of recurrence of coarctation of the aorta is higher in subgroups with associated comorbidities such as prematurity and very low birth weight.<sup>13</sup> Other studies have demonstrated that complex cardiac surgery can be performed in low-weight infants with acceptable but increased rates of morbidity and mortality. At the same time other centres have documented low mortality rates after repair of coarctation of the aorta in small infants.<sup>14</sup> These findings are important since the majority of neonates and young infants with persistent ductus arteriosus dependent critical coarctation and depressed left ventricle systolic function would not tolerate long waiting periods and thus imperative surgical repair to release obstruction is crucially needed without delay.

In our study the average age in the depressed left ventricle systolic function Group was 1.22 months while 6 (24%) of them were neonates, and the average weight was  $3.48 \pm 0.82$  kg, being significantly lower compared to the Control Group. At the same time, in our follow-up, there were no cases of recurrent aortic arch obstruction in midterm up of 6 to 12 months after surgery and there was no mortality.

Our results concur with the previously published reports and reinforce one more time the emerging clinical practise that cardiac surgery can be performed safely with excellent outcomes, low rate of mortality and morbidity in neonates with coarctation of the aorta and depressed left ventricle systolic function, commonly presenting with cardiogenic shock (2). Further, few of our patients were premature babies with low body weight below 2.2 kg who presented with depressed left ventricle systolic function and required urgent coarctation repair with satisfactory results and good overall outcome.<sup>15</sup>

## 6. Study limitations

There are several limitations to our study: (1) the first limitation comes with the fact that this is a retrospective study and thus subject to all of the inherent biases that are inevitably related to

this type of investigation. (2) Our experience is the reflection of a single tertiary cardiac center, although our medium size tertiary pediatric cardiac program involves the whole spectrum of complex heart surgeries (except for heart transplantation). This may limit generalization of our findings. (3) We also lost the follow-up in few patients who were referred from other hospitals and we were not able to collect their full data post-surgery; they were necessarily removed from the study. As a result the number of the patients included was decreased due to residence in distant cities. (4) Another limitation is the fact that we did not look for certain parameters specific for myocardial function rather than left ventricle systolic function such as the myocardial performance index that require prospective follow-up of the patients with tissue Doppler measurements. Future studies are warranted to look for such myocardial function parameters for a better understanding of left ventricle mechanics and performance in the setting of loading and unloading conditions, particularly in children with depressed function after surgical repair such as the group of patients we reviewed in this study with coarctation of the aorta.

## 7. Conclusion

A significant number of patients with coarctation of the aorta have depressed left ventricle systolic function. All patients in our study recovered well after surgery and most of them showed improvement in their left ventricle systolic function within 4 weeks after surgery. Delayed recovery may hint to the presence of residual lesions or complications that may affect myocardial ability to regain normal function and dimensions.

## Ethical considerations

This study is a retrospective study with review of medical records, it was not necessary to use an informed consent from the families of the patients.

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This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

## Conflicts of interest

None.

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