Early postoperative physical therapy for improving short-term gross motor outcome in infants with cyanotic and acyanotic congenital heart disease

Running title: Early postoperative physical therapy for CHD

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Implications of Rehabilitation

- Infants and toddlers with cyanotic congenital heart disease are likely at greater risk of gross motor delays and have a prolonged recovery period of gross motor ability compared to those with acyanotic congenital heart disease.
- Early postoperative physical therapy for patients with congenital heart disease after cardiac surgery promoted gross motor recovery.
- The postoperative recovery period to preoperative mobility grade was affected by pre-, intra-, and postoperative factors.
- Rehabilitation experts should consider the risk of gross motor delays of patients with congenital heart disease after cardiac surgery and the early postoperative physical therapy to promote their gross motor recovery.

ABSTRACT

Purpose: We analysed the gross motor recovery of infants and toddlers with cyanotic and acyanotic congenital heart disease who received early postoperative physical therapy to see whether there was any difference in the duration to recovery. **Methods:** This study retrospectively evaluated the influence of early physical therapy on postoperative gross motor outcomes of patients with congenital heart disease. The gross motor ability of patients with cyanotic (n = 25, average age: 376.4 days) and acyanotic (n = 26, average age: 164.5 days) congenital heart disease was evaluated to using our developed a new nine-grade mobility assessment scale. **Results:** Physical therapy was started at an average of 5 days after surgery, during which each patient's gross motor ability was significantly decreased compared with the preoperative level. Patients (who received early postoperative physical therapy) with cyanotic (88.0%) and acyanotic congenital heart disease (96.2%) showed improved preoperative mobility grades by the time of hospital discharge. However, patients with cyanotic congenital heart disease had a significantly prolonged recovery period compared to those with acyanotic congenital heart disease ($p < 0.01$). The postoperative recovery period to preoperative mobility grade was significantly correlated with pre-, intra-, and postoperative factors. **Conclusions:** Our findings suggested that infants with cyanotic congenital heart disease are likely at a greater risk of gross motor delays, the recovery of which might differ between infants with cyanotic and acyanotic congenital heart disease after cardiac surgery. Early postoperative physical therapy promotes gross motor recovery.

Key words: Paediatrics, congenital heart disease, gross motor ability, postoperative rehabilitation, cyanotic and acyanotic heart disease

Introduction

Congenital heart disease (CHD) is one of the most common birth defects, and nearly one-third of those who are affected require surgical intervention during infancy [1]. Since the survival of infants with CHD has improved due to advances in cardiothoracic surgery, there is an increasing emphasis on functional outcomes rather than mortality [2]. A number of studies have reported gross motor developmental delays in infants who undergo early cardiac surgery for CHD [3-7]. The gross motor developmental delay can be attributed to a number of pre-, intra-, and postoperative factors [8, 9]. In the clinical setting, we often observe reduced gross motor ability in infants with CHD after cardiac surgery; for example, an infant who was capable of head control and walking before surgery was incapable of doing so thereafter. Parents of infants with CHD worry about gross motor delays after cardiac surgery, which likely persist until hospital discharge. Although postoperative hospital cardiopulmonary rehabilitation exercise programs reportedly reduced mortality and improved the exercise performance of adults with coronary heart disease as well as children who had undergone heart surgery[10,11], there are few reports of the ability of early postoperative rehabilitation programs to improve gross motor ability in patients with CHD. The effect of early physical therapy intervention on gross motor ability recovery is an important topic. Therefore, we investigated the effects of early physical therapy intervention programs on gross motor ability in infants and toddlers with CHD after cardiac surgery.

Although there are tools to evaluate the motor development in infants such as the Peabody Developmental Scale and Alberta Infant Motor Scale [12,13], they are more time-intensive, which might be detrimental to infants' recovery after cardiac surgery. In this study, we developed a new short and simple gross motor grading system to evaluate patients after cardiac surgery that can be applied to all physical therapy programs.

Neonates with cyanotic CHD who undergo cardiac surgery are known to be at greater risk of motor delay [12,14]. Infants with cyanotic CHD have lower brain volume [15] and more severe neurodevelopmental delays [3] than those with acyanotic CHD. The proportion and frequency of neurodevelopmental delays are related to CHD complexity [13,16]. Clinically, infants with cyanotic CHD have severe congenital heart defects, and we must be careful about infants crying during physical therapy because it may trigger cyanotic symptoms. Additionally, our anecdotal experience seems to suggest that infants with cyanotic CHD have a prolonged recovery period prior to hospital discharge. However, to our knowledge this has not been studied systematically at our institution or reported in the literature.

This study aimed to compare the gross motor recovery of infants and toddlers with cyanotic and acyanotic CHD receiving early postoperative physical therapy programs to using our developed a new nine-grade mobility assessment scale and examine the pre-, intra-, and postoperative factors influencing postoperative gross motor recovery and the interval between surgery and the initiation of physical therapy in patients with CHD.

Materials and Methods

Design

This study was designed to retrospectively evaluate the influence of early physical therapy programs on short-term gross motor outcome in infants and toddlers with CHD who underwent cardiac surgery. All of the work was conducted in accordance with the Declaration of Helsinki and was approved by the ethical committee of Kagoshima University Graduate School of Medical and Dental Sciences. We received informed consent from all the caregivers of the participating infants to publish their anonymized examination results.

Patients

Seventy-six infants and toddlers (age < 3 years old) with CHD who underwent palliative or functional radical open heart surgery were admitted to the paediatric ward and underwent an early physiotherapy program between April 2013 and March 2015 at Kagoshima University Hospital. Sixteen infants with chromosomal abnormalities or congenital syndromes such as 22q deletion spectrum or Down syndrome were excluded from the study. The exclusion criteria were: (1) underwent several surgeries in a single hospital stay, (2) hospitalization for >100 days for serious complications after cardiac surgery, and (3) attended physical therapy programs fewer than five times. After the participants were screened for the exclusion criteria, data from 51 patients were analysed (Table 1). Based on the clinical symptoms, 25 patients were classified as having cyanotic CHD, while the other 26 patients as having acyanotic CHD (Table 1). All patients received optimal medications according to their postoperative condition such as antibiotic agents, sedatives, diuretics, cardiotonic agents, and anti-arrhythmic agents.

Physical therapy intervention

At our hospital, we provide early physical therapy programs for infants with CHD who undergo cardiac surgery to prevent respiratory complications and improve gross motor ability. All patients with CHD stayed in the intensive care unit (ICU) after surgery; subsequently they were admitted to the paediatric ward until hospital discharge. The physical therapy program was recommended by the rehabilitation doctor and the paediatrician to prevent respiratory complications and improve gross motor ability. If the patient was at risk of respiratory complications such as atelectasis after surgery, physical therapy was performed while the patient was receiving mechanical ventilation in the ICU.

Physical therapy consisted of respiratory exercises to prevent respiratory complications and therapeutic exercises of extremities and trunk to improve the patients' gross motor abilities one to three times a day for 20 to 60 minutes each on five or six days a week. Electrocardiography was performed and arterial oxygen saturation was monitored during the physical therapy sessions. We monitored each patient closely to detect any rapid changes in the vital signs or symptoms of cyanosis. We also noted all patient-specific contraindications, such as exacerbations of heart failure, edema, sustained grumpiness, respiratory distress.

Respiratory physical therapy included postural drainage therapy, thoracic expansion, chest mobilization, and squeezing (manual breathing assist with postural drainage) (Figure 1A). If the patient had concomitant atelectasis and pneumonia, respiratory physical therapy was performed in cooperation with doctors, nurses, or caregivers (family). Therapeutic exercises were performed >1 hour after nursing or eating to prevent inactivity and improve gross motor ability. The therapeutic exercises were performed while each patient was awake. If the patient was wary of strangers, the parent/caregiver performed the program under instruction from the physical therapist.

Gross motor ability was assessed using a simple and original nine-grade mobility assessment system based on the gross motor development of infants and toddlers. The nine-grade mobility assessment scale is observational in nature and can be performed in approximately five minutes; thus, it is easy to perform in the ICU or sickroom and is not stressful to patients. We performed a therapeutic exercise program corresponding to each grade to evaluate the gross motor ability of the patients as follows:

Grade 1: The infant is unable to move four limbs against gravity. For exercise therapy, we induced anti-gravity movement of the four limbs using passive exercise or active assistive movement. Muscular contractions of the four limbs, trunk, and neck were induced using postural reflection such as righting reaction. Sitting consisted of holding up the head at less than 30° (Figure 1B).

Grade 2: The infant is able to move the four limbs against gravity. For exercise therapy, we perform a stability exercise of the neck and trunk muscles using the righting reflex or by moving the infant's centre of gravity. In the supine position, the neck and head were positioned medially. We facilitated the activity of the neck rotation muscles in the supine position. In the prone position, we facilitated the extensor muscle activities of the trunk and neck. We also educated the caregivers on how to hold the infant's neck.

Grade 3: The infant can hold his/her neck steady by himself/herself. For exercise therapy, we performed a passive sitting balance exercise by moving the centre of gravity with assistance and facilitate the stability of the neck and trunk while sitting. We also facilitated the rotation movement of the neck and trunk using rolling over and trunk extensor muscle activities in the prone position. The infants practiced using forearm support in the prone position.

Grade 4: The infant can roll over in both directions. For exercise therapy, we performed sitting balance exercise and voluntary reaching movement exercises of the upper limbs using toys to facilitate the back extensor muscles in the sitting position (Figure 1C). The sitting balance exercise was performed using a cube chair. We also performed developmental exercises such as rolling over, arising from a lying down position, creeping, and crawling with the support by physical therapist.

Grade 5: The infant is able to sit without support. For exercise therapy, we continued the exercise programs in stage 4 and performed a standing exercise starting from a sitting position on a chair.

Grade 6: The infant is able to pull up to stand but is not able to walk. For exercise therapy, we performed a standing balance exercise using the centre of gravity movement, a reaching movement of the upper limbs, and a prolonged standing time (Figure 1D). An assisted walking exercise was performed with the infant holding onto a table and wall.

Grade 7: The infant is able to walk while holding on to something such as a furniture or wall. For exercise therapy, we performed a walking exercise by leading their trunk and pelvic movement and pulling their hand or using a walker.

Grade 8: The infant or toddler is able to walk alone. For exercise therapy, the infant performed walking exercises with the physical therapist watching closely and the walking distance was gradually extended. If their walking balance was stable, they were trained next walking or side stepping.

Grade 9: The infant or toddler is able to run. For exercise therapy, walking exercise was performed on various surfaces such as flat ground, hilly areas, and rugged ground: the infant was also trained in stair climbing while the physical therapist monitored their vital signs. Short-distance running was also performed.

Outcome measures

Pertinent medical data, including age, height, and weight at the time of surgery, diagnosis, date of surgery, operative procedure, number of surgeries, duration of surgery, duration of anaesthesia, duration of cardiopulmonary bypass, aortic clamp time, duration of postoperative hospital stay, duration of ICU stay, duration of mechanical ventilation in the ICU, interval between surgery and initiation of physical therapy, duration of physiotherapy intervention, medication, and major complications were noted from the hospital medical records. The gross motor ability of the patients was assessed by a physical therapist who was blinded to the study using parent questionnaires and rehabilitation records. We assessed the infants' nine-grade mobility levels based on their gross motor ability before surgery, at physical therapy initiation, and until discharge. We examined the inter-evaluator assessment reliability. To evaluate inter-rater reliability among the four evaluators (physical therapists), the intraclass correlation coefficient (ICC [2, 1]) was calculated. The overall ICC (95% confident interval) between evaluators was excellent (0.955 [0.883–0.987]).

Statistical analysis

Comparisons between patients with cyanotic and acyanotic CHD were performed using

Student or Welch t test after testing for equality of variance. Student t test was used to analyse surgery time, anaesthesia time, aorta clamp time, duration of ICU stay, duration of mechanical ventilation in the ICU, and interval between surgery and initiation of physical therapy. Welch t test was used to examine age, height, and weight at the time of surgery, perfusion time, duration of postoperative hospital stay, duration of physical therapy intervention, and the recovery period to preoperative mobility grade. The diagnosis and the operative procedure in each group were analyzed using chi-squared test for independence. Cohen effect size index d was used to evaluate the intergroup differences. Wilcoxon signed-rank test was used to compare the estimated preoperative mobility grades in patients with cyanotic and acyanotic CHD. The Kruskal-Wallis test and Bonferroni correction applied to Wilcoxon signed-rank test was used to compare the mobility grades preoperatively, at postoperative physiotherapy initiation, and at discharge. In addition, the Mann-Whitney U test was used to compare patients with cyanotic and acyanotic CHD during postoperative physical therapy initiation and at hospital discharge. Pearson product-moment correlation or Spearman rank correlation was used to correlate each variable. The statistical analysis was performed using IBM SPSS Statistics for Windows version 21 (Chicago, IL, USA), and values of $p < 0.05$ were considered statistically significant. Data are expressed as mean ± standard deviation (SD).

Results

Comparison of cyanotic and acyanotic CHD in pre-, intra-, and postoperative factors

Table 1 shows the demographic characteristics and pre-, intra-, and postoperative factors of patients with CHD. In the preoperative factors, the age of all patients with CHD at the time of surgery was heterogeneous. The average age, height, and weight at surgery of patients with cyanotic CHD were significantly higher than those of patients with acyanotic CHD ($p < 0.05$). The age and the weight had a large intergroup effect size, while the height had a medium effect size. The patients in both groups had significantly different diagnoses ($p < 0.001$) and complications, and the diagnoses overlapped in patients. The patients with cyanotic CHD had worse congenital heart deficits, such as tetralogy of Fallot and a single ventricle defect, than patients with acyanotic CHD.

The intraoperative factors were diagnosis, palliative measures taken, and radical operation performed. The patients with CHD underwent a number of operations on different parts at a single cardiac surgery. Patients with cyanotic CHD underwent Fontan completion for the complex heart deficit. In addition, one to three cardiac surgeries were performed on the infants with cyanotic CHD until the time this paper was written (one surgery, 14 patients; two surgeries, five patients; three surgeries, six patients). On the contrary, a ventricular or atrial septal defect closure as well as patent ductus arteriosus ligation for functional radical surgery was performed on patients with acyanotic CHD. Patients with acyanotic CHD underwent one surgery each until this study. The duration of surgery and anaesthesia in infants with cyanotic CHD was significantly longer than that in patients with acyanotic CHD ($p < 0.001$). The surgery time and anaesthesia time had a large effect size, and the aorta clamp time had a medium effect size between groups. The cardiopulmonary bypass time was longer in infants with cyanotic CHD than in those with acyanotic CHD, but the difference was not significant.

In postoperative factors, all examined parameters in patients with cyanotic CHD were longer than in patients with acyanotic CHD. The postoperative hospital stay and physiotherapy intervention in patients with cyanotic CHD were significantly longer than in patients with acyanotic CHD ($p < 0.01$). The postoperative hospital stay and duration of physical therapy intervention had a large intergroup effect size.

Gross motor recovery of patients with cyanotic and acyanotic CHD after cardiac surgery

Figure 2 shows the recovery process of gross motor ability using nine-grade mobility scale after surgery. The mobility grade in each group was significantly different in three time points (preoperatively, at postoperative physiotherapy initiation, and at discharge) by the Kruskal-Wallis test ($p < 0.001$). At the time of physical therapy initiation (average of 5 days), the gross motor ability of all patients was significantly delayed compared with their preoperative gross motor ability (median, grades 3 and 2, respectively, $p < 0.01$) by the Bonferroni correction applied to Wilcoxon signed-rank test. Twenty-two patients with cyanotic CHD (88.0%) and 25 with acyanotic CHD (96.2%) had improved to their preoperative mobility grade at discharge (average of 25 days). However, one patient with cyanotic CHD and another with acyanotic CHD did not recover the preoperative mobility grade even at the time of discharge. Interestingly, the preoperative mobility grade of six infants with CHD (11.8%; cyanotic CHD in four; acyanotic CHD in two) was better than their preoperative mobility grade at discharge (Figure 2). Although their postoperative hospital stay was prolonged by complications, two infants with cyanotic CHD had better postoperative mobility grade than their preoperative mobility grade at discharge. One patient each from the cyanotic and acyanotic CHD groups had a late recovery period of > 60 days (cyanotic) or 35 days (acyanotic) because of postoperative complications such as chylothorax, thoracic drainage, and wound infection. The average duration of time after surgery that it took each patient to return to his/her preoperative mobility grade was 14.5 ± 10.6 days. Patients with cyanotic CHD had a significantly prolonged recovery period to preoperative mobility grade compared with infants with acyanotic CHD (19.5 ± 12.0 and 10.1 ± 6.8 days, respectively, $p = 0.003$; Figure 2). The large intergroup effect size was observed with the recovery period to preoperative mobility grade ($d = 0.97$).

We also examined whether pre-, intra-, and postoperative factors are associated with recovery of postoperative gross motor skill in 47 infants using the nine-grade mobility assessment scale (Table 2). The postoperative recovery period to preoperative mobility grade was significantly correlated with age, height, and weight at the time of surgery, duration of surgery and anaesthesia, duration of postoperative hospital stay, and interval between surgery and initiation of physical therapy, which suggests that the recovery of gross motor ability was affected by pre-, intra-, and postoperative factors.

Physical therapy interventions after cardiac surgery

Physical therapy programs were started at an average of 5 days (range, 1–22 days) after surgery in infants with CHD (Table 1). The interval between surgery and the initiation of physical therapy was not different between cyanotic and acyanotic CHD. Forty-eight patients underwent respiratory physical therapy (cyanotic CHD, 92.0%; acyanotic CHD, 84.6%) and exercise therapy (all patients). Respiratory physical therapy was provided to 28 patients in the ICU (cyanotic CHD, 60.0%; acyanotic CHD, 50.0%). Among them, six with cyanotic CHD and four with acyanotic CHD underwent respiratory physical therapy under mechanical ventilation. The percentage of postoperative respiratory complications in patients with cyanotic CHD was higher than that in patients with acyanotic CHD (cyanotic CHD, 32.0%; acyanotic CHD, 4.0%).

We examined the influence of early physical therapy programs on infants with CHD who underwent cardiac surgery ($n = 51$). The interval between surgery and initiation of physical therapy was significantly correlated with postoperative hospital stay ($r = 0.53$, $p < 0.01$), duration of ICU stay ($r = 0.80$, $p < 0.01$), and duration of mechanical ventilation ($r = 0.76$, $p < 0.01$), suggesting that early postoperative physical therapy initiation reduced the duration of ICU and hospital stay and use of mechanical ventilation.

Discussion

We developed this nine-grade mobility assessment system to assess the gross motor ability of infants and toddlers with CHD after surgery. Our nine-grade mobility assessment system not only assesses the patient's gross motor ability but also includes therapeutic exercises that correspond to each grade. Our original nine-grade mobility assessment system showed an excellent inter-examiner ICC and can be used to evaluate short-term gross motor outcomes of infants who undergo surgery for CHD.

Few reports have evaluated early therapeutic interventions in infants with CHD [12]. This study showed that infants with CHD have reduced gross motor ability after surgery. Patients with cyanotic CHD have a prolonged recovery period of gross motor ability. Our results suggested that infants with cyanotic CHD might be at greater risk of gross motor delay and that the recovery of gross motor ability might differ between infants with cyanotic and acyanotic CHD after cardiac surgery because the former had more severe congenital heart defects or other complications. The pathophysiological difference between patients with cyanotic and acyanotic CHD might be associated with a risk of gross motor delay after cardiac surgery.

Chock et al [17] demonstrated that infants undergoing surgical intervention for CHD are at risk of developing neurodevelopmental abnormalities, which may not become apparent until months after hospital discharge. Thus, the parents of infants with CHD are usually anxious about postoperative gross motor delays. Without therapeutic intervention, the gross motor developmental delay complications of early surgery in children with CHD persist for a long period [13, 16]. However, most patients with CHD who received early postoperative physical therapy programs improved to the preoperative rate by discharge. At discharge, we interviewed the parents about the infant's physical therapy intervention and gross motor ability after surgery. Most parents realized the gross motor delay of their infants and were initially anxious about whether they would recover to the preoperative rate. They indicated that early physical therapy intervention helped in the recovery of infant's preoperative gross motor ability and that their anxiety about the gross motor delay of their infants was reduced because of the advice and education provided by the physical therapists. This study's findings suggest that early postoperative physical therapy intervention might effectively promote the gross motor ability of infants with CHD, reduce the parents' postoperative anxiety, and further educate parents about home-based interventions after discharge.

Interestingly, this study showed that six of the 51 patients with CHD had improved postoperative gross motor ability compared with the preoperative gross motor ability at discharge, suggesting that infants with CHD might have a high motor ability before surgery that is further promoted by the postoperative physical therapy intervention. In this study, rehabilitation service was not implemented in our patients with CHD before surgery. Parental support is required to implement the rehabilitation intervention at home. However, some barriers to implementation of home-based interventions such as children's illness or lack of interest were identified in the parent questionnaire [13]. In our hospital, if infants with CHD who underwent cardiac surgery needed more physical therapy interventions, they underwent ambulatory physical therapy in the hospital near their home.

Factors associated with developmental delay include prolonged deep hypothermic circulatory arrest, prolonged cardiopulmonary bypass, older age at the time of surgery, higher number of hospital stays, palliative procedure, higher number of days in the ICU, and lower pre- and postoperative neurodevelopmental scores [8,13,14,18]. Similar to other studies, our analysis indicated that the recovery of postoperative gross motor ability was influenced by pre-, intra-, and postoperative factors. Our finding showed that age, height, and weight at the time of surgery impact the postoperative gross motor recovery. Our patients with cyanotic CHD who were older than the patients with acyanotic CHD underwent surgery several times because of complex heart deficits, and because patients of older age have a high motor ability before surgery. Therefore, they may require a longer time for recovery of once delayed gross motor ability after cardiac surgery.

A prolonged ICU stay and use of mechanical ventilation leads to muscle weakness [19,20], which might have contributed to the postoperative decrease in gross motor ability of infants with CHD. Interestingly, our results showed that early physical therapy intervention for infants who underwent cardiac surgery reduced the duration of hospital stay, suggesting that it might contribute to reducing medical costs as well. Additionally, these findings suggested that early postoperative physical therapy interventions for infants with CHD enhanced gross motor ability recovery.

The present study had several limitations. We used a small sample size and were unable to compare the patients with control patients who did not undergo early physical therapy programs since it is ethically impossible. Additionally, we did not analyse the effects of the difference in the surgical procedure and medication. Palliative surgeries are associated with poorer neurodevelopmental outcomes than corrective surgeries [1]. Sedatives may also influence mobility grade during the early postoperative period. Despite these limitations, our study provided evidence of the influence of early physical therapy programs on the recovery of gross motor ability of patients with cyanotic and acyanotic CHD. Stieber et al. [13] reported that completing the rehabilitation program enabled children who underwent cardiac surgery to increase their rate of development to an age-appropriate level. Our findings suggested that early physical therapy for infants who underwent cardiac surgery promotes the postoperative recovery of gross motor ability.

We believe that the gross motor delay due to cardiac surgery would improve to the preoperative level at hospital discharge. Further studies are needed to explore the long-term neurodevelopmental outcomes of our participants.

Conclusion

This study's findings suggested that the infants with CHD who underwent cardiac surgery experienced delays in short-term gross motor skills; notably; infants with cyanotic CHD have prolonged postoperative gross motor skill recovery times. This study showed that early physical therapy for infants who underwent cardiac surgery promotes the postoperative recovery of gross motor ability and reduces the duration of hospital stay. Early postoperative physical therapy programs may effectively improve the infants' gross motor ability to their preoperative level, reduce the parents' postoperative anxiety, and further educate the parents on how to integrate home-based interventions into their family life. Finally, such interventions may also reduce the risk of developmental motor delays in infants with CHD later in life.

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Declaration of interest section

The authors declare no competing financial interests.

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Figure Legends

Figure 1. Early physical therapy program after cardiac surgery. (A) Infant undergoing respiratory physical therapy. (B) Infant extending head <30° in the intensive care unit. (C) Infant performing a sitting balance exercise and voluntary reaching movement exercise of the upper limbs using toys to facilitate the back extensor muscles in the sitting position. (D) Infant performing a standing balance exercise in an effort to prolong standing time.

Figure 2. Recovery process of gross motor ability using the nine-grade mobility assessment scale after surgery. At the time of physical therapy initiation (▲), the mobility grades of all infants are lower than their preoperative rate (●). Twenty-two infants with cyanotic congenital heart disease

(CHD) and 25 with acyanotic CHD improved to their preoperative mobility grades by the time of discharge (■). One patient each from the cyanotic and acyanotic CHD groups did not recover their preoperative mobility grade at discharge (□). Interestingly, six infants with CHD had better mobility grades than their preoperative level at discharge (□*).

Table 1. Patient demographics and clinical characteristics

	Total (n = 51)	Cyanotic CHD (n = 25)	Acyanotic CHD (n = 26)	P Value (C vs A)	Effect size (C vs A)
Preoperative factors					
Age (days)	268.4 ± 234.7	376.4 ± 272.0	164.5 ± 122.0	0.001	1.01
Boys/girls	26/25	14/11	12/14		
Height (cm)	63.6 ± 11.6	67.7 ± 13.6	59.8 ± 7.3	0.017	0.73
Weight (kg)	6.2 ± 2.6	7.3 ± 3.0	5.2 ± 1.6	0.004	0.88
Diagnosis (number of subjects)				<0.001	
Ventricular septal defect (VSD)	27	3	24		
Atrial septal defect (ASD)	19	7	12		
Patent ductus arteriosus (PDA)	13	6	7		
Tetralogy of Fallot (TOF)	9	9	0		
Double outlet right ventricle (DORV)	3	3	0		
Transposition of the great arteries (TGA)	2	2	0		
Single ventricle defect	2	2	0		
Hypoplastic left heart	4	4	0		
Pulmonary artery stenosis and atresia	9	6	3		
Intraoperative factors					
Operative procedure (number of subjects)				<0.001	
VSD closure	27	4	24		
ASD closure	14	5	9		
Fontan	7	7	0		
PDA ligation	15	4	11		
Ligamentum arteriosum ligation	3	0	3		
Radical surgery for TOF	5	5	0		
Glenn procedure	3	3	0		
Surgery time (minutes)	349.0 ± 94.6	403.6 ± 85.2	296.6 ± 70.4	<0.001	1.37
Anesthesia time (minutes)	467.1 ± 103.3	527.8 ± 90.0	408.7 ± 78.8	<0.001	1.41
Perfusion time (minutes)	153.7 ±62.6	176.1 ± 65.4	132.2 ± 51.2	0.141	0.75
Aorta clamp time (minutes)	79.3 ± 47.0	76.7 ± 57.1	81.6 ± 35.2	0.062	0.10
Postoperative factors					
Postoperative hospital stay (days)	25.1 ± 14.2	31.1 ± 16.2	19.3 ± 8.7	0.003	0.91
ICU stay (hours)	121.3 ± 141.7	134.6 ± 164.0	108.4 ± 114.9	0.267	0.19
Duration of mechanical ventilation in ICU (hours)	63.8 ± 132.0	66.0 ± 160.0	61.7 ± 97.8	0.518	0.03
Duration up to physical therapy initiation (days)	4.9 ± 4.4	5.0 ± 4.6	4.8 ± 4.3	0.855	0.04
Duration of physical therapy intervention (days)	17.9 ± 12.1	23.4 ± 14.1	12.7 ± 6.2	0.002	0.99

Data are expressed as mean ± SD or number. C: cyanotic CHD, A: acyanotic CHD

Patients have more than one type of heart lesion and surgery.

Table 2. Correlation coefficients between the recovery period of mobility grade to preoperative rate and preoperative, intraoperative, and postoperative factors

	Infants (n = 47)
Preoperative factors	
Age (days)	0.65**
Height (cm)	0.55**
Weight (kg)	0.55**
Intraoperative factors	
Surgery time (minutes)	0.52**
Anesthesia time (minutes)	0.48**
Perfusion time (minutes)	0.18
Aorta clamp time (minutes)	- 0.17
Postoperative factors	
Postoperative hospital stay (days)	0.82**
ICU stay (hours)	0.22
Duration of mechanical ventilation in the ICU (hours)	0.12
Duration up to physical therapy initiation (days)	0.37*

*p < 0.05, **p < 0.01.

Fig.1

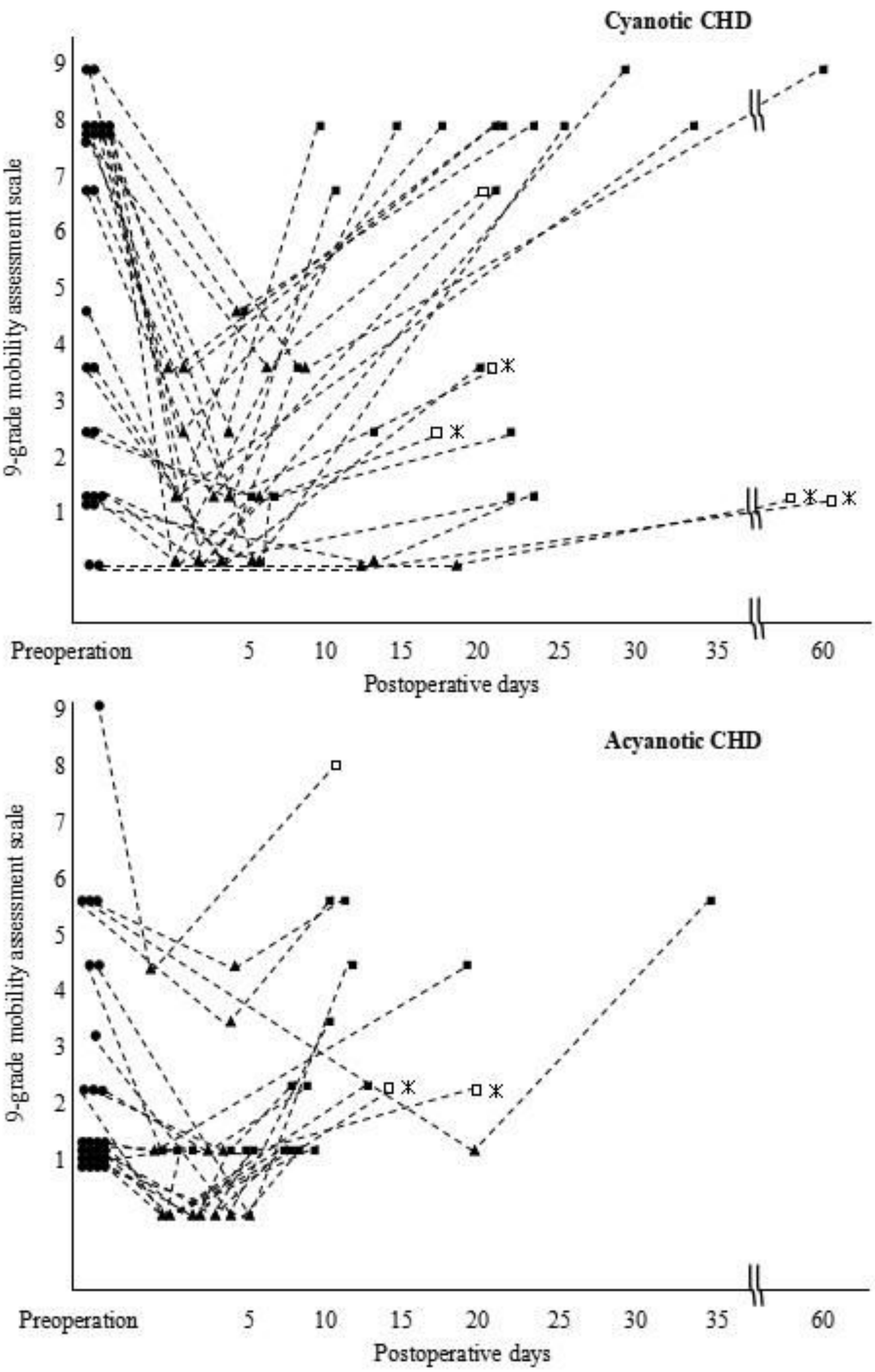
Cyanotic CHD
9-grade mobility assessment scale
9
8
7
6
5
4
3
2
1
Preoperation
5
10
15
20
25
30
35
60
Postoperative days
Acyanotic CHD
9-grade mobility assessment scale
9
8
7
6
5
4
3
2
1
Preoperation
5
10
15
20
25
30
35
60
Postoperative days

Fig.2