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Cardiac Rehabilitation Following Open-Heart Surgery In Children

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Mini Review

Abstract

Congenital heart disease (CHD) is the most common congenital abnormality. Nearly one-third of children with CHD require surgical intervention, either palliative or open-heart surgery. Children with CHD are initially at risk for motoric, cognitive, speech, and feeding disorders. They also have similar risks after undergoing open-heart surgery using cardiopulmonary bypass (CPB). Cardiac rehabilitation is necessary after open-heart surgery. The references demonstrate that postoperative cardiac rehabilitation positively affects optimal growth and development in children.

Keywords: *congenital heart disease (CHD), open-heart surgery, cardiopulmonary bypass (CPB), pediatric cardiac rehabilitation*

Background

Congenital heart disease (CHD) is the most common abnormality of the heart structure, blood vessel, and heart function. Currently, CHD incidence worldwide is estimated at 0.8% (8 babies per 1000 live births) or about 40,000 babies per year. In 2017, the global CHD incidence was 17.9 per 1000 children, with 19.1 per 1000 for male and 16.6 per 1000 for female.[1,2,3]

However, the types and severity of this disorder vary widely. Some conditions only require routine monitoring; however, one-third of children require surgical intervention or heart transplants to reduce mortality.[2,4,5,6] Cardiac surgery is an intervention to overcome heart disorders when pharmacological and supportive therapies fail. In 2002 alone, 27,772 CHD surgeries were performed in Europe. In 2003, the highest number of surgeries, i.e., 5,868 surgeries, was conducted in Germany, in which 4,415 of those used cardiopulmonary bypass (CPB) machines.[3,4]

CHD surgeries are classified into closed and open-heart surgery. Open-heart surgery is performed using a CPB machine that replaces the heart-lung function during surgery. Like other medical procedures, CHD surgeries also have risks and complications, including hemorrhage, infections, lung disorders, heart rhythm disorders, kidney disorders, stroke, and death. CPB can trigger inflammatory responses and postperfusion syndrome, also known as "pump head". Postperfusion syndrome in children can cause growth and developmental disorders, particularly related to permanent neurological effects.[8] After undergoing CPB procedure, children may suffer from complications related to pre, intra, and postoperative factors.[7,8,9] Pediatric patients with CHD are at risk of motoric, cognitive, speech, and feeding disorders after surgery, particularly open-heart surgery. The advancement of science and technology can minimize the complications and risks that accompany surgeries in the preparation,

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anesthetics, surgical techniques, cardiopulmonary bypass machines, and post-surgical patient management.[7,8,9,10] Postoperative pediatric cardiac rehabilitation is vital because it positively affects the child's growth and development.[9,10]

The Effects of Cardiopulmonary Bypass (CPB)

In general, cardiac surgeries are performed using two methods, i.e., temporarily stopping the heart (on-pump) and with the heart still beating (off-pump). The temporary cardiac arrest requires a replacement device for the heart-lung function, i.e., CPB machine, to maintain the circulation system. This technique maintains blood and oxygen circulation in the body.[11,12]

CPB takes over the heart-lung function by circulating and oxygenating the blood. The purpose of this machine is to maintain perfusion to other organs and tissues. The surgeon inserts a cannula to the right atrium, vena cava, or femoral vein to draw blood from the body. The cannula is connected to a tube filled with isotonic crystalloid fluid. The venous blood is filtered, oxygenated, cooled, warmed, and returned to the body. The cannula returning from the machine is reinserted through the ascending aorta or femoral artery. A hypothermic state is maintained at 28 - 32^{o}C during surgery to reduce oxygen demand and basal metabolism rate. Cooled blood is usually more viscous; therefore, a crystalloid solution is administered to reduce its viscosity. Protection is required during surgery with CPB to avoid damage to the heart muscles. Cardioprotection is carried out using hypothermic or cardioplegic techniques, which are often used together to reduce cardiac muscle oxygen consumption and, thereby, reduce cardiac muscle ischemia during CPB use.[13]

CPB can cause negative effects in the form of inflammatory responses due to extreme conditions that trigger cell activation when in contact with foreign surfaces, i.e., bypass circuits, mechanical stress due to frictions, tissue and reperfusion ischemia, hypotension, non-pulsatile perfusion, and hemodilution with anemia relative. Moreover, CPB can cause qualitative and quantitative platelet disorder. The concentration of pro-coagulant decreases due to hemodilution. The inflammatory, coagulation, complement, and fibrinolytic pathways are activated.[13]

Global inflammation triggers tissue responses that activate cellular and humoral cascades, including complement, coagulation, and fibrinolytic pathways. Also, it triggers endotoxin release, cytokine production, endothelial activation with an expression of leukocyte adhesion molecules, leukocyte and platelet activation, as well as production and release of free radical oxygen, nitric oxide, and proteolytic enzymes. These processes may cause plasma leakage and multiorgan dysfunction. Therefore, close monitoring is required when using the CPB machine.[11,12,13,14]

Blood contact with foreign bodies stimulates kallikrein production. This substance triggers positive feedback of factor XII which activates the coagulation and fibrinolytic cascades, as well as the bradykinin and the renin-angiotensin system. Gas microemboli particles caused by CPB are primarily associated with brain damage, impacting the child's future development.[7,8,9,12,15]

The Planning of Pediatric Rehabilitation Following Open Heart Surgery

The availability of long-term treatment facilities for patients with congenital abnormalities confirms that quality life-long care, including rehabilitation, is required for pediatric, adolescent, and adult patients. However, individual assessment is needed for a rehabilitation decision.[9,10] Rehabilitation should start immediately after surgery. However, it can also be carried out several years after the initial intervention.[9,10]

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Postoperative children often complain of incision and drainage pain, persistent pain on the neck and shoulder, chest pain, breathing problems, weakness, chest wall pain when lying on their side, wound healing problems, and sleep disturbances, i.e., insomnia and nightmares. They also experience feeding problems and depression. Moreover, they are dissatisfied with supportive postoperative care and ineffective treatment.[7] Every cardiac surgery has the potential for complications that can lead to morbidity and mortality in children.[7,10]

Children with CHD are populations with particular vulnerabilities, including hemodynamic fluctuations, respiratory problems, major cardiac surgeries, CPB, brain injuries, and postoperative circulation complications.[7,8,9,10]

The Purpose of Rehabilitation

Children with CHD tend to experience development disorders of the nervous system. A reduced supply of oxygen and nutrients, associated with decreased circulation, may cause delayed brain development.[7,8,10,15,16,17]

Rehabilitation for this group of patients should be conducted in three phases. Each phase is managed by a rehabilitation team that includes somatic, educational, psychological, and social elements.[10,15,16,17]

Every child has the right to appropriate physical, mental, and emotional development. The main goal of rehabilitation is to eliminate or minimize disease-related disorders and disabilities, as well as to prevent possible secondary effects. Also, it is needed to improve self-management and self-responsibility, increase social equality, and prevent discrimination. It is essential to reintegrate the affected people into schools, education, work, family, and society. Moreover, it is vital to improve the overall quality of life, reduce disease-related morbidity, limit the adverse physiological and psychological effects of heart disease, reduce the risk of sudden death, control heart symptoms, increase functional capacity, and improve psychosocial status.[15,16,17,18,19]

Rehabilitation needs in children vary according to the disease severity, duration from intervention, postoperative sequelae, comorbidities, families, social situations, and others.[16,17,19,20]

Pediatric cardiac rehabilitation elements include a fun exercise program, nutritional information, family involvement, emotional support, and education. A postoperative pediatric cardiac rehabilitation program should not imitate adult programs but require creative techniques for children to follow properly. A team that consists of cardiovascular anesthesiologists, cardiac intensive care specialists, cardiologists, cardiothoracic surgeons, development specialists, neurologists, a nurse practitioner coordinator, nurses, nutritionists, occupational therapists, pain management specialists, physical therapists, social workers, and speech or language therapists are required to carry out the rehabilitation program.[16,17,18,19,20]

Indication for Rehabilitation

Pediatric rehabilitation begins immediately after surgery. It is desirable to initiate the program within 24 - 48 hours postoperatively. However, the time for each child can be determined by an individually adapted approach.[17]

The physical exercise therapy is initiated on the first day following surgery after considering the child's development history, previous interventions, cardiac diagnosis, history of other surgeries, and complications from the surgical procedure. There should be appropriate patient selection, proper monitoring, competent personnel, basic life support, including defibrillators, established emergency procedures, and warm-up and cool-down procedures.[17,19,21]

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Patient assessment includes vital signs (heart rate, blood pressure, breathing sound, quantity and color of discharge), pacemaker settings, blood gas analysis, ventilator settings, and medication history. Furthermore, it is necessary to assess whether there are signs of cyanosis on the lip, skin, or nails.[17]

Postoperative physical exercise in children with CHD can increase physical capacity and cardiac output. However, it must be carried out carefully.[11] Following pediatric CHD surgery, physical exercise can increase exercise capacity, encourage children to participate in social and productive activities, and motivate them to continue exercising.[10,16,17,19,21]

The Rehabilitation Phases

The rehabilitation consists of four phases.

Phase I Rehabilitation

Rehabilitation focuses on somatic care, including medical care. In older children (adolescents), rehabilitation is primarily targeted to achieve early mobilization. The important goals are pain reduction, thrombosis prophylaxis, circulatory system stabilization, and management of existing neurological deficits. Physicians are expected to provide information and counseling to families regarding the child's illness as well as the psychosocial and emotional effects that may occur.[10,15,17,19]

Postoperative catabolic stress requires adequate nutritional supplementation. It is recommended to administer enteral nutrition to children postoperatively to help fulfill adequate dietary needs, as well as reduce the duration of ventilation use and the risk of infection.[18,22,23]

The rehabilitation time is determined on the first-day post-surgery by considering the child's illness and previous therapies, diagnosis of heart defect, type of surgery performed, and intra or post-procedure complications.[17]

Once the child can follow language instructions, breathing exercise becomes an essential component of the therapy. Painkillers suppress spontaneous breathing; therefore, deep breathing exercise is vital. In younger children, this exercise can be carried out by blowing bubbles or windmills. Passive mobilization of the extremities is carried out on the first-day post-surgery. This exercise is limited if the child is still on intravenous access; however, it is possible to move the extremities forming a 90° angle.[16,17,19]

Apart from physical exercise, rehabilitation such as occupational therapy, speech therapy, and feeding therapy is needed to support CPB recovery in children. Occupational therapy is required in children with CHD to improve their quality of life.[20] The intubation duration and breathing problems may cause difficulties in postoperative feeding. Thus, it is necessary to carry out post-surgery feeding therapy in children.[18,22,23]

Phase II Rehabilitation

This stage is a continuation of phase I, which can be applied to either outpatient or inpatient care.[17]

Phase III Rehabilitation

This phase requires home-based regular therapy. The management includes improving psychomotor aspects. Children are allowed to remain active under medical supervision.[17]

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Phase IV Rehabilitation

Children can carry out community-based independent training to build self-confidence and generate a positive psychological impact. This action can optimize a child's development after heart surgery. Pediatricians, pediatric cardiologists, social workers, psychologists, and nutritionists significantly influence the prognosis of the postoperative child. To date, children live with excessive protection due to parents' concerns regarding the child's heart defect.[16-25]

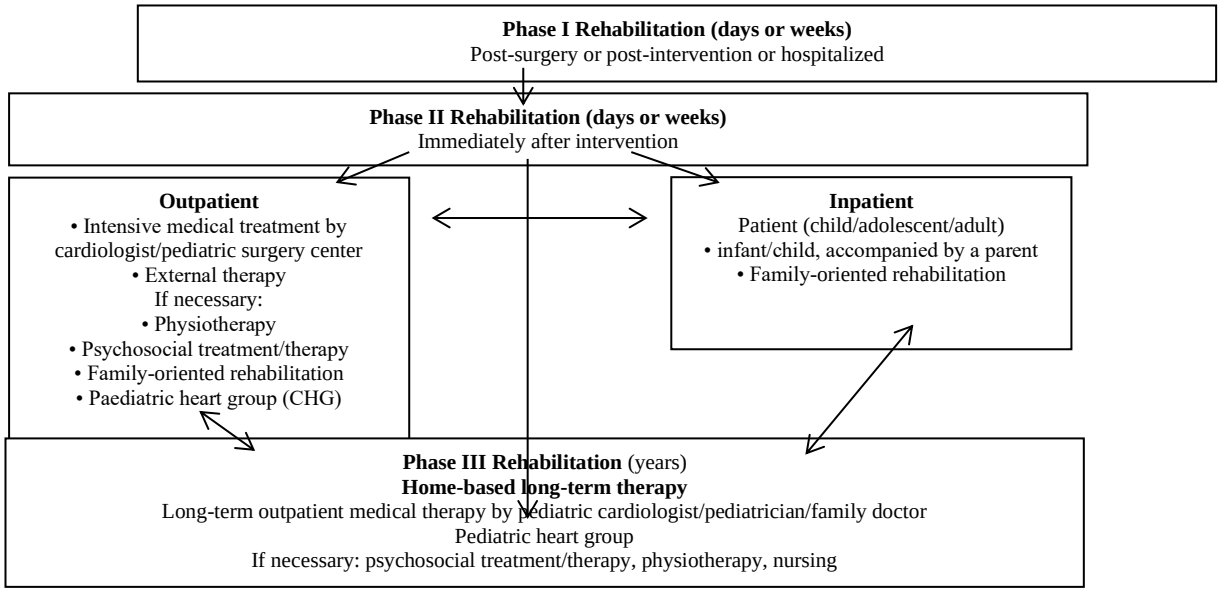

Figure
Rehabilitation Organization and Phases in CHD Patients

The exercise training program in children is a 60-minute session consisting of 20 - 30 minute main exercise at 2 - 3 sessions per week for 10 - 12 weeks. The intensity of the main training is generally set at 60 - 80% of maximum heart rate. However, children should start their program with an intensity around the AT (anaerobic threshold), followed by a change in training capacity over time and a gradual increase towards more intense training at a longer duration.[16,17,19]

Risks of Cardiac Rehabilitation

The risk of a heart attack in children undergoing cardiac rehabilitation is 1:111,966 person-hours, while the mortality risk is 1:783,972 working hours; thus, a safe and effective strategy is required.[17]

Dedieu et al. demonstrated that cardiac rehabilitation in children following CHD surgery could increase the patient's functional capacity. The rehabilitation program was carried out 1 - 2 months post-surgery. The first phase was a relaxation exercise. The second phase was a few minutes of relaxation, followed by an aerobic exercise, carried out two days per week for two months. Finally, the third phase was an exercise phase performed by patients at home.[21]

Children with CHD are at risk of developing neurological and socioemotional disorders. Rehabilitation programs have been shown to improve physical abilities and psychosocial development. However, an application standard for heart disorder rehabilitation program is not yet available.[17]

Ruttenberg et al. demonstrated that a dynamic exercise program in post CHD surgery could increase functional capacity.[16] While Launois et al. proved that a cardiac rehabilitation program, i.e., the

Six-Minute Walking Test program, was able to improve functional capacity in post-heart transplantation patients.[25]

The exercise is based on the child's individual needs, metabolic stress test, cardiac markers, echocardiography, physical capacity, and medical history. Moreover, cardiac rehabilitation also involves education regarding physical activities for children according to their heart condition.[10,16,17,19,21,24]

A study demonstrated that palliative improvement, age, genetic disorders, duration of hospitalization, and residual surgery lesions are factors that increase the need for rehabilitation in children with CHD following CPB surgery.[9]

Conclusion

Pediatric cardiac rehabilitation, which employs a suitable method and intensive monitoring immediately after open-heart surgery, has many benefits in improving the child's quality of life; thus, having optimal growth and development.

Conflict of interest statement

The authors declare that they have no competing interests.

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