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REVIEW ARTICLE

Immediate post-operative care following cardiac surgery

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Abstract

Objective: Present a care for routine for children who were submitted to a cardiac surgery.

Source of data: Realized a bibliographic revision through searching sites (Medscape, MD Consult, PubMed), analyzing the suggested conducts by various services out of Brazil and comparing with the routine of the Hospital Infantil Pequeno Príncipe, in Curitiba, where approximately eight thousand cardiac surgeries were realized in children, from 1977 to April 2003.

Summary of the findings: The referred service is a reference in Paraná State and neighbor states. The evolution of diagnosis conditions, the prepare of the clinic and surgical team, a better equipped Intensive Care Unit (ICU) with a more advanced monitoring, ICU team with trained people in all areas to do cardiac surgery postoperative, adequate hospital structure offering advanced care for in all pediatrics correlate specialties, make the result of surgical interventions realized in children with congenital and acquired heart diseases especially in newborn and babies with complex heart diseases, to present a sensitive improvement when compared with past years.

Conclusions: Children with heart diseases, specially the complex ones, must be sent to a centre of reference place, where there are conditions to a global care for before, during and after the surgery.

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Introduction

Nowadays, with improvements and refinements of pediatric intensive care units (ICUs), children suffering from congenital heart diseases, even the more complex ones, have an improved survival rate. In addition, the diagnosis of heart diseases has become more precise and hemodynamic alterations are better understood, thus allowing a thorough understanding of a child's condition before operating and also enabling prediction of postoperative complications. Such children should be referred to specialized centers for appropriate pre, per and post operative care.[1-3]

Alterations resulting from surgery

When we admit a patient to the ICU, we should confirm with the surgeon and anesthetist a number of different items that are of fundamental importance to a satisfactory post-op.

1. PICU, Hospital Infantil Pequeno Príncipe, Curitiba, PR, Brazil.
2. ICU for Heart Disease, Hospital Infantil Pequeno Príncipe, Curitiba, PR, Brazil.

– ***Heart disease diagnosis*** - This is necessary if we are to understand the hemodynamic alterations presented before surgery, whether it is a cyanotic or acyanotic heart disease, if there is pulmonary overflow and if the heart disease is simple or complex.

– ***The procedure performed*** - Corrective or palliative surgery so we know what monitoring parameters are expected and what hemodynamic alterations there are.

– ***Time in surgery*** - Large scale, prolonged surgery leads to a series of metabolic and hormonal alterations in addition to increasing metabolism by 50 to 100%.

– ***Anesthetics used*** - Knowing the pharmacology of these elements we expect alterations such as myocardial depression from halothane.

– ***Time on extracorporeal circulation (ECC)*** - ECC is when blood from systemic veins, generally the cavas, is drained by an oxygenator which provides oxygen (O_2) and removes carbon dioxide(CO_2), and the blood thus arterialized returns to the root of the aorta. The ECC circuits are filled with a solution called perfusate, which may be composed of crystalloids or colloids, depending upon which hematocrit is desired.[5,6] During ECC we may find the following alterations[7]:

Hypothermia - This is used to reduce O_2 consumption resultant on cellular metabolism. It can be classified as mild (temperatures between 35 and 28 ^oC), moderate (temperatures between 27 and 21 ^oC), profound (below 20 ^oC - total cardiocirculatory arrest). Hypothermia causes accentuated heat loss and systemic alterations such as tissue hypoxia, lactic acidosis and increased peripheral vascular resistance. Tissue can recover from a cardiocirculatory arrest duration of up to 45 minutes.

Hemodilution - When crystalloids are used in the perfusate to reduce blood viscosity. This reduces peripheral and pulmonary vascular pressure and colloid osmotic pressure. In order to avoid this last effect, partial hemodilution may be performed, adding colloids to the perfusate.

Coagulopathy - From the use of heparin and inadequate neutralization with protamine. Consumption occurs of coagulation factors, factors of platelet destruction or adherence to tubes and also fibrinolysis. These alterations increase with duration of ECC.

Systemic Inflammatory Response Syndrome - There is increased vascular permeability with transendothelial loss of liquids and proteins and increased interstitial liquid. Due to the exposure of blood to non-endothelial surfaces there occur macrophage, neutrophil and platelet activation and liberation of cytokines such as tumor necrosis factor and interleukins, causing endothelial lesions.[9,10]

Water retention - In 30 to 60% volemia. This results from the increased vascular permeability, reduced plasma colloid osmotic pressure and increases in renin and antidiuretic hormones. This retention occurs within the interstitial compartment leading to edema, primarily at the pulmonary level.

– ***Period of aorta occlusion*** - Can lead to ischemia in certain organs.

– ***Volume of blood products, blood, plasma, platelets and cryoprecipitate received.***

– ***Volume of transoperative diuresis.***

– ***Transoperative intercurrent events*** - Low cardiac output on leaving perfusion, hypoxemia, arrhythmia, acidosis, lesions of the thoracic duct, embolisms, cardiac structure lesions, previously undiscovered cardiac anomalies.

– ***Vasoactive drugs used during surgery.***

– ***Difficulties with intubation.***

– ***Presence of secretions within the respiratory tract.***

– ***Infections before the patient undergoes surgery*** which may increase systemic inflammatory response and length of hospital stay.

– ***Other associated diagnoses, malformations or genetic syndromes.***

Post-operative care

The transportation of the child from the theatre to the intensive care unit requires special care. A member of both the surgical and anesthetic teams should accompany the child. We should remain alert to the possibility of lost drains, catheters and probes, hypoventilation or accidental extubation and we should be monitoring heart beat and arterial pressure.

We present the care routine that is used at the Cardiology ICU at the Hospital Infantil Pequeno Príncipe in Curitiba. When the child arrives, the initial steps are:

– Suitable positioning on the bed.
– Identification of vascular access: drug infusion, venous hydration, catheters for monitoring: Central Venous Pressure (CVP), Average Arterial Pressure (AAP), Left Atrium Pressure (LAP), etc.
– Open thoracic drains.
– Place thoracic drainage bottles in a suitable recipient.
– Check probes: nasogastric and vesicle.
– Investigate the position of the tracheal cannula and its correct fixation.
– Check the position of nasogastric tube.
– Set respirator parameters.
– Connect the patient to the respirator.
– Once the patient has been admitted to the ICU, we perform an initial physical evaluation: skin and mucosa color, capillary refill, level of hydration, sounds of

recovery, listening to sounds and general physical examination. Routine tests are requested; gasometry, sodium, potassium, calcium, glycemia, hematocrit and hemoglobin three times a day for the first 2 days and once a day after extubation and hemodynamic stabilization. Chest x-ray, urea and creatinine and coagulation tests are requested daily until stabilization. Obviously, depending upon the clinical and hemodynamic status of the patient, this routine can be changed.

– Prophylactic antibiotic therapy. Use cefazolin, 100 mg/kg/day for 48 hours. After these precautions we move on to monitoring proper. Some services add gentamycin for children less than 10 kg.[12]

Basic monitoring

Heart beat

By means of an oscilloscope with an alarm triggered by frequency and which detects cardiac arrhythmia.

Arterial Pressure

Cannulation of the radial artery is performed as a first choice, or when not possible the dorsalis pedis or femoral arteries are used, thus taking direct measurements of average arterial, diastolic and systolic pressures. The line is held by a pressurizer which supplies a continuous infusion of heparin with saline (1 U/ml). This gives us an idea of hemodynamic status.

Central venous pressure (CVP) or right atrium pressure

A catheter is fitted at the junction between the vena cava superior and the right atrium by percutaneous puncture of the internal jugular vein or the subclavian vein.[14] Often the surgeon will place the catheter in the right atrium and exit through the chest wall. This allows us to evaluate right ventricle function and pre-load.

Urinary output

A Folley catheter is fitted at the surgical unit which is coupled to a closed system.

Nasogastric tube

Installed by the surgical team and maintained open for at least 6 hours post-extubation.

Mediastinum and/or pleural drains

These are coupled to drainage collectors with water seals and continuous suction.

Rectal temperature

Permits a more accurate evaluation of the child's internal temperature.

Respiratory parameters

The following should be monitored: FiO_2, flow, respiratory frequency, tidal volume, inspiratory pressure, final positive pressure, inspiratory and expiratory periods, and pulse oximetry which is an indirect method for measuring tissue oxygenation.

Invasive monitoring

Generally used for more serious or complicated heart conditions and in cases with associated pulmonary hypertension or myocardial dysfunction.

Left atrium pressure[14]

Fitted by the surgeon into the left atrium and exiting via the mediastinum to the chest wall; should be handled only by experienced personnel and it its use for infusion is prohibited. It provides a good evaluation of left ventricular function.

Pulmonary artery pressure[14]

Used in cases where there is severe pulmonary hypertension, i.e. when pulmonary pressure is half or two thirds of systemic pressure. Measured with a Swan-Ganz catheter, or, as is the case at our center, the surgeon places a catheter at the trunk of the pulmonary artery.

Cardiac output

Using a Swan-Ganz catheter assessed by thermodilution. This is not generally a routine practice in the majority of Brazilian ICUs, primarily because of technical difficulties.

Systemic and pulmonary vascular resistance

Also measured when we have a Swan-Ganz, calculated based on RA, LA, AAP, AP and Cardiac output measurements.

Bidimensional or Doppler echocardiography

Routinely performed for all patients at least once a day until stabilization, when it is performed at longer intervals. It is the method of choice at our service for evaluating heart chambers, how corrections made have turned out, whether residual abnormalities persist, the presence of pericardiac hemorrhaging or cardiac tamponade, global analysis of the ventricles, left ventricle shortening calculation and for estimating ventricular function and intrachamber and transvalvular pressures.

Pacemaker

Electrodes for a pacemaker are generally fitted if there is a chance of the conduction system being damaged as in surgery for IVC, tetralogy of Fallot or atrioventricular canal defect, which may cause Arrhythmia.

Complications during immediate post-op

Cardiac output alterations

Cardiac output depends on 4 factors: a) myocardial contractility; b) venous return(pre-load); c) resistance to blood exiting the left ventricle (post-load), d) heart rate. Alterations to any of these factors will lead to a syndrome of low cardiac output which is characterized by perspiration and signs of psychomotor agitation, cold extremities, blue or pale lips, absent or filiform peripheral pulses, hypotension, and oliguria. When evaluating a child with low cardiac output, we must also rule out other conditions which may deprive the myocardium such as acidosis, hypoglycemia, hypocalcemia and hypokalemia.

Contractility

Alterations to myocardial contractility in post-op may be due to anatomical defects or diminished cardiac function at pre-op; ventriculotomy; cardioplegia; ischemia due to ECC; period of ECC and anesthetics. Less complex heart diseases which are not associated with ventricular dysfunction and/or pulmonary hypertension rarely cause low output during post-op, in contrast to complex ones.

If the child does not have any acid-base or metabolic disturbance, is well oxygenated with normal volemia, pain under control, has normal temperature and has altered myocardial contractility, inotropic drugs are indicated.

Digitaline is normally used for the first 12 to 24 hours at doses of 10 µg/kg/day via oral route or intravenous if for an attack dose. Should not be used if there is bradycardia and care should be taken when calcium is used in conjunction.

Dopamine is the most commonly used drug in post-op because its large number of different effects: at a dose of 2 to 5 µg/kg/min it has a delta effect with renal, splenic and peripheral vasodilation, with a discrete positive inotropic effect; at a dose between 5 and 10 µg/kg/min it has a greatly accentuated effect, with more accentuated positive inotropism and increases heart rate without increasing systemic arterial pressure. At doses > 10 µg/kg/min there is an accentuated alpha effect with increased systemic vascular resistance, increased arterial pressure and peripheral, renal and splenic vasoconstriction. There are also positive inotropic and chronotropic effects. There are reports that these effects only occur at doses above 15 µg/kg/min and that pulmonary pressure is also increased.

In small children who have few sympathetic fibers in the myocardium, these effects may occur at higher doses.

Another drug that is widely used is dobutamine which is a sympathomimetic amine synthesized from dopamine which activates the myocardial beta1 receptors and, to a lesser extent, the peripheral beta2 and alpha receptors. Improves contractility better and has fewer peripheral effects when compared with dopamine. Used at doses of 5 to 10 µg/kg/min, frequently in association with dopamine, in dopaminergic doses in order to obtain the best effects from these drugs. In larger doses dobutamine may cause tachycardia. On the practical side, dopamima was always used at an initial dose of 5 µg/kg/min and when there was not sufficient response, dobutamine at 10 µg/kg/min would be associated. Nowadays there is a tendency to make better use of dopamine, i.e. use it in doses of up to 10, when there should be a dopa effect and a beta effect from dobutamine. We would work thus with one drug obtaining both effects. In cases where there is myocardial dysfunction with no peripheral alterations, the choice would be to use dobutamine in isolation. In cases which do not respond to dopamine or dobutamine or there is arterial hypotension, we use adrenaline, which, in doses of up to 0.3 µg/kg/min tem efeito mais efeitos beta1 and beta2 and in doses above 0.3 also has an accentuated alpha effect.

Isoproterenol is a drug with an accentuated beta effect which provokes increased heart rate and positive inotropism. As it increases heart rate it results in an increase in oxygen consumption by the heart and risk of arrhythmia. It is indicated when there is severe bradycardia at doses of 0.1 to 1.0 µg/kg/min. When inotropic agents are used in isolation and fail to improve myocardial contractility we can employ vasodilators. The most often used is sodium nitroprusside at a dose of between 0.5 and 5.0 µg/kg/min. Prolonged use can result in cyanotic accumulation with repercussions for the central nervous system. When it is possible to use the oral route, we use nifedipine (1 to 2 mg/Kg) or captopril (1 to 3 mg/Kg).

Bipyridine derivatives (amrinone and milrinone) have inotropic effects and act as peripheral and pulmonary vasodilators, simulating the effects of drugs used in association. They act by inhibiting phosphodiesterase, increasing cyclic AMP - 3 activity, and act directly on the heart and vessels. We prefer to use milrinone, as it has a shorter half-life (2 to 3 hours) than amrinone (6 to 8 hours), at attack doses of 50 µg/Kg over 3 to 5 minutes followed by a continuous infusion of 0.75 µg/Kg/min.[15,6]

Pre-load

Defined as final diastolic filling. In the absence of atrioventricular valve lesions, final diastolic pressure corresponds to average atrium pressure, and so we can control volemia by means of right atrium pressure (CVP) and left atrium pressure (LAP). The ideal value for atrial pressures is that the reach 15 mmHg, with zero at the midaxillary line. They may reach 18 mmHg in the right atrium and 20 mmHg in the left when there is hypotrophy, hipocontractility, partial obstruction of ventricular exits or pulmonary hypertension. During post-op for IAC or heart diseases with significant right atrium dilation, such as anomalous pulmonary vein drainage, the right atrium is overly complacent and CVP oscillates between 5 and 10 mmHg. In surgery where there is cavopulmonary or

atriopulmonary anastomosis, CVP should remain between 18 and 20 mmHg.

The volume of crystalloids offered during the first 24 hours, at our unit, is as follows: 40% of basic needs in the form of glucose solution with calcium, for surgery involving ECC and 60% for surgery without ECC.

We use colloids when there have been losses and to maintain hemoglobin (Hb) and hematocrit (Ht) at levels that are ideal for each type of heart disease:

– Acyanotic heart diseases: Hb 10, Ht 30 to 35%;
– Cyanotic heart diseases: Hb 15, Ht 40 to 45%;
– Blalock-Taussig: Hb 13 to 14, Ht 40%, in order to avoid obstructing the shunt.

Losses can also be replaced with crystalloid solution (saline solution or Ringer's lactate) when colloids are not immediately available or there has been little bleeding or protein loss.

When children are edematous on arrival, we use furosemide at a dose of 1 to 4 mg/Kg/day, always checking that there is no hypoalbuminemia or renal deficiency. This system of infusion of liquids is not a rigid standard and can be modified depending upon the situation. After stabilization and extubation, oral ingestion is begun and intravenous liquid administration is restricted even further.

Post-load

The resistance to the exit of the ventricular systolic volume. Systemic arterial pressure (SAP) and pulmonary pressure are both factors related to post-load. Systemic arterial pressure should be maintained at a maximum of 20% above and 10% below normal values for age. Pulmonary pressure should not pass half systemic pressure.

Systemic arterial hypertension

There are a number of different factors which can increase systemic arterial pressure during immediate post-op: pain, hypothermia, hypoxia, acidosis, incipient hypovolemia, sympathetic discharge on waking. Elevated SAP can cause sutures to rupture or provoke bleeding.

Initial measures would be to give adequate sedation and pain relief, correct volemia and then employ drugs. The initial drug of choice is sodium nitroprusside in continuous infusion at a dosage of 0.5 to 10 µg/Kg/min. After 48 hours of use, we have to worry about cyanide levels.

Once the child is stabilized and is receiving medication by mouth, if hypertension persists we can nitroprusside by one of the following drugs: hydralazine (3 to 5 mg/Kg/day), nifedipine (0.5 to 2 mg/Kg/day), captopril (1 to 3 mg/Kg/day), propanolol (1 to 4 mg/Kg/day). This last is not used when there is hypocontractility.

Pulmonary hypertension

This is a condition found during post-op in children who had already had elevated pulmonary pressure (over half or 2/3 of systemic pressure) or who had heart diseases with a significant left-right shunt.[17] Other factors such as pain, agitation, acidosis, hypercapnia or tracheal aspiration can increase pulmonary pressure. In such cases children should arrive with a catheter fitted in the pulmonary artery for better pressure evaluation. Clinically, pulmonary hypertension manifests as a sharp drop in oxygen (hypoxemia), agitation, tachycardia, tachypnea and arterial hypotension. There is a failure in the right ventricle.

In cases when pulmonary hypertension is to be expected, children remain sedated for the first 24-48 hours until they have been stabilized. This problem often occurs during closure of the thorax, which leads us to leave the thorax open for some time after surgery.

Initial treatment consists of hyperventilation (pCO_2 between 25 and 30), oxygenation and suitable sedation (we use fentanyl + midazolam). In some cases, when it is desirable to maintain pH at around 7.5, we use sodium bicarbonate to increase pH. A number of different have been used, but have not shown efficacy in selectively reducing pulmonary pressure: tolazoline, nitroglycerine, sodium nitroprusside.

To date, the best results have been from the use of inhaled nitric oxide which has a selective pulmonary vasodilator effect.[18] Nitric oxide has an average half-life that is extremely short because it bonds with hemoglobin, which explains the absence of systemic effects. Suitable equipment is connected to the ventilator circuit. Initially the dose is 10 ppm which is increased until a better response obtained, which appears to be at around 20 ppm (sometimes 60 ppm is reached and there are reports of up to 80 ppm. Neither the ideal duration nor concentration are yet known. When it is employed we should be monitoring nitrogen dioxide and metahemoglobin.

We also use milrinone which reduces pulmonary pressure and improves cardiac output. When nitric oxide is not available, this is a good option for reducing pressure. Normally the use of an inotropic drug is necessary in pulmonary hypertension cases.

Alterations to heart rate and rhythm

Arrhythmia is common during post-op for cardiac surgery and is not only caused by the surgery itself. It may also be caused by potassium disturbances, hypoxia, acidosis, hypercapnia or ventricular dysfunction. When it results from surgery itself it is caused by manipulation of the conductive system or the presence inflammatory processes of the pericardium.

Sinus tachycardia may be the result of pain, anxiety, fever, hypovolemia, cardiac deficiency or the use of inotropic

and can revert with the control of these factors. In some cases it can only be controlled by Digitaline.

Junctional rhythm or atrioventricular disassociation is common in the post-op of surgery that manipulates the atrioventricular node such as Senning and Mustard surgery for repair of transposition of the great arteries, correction of atrioventricular septal defect or perimembrane IVC.[9,29] Heart rates are elevated (150-250 bpm) leading to low cardiac output and metabolic acidosis which makes treatment more difficult. The drug we use most often in this situation is propafenone: attack with 2 mg/kg EV over 2 hours and maintenance at 4 to 8 µg/Kg/min. In refractory cases electrical cardioversion or atrium pacemakers can be used.

When correcting atrioventricular septal defects or the interventricular septal defect of the tetralogy of Fallot it is common that a blockage appears in the right branch, which has no clinical repercussions initially as long as it does not evolve into total AV Blockage.

Paroxysmal atrial or supraventricular tachycardia occurs with surgery that involves the atria. Treatment consists of vagal maneuvers, the use of adenosine at a dose of 0.1 to 0.2 mg/kg in bolus, which dose can be repeated. As treatment options we have amiodarone 5 to 10 mg/kg infused over 1 hour or digitaline 10 µg/kg/day divided into two doses. In cases where there is low cardiac output or poor peripheral perfusion synchronized electrical cardioversion is indicated at 0.5 to 1 J/kg, which can be repeated. Atrial flutter is also treated with cardioversion, amiodarone or digitaline if it appears.

Atrial fibrillation can be treated with amiodarone, digitaline and cardioversion in unstable cases.

Ventricular tachycardia is rarer during post-op, but when it occurs it can be serious. Lidocaine is used at doses from 1 to 2 mg/kg in bolus and if the response is good we continue with 20 to 50 µg/kg/min. In cases that do not respond, or where there is poor perfusion, synchronized electrical cardioversion is indicated at 0.5 to 1 J/kg which can be repeated. This situation associated with low cardiac output may act like ventricular fibrillation, in these cases defibrillation is performed or asynchronous cardioversion at 2 J/kg, which can be increased to 4J/kg if there is no response. Conduct for fibrillation is the same and after two defibrillations we alternate adrenaline at 0.01 mg/kg with defibrillation until the situation improves.

For bradyarrhythmia after withdrawal of digitaline and beta blockers, atropine at 0.02 mg/kg/dose or isoproterenol in continuous infusion 0.1 to 1 µg/kg/min are used. When cardiac output is very low (with total AV blockages) the use of a pacemaker connected to epicardial electrodes fitted by the surgeon, until the situation reverts.

If there is no response a transesophageal pacemaker can be used and then a definitive pacemaker if there is still no improvement.

For treatment of arrhythmia, we should first rule-out causes that are not connected to surgical manipulation and correct them when necessary.

Respiratory system

Children who have undergone cardiac surgery are generally transported to the ICU intubated. Those who had simpler pathologies such as PCA, IAC, sometimes coarction of the aorta and IVC, patients may be extubated at the surgical unit.[21] In other cases, or when there is incomplete hemodynamic stabilization, the ideal approach is to extubate after clinical and laboratory examinations, with the child well-monitored. Respiratory alterations during post-op may be related to a number of different causes such as pulmonary and cardiac function at pre-op, ECC and degree of sedation. In the ICU children are put on the ventilator, initially on controlled ventilation and we make a clinical assessment to verify thorax expansion and symmetry of breathing sounds. Parameters are adjusted, respiratory frequency according to age and the other parameters depend on arterial gasometry. The fraction of inspired oxygen (FiO_2) should be sufficient to maintain PaO_2 between 80 and 90 mmHg and arterial oxygen saturation (SaO_2) above 90%. In palliative surgery such as aorto-systemic shunts, PaO_2 should be at around 45mmHg and SaO_2 70 %.

We attempt to always offer the lowest FiO_2 which achieves these values. The PaO_2 level should only be higher in pulmonary hypertension cases. Inspiratory pressure should be the lowest possible which still maintains $PaCO_2$ between 35 and 45 mmHg, and can also be lower in pulmonary hypertension cases. Positive end-expiratory pressure is maintained at between 3 and 4 mmHg to avoid microatelectasis. In cases of severely compromised lungs and low SaO_2 levels we can increase PEEP to improve oxygenation, but not at the cost of increasing inspiratory pressure and tidal volume which are more aggressive to the lungs. Positive end-expiratory pressure should not exceed 12 to 15 mmHg and should not be used when cardiac output is low or with Fontan surgery, since it can greatly reduce venous return (pre-load).

When children are hemodynamically stable, there is no need for FiO_2 to be above 0.4 to maintain PaO_2 and SaO_2, are conscious and can control their own breathing, are no longer on sedatives, metabolically compensated, we proceed to extubation, offering oxygen with a catheter or mask, With newborns and small infants, after extubation we maintain continuous positive airway pressure (CPAP) for some time.

Respiratory physiotherapy, begun on the first day after arrival at the ICU contributes greatly to adequate ventilation and successful extubation.

The primary complications related to respiratory apparatus are[22]:

– *Pneumothorax* due to opening the pleura during surgery. If this is extensive or hypertense it should be drained.

– *Atelectasis* - May be prevented with suitable physiotherapy, change of bed position and PEEP.
– *Post-extubation edema of the glottis* - The patient should be sedated, use dexamethasone (0.6 mg/kg/day), use humidified oxygen. If there is no improvement, re-intubate with a smaller caliber cannula, maintaining corticoids and extubate when there is escape at the cannula or after laryngoscopy. Tracheostomy is indicated if there is subglottic stenosis. In our locale, after extubation we give inhaled adrenaline and, if there has been prolonged intubation (> 1 week), we use corticoids before extubating.
– *Diaphragm paralysis* - Due to hypothermia, inflammation or lesions of the phrenic nerve. The diagnosis can be masked while the child is intubated and ventilated and is confirmed with x-rays. A diaphragm tuck should be performed when there is no improvement with conservative treatments.
– *Pneumonia* - More frequent the longer the duration of mechanical ventilation. Antibiotics should be used according to culture results and the microbiological profile of the locale.
– *Acute respiratory distress syndrome* - This is part of the Systemic Inflammatory Response Syndrome triggered by the stress of large scale surgery and can be caused by alterations to the alveolar-capillary membrane due to ECC. Treatment aims at maintaining sufficient PaO_2 without damaging the lungs. A number of different protective ventilation techniques are used.

Renal system

During cardiac surgery post-op, renal deficiency can be caused by low cardiac output and is related to other factors such as age, duration of surgery and ECC, use of nephrotoxic substances such as aminoglycosides. It is more common with cyanotic heart diseases and can form part of the Multisystem Organ Failure that occurs in cases that progress badly in post-op, complicate with sepsis and the child's output remains low for a prolonged period.

When diuresis is below 1 ml/Kg/hour, there is hematuria in urine output, potassium continues above 5 mEq/l and creatinine is above 1 mg/dl we suspect that the child is developing renal deficiency.

If there is oliguria after the correction of volemia we use furosemide at a dosage of 1m/kg up to a maximum of 6 mg/Kg/day in an attempt to stimulate diuresis. We have tried on a few occasions using mannitol at doses of 0.25 mg/kg to stimulate the kidneys. If after stimulation and restricted hydration hypervolemia remains and urea and creatinine levels are increased, peritoneal dialysis is indicated which may not be effective with poorly perfused patients. Another method which can be employed is hemofiltration, which causes fewer hemodynamic alterations, when compared with hemodialysis.

The use of dopamine at "renal" doses (2.5 µg/kg/min) proved not to be effective, did not improve urinary flow and had no inotropic effect. If dopamine is chosen the dose should be from 5 µg/Kg/min on.

Hemorrhagic disorders

Bleeding is one of the most common complications to occur in post-op and its etiology must be differentiated: whether it is due to coagulation disturbances of because of inadequate hemostasis in surgery.

Extracorporeal circulation causes a series of alterations to hemostasis due to the passage of the blood along non-epithelial surfaces. Heparin used for ECC anticoagulation inhibits the formation of thrombin and factors IX, X, XI and XII. Other causes would be transfusion reactions, thrombocytopenia, DIVC and hepatic deficiency. With cyanotic heart diseases due to hypoxia and hyperviscosity there is a greater chance of coagulopathy.

Correct conduct is to request a coagulation study on admission. If there are alterations we initially neutralize the heparin that was used, employing 1 mg of protamine to neutralize 100U of heparin. If coagulation tests remain altered we use coagulation factors; platelets 1U/4 Kg when counts are below 30,000/mm^3; fresh plasma 10 to 20 ml/Kg and cryoprecipitate 1 to 2U if we have abnormal activated partial thromboplastin time (APTT) thrombin time (TT).

In ICVD cases we use all of the factors cited and we must eliminate the basic cause.

Hemofiltration may improve the coagulopathy due to ECC.[25]

When there is bleeding and a normal coagulation test, we perform an infusion of plasma and concentrated erythrocytes or whole blood and if there is a 30% volemia loss in one hour then further surgical intervention is indicated.

Volemic and hydroelectrolytic balance

As has been stated, the surgical act leads to sodium and water retention. Because of this, after operations involving ECC, we offer 40% of daily water requirements, while hydration balancing is performed and pressure is monitored (CVP, LAP) and replacement is performed depending on losses and diuresis control, preferably in the form of colloids (plasma or albumin) taking care with Respiratory Distress Syndrome.

Sodium is not used in post-op unless controls show refractory hyponatremia. Potassium is also not prescribed initially, and is prescribed whenever below 4 mEq/l, for maintenance or rapid correction if below 2.5 mEq/l, always bearing in mind that there is potassium wastage due to ECC When there is hyperkalemia we use calcium, bicarbonate and glucose. Calcium is prescribed from the start at doses of 100 to 200 mg/Kg/day. Calcium may be

low with newborns and infants or because of the use of sodium citrate in blood products.

Neurological problems

Neurological problems in cardiac surgery post-op may be caused by many factors: hypothermia and inadequate cerebral perfusion during the operation, ECC, duration of cardiac stoppage, ischemia and hypoxia due to gaseous embolisms, cerebral edema secondary to water retention, metabolic disturbances such as hypoglycemia, hypocalcemia, hyponatremia, acidosis and hypomagnesemia.[7,8] They may manifest in the most varied of manners such as agitation, convulsions, coreoatetosis[29] (due to ECC) and coma. Patients on sedatives and pain relief make neurological evaluation difficult. When there is a suspicion of some type of brain damage adequate neurological examination is necessary and a Glasgow coma scale score should be calculated and an electrocardiogram and cerebral tomography be requested. The patient must be very well monitored, tissue oxygenation and perfusion must remain adequate. Metabolic disturbances must be corrected and the cerebral edema and convulsions treated in the normal manner.

Problems with the digestive system

A paralyzed ileum is common in post-op, it is transitory and the patient should leave surgery with a nasogastric tube in place. This occurs because of the anesthetics and the low flow during ECC.

In surgery involving ECC liver deficiencies are common. There are increased transaminase levels and jaundice which may also occur because of hemolysis in the ECC circuits. The use of anesthetics such as halothane can worsen hepatic lesions.

Gastrointestinal hemorrhages occur because of coagulation disorders or stress.

Infections

At our center the most common infections during cardiac surgery post-op are:

– Pneumonia, generally associated with prolonged mechanical ventilation.
– Central catheter infections.[23]
– Skin and soft tissue infections.
– Sepsis.

During the first 24 hours it is common for fever to appear and a hemagram with a left-hand bias, both due to the systemic inflammatory response to surgery.[28] This, however is not an early sign of infection. When we suspect infection, we collect blood cultures, material from the surgical area if available, urine culture, bronchiolar lavage culture and material from catheters. We use empirical antibiotics until the culture results are received, based on the epidemiological profile of our hospital, where the most common germs are: non-betalactamase-producing *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Kebsiella pneumoniae*. Other more opportunistic gram-negative bacteria and fungal infections are suspected in prolonged cases with slow development.

With catheter infections we remove them if there is hyperemia or cutaneous secretions where it is implanted. Cultures taken from catheters are valued when the same germ grows in the peripheral blood culture or the catheter culture shows positive first.

Other complications

Chylothorax

This occurs from the lesion of the thoracic duct during surgery, and is suspected from the presence of milky liquid in the pleural drain, which indicates increased triglycerides. Treatment is generally conservative with fats being withdrawn from the diet or triglycerides restricted to medium-chain ones. Rarely is surgery indicated.

Cardiac tamponade

This is characterized by muffled breathing, cervical venous gurgitation and low output. Confirmed by echocardiogram and drainage should be performed immediately.

Post-pericardiotomy syndrome

This manifests with the presence of fever, pericardiac attrition, and when the child is able to communicate, with chest pain. Echocardiograms show the presence of pericardiac hemorrhage and the need for drainage. Initial treatment includes the use of corticosteroids.

Systemic Inflammatory Response Syndrome[24]

As was mentioned earlier, there are tumor necrosis factor and other cytokines liberated into circulation, and this can evolve into Multisystem Organ Failure and there are reports that it is more accentuated when there have been predisposing factors at pre-op and that it is improved by the use of methylprednisolone.[26]

Sedation and pain relief

Alterations resulting from pain and agitation during post-op have been widely studied.[30] We routinely use an opioid for pain relief, intermittent morphine, 0.1 mg/kg/dose every 2 hours or continuously 20- 50 µg/kg/hour or fentanyl 2 to 5 µg/kg/hour. Morphine should be avoided when there is arterial hypotension and fentanyl can cause bradycardia and a rigid chest wall.[31] After the first 24 hours, with the patient extubated and stable, analgesia is reduced. If the patient remains unstable or is highly agitated making the control of hypoxemia and pulmonary hypertension

difficult, in addition to pain relief we sedate with continuous midazolam at an initial dose of 05 µg/kg/min which can be increased depending upon need up to 6 µg/kg/min. Sometimes chloral hydrate is used at 50 mg/kg/dose.

In very serious situations when we are unable to sedate the patient properly we use muscular blocking agents for short periods.

Nutrition

We begin feeding as soon as the child presents intestinal noises, generally after the first 24 hours. In mild cases, with the patient extubated, stable and lucid we begin feeding by mouth. In other cases we prefer post-pyloric enteral nutrition. We reduce the quantity of infused liquids as soon as feeding commences.

In cases where hemodynamic instability persists or enteral nutrition was not tolerated, we employ total parenteral nutrition.

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