

Lack of difference between continuous *versus* intermittent heparin infusion on maintenance of intra-arterial catheter in postoperative pediatric surgery: a randomized controlled study

Similaridade entre infusão contínua versus intermitente de solução de heparina na manutenção de cateter intra-arterial em pós-operatório de cirurgia pediátrica: estudo randomizado controlado

Similitud entre infusión continua versus intermitente de solución de heparina en el mantenimiento de catéter intra-arterial en post-operatorio de cirugía pediátrica: estudio randomizado controlado

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ABSTRACT

Objective: To compare two systems of arterial catheters maintenance in postoperative pediatric surgery using intermittent or continuous infusion of heparin solution and to analyze adverse events related to the site of catheter insertion and the volume of infused heparin solution.

Methods: Randomized control trial with 140 patients selected for continuous infusion group (CIG) and intermittent infusion group (IIG). The variables analyzed were: type of heart disease, permanence time and size of the catheter, insertion site, technique used, volume of heparin solution and adverse events. The descriptive variables were analyzed by Student's *t*-test and the categorical variables, by chi-square test, being significant $p < 0.05$.

Results: The median age was 11 (0–22) months, and 77 (55%) were females. No significant differences between studied variables were found, except for the volume used in CIG ($12.0 \pm 1.2 \text{ mL}/24 \text{ hours}$) when compared to IIG ($5.3 \pm 3.5 \text{ mL}/24 \text{ hours}$) with $p < 0.0003$.

Conclusions: The continuous infusion system and the intermittent infusion of heparin solution can be used for intra-arterial catheters maintenance in postoperative pediatric surgery, regardless of patient's clinical and demographic characteristics. Adverse events up to the third postoperative day occurred similarly in both groups. How-

ever, the intermittent infusion system usage in underweight children should be considered, due to the lower volume of infused heparin solution [ClinicalTrials.gov Identifier: NCT01097031].

Key-words: postoperative care; pediatrics; catheterization, peripheral.

RESUMO

Objetivos: Comparar dois sistemas de manutenção de cateteres arteriais em pós-operatório de cirurgia cardíaca pediátrica, utilizando infusão contínua ou intermitente de solução de heparina, e analisar os eventos adversos relacionados ao local de inserção do cateter e o volume de solução de heparina infundido.

Métodos: Ensaio clínico randomizado controlado, com 140 pacientes selecionados para o Grupo Infusão Contínua (GIC) e o Grupo Infusão Intermitente (GII). As variáveis analisadas foram: tipo de cardiopatia, tempo de permanência e tamanho do cateter, local de inserção, técnica empregada, volume de solução de heparina e eventos adversos. Utilizou-se o teste *t* de Student para variáveis descritivas e o teste do qui-quadrado para variáveis categóricas, sendo significante $p < 0,05$.

Resultados: A mediana de idade foi de 11 (0–22) meses, sendo 77 (55%) do sexo feminino. Não houve diferença

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significativa nas variáveis analisadas, com exceção do volume infundido no GIC ($12,0 \pm 1,2 \text{ mL}/24 \text{ horas}$), quando comparado ao do GII ($5,3 \pm 3,5 \text{ mL}/24 \text{ horas}$), com $p < 0,0003$.

Conclusões: Tanto o sistema de infusão contínua quanto o sistema intermitente de solução de heparina podem ser utilizados na manutenção de cateter intra-arterial em pós-operatório de cirurgia pediátrica, independentemente das características clínicas e demográficas dos pacientes, bem como da ocorrência de eventos adversos até o terceiro dia pós-cirúrgico. Entretanto, deve-se considerar a utilização do sistema de infusão intermitente em crianças de baixo peso, devido ao menor volume de solução de heparina infundido [registro no *Clinical Trials* sob o nº NCT01097031].

Palavras-chave: cuidados pós-operatórios; pediatria; cateterismo periférico.

RESUMEN

Objetivos: Comparar dos sistemas de mantenimiento de catéteres arteriales en post-operatorio de cirugía cardíaca pediátrica, utilizando infusión continua o intermitente de solución de heparina, y analizar los eventos adversos relacionados al local de inserción del catéter y el volumen de solución de heparina infundido.

Métodos: Ensayo clínico randomizado controlado, con 140 pacientes seleccionados para el Grupo Infusión Continua (GIC) y el Grupo Infusión Intermitente (GII). Las variables analizadas fueron: tipo de cardiopatía, tiempo de permanencia y tamaño del catéter, local de inserción, técnica empleada, volumen de solución de heparina y eventos adversos. Se utilizó la prueba *t* de Student para variables descriptivas y la prueba del chi-cuadrado para variables categóricas, siendo significativa $p < 0,05$.

Resultados: La mediana de edad fue de 11 (0–22,1) meses, siendo 77 (55%) del sexo femenino. No hubo diferencia significativa en las variables analizadas, excepto por el volumen infundido en el GIC ($12,0 \pm 1,2 \text{ mL}/24 \text{ horas}$), cuando comparado al del GII ($5,3 \pm 3,5 \text{ mL}/24 \text{ horas}$), con $p < 0,0003$.

Conclusiones: Tanto el sistema de infusión continua cuanto el sistema intermitente de solución de heparina pueden ser utilizados en el mantenimiento de catéter intra-arterial en post-operatorio de cirugía pediátrica, independiente de las características clínicas y demográficas de los pacientes, así como de la ocurrencia de eventos adversos hasta el tercer día del post-quirúrgico. Sin embargo, se debe considerar la

utilización del sistema de infusión intermitente en niños de bajo peso, debido al menor volumen de solución de heparina infundido (registro en el *Clinical Trials* bajo el nº NCT01097031).

Palabras clave: cuidados post-operatorios; pediatria; cateterismo periférico.

Introduction

The process of post-operative cardiac surgery depends on several factors, from the type of heart disease and the weight of the patient to the hospital structure, including a team of specialized health and appropriate equipment. In the clinical context of the child in the postoperative period, the monitoring of invasive blood pressure is an important parameter to consider in order to detect rapid oscillations of pressure and obtain samples for laboratory tests⁽¹⁻⁷⁾. However, the approach in dealing with the patency and maintenance of arterial catheters routinely used in pediatric intensive care is not fully established. Studies show that, although the use of arterial catheters is essential for patient care, the occurrence of adverse events that should be detected and treated early is frequent⁽⁸⁻¹⁴⁾.

A systematic review and meta-analysis evaluated the effect of heparin, length of stay, and complications of arterial and venous catheters in children and adults admitted to intensive care. The findings indicate that the intermittent use of heparin solution in concentrations of 10UI/mL was beneficial, compared to the isolated use of 0.9% saline solution. With this concentration of heparin solution, catheters remained permeable for a longer time compared to the group receiving saline solution at 0.9%⁽¹⁵⁾.

Recent study included review of clinical trials comparing different methods of maintaining patency of central venous catheters in adults. The authors concluded that there is not enough evidence to suggest the best technique to be employed and claimed that new studies are needed^(16,17).

Due to the lack of evidence regarding the most suitable technique for the maintenance of arterial catheters in children by means of an infusion of heparin solution system or intermittent infusion of heparin solution, safe strategies are needed to secure the highest care for this population in greater risk. Thus, the objectives of this study were to compare two systems of arterial catheters maintenance in postoperative pediatric cardiac surgery using continuous or intermittent infusion of heparin solution, and to describe

the clinical and demographic characteristics of children and analyze adverse events related to the site of catheter insertion and the volume of heparin solution infused.

Method

Randomized controlled trial comparing two systems of maintenance and patency of arterial catheters in patients consecutively admitted in the Intensive Care Unit of a Cardiology Hospital from October 2007 to April 2009.

Randomization was performed by random drawing with sealed envelopes containing the group in which the patient would be included: Continuous Infusion Group (CIG) or Intermittent Infusion Group (IIG). The study was registered in Clinical Trials under No. NTC01097031. The nursing staff of the unit prepared and administered the heparin solution, according to the established routine: vials of intravenous heparin 5.000UI/mL diluted with saline solution at 0.9% in 250mL bottles, yielding a final concentration of 4IU/mL. After the final dilution stability of the solutions had 24 hours, and replaced as they had completed this period.

Children of both sexes were included, weighing <15kg, submitted to cardiac surgery and admitted to the Pediatric Intensive Care Unit. Other pediatric surgeries and weight above 15kg were considered exclusion criteria.

In IIG, patients were randomly selected for maintenance and patency of arterial catheters for intermittent infusion of heparin. BD[®] syringes with 5 ml heparin solution with a concentration of 4IU/mL (heparin/saline solution 0.9%) were used. The system was connected to the patient and to the pressure transducer via BD[®] extenders; the pressure transducer, in turn, was connected to the monitor to display the continuous curve of blood pressure. Infusions were made only when needed: in cases of blood reflux for system calibration and laboratory exams.

In CIG, patients were randomly selected to maintain and permeabilize arterial catheters by continuous infusion with a Nikiso[®] infusion pump syringe at a rate of 0.5mL/h, with a solution of heparin at a concentration of 4IU/mL (heparin/saline solution at 0.9%). The system was connected to the patient and the pressure transducer, using the infusion pump in a total of 12mL of a solution of heparin per 24 hours. When needed, to perform laboratory samples, flushes of heparin solution were conducted manually by an infusion pump with appropriate volume to fill with extents solution of heparin and a good view on the monitor pressure curve.

For data collection, we elaborated an instrument in which the demographic and clinical variables were recorded to characterize the sample, such as age, weight, sex, type of heart disease, surgery, catheter insertion site, volume of heparin solution, and time of catheter permanence. Adverse effects such as bleeding (presence of blood in the dressing or at the site of puncture of the catheterized artery); edema (abnormal accumulation of fluid in the local interstitial site and observed by increased circumference of the catheterized limb over the opposite limb); hematoma (accumulation of blood in the subcutaneous tissue at the puncture site and noticed on palpation), poor perfusion (inappropriate initial stage of capillary refill); ischemia (more advanced stage of perfusion in which there is damaged tissue); presence of blood clots (absence of blood reflux into the catheter and presence of thrombus within it after removal)⁽¹⁸⁾.

The health care team of the unit under study (doctors and nurses) registered all variables and one of the authors collected data in four distinct stages: immediate postoperative period (IPO) – from the patient's arrival in the Pediatric Intensive Care Unit up to 24 hours; first postoperative day (1st PO) – after 24 hours up to 48 hours after surgery; second day after surgery (2nd PO) – after 48 hours up to complete 72 hours; third postoperative day (3rd PO) – 72 hours after surgery.

The study was developed in accordance with the Guidelines and Standards for Research Involving Humans, and was approved by the Research Ethics Committee of the Institute of Cardiology of Rio Grande do Sul/Fundação Universitária de Cardiologia). Parents/guardians were invited to participate and signed the informed consent form.

Data were analyzed with the Statistical Package for Social Sciences (SPSS) 14.0. Categorical variables were described by absolute and relative frequencies, and continuous variables as mean and standard deviation, or median and interquartile range (25th and 75th percentiles) according to whether they follow normal distribution or not. We used Person's chi-square test to compare categorical variables. Student's *t* test was used to compare the means and medians between groups, according to whether the parametric assumptions were respected or not. Significance was established at $p < 0.05$.

For a sample of 70 subjects in each group, there was a standard deviation of 15.5 and 14.8, to detect a difference greater than 8 days of catheter permanence, power of 87% was obtained.

Results

We selected 141 children in postoperative of cardiac surgery, and one did not participate in the study due to lack

of consent from parents/guardians (Figure 1). Thus, 140 patients were included, being 77 (55%) female. The median age was 11 months (from 0 to 22.1 months) and the median weight was 7.4kg (1.9–14.9kg).

As for the most common congenital heart defects, 26 (18.6%) children were diagnosed with tetralogy of Fallot, 14

(10%) with ventricular septal defect (VSD) and 13 (9.3%) with pulmonary atresia with VSD for both groups analyzed (Table 1).

Regarding adverse events during the 3 first postoperative days, there was bleeding, edema, hematoma, poor perfusion, ischemia, or blood clot in 63 (45%) children, with no significant difference when comparing the two groups ($p=0.82$) (Table 2).

Still considering the two groups, in 28 (20%) cases there was no breach of catheters and 27 (19.3%) children were

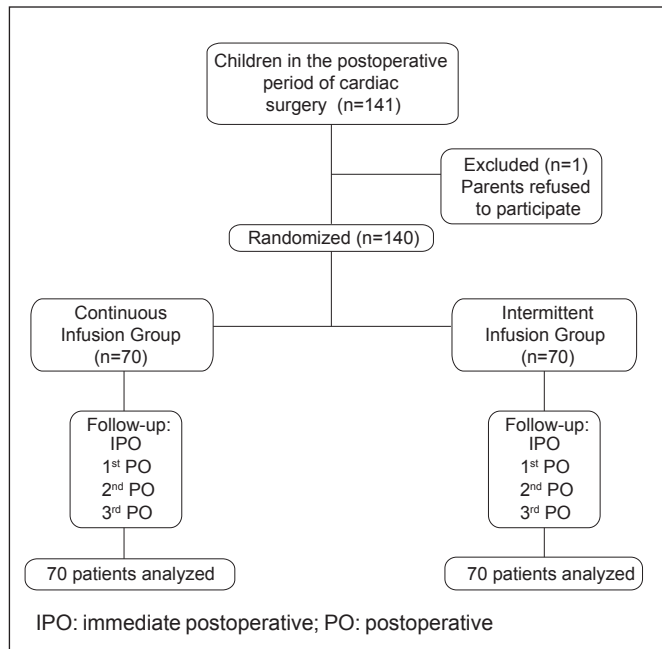


Figure 1 - Flowchart of patients included in the study

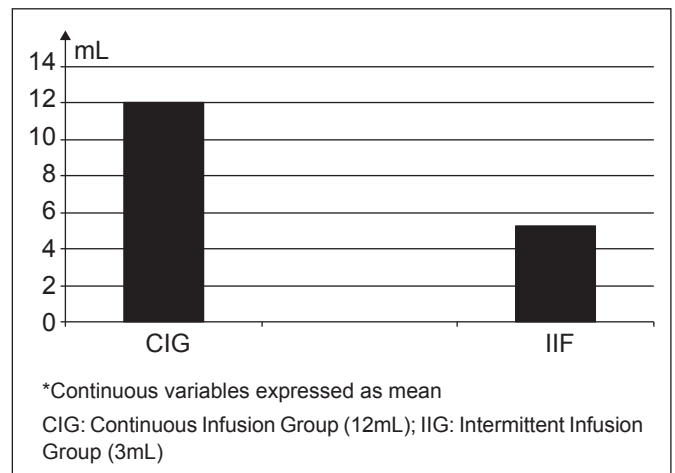


Figure 2 - Volume of heparin solution used every 24 hours in both groups

Table 1 - Clinical and demographic characteristics of the population (n=140)

Variables	Continuous Infusion n (%)	Intermittent Infusion n (%)	Total n (%)	p-value**
Age (months)*	7.7 (0.8–19.5)	14.6 (6.3–22.1)	11 (0–22.1)	0.10
Weight (kg)*	6.2 (3.6–9.6)	7.7 (4.7–10.3)	7.4 (1.9–14.9)	0.13
Female sex	41 (58.6)	36 (51.4)	77 (55)	0.49
Diagnosis				
Tetralogy of Fallot	14 (20.0)	12 (17.1)	26 (18.6)	
VSD	8 (11.4)	6 (8.6)	14 (10.0)	
Pulmonary atresia with VSD	10 (14.3)	3 (4.3)	13 (9.3)	
Atrioventricular septal defect	5 (7.1)	7 (10.0)	12 (8.6)	
Coarctation of the aorta	7 (10.0)	4 (5.7)	11 (7.9)	
Hypoplastic LV	3 (4.3)	3 (4.3)	7 (5.0)	
IAC	3 (4.3)	3 (4.3)	6 (4.3)	
Pulmonary atresia without VSD	3 (4.3)	3 (4.3)	6 (4.3)	
DORV	1 (1.4)	2 (2.9)	3 (2.1)	
IAC with IVC	2 (2.9)	1 (1.4)	3 (2.1)	
Pulmonary stenosis	2 (2.9)	1 (1.4)	3 (2.1)	
Patent ductus arteriosus	1 (1.4)	2 (2.9)	3 (2.1)	
Ebstein Anomaly	2 (2.9)	1 (1.4)	3 (2.1)	
Interrupted aortic arch	2 (2.9)	1 (1.4)	3 (2.1)	
Transposition of the great vessels	2 (2.9)	1 (1.4)	3 (2.1)	

*Continuous variables expressed as median and interquartile range; **descriptive level of probability of the Fisher's exact test; IVC: interventricular communication; LV: left ventricle; IAC: interatrial communication; DORV: double outlet right ventricle

Table 2 - Adverse effects related to site of catheter insertion

	Continuous infusion n (%)	Intermittent Infusion* n (%)	Total* n (%)	p-value
Adverse events (IPO)	9 (12.8)	8 (11.4)	17 (12.1)	0.77
Bleeding	0	1 (1.4)	1 (0.7)	1.00
Edema	0	0	0	1.00
Hematoma	0	1 (1.4)	1 (0.7)	1.00
Malperfusion	1 (1.4)	1 (1.4)	2 (1.4)	1.00
Ischemia	6 (8.6)	1 (1.4)	7 (5)	0.11
Presence of clot	2 (2.9)	4 (5.7)	6 (4.3)	0.68
Adverse events (1st PO)	13 (20.6)	9 (14.3)	21 (17.5)	0.48
Bleeding	2 (3.2)	0	2 (1.6)	0.24
Edema	0	0	0	1.00
Hematoma	0	1 (1.6)	1 (0.8)	0.49
Malperfusion	0	0 (0)	0 (0)	1.00
Ischemia	4 (6.3)	2 (3.2)	6 (4.8)	0.68
Presence of clot	7 (11.1)	5 (8.1)	12 (9.6)	0.76
Adverse events (2nd PO)	10 (25.6)	13 (30.2)	23 (26.4)	1.00
Bleeding	3 (6.8)	1 (2.3)	4 (4.6)	0.61
Edema	0	0	0	1.00
Hematoma	0	2 (4.7)	2 (2.3)	0.24
Malperfusion	2 (4.5)	1 (2.3)	3 (3.4)	1.00
Ischemia	2 (4.5)	2 (4.5)	4 (4.6)	1.00
Presence of clot	3 (6.8)	7 (16.3)	10 (11.5)	0.19
Adverse events (3rd PO)	10 (25.6)	13 (30.2)	23 (26.4)	1.00
Bleeding	3 (6.8)	1 (2.3)	4 (4.6)	0.61
Edema	0	0	0 (0)	1.00
Hematoma	0	2 (4.7)	2 (2.3)	0.24
Malperfusion	2 (4.5)	1 (2.3)	3 (3.4)	1.00
Ischemia	2 (4.5)	2 (4.7)	4 (4.6)	1.00
Presence of clot	3 (6.8)	7 (16.3)	10 (11.5)	0.19

IPO: immediate postoperative; PO: postoperative

discharged from the intensive care unit until the 3rd day after surgery, reasons that led to the removal of catheters.

When evaluating the insertion site of the catheter, in 56 (40%) children the left radial artery was used, and in 40 (28.6%) children, the right radial artery, for both groups. Puncture through transfixation of the artery was used in 138 (97.9%) children, and only in one (1.4%) child for each group, dissection was used. The caliber of the most used catheter was 24G in 78 (55.7%) children.

Regarding the time of permanence of the catheters, the median was 48 (24 to 70.5) hours in CIG and 48 (32 to 76.5) hours in IIG. As no difference greater than 8 days of catheter permanence was found, there was no difference between groups ($p=1.0$). Comparing the average volume used in the IIG ($5.3\pm 3.5\text{mL}/24$ hours) with the CIG ($12.0\pm 1.2\text{mL}/24$ hours), the findings showed a significant difference ($p<0.0003$) (Figure 2).

Discussion

The invasive blood pressure monitoring in children has been widely used in various services of Pediatrics. Currently, arterial catheterization is a procedure indicated whenever a child is undergoing heart surgery. Because is it easily achievable, especially when punctured, it allows obtaining fast and accurate blood pressure and thus also provides the collection of blood samples for laboratory tests⁽¹⁹⁾. The success of invasive measurement of blood pressure only occurs when the system maintaining catheter patency does not compromise patient safety or the accuracy and reproducibility of the measurement.

The present study compared two systems of maintenance and permeabilization of arterial catheters in children. The main result demonstrated was related to the volume of

heparin solution used in both groups. The mean volume used in the IIG was lower when compared to the CIG.

The continuous infusion system is a comfortable method for the handler and provides a larger safety margin regarding the volume infused, compared to the technique of rapid flushes. The method of intermittent infusion provides better observation of the entire system as to the presence of air and blood clotting through reflux of blood by negative pressure via syringe. According to a study conducted in children, systems of continuous infusion decreased the incidence of distal embolization from 23 to 0% and also provide a better control of the amount of infusion of heparin⁽²⁰⁾.

The occurrence of a greater number of complications is related to the patients that present shock or low output⁽²¹⁾. It is possible that the large number of clots noticed in the present study was associated to the severity of patients. Because they are cardiopaths, many submitted to cardiac surgery with cardiopulmonary bypass, they often presented heart failure and low-output state.

Usually, children under 5 years old have a higher rate of complications of arterial catheterization, requiring greater care in monitoring invasive blood pressure due to rapid changes which are subjected to hemodynamic instability and the use of vasoactive drugs in the postoperative⁽¹¹⁾. In this study, there were no significant differences regarding age and weight of children related to adverse events. In another observational, retrospective study, conducted with 1,473 children up to 20kg, there was often temporary occlusion of the cannulated artery⁽⁸⁾. The puncture site usually chosen and with greater ease of access was radial and brachial, followed by femoral, coincident with data obtained in this study.

There was great variability in the time of patency of the catheters with a median of 48 hours in both groups. Some studies showed higher mean of time of permanence, with an average duration of 72 hours for arterial catheters⁽²²⁾. Other observed mean permanence time of 48 hours^(22,23). Authors reported that the use of the arterial catheter should not exceed 96 hours to reduce the risk of infection⁽²⁴⁾. In this study, the great variability of time related to the duration of the arterial catheter is probably due to the great variability in length of stay in the Intensive Care Unit. Many of these patients had serious postoperative complications, requiring prolonged mechanical ventilation, peritoneal dialysis, and continuous monitoring to record blood pressure and to obtain samples for laboratory specimens.

Comparing the average volume used in the IIG (5.3 ± 3.5 mL/24 hours) with the mean of CIG (12 ± 1.2 mL/24 hours), there was a significant difference in the daily values of heparin

solution infused in each group. It is questionable whether this difference, which is statistically significant, has some impact on clinical practice. On the other hand, the control of blood volume in pediatric patients is one of the primary precautions for the good hemodynamic evolution. In very young children, the necessary volume to infuse drugs may contribute to volume overload^(25,26).

The dose of heparin used in the literature ranges from 0.1–10UI/mL⁽²⁷⁾. In this study, we used concentrations of heparin solution at 4UI/mL in both groups. The findings showed that 45% of patients had some adverse event. Among these, 25% showed the presence of blood clot, a relatively high rate when compared to other studies. Some authors demonstrated a low complication rate, with only 3% of catheter occlusion when using a heparin solution continuously, at 3mL/h⁽²⁶⁾. A study performed with adult patients reported no difference in patency of the catheters when comparing maintenance with normal saline at 0.9% and saline solution at 0.9% with heparin, but found differences in the accuracy of the values of blood pressure measurement, and the most accurate values were observed in the group using heparin⁽²⁸⁾. In children from 1 month to 2 years old catheterized in the radial artery and connected to a device with a continuous infusion, at 3mL/h with heparinized isotonic saline at 1IU heparin / mL, there was a higher number of haemorrhage and ischemia in the first 72 hours⁽²⁹⁾.

Volume overload and renal failure are factors that contribute significantly to increased postoperative morbidity and mortality, especially in newborns. Fluid restriction is a resource that is used frequently, often to the tolerated extent. In such circumstances any volume infused can be significant⁽²⁹⁾.

It can be concluded that the choice of the system of continuous or intermittent infusion of a solution of heparin to maintain intra-arterial catheter, is independent of the clinical and demographic characteristics of the infants or the occurrence of adverse events during the first 3 days of postoperative, as evidenced in the sample. However, the use of the intermittent infusion in children of low birth weight should be considered, due to a lower volume of heparin solution infused.

Characteristics such as caliber of catheters, choice of insertion site, and technique used for insertion showed no evidence of increased length of stay in both groups. A limitation of the study lies in the fact that the number of times the catheter was manipulated by different professionals was not registered. The greater manipulation of catheters through the rapid flushes technique may have occurred in the system of intermittent infusion, which could influence the effectiveness of this system. Therefore, further studies are needed on the topic.

References

1. Miyague NI, Cardoso SM, Meyer F, Ultramari FT, Araújo FH, Rozkowisk I *et al.* Estudo epidemiológico de cardiopatias congênitas na infância e adolescência. Análise em 4.538 casos. *Arq Bras Cardiol* 2003;80:269-73.
2. World Health Organization [homepage on the Internet]. Geneva: causes of death in neonates and children under five in the world: the global burden of disease [cited 2009 Jun 10]. Available from: http://www.who.int/child_adolescent_health/media/causes_death_u5_neonates_2004.pdf
3. Auler JO Jr, Barreto AC, Gimenez SC, Abellan DM. Pediatric cardiac postoperative care. *Rev Hosp Clin Fac Med Sao Paulo* 2002;57:115-23.
4. Jansen D, Silva KV, Novello R, Guimarães TC, Silva VG. Nursing assistance in child with heart disease. *Rev SOCERJ* 2000;13:22-9.
5. Albisetti M, Schmutz M, Haas R, Eckhardt BP, Bauersfeld U, Baenziger O *et al.* Arterial thromboembolic complications in critically ill children. *J Crit Care* 2005;20:296-300.
6. World Health Organization [homepage on the Internet]. Geneva: The global burden of disease: causes of death in neonates and children under five in the region of the Americas [cited 2009 Jun 10]. Available from: <http://www.who.int/>
7. Atik FA. Monitorização hemodinâmica em cirurgia cardíaca pediátrica. *Arq Bras Cardiol* 2004;82:199-208.
8. Schindler E, Kowald B, Suess H, Niehaus-Borquez B, Tausch B, Brecher A. Catheterization of the radial or brachial artery in neonates and infants. *Paediatr Anaesth* 2005;15:677-82.
9. Clark VL, Kruse JA. Arterial catheterization. *Crit Care Clin* 1992;8:687-97.
10. Pérez LP, Rivero MP, Sigler OM, Morejón AG. Cateterización de la arteria radial. *Rev Cub Cir* 1988;27:28-31.
11. Smith-Wright DL, Green TP, Lock JE, Egar MI, Fuhrman BP. Complications of vascular catheterization in critically ill children. *Crit Care Med* 1984;12:1015-7.
12. Adar R, Rubinstein N, Blieden L. Immediate complications and late sequelae of arterial catheterization in children with congenital heart disease. *Pediatr Cardiol* 1983;4:25-8.
13. Furfaro S, Gauthier M, Lacroix J, Nadeau D, Lafleur L, Mathews S. Arterial catheter-related infections in children. A 1-year cohort analysis. *Am J Dis Children* 1991;145:1037-43.
14. Shah PS, Shah VS. Continuous heparin infusion to prevent thrombosis and catheter occlusion in neonates with peripherally placed percutaneous central venous catheters. *Cochrane Database Syst Rev* [serial on the Internet]. 2008;(2):CD002772 [cited 2013 Jun 17]. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/18425882>
15. Randolph AG, Cook DJ, Gonzales CA, Andrew M. Benefit of heparin in peripheral venous and arterial catheters: systematic review and meta-analysis of randomised controlled trials. *BMJ* 1998;316:969-75.
16. Mitchell MD, Anderson BJ, Williams K, Umscheid CA. Heparin flushing and other interventions to maintain patency of central venous catheters: a systematic review. *J Adv Nurs* 2009;65:2007-21.
17. Maya LC, Restrepo NH. Cateterismo arterial en pacientes pediátricos. Experiencia con 100 líneas arteriales. *Pediatría (Bogotá)* 1994;29:97-101.
18. Guyton AC, Hall JE. Textbook of medical physiology. 11th ed. Philadelphia: Elsevier Saunders; 2006.
19. Jalonen J. Invasive haemodynamic monitoring: concepts and practical approaches. *Ann Med* 1997;29:313-8.
20. Bozzo RB. Monitoreo invasivo de la presión arterial en el niño. *Pediatría (Santiago de Chile)* 1991;34:22-31.
21. De Neff M, Heijboer H, van Woensel JB, de Haan RJ. The efficacy of heparinization in prolonging patency of arterial and central venous catheters in children: a randomized double-blind trial. *Pediatr Hematol Oncol* 2002;18:553-60.
22. Saladino R, Bachman D, Fleisher G. Arterial access in the pediatric emergency department. *Ann Emerg Med* 1990;19:382-5.
23. Swanson E, Freiberg A, Salter DR. Radial artery infections and aneurysms after catheterization. *J Hand Surg Am* 1990;15:166-71.
24. Kulkarni M, Elsner C, Ouellet D, Zeldin R. Heparinized saline versus normal saline in maintaining patency of the radial artery catheter. *Can J Surg* 1994;37:37-42.
25. Subramanian S, Agarwal R, Deorari AK, Paul VK, Bagga A. Acute renal failure in neonates. *Indian J Pediatr* 2008;75:385-91.
26. Chow JM, Douglas D. Fluid and electrolyte management in the premature infant. *Neonatal Netw* 2008;27:379-86.
27. Shah PS, Ng E, Sinha AK. Heparin for prolonging peripheral intravenous catheter use in neonates. *Cochrane Database Syst Rev* [serial on the Internet]. 2002;(4):CD002774 [cited 2012 Aug 18]. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/12519576>
28. Souza N, Carvalho AC, Carvalho WB, Souza RL, Oliveira NF. Complicações da cateterização arterial em crianças. *Rev Assoc Med Bras* 2000;46:39-46.
29. Duke T, Molyneux EM. Intravenous fluids for seriously ill children: time to reconsider. *Lancet* 2003;362:1320-3.