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SYSTEMATIC REVIEW

Anesthetic management of neonates undergoing diagnostic and therapeutic cardiac catheterization: a systematic literature review☆

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KEYWORDS
Cardiac catheterization;
Newborn infant;
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Anesthesia;
Perioperative care;
Heart diseases

Abstract
Background: Several interventional cardiology procedures are required in neonates with congenital heart disease. Interventional cardiology procedures have a higher risk of cardiac arrest compared to other interventions. At present, there is great heterogeneity in the perioperative management of congenital heart disease neonates undergoing diagnostic cardiac catheterization or therapeutic cardiac catheterization.
Study objectives: Primary aim: Provide a systematic review of the most effective and/or safe anesthetic and perioperative management in neonates with congenital heart disease who undergo diagnostic cardiac catheterization or therapeutic cardiac catheterization. Secondary aim: Identify the medications, monitoring parameters and airway management used in the same population.
Design: Systematic literature review.
Setting: Catheterization laboratory.
Methods: Literature was searched (December 2017) in electronic databases Medline, EMBASE, ScienceDirect, *BIREME-Lilacs-Biblioteca Virtual de la Salud*, Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects and Health Technology Assessment Database.

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Main results: From 130 records identified, four studies met inclusion criteria and quality assessment. None of the studies were relevant to the primary objective. Regarding the secondary objectives, one study compared the efficacy and adverse effects of racemic ketamine and its S(+) ketamine enantiomer, one study reported the efficacy of subarachnoid anesthesia for high-risk children undergoing diagnostic cardiac catheterization, one study identified the factors associated to high severity adverse events related to sedation, anesthesia and airway, and one study retrospectively analyzed cardiac catheterization procedures in neonates weighing less than 2.5 kg.
Conclusion: There are no evidence-based recommendations available for congenital heart disease neonates undergoing cardiac catheterization. More studies are required to evaluate the ideal anesthetic and perioperative management in this population.

PALAVRAS-CHAVE
Cateterismo cardíaco;
Recém-nascido;
Prematuro;
Anestesia;
Cuidados perioperatórios;
Doenças cardíacas

Manejo anestésico de neonatos submetidos a cateterismo cardíaco diagnóstico e terapêutico: uma revisão sistemática da literatura

Resumo
Introdução: Vários procedimentos de cardiologia intervencionista são necessários em neonatos com doença cardíaca congênita. Os procedimentos de cardiologia intervencionista têm um risco maior de parada cardíaca em comparação com outras intervenções. Atualmente, há grande heterogeneidade no manejo perioperatório de neonatos com doença cardíaca congênita submetidos a cateterismo cardíaco diagnóstico ou cateterismo cardíaco terapêutico.
Objetivo: Objetivo principal: fornecer uma revisão sistemática do manejo anestésico e perioperatório mais efetivo e/ou seguro em neonatos com doença cardíaca congênita submetidos à cateterismo cardíaco diagnóstico ou cateterismo cardíaco terapêutico. Objetivo secundário: Identificar os medicamentos usados, parâmetros monitorizados e manejo das vias aéreas utilizado na população estudada.
Desenho: Revisão sistemática da literatura.
Local: Laboratório de hemodinâmica e cateterismo cardíaco.
Método: Foi realizada busca na literatura (Dezembro de 2017) nos seguintes bancos de dados eletrônicos: Medline, EMBASE, ScienceDirect, BIREME-*Lilacs-Biblioteca Virtual de la Salud*, *Cochrane Database of Systematic Reviews*, *Database of Abstracts of Reviews of Effects* e *Health Technology Assessment Database*.
Resultados principais: Dos 130 registros identificados, quatro estudos obedeceram aos critérios de inclusão e de avaliação de qualidade. Nenhum dos estudos foi relevante para o objetivo principal. Em relação aos objetivos secundários, um estudo comparou a eficácia e os efeitos adversos da cetamina racêmica e seu enantiômero S(+) cetamina, um estudo relatou a eficácia da anestesia subaracnóidea em crianças de alto risco submetidas ao cateterismo cardíaco diagnóstico, um estudo identificou os fatores associados à maior gravidade de eventos adversos relacionados à sedação, anestesia e vias aéreas, e um estudo analisou retrospectivamente os procedimentos de cateterismo cardíaco em neonatos com peso inferior a 2,5 kg.
Conclusão: Não há recomendações baseadas em evidências disponíveis para neonatos com doença cardíaca congênita submetidos a cateterismo cardíaco. Mais estudos são necessários para avaliar o manejo anestésico e perioperatório ideal nessa população.

Introduction

Neonates with Congenital Heart Disease (CHD) who require Interventional Cardiology Procedures (ICP) have a high probability of complications and fatal outcomes. Compared with other interventions performed outside the operating room, ICPs have an increased risk by up to 9.3 times of cardiac arrest,[1] and although the average mortality in the Catheterization Laboratory (CL) is low (0.2%–0.29%), mortality rates in patients who suffer a circulatory arrest or who present life-threatening events increase between 15% and 19%.[2]

These patients are a real challenge to the anesthesiologist. In addition to facing the limitations of the CL,[3,4] the anesthesiologist must understand the pathophysiology of this diverse group of diseases and the effect of the intervention and the anesthetic drugs on the patient. All of this,

in order to achieve adequate perioperative care defined as patient immobility, hemodynamic stability, pain management, and maintenance of acid base balance.

At present, there are no specific guidelines for the perioperative management of CHD neonates undergoing Diagnostic Cardiac Catheterization (DCC) or Therapeutic Cardiac Catheterization (TCC) in such a particular space as CL. Also, there is a great heterogeneity of Anesthetic Techniques (AT) used in these patients.[5] This systematic review aims to discern the most effective and/or safe AT and perioperative management for CHD neonates undergoing DCC or TCC.

Objective

Primary objective

To identify the most effective and/or safe anesthetic and perioperative management in neonates with CHD who undergo DCC or TCC.

Secondary objectives

Identify the medications used for the AT in neonates and the recommendation on dosage and routes of administration.

Identify the vasoactive medications used in the management of neonates, if required, and the recommended dose.

Define the monitoring parameters required in CHD neonates undergoing DCC or TCC.

Identify the airway management in CHD neonates undergoing DCC or TCC.

Methods

Study design

This systematic review was developed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[6]

Inclusion criteria

Studies describing or comparing different anesthetic techniques used to perform DCC or TCC in full term or premature CHD neonates, and studies reporting the effectiveness and adverse effects derived from each technique.

Studies describing or comparing different types of intraoperative monitoring and/or airway management in CHD neonates undergoing DCC or TCC.

Studies describing or comparing the use of vasopressor and/or inotropic medications in CHD neonates undergoing diagnostic and/or therapeutic cardiac catheterization.

Types of studies accepted: Controlled clinical trials and cohort studies. Since we anticipated finding a lack of enough studies to answer the research question, we decided to include case-control studies, case series, and case reports.

Type of population to be studied: The target population was full term or premature neonates with CHD undergoing DCC or TCC.

Exclusion criteria

Letters to the Editor and non-systematic review studies.

Types of interventions

For the primary objective, studies describing or giving recommendations on the AT in neonates with CHD undergoing DCC or TCC.

For the secondary objectives, interventions to be evaluated were comparisons between or descriptions of different AT used for CHD neonates undergoing DCC or TCC, airway management strategies, types of monitoring used during and after the procedure, selection criteria, dose, if required, and route of administration for vasoactive medications.

Types of outcomes measured

For the primary objective, outcomes to be measured were success rate (defined by immobility of the patient or completion of the procedure) and complication rate or percentage related to AT for procedures.

For the secondary objectives, anesthetic drugs used, dosage, route of administration; success and complication rates between the different airway management strategies (spontaneous ventilation vs. artificial airway), interventions that would allow for the measuring of the need and safety of using invasive vs. non-invasive monitoring, and any result that would allow for the inference of the indication, dose, route of administration, type of vasoactive medication used, and complications derived from it.

Data collection and analysis

After approval by the Institutional Research Committee (Ref. 2017/10), a strategy was designed with MeSH and free terms that described the population and interventions (Table 1S, Supplementary Data). A high sensitivity filter was used to run the literature searching. It was conducted in the following databases: Medline, EMBASE, ScienceDirect, *BIREME-Lilacs-Biblioteca Virtual de la Salud*, Cochrane Database of Systematic Reviews (CDSR), Database of Abstracts of Reviews of Effects (DARE) and Health Technology Assessment Database (HTA). The search was limited to studies published between January 1st, 2000, and December 31st 2017, conducted in humans with ages from birth to 30 days and without any other restriction. It was completed with manual search (*snowball* method) wherein the references of the articles included were considered, applying the same selection criteria as indicated above.

An initial selection of articles was made by title and then by abstract, according to the inclusion and exclusion criteria and the full text of selected studies were obtained (Fig. 1A). To obtain the complete texts where these were not publicly available, we contacted the authors. Doubts about the inclusion of some articles were solved by agreement between two authors.

The relevant information was extracted from the selected studies and recorded in SIGN50 standardized formats[7] and in evidence tables (format taken from NICE).[8]

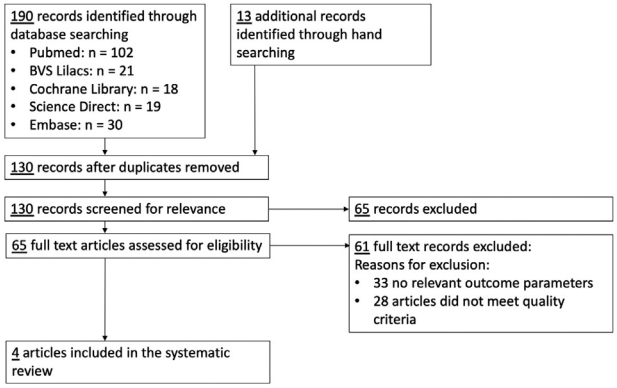

Figure 1 PRISMA flow diagram for included studies.

A new format was designed to record the information on case series and case reports (Supplementary Data). The following information was collected: patient data, anesthetic technique and medication (with effectiveness defined by the immobility of the patient or complete realization of the procedure), monitoring method, airway management technique, and use of vasoactive medications, recording efficacy and safety (defined by the risk of complications such as: hypotension, decreased oxygen saturation, circulatory arrest and/or hypercapnia).

An evaluation of the quality of articles was made by each one, and a level of evidence was assigned according to the *Oxford Centre for Evidence-based Medicine* classification.[9]

Results

Study selection

The initial electronic search found 190 studies, and 13 further articles were found through review of references (snowball methodology). After removing duplicates, 130 titles and abstracts were reviewed to ascertain their relevance to the primary and secondary objectives. No study was relevant to the primary objective. Regarding the secondary objectives, a full text was obtained from 65 records and 65 were excluded. Of these 65 records, a full text was read: 33 did not describe relevant outcomes, and 28 did not meet the quality criteria. Thus, four articles remained which were of sufficient quality and contained relevant information to be included in the final analysis of our secondary objectives (Fig. 1A).

Characteristics of included studies

Table 1A shows the characteristics of the four included studies: two case series, a cohort, and a clinical trial.

Anesthetic technique and anesthetic medications

In the double blind randomized clinical trial conducted by Pees et al.,[10] the efficacy and adverse effects of racemic ketamine and its S(+) ketamine enantiomer were compared in DCC and TCC procedures in neonates and children between 0–11 years of age. A total of 100 patients were randomized to receive midazolam plus racemic ketamine or S(+) ketamine at a 1 $mg.kg^{-1}$ dose, depending on the study group, plus a 0.5 $mg.kg^{-1}$ booster dose and midazolam every 30 minutes according to the level of sedation. Results show that significantly lower doses of S(+) ketamine were required compared to racemic ketamine in the 0–1 year-old group; no significant differences were found with the other age groups in the subgroup analysis (2.97 $mg.kg^{-1}.h^{-1}$ vs. 2.36 $mg.kg^{-1}.h^{-1}$, respectively), and an analgesia/sedation estimated power ratio of 1.4:1 was calculated. Diagnostic and non-painful interventions such as ductus closure or atrial septal defects required lower analgesia/sedation doses compared to more painful procedures such as balloon dilation of large arteries ($p = 0.043$). The average awakening time after the last dose was 127 minutes, and 96 minutes for the racemic ketamine and the S(+) ketamine group, respectively, without a statistically significant difference. Severe adverse effects were more common with the racemic solution. The authors concluded that S(+) ketamine is highly efficient in analgesia/sedation in neonates and children for DCC and TCC procedures. Also, it allows spontaneous ventilation with low risk of severe adverse effects (need for orotracheal intubation, airway obstruction, or allergy) compared to racemic ketamine. As for the quality of the study, it carries a high risk of selection bias as the randomization method is not described neither is clear if the assignment of patients to each group was blinded or not. There is, therefore, no guarantee that the patient groups have similar baseline characteristics and would be comparable. Furthermore, as it is not clear if the staff was blinded, there is a risk of development bias, which may alter interventions from what was originally planned (1-B level of evidence, according to CEBM, Oxford).

In their case series, Katznelson et al.[11] reviewed the efficacy of subarachnoid anesthesia for high risk children undergoing DCC. This study included 12 premature infants under 12 months of age who had been recently extubated (< 2 weeks) after a prolonged period of mechanical ventilation (> 1 week) and who presented respiratory compromise caused by excessive respiratory effort with retractions or poor respiratory effort or apnea. Spinal anesthesia was applied with 0.5% hyperbaric bupivacaine at a 1 $mg.kg^{-1}$ dose and sedation with midazolam 0.1 $mg.kg^{-1}$ or ketamine 1 $mg.kg^{-1}$ every 5 min, if required. A failed anesthesia was considered when there was no analgesia and paralysis of extremities, other sedatives (excluding midazolam) were required, or orotracheal intubation within 24 hours was needed. Five of these children were neonates with ages between 4 days and 4 weeks, weight between 2,680 g and 3,900 g, anesthetic time between 9 0–1 20 minutes, procedure time between 75–105 minutes, with cardiac pathologies including hypoplastic left heart syndrome, transposition of large arteries, pulmonary stenosis, and abnormal pulmonary venous drainage. In all five neonates, the procedure was performed successfully, without needing sedation and without significant changes in the hemodynamic variables, oxygen saturation, and CO_2. This anesthetic technique is a possible alternative for high risk children under 6 months of age undergoing DCC; however it is clear that further studies such as RCTs are needed. This study with a small sample of selected patients is considered a 3D level of evidence, according to the Oxford guidelines.[9]

Table 1 Characteristics of the included studies.

First author, year, country	Type of study	Patients/ Procedures	Patient characteristics	Factor(s) prognosis	Follow-up duration	Outcome measures	Results
Simpson JM, 2001; United Kingdom [13]	Case series	Interventional procedures: Patients: 29 (31 procedures); Male/Female: 16/15 (52/48%); Average age (days): 5 (1–126). Average weight (kg): 2.1 (0.7–2.4). Ventilation: Controlled 21(65%), spontaneous ventilation 8(35%). Diagnostic procedures: Patients: 80. Average age (days): 9 (1–135). Average weight (kg): 2.3 (1.1–2.49). Ventilation: Controlled 45(56%), spontaneous ventilation 8(35%).	Neonates with congenital heart disease and weight $\leq$ 2.5 kg. Various cardiopathies. Diagnostic: 80 Therapeutic: 31	Preterm neonates with low weight at the time of the procedure ($\leq$ 2.5 kg)	General: 24 h post-procedure. Pulmonary Balloon valvuloplasty patients: 31 months (1–10 years) post-procedure.	Major/minor complications occurred up to 24 h after the procedure.	Interventional procedures (n = 31) - Arterial catheter: 6 (19%) - Venous access in 29 (94%) Complications: -Mortality: 3(4%). -Non-fatal major 12(15%) -Minor 11(14%). -Incidents 2(2%). - Complications in intervention 35/80 (43%) vs. diagnoses: 13/80(16%) (p = 0.009). Respiratory deterioration requiring ventilation and orotracheal intubation (OTI): 3 (10%) in intervention and 1(1%) diagnosis.
Katznelson R, 2005; Israel [11]	Case series	12 patients Premature	Average age: 16.85 weeks (range 0.5–48, median 8.5).	History of prematurity.	24 hours	Average anesthesia time: 98.3 min (range 8 0–1 20, median 100).	SA can be useful and safe for neonates

Table 1 (*Continued*)

First author, year, country	Type of study	Patients/ Procedures	Patient characteristics	Factor(s) prognosis	Follow-up duration	Outcome measures	Results
		Subarachnoid anesthesia (SA)	Average weight: 4,810 g (range 2,680–8,000, median 4,257.5) Procedure: diagnostic cardiac catheterizations (varied cardiac pathologies)			Average procedure time: 75.08 min (range 45–115, median 74). Additional IV sedation: Required in 6 patients (was done with midazolam).	
Lin CH, 2015; USA [5]	Analytical study, prospective cohort	Total of patients: 13,611. Neonates: 890	Age: < 1 month 890, < 1–< 12months 2,467, 1–9 years 5,212, 1 0–1 7 years 2,939, >18 years 2,103	Pediatric patients/ congenital heart disease:	Patients undergoing cardiac catheterization between February 1st, 2007, and June 31st, 2010, in 8 USA institutions.	Occurrence of complications Rates (for patients)	Adverse event: hypotension 93 cases (0.68%).
		Under 18 years old: 11,508	Weight: <4 kg 1,161, 4–9 kg 2,944, 1 0–1 9 kg 3,267, >20 kg 6,234 Gender: Male 7189, female 6422	Complications related to sedation Complications related to airway management 5-level severity scale/ CHARM		Adjusted rates (for institutions participating in C3PO)	Predictors of adverse events: -Low weight: <4 kg and weight 4–19 kg, -Presence of non-cardiac comorbidity -Low mixed venous oxygen saturation (single ventricle <50% or two ventricles)

(*Continued*)

First author, year, country	Type of study	Patients/ Procedures	Patient characteristics	Factor(s) prognosis	Follow-up duration	Outcome measures	Results
							Predictors of conversion from spontaneous breathing to intubation -Minor patients -Patients undergoing high-risk procedure -Patients with inotropic support
Pees C, 2003, Germany [10]	Double-blind clinical trial	100 patients (50 patients racemic ketamine/ 50 patients S(+) ketamine). Non-randomized	Age: 2 days–11 years Different types of congenital heart disease.	Induction: Oral midazolam: 0.5 mg.kg^{-1} -IV Midazolam: 0.2 mg.kg^{-1} -Racemic ketamine/ S(+): 1 mg.kg^{-1} Maintenance: -Racemic ketamine/ S(+): 0.5 mg.kg^{-1} as needed -Midazolam: 0.1 mg.kg^{-1} Rescue (exclusion): -Phenobarbital -Promethazine	Total doses of ketamine Awakening time Movements Awareness, Airway obstruction Nausea/ vomiting Need for other medications.	Trans-operative/ post-anesthesia care unit	Dose: -Racemic ketamine: 3.12 mg/kg/h -S(+) ketamine: 2.28 mg/kg/h Side effects: -Inadequate sedation -Airway obstruction -Vomiting -Awareness, movement, behavior, nausea/ vomiting score

Airway management and monitoring

In the cohort study by Lin et al.,[5] the data collected from *C3PO* (Congenital Cardiac Catheterization Project on Outcomes) were analyzed retrospectively.[12] This study included a total of 13,611 patients, 890 of whom were neonates. The following factors were identified as predictors of high severity adverse events related to sedation, anesthesia, and airway: low weight (< 4 Kg, OR = 4.4, 95% CI 2.3–8.2, weight: 4–19 Kg, OR = 2.1, 95% CI 1.3–3.6), presence of non-cardiac comorbidity (OR = 1.7, 95% CI 1.1–2.6) and low mixed venous oxygen saturation (single ventricle < 50%, or two ventricles < 60%, OR = 2.3, 95% CI 1.4–3.6). Spontaneous ventilation was chosen as an initial strategy of airway management in one-third of cases, requiring conversion to intubation in 1.8% of cases. Predictors of conversion from spontaneous breathing to intubation were: younger patients (1–11 months, OR = 5.2, 95% CI 2.3–11.4), patients undergoing high risk procedures (Category 3: OR = 5, 95% CI 3.1–8.2 and category 4: OR = 10.1, 95% CI 6.5–15.6)[16] and patients with inotropic support requirement (OR = 11.0, 95% CI 8.6–14). Having an artificial airway was found to be an independent predictor of high severity adverse events and higher ORs for adverse events, compared to spontaneous breathing. The authors concluded that a risk stratification of patients prior to the procedure can help decide the airway management strategy, preserve anesthetic resources and possibly also reduce the risk of anesthesia related and non-anesthesia related adverse events during cardiac catheterization. This study has some important limitations: the information in the database was collected prospectively and analyzed retrospectively, and the database was designed to record data related to the procedures, rather than the anesthetic events. However, we consider that the study has a 2++B level of evidence according to the Oxford guidelines[9] as it was well conducted, has a low risk of confusion bias and a moderate probability that the relationship established be causal.

The case series by Simpson et al.,[13] retrospectively analyzed cardiac catheterization procedures in neonates weighing less than 2.5 kg, with an emphasis on intervention results. 111 procedures were performed in 107 patients under intravenous sedation with morphine and midazolam and intravenous infusion of morphine for neonates who were already ventilated. In total, 31 interventional procedures were performed with a 100% success rate. The average age of patients was 5 days, and their average weight was 2.1 kg. Most of the procedures were atrial balloon septostomy (n = 16), but others were pulmonary balloon valvuloplasty (n = 10), pulmonary artery angioplasty (n = 1), myocardial biopsy (n = 1), and coil occlusions of collateral vessels (n = 3). Eighty diagnostic procedures were performed on patients with an average age of 9 days and an average weight of 2.3 Kg. The most common complications were arrhythmias (10%) and respiratory deterioration that required ventilation and OTI in 10% of the intervention group and 1% in the diagnostic group. The complication rate in the interventional procedures was higher (43%) than in the diagnostic procedures (16%) ($p = 0.009$), and the complications in the very low birth weight subgroup were not more common than in the 1.5–2.5 kg subgroup. Based on these results, the authors suggest that interventional procedures can be performed safely in low birth weight patients, and low weight should not be a limitation. The high incidence of respiratory deterioration in interventional patients, frequently related to sedation, leads them to recommend ventilation and elective OTI in patients weighing < 2.5 kg, and emphasize the advantage of the umbilical vessel approach due to the low incidence of vascular complications. This study has a 3D level of evidence according to the Oxford guidelines.[9]

Vasoactive medications

No studies related to this topic were found.

Discussion

This systematic review was carried out to find studies showing the safe and effective perioperative management of neonatal patients undergoing DCC and/or TCC. We expected to find recommendations on monitoring, management of the airway and the use of medications like anesthetics and/or vasoactives.

However, although we carried out a systematic, flexible search in the main medical databases (including case series studies and case reports), we found that there is little literature available relating to the perioperative management of neonates undergoing DCC and/or TCC, even though *a posteriori* exploratory search in the PROSPERO register of reviews database[14] was made, with no results.

We anticipated this situation to occur, particularly related to interventional studies, but not at this level. We ascribe it to several factors; experimental and observational-analytical studies are not easy to carry out in neonates due to their implicit fragile clinical status, particularly in those with CHD, and their medical-legal situation, as they cannot exercise autonomy themselves. Additionally, it is possible that studies with that type of patients, that have small sample size or non-conclusive outcomes, are not reported because of their less frequent acceptance for publication, which leaves that information out of reach. However, we were surprised by the absence of reliable evidence in other types of studies, such as cohorts, case series or even case report. This lack of data prevents us from pooling the results by topic as well as from drawing conclusions about the perioperative management of these patients, which was the initial objective of our review. Therefore, we can report our findings and some interesting data.

We highlight the importance of the work of Bergersen et al.[2,5,12,15–17] in developing the CHARM (Catheterization for Congenital Heart Disease Adjustment for Risk Method) risk prediction model, adjusted by type of procedure, hemodynamic variables and age, which was created to equitably compare the adverse events rates between institutions performing DCC and TCC. This model was applied in the work of Lin et al.,[5] which is part of the series of articles published by Bergersen et al. and that have been funded by the American Heart Association, to determine predictors of adverse events related to sedation, anesthesia and airway management strategies. Taking into account the criteria proposed by the working group would help assess the risk of patients before a procedure and therefore to prepare the neces-

sary resources (i.e., potential need for ECMO or surgery), to understand the risk and better inform the patients' relatives, to accurately complete the informed consent, and to mitigate the risk of anesthetic adverse events during cardiac catheterization, where possible.

The literature suggests that procedures performed with sedation should be chosen with caution in younger patients, in those who have a high probability of requiring continuous vasopressor or inotropic support, and in those undergoing high risk procedures as they have a higher probability of conversion to intubation (OR = 11, 95% CI 8.6–14). This in turn is related to a high risk of occurrence of high severity adverse events during the procedure (27% vs. 2%, $p < 0.001$). On the other hand, low risk patients undergoing DCC procedures have a very low rate of adverse events when managed with spontaneous ventilation.

These findings are useful as they help assessing patients in advance and choose the most appropriate airway/sedation management strategy per their condition and the type of procedure. However, further studies are needed to determine the impact of different airway/sedation management strategies on physiological measurements made during ICP.[5]

Spinal anesthesia can be a very good option for DCC procedures in children at high risk of respiratory deterioration and in preterm infants, as general anesthesia and orotracheal intubation are avoided. This could offer greater hemodynamic stability and less frequent desaturation and hypercapnia as a result of sedation, as other studies have shown.[18] One of the limitations of this type of anesthesia is that it limits the time to perform the procedure, as it is a single dose that can lasts up to 120 minutes, and a booster dose cannot be given.[11]

Ketamine, a drug that is increasingly used in anesthesia and other related fields,[19] is a good anesthetic option for neonates with congenital heart disease, as it does not stop spontaneous ventilation, does not seem to aggravate pulmonary hypertension, and avoids airway manipulation, which is strongly related to perioperative complications.[20] Its use on CHD neonates is open for exploring.

We did not find any study that specifically addressed monitoring recommendations for these patients, apart from non-invasive blood pressure, electrocardiogram, pulse oximetry, capnography, and temperature. However, in his case series, Simpson et al. highlight the advantage of the umbilical vessel approach, which is due to its low incidence of vascular complications in cases of therapeutic procedures.[13] This advantage is not a recent discovery, and it has been demonstrated in other studies with regards to different conditions, specifically in the Neonatal Intensive Care Unit.[21,22]

Conclusion

There are no structured reports, recommendations or perioperative management guidelines for CHD neonates undergoing cardiac catheterization. The series of articles by Bergensen et al. has made an important contribution to the scales for calculation of the risk of complications in that population. However, regarding the AT for neonates with CHD, it is still necessary to obtain, from experience or from expert consensus, specific data with a more extensive development on other topics, such as anesthetic technique, anesthetic drugs and airway management.

Although PRISMA methodology is the recommended one to make systematic literature reviews and clinical practice recommendations derived from the review, in the absence of literature it is not useful at all. In those situations, it could be better to invest efforts on clinical recommendations development following a different methodology such as proposed by GRADE Working Group,[23] that considers both literature and expert consensus to make recommendations. Future works should be directed to that aim.

Conflicts of interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.bjane.2020.06.005.

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