10-21-2011

Current Approaches to Pediatric Heart Catheterizations

Philip A. Bernard
University of Kentucky, philip.bernard@uky.edu

Hubert O. Ballard
University of Kentucky, hoball2@uky.edu

Douglas Schneider
University of Kentucky, douglas.schneider@uky.edu

Right click to open a feedback form in a new tab to let us know how this document benefits you.

Follow this and additional works at: https://uknowledge.uky.edu/pediatrics_facpub

Part of the Pediatrics Commons

Repository Citation
Bernard, Philip A.; Ballard, Hubert O.; and Schneider, Douglas, "Current Approaches to Pediatric Heart Catheterizations" (2011).
Pediatrics Faculty Publications. 154.
https://uknowledge.uky.edu/pediatrics_facpub/154

This Article is brought to you for free and open access by the Pediatrics at UKnowledge. It has been accepted for inclusion in Pediatrics Faculty Publications by an authorized administrator of UKnowledge. For more information, please contact UKnowledge@lsv.uky.edu.
Current Approaches to Pediatric Heart Catheterizations

Notes/Citation Information
Published in Pediatric Reports, v. 3, no. 3, e23, p. 93-96.

©Copyright P.A. Bernard et al., 2011

Licensee PAGEPress, Italy

This work is licensed under a Creative Commons Attribution NonCommercial 3.0 License (CC BY-NC 3.0).

Digital Object Identifier (DOI)
http://dx.doi.org/10.4081/pr.2011.e23
Current approaches to pediatric heart catheterizations

Philip A. Bernard,1 Hubert Ballard,2 Douglas Schneider3
1Department of Pediatrics, Heinrich A. Werner Division of Pediatric Critical Care; 2Department of Pediatrics, Division of Neonatology; 3Department of Pediatrics, Division of Cardiology, Kentucky Children’s Hospital, University of Kentucky, USA

Abstract

Sedation for pediatric cardiac catheterization is a common requirement in many institutions. As the field of cardiac catheterization has evolved, the provision of sedation for these procedures has been varied. Increasingly the demand is for dedicated personnel focused on monitoring and delivery of sedation while in the catheterization suite. This article describes the considerations one must use when undertaking these cases.

Introduction

Modern pediatric cardiac catheterization began with in 1947 when Bing described using catheterization for diagnosis of congenital heart disease. In the ensuing period, echocardiography has become increasingly refined and has supplanted the need for many diagnostic catheterizations. However, interventional catheterizations have increasingly become a mainstay of pediatric care. Pediatric interventional catheterization began in earnest in 1968 with balloon atrial septostomy4 and quickly became a common procedure in pediatric catheterization. Numerous advances occurred in the 1980s and 1990s. Modern pediatric cardiac catheterization can now treat a number of conditions including patent ductus arteriosus, atrial septal defects, ventricular septal defects, collateral vessels, valve stenosis, vessel stenosis, and conduction abnormalities. Increasing minimally-invasive procedures has strained the traditional model of anesthesia-directed care in the operating room environment with a variety of providers now administering anesthesia and sedation for children.2 Pediatric heart catheterizations have increased exponentially in recent years.2 Sedation has traditionally been under the direction of the performing cardiologist. However, the need to have the patient be motionless has increased as the number of interventions has increased. In addition, there is increased recognition that dedicated personnel focused on monitoring of the patient during sedation are associated with improved safety. As the demand for sedation outside of the operating room has increased, a number of providers have gained experience in providing for the sedation and analgesia of these patients. In addition to a number of different provider models, wide variations exist in approaches to sedation regimens.4 The different types of practitioners as well as the special circumstances that accompany congenital heart disease require special emphasis.

Composition of sedation team

A striking variety of practice models exist in pediatric catheterization suites. Depending on the practice setting, pediatric cardiologists, registered nurses, Certified Registered Nurse Anesthetist’s (CRNA), anesthesiologists, hospitalists, pediatric emergency physicians, and pediatric intensivists may perform the primary role of sedation. Regardless of the provider, it is essential that safe and effective sedation be practiced. Debate continues for and against non-anesthesiologists performing these sedations.5,6 Regardless of the team composition, consistency in NPO guidelines, monitoring, and ability for resuscitation must be kept. The reader is referred to excellent general guidelines available through the 2006 American Academy of Pediatric Sedation Guidelines and the 2002 American Society for Anesthesiologists Practice Guidelines for Sedation and Analgesia by Non-Anesthesiologists.8,9

Pre-procedural considerations

Prior to sedation, adequate consideration of a patient’s physiologic status must be undertaken. Important features include underlying physiology, comorbidities and procedure to be performed. Some cooperative patients (older children and adults with congenital heart disease) may be able to have anxiolysis or light sedation and achieve excellent outcomes. Younger children will however require deep sedation (minimal response to painful stimuli) at least initially. The goals of catheterization must be reviewed (Table 1).

Congenital heart disease

Patients with congenital heart lesions are a common group of children undergoing pediatric cardiac catheterization. Understanding of the specific lesion and how hypotension, hypoxia or hypercarbia, and supplemental oxygen alter the patient’s hemodynamics is critical. Volume status changes and afterload alterations can severely alter the physiology of both cyanotic and acyanotic lesions.

Included in the preoperative checklist is a review of the latest echocardiogram, hospital history, and previous surgical procedures. The authors strongly recommend that sedation is undertaken only by practitioners intimately familiar with the cardiovascular physiology of these conditions. Choices such as supplemental oxygen, assisted or mechanical ventilation changes in acid-base status, and alterations of systemic and pulmonary vascular resistance will alter interpretation of diagnostic data.

Interventional catheterization

Interventional catheterizations require special consideration. The technical nature of these procedures demands minimal spontaneous movement. Many interventions are more painful (e.g. aortic angioplasty) than a diagnostic catheterization; requiring substantially more attention to anesthetic needs. In addition, closure devices for atrial septal defects and ventricular septal defects alter the hemodynamics of the patient. Relatively high complication rates are associated with closure devices that alter sedimentation.10,11 The practitioner must be able to rapidly address cardiorespiratory changes in these patients. As with all deep sedations, expertise in airway management and intubation is a must.12

Radiofrequency ablation

The need for sedation has increased as techniques for radiofrequency ablation have advanced. Many of these children have congenital heart disease, in addition to managing the arrhythmia-induced cardiovascular changes that are prerequisite with these patients. These patients also have longer procedure times than other candidates for procedural sedation. Joung et al found that their procedure times for atrial tachycardias averaged 131.0±48.8 minutes. However, they also found that the procedure time was reduced.
when the patient received sedation rather than general anesthesia.13 Concerns that the seda-
tion or anesthesia regimen may alter the con-
duction pathways and invalidate the electro-
physiology study may be exaggerated.14,15

Goals of catheterization
As with any procedure, the sedation tech-
nique will vary depending on the goal of the
procedure. For instance, in a diagnostic catheterization to determine the degree of
reversible pulmonary vascular disease, multi-
ple variables would need to be considered. Hypo-
or hyperventilation, supplemental oxy-
gen, and acid-base status need to be manipu-
lated. Therapeutic agents that alter vascular
tone will ultimately alter the interpretation of
the study.16 The proceduralists must communi-
cate their interventions with particular atten-
paid to the ramifications on the patient’s
hemodynamics.

Sedation regimens
The ideal sedative agent does not exist.

Demerol, Phenergan and Thorazine
Traditionally, agents such as Demerol,
Phenergan, and Thorazine (DPT) have been
used in pediatric catheterizations. Benefits of
its use included oral or intramuscular adminis-
tration. However, variable efficacy and a
marked complication and side effect profile
have been documented. Other oral agents have
been documented to have superior efficacy to
DPT.17 In 2005, the American Academy of
Pediatrics retired its policy on DPT and instead
wrote Neither the combination itself nor its
dosage is based on sound pharmacologic data.
There is a high rate of therapeutic failure as
well as a high rate of serious adverse reactions,
including respiratory depression and death,
associated with its use. Even when it is effect-
tive, DPT appears to lack many of the desirable
characteristics of a sedative for children.

While many practitioners may have experi-
ence and expertise using this combination of
medications, this regimen is likely to have
greater complications and adverse effects than
other regimens. In 2004, a black box warning
was added to promethazine contraindicating
its use in children under 2 years of age second-
ary to the severe adverse-events, including
death. Most practitioners have discontinued
this practice.

Midazolam
Midazolam is a short-acting benzodiazepine
with a large body of evidence in pediatric care.
Among the reason for midazolam’s popularity
is its ability to be given through a variety of
routes, including nasal administration.
Commercially, it is the most commonly used
pediatric premedication for generalized anes-
thesia.18 In the anesthetic setting, premedica-
tion use in children under 2 years of age second-
ary to respiratory depression outside of a fairly nar-
row therapeutic window. Like all of the sedia-
tive regimens listed here, propofol provides no
analgesic activity. In fact, there is some evi-
dence that propofol given in sub-anesthetic
doses induces hyperalgesia.27 In addition,
propofol induces clinically relevant changes in
cardiac index with decreases in afterload and
toe and preload.28

Propofol
The commercial availability of propofol in
1989 brought the ability to induce general anes-
thesia outside of the confines of the operat-
ing room. Expensive inhaled anesthesia
machines and scavenger devices introduced
the concept of safari teams.25 In addition, non-
anesthesiologists became increasingly com-
fortable with this medication and propofol

services were introduced.26

It is important to note there are currently
three preparations of propofol approved for use
by the FDA. One of these preparations uses
benzyl alcohol as its emulsion agent. Infants
have had significant toxicity and even death as
a result of high doses given as a preservative.

Propofol has a number of properties that
make it advantageous over other sedation reg-
imens. It has many, but not all, of the proper-
ties of an ideal sedative drug. It has a pre-
dictable onset of action, a short half-life with a
rapid recovery time, and is easily titratable.
However, propofol is associated with profound
respiratory depression outside of a fairly nar-
row therapeutic window. Like all of the seda-
tive regimens listed here, propofol provides no
analgesic activity. In fact, there is some evi-
dence that propofol given in sub-anesthetic
doses induces hyperalgesia.27 In addition,
propofol induces clinically relevant changes in
cardiac index with decreases in afterload and

toe and preload.28

Prolonged propofol sedation should not
occur in children. In 2001, the FDA issued a
black box warning which reported the results of
a study of 327 sedated patients in pediatric
intensive care units treated with either propo-
fol or standard sedative agents. In this unpub-
lished study, a significantly higher number of
patients died in the propofol arms of the study.
Many speculate that the increased incidence of
mortality may be due to propofol infusion syn-
drome. The syndrome, characterized by a pro-
found metabolic acidosis, rhabdomyolysis, and
ensuing death was first described in chil-
dren.29 The mechanism of action, thought to be
mitochondrial poisoning, has yet to be
elicited. In adults, recent reports show that
even short-term administration of propofol can
cause a metabolic acidosis.30 These findings
are also present in children undergoing card-
diac catheterization (unpublished data –
Turner). Some believe this acidosis may be an
early indication of propofol infusion syn-

Table 1. Goals of catheterization.

| 1. Analgesia, anxiolysis, and amnesia for patient |
| 2. Easy separation from parents at start of case |
| 3. Maintain airway and appropriate ventilation |
| 4. Monitor and maintain appropriate acid-base status |
| 5. Minimize cardiovascular stress on the patient |
| 6. Optimize hemodynamic status before, during, and after the procedure, tailored to the specific physiology of the individual patient |
| 7. Immobilization for precision, particularly when interventions are needed |
| 8. Smooth transition to awake state after procedure, minimizing cardiovascular stress upon awakening (avoiding/minimizing agitation, hypertension, coughing fits, tachycardia, etc) |
| 9. Provide appropriate conditions for obtaining useful cath data (i.e. testing with nitric oxide, valsalva, spontaneous breathing vs positive pressure ventilation, etc) |
In the setting of pediatric catheterization, propofol (usually in combination with an analgesic) has been used with increasing frequency. In practice, PVR remains constant; while SVR decreases. Diagnostic data needs to be interpreted with this in mind as this does decrease shunt ratios. In addition to patients with cardiomyopathies, congenital cyanotic heart lesions may be particularly susceptible to deterioration.

Propofol and ketamine

In an effort to preserve SVR while retaining the positive aspects of propofol (quick onset of action, predictable response, rapid recovery time), some practices have incorporated the addition of ketamine infusions. Ketamine and propofol have opposing influences on blood pressure, heart rate, and SVR. In addition, ketamine supplementing a propofol infusion has been shown to preserve respiratory function and upper airway control in several studies. Recovery times were 20 minutes in a group of children given propofol at 25 ug/kg/min with the addition of ketamine at 12.5 ug/kg/minute.

Dexmedetomidine

Dexmedetomidine is a $\alpha_2$ agonist sedative and mild analgesic approved by the FDA in 1999 which preserves cardiorespiratory function. It has similar actions to clonidine, another $\alpha_2$ agonist. However, dexmedetomidine has a short half-life elimination of 6 minutes and terminal half-life of 2 hours. Although approved for mechanically ventilated adults for periods less than 24 hours, experience is increasing in using this medication in children. Over 2300 sedations have been reported to the pediatric sedation research consortium (Berkenbosch – unpublished data).

Munro et al sedated 20 children for cardiac catheterization with dexmedetomidine. Patients were given 1 ug/kg loading dose over 10 minutes followed by an infusion of 1 ug/kg/hr. Of these 20 patients, 12 patients required a bolus of propofol for movement, increasing BIS values, or prior to stimulation. The patients had stable hemodynamics throughout.

Tosun et al. compared the combination of dexmedetomidine-ketamine to propofol-ketamine in 44 patients. Two regimens were compared:

1. dexmedetomidine 0.7 ug/kg loading dose over 10 minutes followed by an infusion of 1 ug/kg/hr and ketamine 1mg /kg bolus with 1 mg/kg/hr infusion
2. propofol 1mg/kg bolus followed by an infusion of 100 ug/kg/min and ketamine 1 mg /kg bolus with 1mg/kg/hr infusion

In the Tosun study, patients on the dexmedetomidine regimen required more supplemental doses of ketamine for discomfort. No differences in side effects were noted, including hypotension. In addition, recovery times were significantly longer (45 v. 20 minutes; $P=0.01$)

To date, no studies have been performed which examine the effects of dexmedetomidine alone or in combination with other sedatives on pediatric catheterization data including SVR and shunt ratios.

Etidomide

Etidomide is another medication, which has recently fallen out of favor. Documentation of adrenal axis suppression as well as painful induction has decreased its usage in intensive care settings. However, in some institutions, its favorable hemodynamic profile has made it a common medication among children with reserved hemodynamic function. Sarkar et al. examined the hemodynamic responses to 12 children undergoing pediatric cardiac catheterization for ablation of supraventricular tachycardia or ASD closure. There were no significant changes in hemodynamic profiles in these children.

Analgesics

Control of pain is an essential component to a well-performed sedation. The provision of sedative agents does not provide for pain relief. Some agents (e.g. propofol) have hypergesic properties. This must be tempered with the realization that the addition of opioid agents may act synergistically other sedative agents. Topical agents such as EMLA and LMX-4 as well as subcutaneous local anesthetics can dramatically decrease the need for systemic agents. Many our patients require minimal sedation following administration of local lidocaine and catheter insertion. Some older patients may tolerate a catheterization with minimal sedation if their pain needs are cared for.

Special considerations

Regardless of the sedation regimen implemented, pediatric cardiac patients have unique characteristics that need to be acknowledged. For example, the addition of supplemental oxygen can dramatically alter cardiac output, as well as after the interpretation of catheterization data. Alterations in ventilation with positive pressure, hypo- or hyper-ventilation may alter pulmonary blood flow, again leading to data that may be difficult to interpret.

Consideration must be taken into the length of the procedure. Recent reports highlight the potential deleterious effects of sedatives such as ketamine, propofol, and midazolam on the developing brain. As the length of the procedure increases, attention to metabolic substrates (i.e. glucose), environmental stresses, temperature regulation, and pulmonary toilet must be addressed. Coordination of the sedation procedures with the cardiologist is a must to ensuring optimal outcomes.

Post-sedation care is a continuation of the procedure. Qualified personnel, trained in resuscitation from deep sedation and general anesthesia, as well as knowledgeable of congenital heart defects, should monitor these patients until ready for ultimate disposition.

Conclusions

Advances in pediatric catheterization have increased the demand and complexity of patients undergoing these procedures. This patient population presents unique challenges due to the large variability of their underlying anatomy and physiology. Sedation regimens are varied, with importance to the hemodynamic profile of the patients. Dedicated sedation teams are a necessary requirement to optimal performing catheterization labs.

References