

## Digby Leigh Lecture - Anesthesia-Related Cardiac Arrests in Pediatrics

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The attendees will

- 1) understand the changing causes of anesthesia-related cardiac arrest over the last 20 years
- 2) be updated on current etiologies of anesthesia-related cardiac arrest in pediatric patients
- 3) learn prevention strategies for anesthesia-related cardiac arrest

The etiology of cardiac arrest in the pediatric patient has changed over the past 20 years as practice has evolved in the care of these patients. The Pediatric Closed Claims Study in 1993 showed respiratory events were the most common category accounting for 43% of claims with inadequate ventilation seen in half of the respiratory events. The typical profile in this category of inadequate ventilation were healthy, non-obese children breathing halothane spontaneously whose arrest was preceded by hypotension or bradycardia. These children were difficult to resuscitate successfully, 70% died and 30% had permanent central nervous system impairment. Pulse oximetry was used in 7% of the Closed Claim cases and capnometry in 5%.<sup>1</sup> Recently the Pediatric Perioperative Cardiac Arrest (POCA) Registry has provided some new data. Out of 1,089,200 anesthetics, there were 150 cardiac arrests which were deemed anesthesia related (1.4/10,000).<sup>2</sup> Several points are relevant in analysis of this data.

First, an increased incidence of cardiovascular causes (32%) have differed from the Pediatric Closed Claims Study in 1993 where only 13% were from cardiovascular causes. This may have some basis in the fact that using chest compression was necessary as entry criteria for the POCA Registry or the fact that the use of pulse oximetry in 98% and capnography in 86% of cases may be more effective in preventing respiratory than cardiovascular incidents before arrests occur. Most of the cardiac arrests (82%) occurred during induction or maintenance of anesthesia. Bradycardia (54%), hypotension (49%), abnormality of SpO<sub>2</sub> (46%) or inability to measure blood pressure (25%) were the most common antecedent events. Twenty-one percent of arrests occurred during emergency surgery.

Second, infants are at increased risk. Infants <1-year accounted for 55% of the anesthesia related cardiac arrests. Several pediatric studies have confirmed that infants <1-year have the highest anesthetic risk and that mortality is inversely proportional to age with the highest risk in the <1 month of age group. This may be notably related to a higher ASA Physical Status (PS) Classification with underlying patient disease (particularly congenital heart disease) but also to cardiovascular depression by inhalational agents. In infants <30 days of age the MAC of halothane is .87%, as compared with children 1-6 months of age - MAC of 1.08. With isoflurane, the MAC for preterm infants (<32 weeks) is 1.28, 32-37 weeks is 1.41, and for term (0-1 month) 1.60, with 1-6 months being 1.87. Only sevoflurane appears to be different with the MAC being constant at 3.2-3.3% for neonates and infants less than one month, decreasing to 3% at 1-6 months, and 2.5-2.8% for 7 months - 12 years.

Recent studies show sevoflurane may be less of a myocardial depressant and have less potential for producing bradycardia than halothane in infants. Sevoflurane may also be safer for use in children with congenital heart disease (CHD). In comparison with children receiving halothane, the halothane treated patients experienced twice as many episodes of severe hypotension as those who received sevoflurane. Recurrences of hypotension occurred despite increased vasopressor use in the halothane as compared to the sevoflurane treated patients. Risk of hypotension was increased in children less than one year of age compared with older children and patients with preoperative cyanosis had a higher incidence of developing severe desaturation with halothane. Thus sevoflurane may have hemodynamic advantages over halothane in infants and children with congenital heart disease. Another area of concern in relation to inhalational agents is if a patient is intubated without muscle relaxants twice the dose of inhalational agent is needed in 95% of children, which will cause myocardial depression.

Third, 33% of all anesthesia related cardiac arrests occurred in previously healthy ASA PS 1 and 2 patients - mostly medication-related errors (64%). Fifty percent of the arrests caused by halothane cardiovascular depression were seen at inspired concentrations of 2% or less with the median age being 6 months. Controlled ventilation may accelerate the rise in halothane concentration compounded by prolonged exposure due to difficult intravenous access. Four cases of arrest occurred following probable intravascular injection of local anesthetics. These occurred during combined halothane and caudal anesthesia with injection of 0.25% bupivacaine with 1/200,000 epinephrine despite negative test dose and aspiration. They occurred when both needles and catheters were used to deliver the medication. All had ventricular arrhythmias but were successfully resuscitated without injury.

Mortality rate in ASA PS 3-5 patients was 37% compared to 4% in ASA PS 1-2 patients. ASA PS 3-5 was the strongest predictor of mortality followed by emergency status. Overall mortality rate in all arrests was 26%.<sup>2</sup>

Since publication of the initial series 397 additional cases have been submitted to the POCA Registry and 49% of these arrests were related to anesthetic causes. In the data from 1998-2004, the profile has changed. Medication related causes have declined from 37% to 18% of the total due to the decline of cases of cardiovascular depression from inhaled agents. Respiratory causes have increased from 20% to 27% the most frequent etiology being laryngospasm. Cardiovascular causes of arrest increased from 32 to 41%. Hypovolemia (often from hemorrhage) or the metabolic consequences of massive transfusion (usually hyperkalemia) were the most frequent known cause of arrest in this category. The exact cause of arrest could not be determined in some cases in the cardiovascular category – frequently these were children with congenital heart disease and an ASA physical status 3-5. Equipment problems have stayed fairly constant as a cause of arrest in pediatric patients being 7% in 1994-97 and 5% in the 1998-2004 data.

The demographic profile since 1998 has changed the percentage of ASA physical status 1 and 2 decreased from 33% to 25% and the percentage of patients less than 1 year of age decreased from 56 to 38%. This may be due to a decreased incidence in the number of arrests reported due to inhalational agents. These arrests were more likely to occur in ASA physical status one or two patients who were less than 1 year of age. The mortality rate in the two time periods hasn't changed, being 26 and 28% respectively.<sup>3</sup>

New data looking at 92,881 patients in a tertiary care referral center between 1998-2005 the incidence of anesthesia-related cardiac arrest was 0.65/10,000 anesthetics. Both cardiac arrest incidence and mortality were highest among neonates (0-30 days of life) undergoing cardiac procedures. Most patients who experienced perioperative CA (88%) had congenital heart disease.<sup>4</sup>

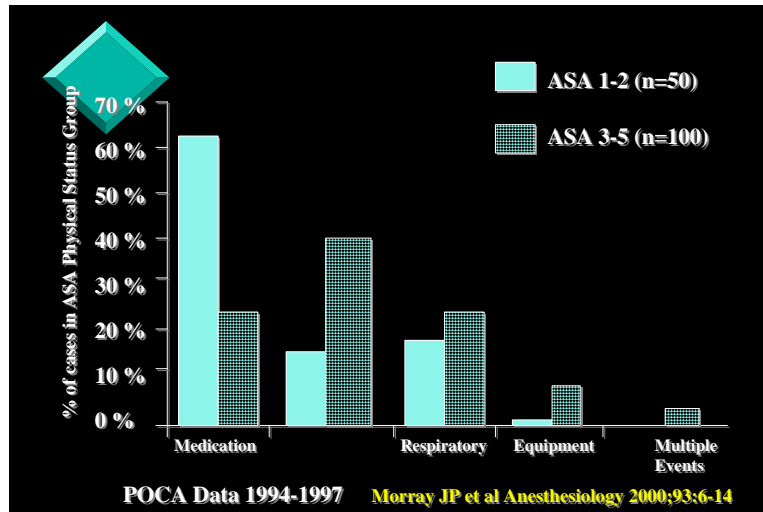
The frequency of anesthesia-related cardiac arrests in patients with congenital heart disease undergoing cardiac surgery was 27.1/10,000 anesthetics with no mortality. Cardiac arrest was highest in the neonates.<sup>5</sup> In a Brazilian tertiary care hospital with 53,718 anesthetics over a 9 year period the incidence of anesthesia-related cardiac arrest was 3.35/10,000 and anesthesia-related deaths 0.56/10,000. Major causes of cardiac arrest were airway management and medication administration errors. Major risk factors were neonates and children <1 yr (prematurity and CHD were factors) and emergency surgery.<sup>6</sup> A final study from an academic pediatric medical center looking at 105,436 procedures (except cardiac cath) over a 5-year period reported an incidence of 2.67/10,000 cases. Risk factors included ASA physical status  $\geq 3$  and children less than 1 year of age. Those providers that spent  $\leq 40\%$  of time in the OR also indicated a risk factor.<sup>7</sup>

Prevention strategies should include:

1. Inhalational agent choice - newer inhalational agents and improved monitoring may have already made a difference
2. Local anesthetics with less potential for toxicity – ropivacaine
3. Regional techniques that include aspiration for blood, test dose and incremental not bolus injection
4. Succinylcholine – limited use to rapid securing of the airway and treatment of laryngospasm
5. Adequate intravenous lines and keeping up with intraoperative blood loss
6. Prevention of hyperkalemia during transfusions – (beware old irradiated blood) and with succinylcholine use
7. Laryngospasm – early treatment and having an IV in place can be helpful
8. Safer techniques for CVP placement – Use of 2D US/Doppler
9. Put high risk children in experienced hands

#### References

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### POCA Data 1998-2004

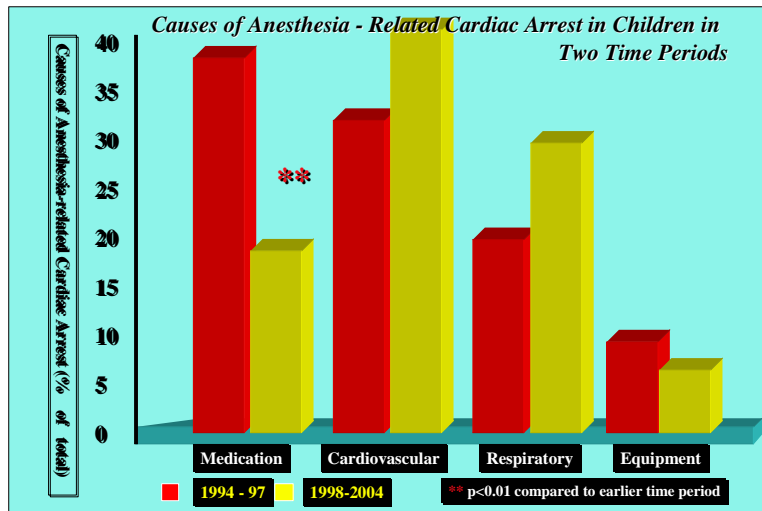
- ❖ 397 new cases from 80 institutions- 193 (49%) are anesthesia-related
- ❖ Medication-related causes decreased from 37% to 18%
  - Near disappearance of cardiovascular depression of inhalational agents
- ❖ Cardiovascular causes increased from 32% to 41%
  - Hypovolemia (often from hemorrhage-spine fusion or craniotomy/craniectomy) or metabolic consequences of massive transfusion(usually hyperkalemia) or hyperkalemia from succinylcholine use

*Bhananker SM et al. Anesth Analg 2007;105:344-50*

### POCA Data 1998-2004

- ❖ Respiratory-related causes increased from 20% to 27% -most frequent cause is laryngospasm
- ❖ Equipment-related causes increased from 7% to 5%, mostly in ASA PS III-V patients related to complications from CVP placement

*Bhananker SM et al. Anesth Analg 2007;105:344-50*



## **Prevention of Cardiac Arrest-1**

- ❖ Inhalational agents-newer inhalational agents and improved monitoring may have already made a difference
- ❖ Local anesthetics with less potential for toxicity - ropivacaine
- ❖ Regional techniques that includes aspiration for blood, test dose and incremental not bolus injection
- ❖ Succinylcholine- limit use-rapid securing of the airway and treatment of laryngospasm

## **Prevention of Cardiac Arrest-2**

- ❖ Adequate intravenous lines and keeping up with intraoperative blood loss
- ❖ Prevention of hyperkalemia during transfusions -(beware old irradiated blood) and succinylcholine use
- ❖ Laryngospasm- earlier treatment and having an IV in place can be helpful
- ❖ Safer techniques for CVP placement- Use of 2D US/Doppler
- ❖ Put high risk children in experienced hands