

INDUCTION OF ANAESTHESIA IN PAEDIATRIC PATIENTS

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Introduction

Induction of anaesthesia in children is achieved with broadly the same anaesthetic agents and techniques as are used in adults. However, there are some important differences in the pharmacology of the agents available when comparing adults and children. Also, the technical difficulties that are associated with small size and the psychological and behavioural issues due to immaturity may make induction of anaesthesia more challenging in the child compared to the adult.

Paediatric anaesthesia has been the subject of this journal before.¹ Analgesic methods in children have also been discussed.² In this short paper, the pharmacology of the induction agents will be covered. The different methods available for inducing anaesthesia will be discussed and the merits of each method compared. Techniques that are specifically designed to overcome difficult situations relevant to paediatric anaesthesia will be discussed.

There are several methods of anaesthetic induction: Gaseous induction, breathing a mixture of volatile anaesthetic agents until loss of consciousness is achieved; Intravenous induction, where an anaesthetic drug is injected intravenously in a dose sufficient to produce unconsciousness; Other, where an induction agent is given by a non-intravenous route, generally orally, rectally or intramuscularly, to produce loss of consciousness.

Pharmacology - the intravenous agents

Sodium Thiopentone. First introduced in the 1930's, this barbiturate has been the mainstay of intravenous induction ever since. It is also known as pentothal or Nembutal. It is supplied as a yellow powder mixed with sodium carbonate and is dissolved in water before use. Solution in water results in an alkaline pH. The concentration in water is important as pain free injection is only reliable with a dilute solution (2.5% or 25mg/ml or less). The solution may result in severe tissue necrosis if injected extravascularly and this is worse with the more concentrated solutions. The induction dose of thiopentone is between 4-6 mg/kg in adults and 5-7 mg/kg in infants and children. Induction of anaesthesia is rapid and generally accompanied by minimal excitatory effects such as involuntary movement or hiccupping. Thiopentone is protein bound and highly lipid soluble. It's effect on the central nervous system, unconsciousness, is terminated by redistribution of the drug which results in recovery of consciousness about 5 minutes after induction by a single dose. If repeated doses are administered, recovery may be significantly prolonged. The drug is metabolized by the liver but the efficiency of this process has little bearing on the anaesthetic duration of action. Children handle thiopentone slightly differently from adults. The induction dose is higher. The elimination half time is reduced and this means that "hang-over" after thiopentone induction, is much less of a problem in children than in adults. When used clinically, anaesthesia is induced rapidly after injection. There is generally

a short pause in respiration, but this rarely lasts more than a few seconds. Respiration then resumes and a volatile agent may be introduced whilst the patient is spontaneously breathing. Heart rate generally rises slightly on injection but there is vasodilation and a drop in cardiac output. This is clinically significant in hypovolaemic patients and those with intercurrent medical conditions but in otherwise healthy patients, is well tolerated. Cardiovascular compromise is less marked than with propofol. Hypersensitivity (allergy) is rare but generally very serious. The risk of anaphylaxis is quoted at 1:50,000 administrations but may carry a 50% mortality. The major specific contraindication is porphyria.

Propofol is a non-barbiturate intravenous anaesthetic agent introduced in the 1980s. It is presented as an aqueous solution in soya oil and egg phosphatide. In a dose of 2.5-4mg/kg, it rapidly induces anaesthesia. In this dose, excitatory movement is common and it is now common practice to use a higher dose in unpremedicated children. Typically, 4mg/kg is administered as a bolus, followed by aliquots of 0.5-1mg/kg to allow a smooth transition from propofol anaesthesia to a vapour based anaesthetic. Even in higher doses, there are more excitatory and involuntary movement than with thiopentone. Unlike thiopentone, repeat doses may be given without unduly affecting the quality of post-operative recovery. Indeed, it is used as a sedative for medium to long term use in the intensive care unit (not in children). An induction dose causes a more prolonged pause in respiration than thiopentone. With higher induction doses, this pause becomes longer and in clinical use, apnoea is frequently produced with this agent. Airway reflexes are depressed after an induction dose and it is said that airway instrumentation is facilitated more using this drug than with alternatives. The cardiovascular effects are dose dependent but a reduction in blood pressure is seen. In the hypovolaemic, this may be profound and dangerous. This effect is greater than with equivalent doses of thiopentone. Although less irritant than thiopentone in the event of extra-vascular injection, the chief disadvantage to the use of this agent in children is pain upon injection. This pain is quite severe and detracts from a smooth induction. It may be alleviated, but not prevented, by the co-administration of lignocaine in a dose of 1mg lignocaine/ml of propofol 1% solution. Propofol infusion syndrome may result if propofol, in high doses, is infused over long periods of time in children who are critically ill. Whilst the mechanism of this syndrome is not completely clear, it appears that this is a safe drug for use as an induction agent in children but it is not licensed as a intravenous sedative in children. In the UK, propofol costs three times more than equivalent dose of thiopentone.

Etomidate is a non-barbiturate induction agent that is used in doses of 0.3-0.4 mg/kg. It's use results in less cardiovascular depression than thiopentone and there is little or no depression in the respiratory rate or depth. It is associated with considerable

involuntary movement after injection and this makes induction much less “smooth” than with other agents. Etomidate is associated with pain on injection. Etomidate inhibits the synthesis of steroids by the adrenal gland and this finding has been used to explain a high mortality noted when this agent was used for sedation of young children on intensive care. Concern over its inhibition of steroid synthesis, pain on injection and practical considerations relating to movement on induction have resulted in unpopularity of this drug for paediatric induction.

Ketamine is a non-barbiturate intravenous anaesthetic with many unusual and useful properties. Although anaesthesia is induced after an 2mg/kg intravenous injection, the presence of movement, opening of eyes and maintained respiration mean there is no clear “end-point” and it appears that induction is more prolonged than with thiopentone. However, there is preservation of heart rate and blood pressure at normal or supra-normal levels. Respiration is maintained at a higher rate and tidal volume. There is some preservation of airway reflexes during anaesthesia with this agent. The protective airway reflexes and increased respiration has led to the popularity of this drug in circumstances where it may be used as a single agent, perhaps with limited access to anaesthetic equipment. However, it must be acknowledged that with overdose, airway reflexes may be lost and respiration depressed and oxygen must always be available for its safe use. An advantage to this drug is the versatility in the manner in which it may be given. Ketamine may be administered via the intravenous, intramuscular, rectal and oral routes. Drawbacks to its use are excessive salivation and unpleasant dreaming. Excessive salivation may be improved with the use of an antisialogogue such as atropine. The dreaming may be reduced by co-administration of a benzodiazepine. Ketamine is relatively inexpensive.

Benzodiazepines. Midazolam and diazepam injection have been used as induction agents. The dose of each member of this class of drugs is very variable. Thus a dose of 0.05 to 0.5mg/kg of midazolam may be required to induce sleep. The time to peak effect is much longer than other induction agents and most anaesthetists find the best use for this class of drugs is as a pre-medicant. As a pre-medication, midazolam is widely used. It is given orally at a dose of 0.5-0.75mg/kg. It rarely produces deep sleep but renders a child placid and co-operative. Further it provides useful amnesia. Studies have demonstrated that midazolam may be used as premedication before day case surgery without delaying discharge.

Pharmacology - volatile agents used for gaseous induction

Ether. The original volatile anaesthetic agent and still much in use world-wide, the high solubility and irritant nature of this agent means it is not an easy induction method in children. Due to the difficulties encountered in obtaining other drugs and equipment, it is still used as a sole anaesthetic in many places but will not be discussed further here.

Halothane was introduced in the 1950s and rapidly became popular for maintenance and volatile induction of anaesthesia in both adults and children. It is administered through a dedicated vaporizer into a carrier gas. It has a MAC of 1.1% in infants and 0.6 in the elderly. The smell is non-irritant and not unpleasant.

The most common method of inducing anaesthesia with halothane is to start with the patient breathing the carrier gas which might be a mixture of oxygen and air or nitrous oxide. Halothane is introduced at 0.5% and then the patient breathes 5 normal breaths, the concentration is increased by 0.5% for another 5 breaths until 5% halothane is reached. Once unconsciousness is produced, the concentration may be reduced to an appropriate level. Halothane is a respiratory depressant and tidal volume is reduced. Respiratory rate may actually be increased a little during halothane anaesthesia but the response to hypoxia or hypercarbia are attenuated. However, these effects are to a lesser extent than with other volatile agents with the exception of ether. The principal disadvantage of halothane is its potentiation of the arrhythmic effects of catecholamines on the myocardium. Arrhythmias, particularly ventricular arrhythmias, are more common with this agent than with other volatile agents. Hypercarbia causes release of catecholamines from the adrenal gland and the combination of mild airway obstruction, hypercarbia and halothane are a frequent cause of arrhythmia under anaesthesia. Usually, these are benign and respond to correction of the airway obstruction but in the presence of administered adrenaline (by sub-cut injection) these arrhythmias may be dangerous. Post exposure hepatitis has been reported with halothane and extensively investigated. Its occurrence in children is not clear but is certainly very rare indeed.

Enflurane and isoflurane are both more pungent than halothane and have no advantages for gaseous induction of anaesthesia

Sevoflurane has been used in Japan since the 1970s. It is a volatile agent with a MAC of 2.3 in infants and 1.8 in adults. Its major advantage is that it has a smell which is non-pungent and it is possible to induce anaesthesia with high concentrations from the outset. It has no arrhythmogenic effect. When compared to halothane, higher concentrations may be used earlier in induction, without complaint. Therefore, it appears to cause a swifter onset of anaesthesia. A disadvantage is that it is a more potent respiratory depressant than halothane and therefore, breath holding may occur before a truly deep stage of anaesthesia is reached. For this reason, some anaesthetists prefer halothane to sevoflurane when performing gaseous inductions for airway obstruction. The other major disadvantage to this agent is its high cost.

Induction of anaesthesia

Gaseous induction of anaesthesia. Anaesthesia is commonly induced in infants and children by means of a “gas induction.” This is less commonly the case with adults, leading some anaesthetists to be unfamiliar or lacking in confidence with this method. Children, understandably, are reluctant to have a “needle” to put them to sleep. Many are aware of an alternative and will prefer this method. Infants may be very hard to cannulate prior to an intravenous induction, meaning that a gas induction becomes preferable. In nearly all cases, anaesthesia will be induced without an intravenous cannula in place and intravenous drugs will be hard to administer, particularly if the anaesthetist is working single handed.

Neonates may lie on the operating table and breathe from an anaesthetic mask attached to a T piece, or similar, low resistance

anaesthetic circuit. Older children will, if adequately informed, frequently behave very well and will lie on the operating table and accept a gas induction. Between these age groups, the skill of the anaesthetist must be fully employed to ensure a smooth induction. Infants and young children are often very reassured by the presence of a parent in the anaesthetic room. This may not be possible in some circumstances but if feasible, pays dividends. With the presence of a parent, the child may receive a cuddle whilst having a gas induction. An older child may be persuaded to co-operate by a parent. Various games may be employed to distract children enough for them to receive a gas induction. "Blowing up the balloon" will be familiar to most anaesthetists and is a very effective way of persuading children to "breathe the gas." Another useful technique is to use a strong smelling food substance and rub it in the face mask. Orange peel is a useful way of disguising anaesthetic gases. If rubbed on the mask, a "guess the fruit" game can be enjoyed whilst the child goes to sleep. Clear plastic face masks alleviate the claustrophobia associated with the black rubber face masks. If halothane is used, care should be taken to move up the concentrations incrementally, taking plenty of time to allow the child to breathe comfortably. Increasing the concentration too fast results in coughing. Many anaesthetists prefer to use 70% nitrous oxide before adding halothane as this means the patient is already partially anaesthetized before smelling the halothane. Sevoflurane is more forgiving in this respect. Once the patient is asleep, most anaesthetists switch to 100% oxygen as a carrier gas.

Once the child is asleep, any parents present should be invited to leave. A pulse oximeter may be applied if it has not already been positioned. The child should be disturbed as little as possible. Once asleep, the patient goes through an excitatory phase. If the child is moved about, for instance, to remove clothing, this is often the stimulus that provokes airway reflexes. The anaesthetist should continue holding the face-mask and child's airway, maintaining a clear airway and good ventilation using oxygen and a high concentration of volatile anaesthetic agent, until a deeply anaesthetized state is reached. At this point, the child may be moved to insert an iv cannula, to undress them, to apply other monitoring and to facilitate surgery. If an iv cannula is needed, this is the time to insert it. If a tourniquet is used, the insertion of an iv cannula may be achieved one handed whilst the anaesthetist holds the face mask. However, with harder subjects, another pair of hands, to hold the airway or perhaps, to cannulate the patient, will be invaluable.

The obvious question is what to do about any adverse events that occur before an iv cannula is inserted. The answer is that, with the exception of airway obstruction, all other problems are exceptionally rare. With the anaesthetist holding the patient's airway, he is ideally placed to diagnose and treat airway obstruction as it occurs. Hypoventilation is noted by decreased excursion of the breathing reservoir bag. Airway obstruction may be revealed by noisy breathing or increased work of breathing (increased chest excursion with decreased bag excursion). Normally, correcting the position of the patient's head corrects hypoventilation. Noisy breathing is often due to upper airway collapse during expiration and a small amount of continuous positive airway pressure (CPAP) will resolve it. This is generally

applied by keeping tension on the reservoir bag with one hand. If hypoxia occurs, as evidenced by the pulse oximeter trace or by cyanosis, check that a maximum concentration of oxygen is being given. Increase the CPAP. Occasionally, an oro-pharyngeal airway is helpful but care should be taken that this is not inserted at too light a plane of anaesthesia. It is rare that serious laryngospasm can not be overcome with patience, CPAP, 100% oxygen and correct positioning. If the situation does not resolve consider other causes of airway obstruction and consider applying suction to the pharynx to clear any secretions which may be lying around the larynx. If it becomes necessary to paralyse the patient, after they are asleep, but before an intravenous cannula may be inserted, remember that suxamethonium may be given intramuscularly (5mg/kg) and will work within 2-3 minutes. Many anaesthetists prefer to intubate patients once they are deeply anaesthetized with a volatile anaesthetic agent alone. It has been advocated that suxamethonium may be given intramuscularly into the tongue. I have no personal experience of this. My feeling is that it might render a difficult airway worse by adding intra-oral bleeding to the clinical picture. I have no evidence for or against this route being any faster, or slower, than into any other muscle.

There are some circumstances when inhalational anaesthetic induction is not the method of choice. If a child already has a cannula in situ, perhaps for maintenance fluid therapy, then it is more appropriate to use this cannula. Many children express a preference for intravenous anaesthetic induction. Also, there are numerous occasions where a rapid sequence induction is indicated and here, inhalational induction is completely inappropriate.

Intravenous induction

The main problems with intravenous induction are pain on insertion of the cannula, a natural aversion of children to "needles" and difficulty in insertion. These are all relevant to adults but here we may reason with our patients and explain why it is necessary and why the cannula may be hard to place.

Children as young as five may well understand the reasons behind needing a cannula and may even understand that sometimes it is not easy to insert them and a second go might be required. Whatever the reasoning powers of the child, the whole process may be made much pleasanter by the application of topical anaesthesia to prevent the child feeling the cannula needle. EMLA (eutectic mixture of local anaesthetics) takes about one hour to become effective. If placed over a cannulation site for an adequate amount of time, it is very effective. Amethocaine gel works faster. Unfortunately, these drugs are not uniformly available and sometimes, the only sensible plan is to explain why a cannula is needed and to use the smallest gauge possible. If nitrous oxide is available, the child may breathe a mixture of nitrous oxide and oxygen whilst the cannula is inserted but this technique often seems to combine the worst aspects of both intravenous and inhalational techniques, the child getting a "nasty mask" and a "horrible needle!"

Insertion of a venous cannula may be easy if the veins are obvious. Sometimes, this is a difficult procedure. The task is harder when the child has a large amount of subcutaneous fat, a common situation in toddlers. Veins become smaller in cold, dehydrated and frightened children. A warm, well hydrated, comfortable child

should be our aim and parental presence or pre-medication may well help.

After insertion of an intravenous cannula, suitable monitoring can be attached and an intravenous induction agent injected. The choice of agent is described above but in a healthy child, the normal choice is between sodium thiopentone and propofol. Propofol undeniably results in less "hang-over" in the post-operative period. However, after one hour, this difference between sodium thiopentone and propofol becomes very subtle in children. Pain on injection is a considerable problem, especially when we have gone to such lengths to secure painless venous access. Therefore, unless immediate post-operative discharge is needed, my preference is still for sodium thiopentone. This drug is injected as a single bolus of 5-6 mg/kg, the child painlessly goes to sleep and after the briefest pauses, begins to breathe. Maintenance with a volatile agent may then be substituted without having to recourse to a period of positive pressure ventilation, with a bag and mask, as generally is the case when propofol is used.

Rapid sequence induction

The indication for a rapid sequence induction is the same in adults and children. If a risk of aspiration of gastric contents is foreseen, a rapid sequence induction should be performed.

The procedure for this is the same in children as in adults. A working intravenous cannula is mandatory. The patient should be monitored and positioned on a tilting trolley with suction readily available. Oxygen is administered via a close fitting mask for 3 minutes and anaesthesia induced. As the induction agent works, an assistant applies cricoid pressure to the cricoid ring, with one hand supporting behind the patient's neck. This manoeuvre seals the oesophagus and prevents material from the stomach and oesophagus reaching the pharynx. The traditional agents are sodium thiopentone 5mg/kg and suxamethonium 2-3 mg/kg.

In practice, this procedure presents several problems and it is rare to achieve such good pre-oxygenation in a child as with an adult. Good rapport and explanation works for middle sized children but in the younger or less co-operative, three or four good screams into the oxygen mask is often all that can be

managed. In this situation, it seems sensible to delay administration of the short acting depolarizing muscle relaxant until a few breaths of oxygen are taken. In this technique, an attempt is made to pre-oxygenate the child pre-induction. The thiopentone is administered and sleep induced. Cricoid pressure is applied and the mask closely applied. The child should take a breath quite soon after the thiopentone and once this is seen, suxamethonium administered. The suxamethonium is effective more quickly than in adults at this dose.

A difficult situation is the child with a full stomach, needing emergency surgery, who can't be cannulated. Although not ideal, I think the most practical way forwards here is to induce anaesthesia by volatile induction with the patient in the lateral position. Once anaesthesia is induced, it should be easier to secure intravenous access, apply cricoid pressure, turn the patient supine and perform intubation.

Other means of induction of anaesthesia

In rare instances, induction of anaesthesia is most appropriately conducted using ketamine. Ketamine may be given intramuscularly using a tiny needle and then reliably induces anaesthesia if used in a dose of 7.5mg/kg. Anaesthesia onset takes about 5 minutes. The intramuscular route seems more reliable than the oral route, for which, the dose range quoted in the literature is very wide.

Conclusion

The debates over which drugs and which methods are "best" to use to anaesthetize infants and children are popular at meetings of paediatric anaesthetists. The fact that these debates occur indicates that there are no answers. The skilled, confident anaesthetist, who is prepared to react flexibly and to adopt methods to suit the opportunities presented by a child and it's parents, will have most success.

References

1. Update in Anaesthesia: Issue 11 (2000) Article 14
2. Update in Anaesthesia: Issue 12 (2000) Article 9