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Ketamine

A safe and effective anesthetic agent for children in the developing world

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Abstract Ketamine is used extensively in the developing world (DW) because of its effectiveness, availability, relatively low cost, and presumed safety. This report is a prospective, objective assessment of the efficacy and safety of ketamine when used as the sole anesthetic agent in a general medical practice hospital in the DW in children less than 16 years of age undergoing nonemergent operative procedures. Children undergoing laparotomy, thoracotomy, or craniotomy were excluded. Data analysis included serial arterial hemoglobin saturation (SpO_2) and pulse rate, amount of ketamine utilized, adequacy of anesthesia, and perioperative complications. One hundred thirty-one children undergoing a total of 210 anesthetics were studied. The level of anesthesia was adequate in all cases. The SpO_2 dropped below 90% in 40 (19%) children, below 85% in 25 (12%), and below 80% in 13 (6%). SpO_2 drops occurred significantly ($P = 0.004$) more often after IM than after IV injection. All drops in SpO_2 were abrupt without premonitory signs. Thirty-three (82.5%) of these 40 children responded readily to airway manipulation with a jaw thrust, and only 7 (3.3% of the total series) required face-mask O_2. None required intubation or positive-pressure ventilation. Transient laryngospasm occurred in 1 child, but there were no other complications. In particular, there was no mortality, apnea, emesis, excessive salivation, or significant early or delayed emergence phenomena. Ketamine is quite effective when used as the sole anesthetic agent in DW children. It is relatively safe, but hypoxemia may go undetected unless technologically sophisticated monitoring equipment is available. Proper suction and ventilatory support equipment should be readily available prior to ketamine injection. The first step when hypoxemia is detected is simple airway manipulation, followed by oxygen administration by face mask if needed. Rarely will intubation be indicated. Ketamine is also a good drug for the management of pediatric emergency department procedures in the United States, but all children in these more developed centers should be monitored with a pulse oximeter, since a significant number of children have a precipitous drop in SpO_2.

Key words Ketamine · Pediatric anesthesia · Pulse oximetry · Developing countries

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Introduction

Ketamine, a dissociative anesthetic agent, was first administered to a human volunteer in 1966 [1]. It has since acquired a unique, although controversial, place in clinical practice [12, 16]. It was quickly rejected in Britain, where it was described as a "disaster," and it has subsequently taken many years to realize that ketamine, although not the ideal nonhypotensive substitute for thiopental, is indeed a valuable drug for use in selected situations. There has been a recent increase in interest in the use of ketamine in the United States to facilitate a variety of procedures performed by emergency physicians on pediatric patients in emergency department situations [3, 4].

Ketamine, a potent anesthetic and analgesic agent, can be used safely without intubation since most children retain their protective pharyngeal and laryngeal reflexes. Salivary and tracheobronchial secretions are, however, markedly increased, and prophylactic administration of an antisialogogue such as atropine is mandatory. Ketamine does not usually cause hypotension and, in fact, often increases the blood pressure. It has a relatively rapid recovery period with a low incidence of significant emergence phenomena in children.

Ketamine is currently the most commonly utilized pediatric anesthetic agent in the developing world (DW) because of its safety, effectiveness, availability, and relatively low cost [7, 8, 12, 16]. At the Baptist Medical Centre in Ogbomoso, Nigeria, we have used ketamine as the sole agent or combined with diazepam in over 5,000 pediatric operative procedures and have concluded on the basis of this extensive but undocumented experience that it is very effective and safe.

This report describes a prospective assessment of the efficacy and safety of ketamine when used as the sole anesthetic agent in children in a general medical practice hospital in the DW. The purposes of this study were to assess the safety of ketamine so that health care institutions without sophisticated monitoring capabilities can better understand the potential risks associated with its use as an anesthetic and to acquaint Western-trained surgeons who are planning to work in the DW with a valuable anesthetic technique.

Materials and methods

All children less than 16 years of age undergoing nonemergent procedures were given ketamine as the sole anesthetic agent and studied prospectively after obtaining parental consent. Children undergoing laparotomy, thoracotomy, and craniotomy were excluded since the standard anesthetic technique for these procedures in our hospital is an inhalational agent administered via an orotracheal tube. All children were fasted for at least 4 h prior to operation. Ketamine was administered by a research nurse in a dose of 2 mg/kg body weight IV or 6 mg/kg IM. The IV route was selected for brief (less than 10 min) operative procedures in children who came to the operating room with venous access in place or those in whom venous access did not appear to be difficult to obtain (usually older children); the IM route was selected for all others. Atropine was administered simultaneously in the same syringe in a dose of 0.02 mg/kg. Diazepam was not administered to any of the patients.

The saturation of arterial hemoglobin (SpO_2) and pulse rate (PR) were continuously monitored with a pulse oximeter (Nellcor N-180) and the values recorded prior to injection and at 1, 2, 3, 5, 10, 15, 20, 25, and 30 min after each injection. Abnormal values occurring at other times were also documented. If the SpO_2 dropped to a level of 90%, the child's airway was manipulated using a jaw thrust, and if there was not rapid improvement in the SpO_2, O_2 was administered by face mask. Equipment appropriate for suctioning, endotracheal intubation, and positive-pressure ventilatory support was readily available if needed.

The anesthetic was deemed "adequate" if the surgeon was able to complete the planned procedure without using another anesthetic agent. Children were observed by the research nurse in the recovery area for at least 30 min after operation or until they were fully awake. They were then either returned to their inpatient ward or discharged to be taken home by a parent. Data analysis included serial SpO_2 and PR readings, amount of ketamine utilized per dose, total number of doses needed, adequacy of anesthesia, and perioperative complications.

Results

One hundred thirty-one children underwent a total of 210 anesthetics with ketamine as the sole agent in the 7-month period of this study from April to October 1993. The mean age was 7.8 years (range 3 months–15 years). There were 100 males and 31 females. The American Society of Anesthesiologists (ASA) grading scale was used to assess patients; 123 (93%) children were ASA class I or II, while 8 (7%) were ASA class III. There were 98 (47%) outpatient and 112 (53%) inpatient procedures. One hundred (76.4%) children underwent only one anesthetic in the study while 31 (23.6%) underwent multiple procedures, the largest number being in a 6-year-old female who received 13 ketamine anesthetics over a 4-week period for debridement and skin grafting of an extensive burn wound.

The mean duration of the operative procedures was 28 min (range 1 min–3 h). The least complex procedures were dressing change, abscess drainage, burn-wound debridement, cast application, and wound suturing. More complicated procedures included inguinal herniotomy, orchidopexy, hypospadias repair, skin grafting, and sequestrectomy and drainage for osteomyelitis. The most complicated procedures involved combined orthopedic and plastic surgical operations on the extremities. The longest procedure was 3 h and consisted of external fixation and cross-leg fasciocutaneous flap coverage for a grade IV distal tibial fracture.

Ketamine was given IM in 145 (69%) and IV in 65 (31%) cases. The mean age of children undergoing IM administration was 6 years and mean weight 15.3 kg. The mean age for IV administration was 11.5 years and mean weight 27.5 kg. Of the 145 children with IM administration, 29 (20%) needed at least one additional dose of ketamine an average of 30 min after the first; 7 (4.8%) were given three or more additional IM doses. In 28 (19.3%) cases the duration of the operative procedure exceeded 30 min without the need for additional doses of ketamine. This included 3 children in whom the operation took 70 min and 2 in whom it took 80 min. Twelve children (18.4%) needed additional ketamine after initial IV administration after an average time of 11 min; 19 (29.2%) did not require additional ketamine even though the duration of the operation exceeded 12 min. This included 1 child in whom the operation took 36 min and another in whom it took 41 min. The level of anesthesia achieved was adequate in all 210 cases without the need for additional anesthetic or analgesic agents.

Table 1 summarizes the combined effect of IM ketamine and atropine on SpO_2 and PR. The effects following IV injection are summarized in Table 2. There was no significant change in mean SpO_2 after either IM or IV administration. The PR, as expected, increased in both groups 1 min after injection of ketamine and atropine and then remained at a stable, increased level for at least the next 30 min. These Tables show no decreases in mean SpO_2, but this may be somewhat misleading since the SpO_2 dropped below 90% in 40 (19%) children, below 85% in 25 (12%), and below 80% in 13 (6%). All decreases were abrupt without premonitory signs, at no consistent time after injection, and with a broad range of values from 2 to 21 min.

Thirty-three (82.5%) of the 40 children with SpO_2 readings below 90% responded readily to airway manipulation. Only 7 (3.3% of the total series) required face-mask O_2. None required intubation or positive-pressure ventila-

Table 1 Mean values for arterial oxygen saturation (SpO_2) and pulse rate (*PR*) following IM ketamine and atropine

Minutes after IM injection	Pre-injection	1	2	3	5	10	15	20	25	30
SpO_2	94	94	94	94	94	95	96	95	96	96
PR	123	138	141	141	142	144	146	144	144	145

Table 2 Mean values for arterial oxygen saturation (SpO_2) and pulse rate (*PR*) following IV ketamine and atropine

Minutes after IV injection	Pre-injection	1	2	3	5	10	15	20	25	30
SpO_2	95	95	96	96	96	96	97	96	96	97
PR	117	133	135	135	134	134	133	134	133	133

tion. These findings are consistent with those of Pederson and Benumof in a rural East African hospital [10]. In only 1 child with transient laryngospasm was there any clinical evidence, other than the decreased SpO_2 measurement, of hypoxemia or an occluded airway. This child was successfully managed with a jaw thrust and face-mask O_2 administration. The SpO_2 dropped below 90% in 35 (24%) of the 145 IM cases and only 5 (7.6%) of the 65 IV cases. This relation to the route of administration was statistically significant ($P = 0.004$).

There were no other complications in this series. Specifically, there was no mortality, apnea, emesis, excessive salivation, or significant early or delayed emergence phenomena. None of the 31 children undergoing repeated operative procedures developed tolerance, requiring larger doses of ketamine. There was no prolongation of the inpatient stay and no incidence of conversion from outpatient to inpatient status because of an anesthetic complication.

Discussion

Ketamine has been used extensively as an anesthetic agent for children and adults in our hospital and other health care settings throughout the DW because of its efficacy, low cost, and presumed safety. Availability of a pulse oximeter has enabled us to more objectively assess this presumed safety in our particular hospital. This study specifically examined the efficacy and safety of ketamine when used as the only anesthetic agent for children undergoing a variety of operative procedures commonly performed in DW hospitals.

There is a serious shortage of available anesthesia personnel in the DW; an estimate of anesthesia manpower distribution in 1981 showed less than 1 anesthesiologist per million population in Nigeria (D. ffoulkes-Crabbe, 1989, personal communication). There is a similar shortage in other specialties, including surgery [9]. This means that a majority of the operative procedures in the DW are performed by non-surgeons using anesthesia administered by individuals with little or no specialty training: the operating physician, an operating room nurse, or a technician without formal training in anesthesia. Ketamine is the anesthetic drug most commonly used for pediatric operations in these DW settings where the only monitor may be a finger on the patient's pulse.

In spite of its use in such unsophisticated surroundings, ketamine reportedly is a safe anesthetic agent. Nurse anesthetists at the Baptist Medical Centre in Ogbomoso, Nigeria, are formally trained in anesthesia. Even though they are proficient in other anesthetic techniques, ketamine without the use of an endotracheal tube remains our anesthetic technique of choice for children undergoing operations outside of the chest, abdomen, and head. Ketamine has, however, been successfully used as the sole anesthetic for these latter types of procedures in places where other techniques are not available.

Ketamine is indeed a useful drug, as evidenced by its effectiveness as the sole anaesthetic in these 210 operative procedures. No other anesthetic or analgesic was needed in any of the cases even though several procedures lasted as long as 3 h. In many DW operating rooms, ketamine is the only anesthetic drug available. As a result, laparotomies are often performed under ketamine anesthesia, but the surgeon must be willing to deal with a very "tight" abdominal wall since it does not provide adequate muscle relaxation and may actually increase skeletal muscle tone [17]. Ketamine also increases intracranial pressure and should therefore be used for craniotomy only in true emergency situations when a more appropriate anesthetic technique is not available.

Ketamine can be administered IM or IV. The advantages of IM use are the ease of administration and the prolonged duration of action. The disadvantages are the prolonged (relative to IV administration) recovery phase and relative cost, since more drug (6 mg/kg) is needed IM. IV administration allows the use of less drug (2 mg/kg) per dose and more rapid induction and recovery periods. The cost of supplies related to IV access (butterfly needle) may, however, in our hospital offset the cost savings realized by the decreased amount of drug used IV.

If the child already has an IV line on arrival in our operating room and the operative procedure is to be brief, we prefer IV administration. If, however, there is no IV line, there is probably less trauma to both child and health-care personnel with well-executed IM administration than with trying to start and maintain an IV line. Prior to this report, we did not hesitate to use IM ketamine even for short procedures if attainment of IV access was expected to be difficult. The statistically significant difference in SpO_2 decreases related to route of administration, however, leads to the conclusion that concern for the safety of the child should increase our motivation to obtain IV access for children undergoing brief operative procedures.

The reason for the observed decrease in SpO_2 following IM administration in this study is uncertain but may be related to excessive overall ketamine dosage. The optimal dose for IM administration has never been accurately determined as evidenced by the wide range of suggested values from 0.5 to 17 mg/kg IM [3]. The dose of 6 mg/kg selected for this report is the minimal dose found in the authors' previous experience to consistently achieve the desired level of anesthesia. Further studies are needed to determine the optimal dose required to achieve the desired level of anesthesia without oxygen desaturation.

The clinically detectable complication rate after ketamine administration in this series was remarkably small with only 1 (0.4%) child demonstrating a 30 s period of laryngospasm. Pulse oximeter readings, however, demonstrated that SpO_2 values dropped below 90% in 40 (19%) of these otherwise asymptomatic children. Indeed, without a pulse oximeter we would probably have never known about these potentially dangerous hypoxemic events.

Diazepam is often recommended for use with ketamine to eliminate or at least decrease the intensity of emergence phenomena. We do not use it in children because of its potential respiratory depressive effects. Even though our patients did not receive diazepam, none of them developed clinically detectable prolonged or recurrent emergence phenomena during postoperative recovery area observation. We did not, however, conduct routine postoperative questioning of the children or their parents concerning emergence phenomena. When ketamine is used for adult anesthesia, we do routinely administer diazepam.

There has recently been renewed interest in the use of ketamine (4 mg/kg IM) as a sedative for children undergoing emergency department operative procedures in the United States [2–6, 11, 14, 15]. Controversy exists concerning patient selection and whether the drug should be administered by an anesthesiologist or an emergency physician. This paper does not address these controversies except to point out that all children undergoing ketamine administration should be closely monitored using a pulse oximeter since potentially dangerous levels of oxygen desaturation can be present without associated clinical findings.

This report has implications for practitioners in the DW. Ketamine is an effective agent for use as the sole anesthetic in children in the DW. It is relatively safe, but hypoxemia may go undetected unless technologically sophisticated monitoring equipment is available. Suction equipment, supplemental O_2, a properly sized anesthetic face mask, a positive-pressure breathing bag, and endotracheal intubation equipment should be readily available prior to injection. The practitioner must not ignore the anesthetized child while assuming that ketamine is totally safe. The first step when hypoxemia is detected is simple airway manipulation followed by O_2 administration by face mask if needed. Rarely will intubation be necessary. IV administration appears to be safer than IM administration.

This report has similar implications for pediatric emergency practitioners in the United States. Ketamine is a good drug for the management of pediatric emergency department procedures, but all children receiving it in these more developed centers should be monitored with a pulse oximeter since a significant number (19% in our series) will have a precipitous drop in SpO_2 to below 90%. This should be anticipated, and the emergency department practitioner who administers the ketamine must be able to manipulate the airway, administer supplemental O_2, and intubate the child if needed.

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