Abstract:
Procedural sedation has become a routine pediatric practice in high-income countries with a goal to decrease procedural time and error rates while increasing patient, parent, and provider satisfaction. Unfortunately, procedural sedation is not commonly performed in resource-limited settings due to lack of training, provider availability, medication availability, monitoring and resuscitation equipment, and clinical practice guidelines specific for use in resource-limited settings. This article outlines the development of a pediatric sedation curriculum tailored specifically for use in low- and middle-income countries. This curriculum was piloted in Liberia for pediatric and surgical residents in 2016, and the challenges and next steps for broader implementation of such a curriculum are detailed here. Globally available pediatric procedural sedation is necessary to improve the health care and outcomes of children living in low- and middle-income countries.

Keywords:
sedation; procedural sedation; ketamine; resource-limited setting; pediatric

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Guidance for Implementing Pediatric Procedural Sedation in Resource-Limited Settings

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Pediatric procedural sedation was first introduced in the United States in the 1980s.[1] Over the past 30 years, as the clinical benefits of procedural sedation in children were demonstrated, demand rapidly grew. A plethora of research has been published regarding the safety and efficacy of different sedative drugs in children, most commonly benzodiazepines, nitrous oxide, ketamine, and propofol.[2-5] Research showed that, with the proper monitoring, the benefits of procedural sedation vastly outweighed the risks. Short-term benefits of procedural sedation include decreasing procedure time; decreasing error rates;[6,7] and increasing the comfort and satisfaction level of patients, parents, and providers.[8-10] There may also be long-term benefits, as evidence suggests that inadequately treated pain in children can lead to lasting effects on brain development, immune response, pain sensitivity, and behavior.[11,12] Given these data, it is possible that children undergoing procedures who do not receive appropriate analgesia and anesthesia may experience ramifications for the rest of their

lives. Fortunately, procedural sedation and analgesia are now a routine pediatric practice, and multiple professional organizations including the American College of Emergency Physicians, the American Academy of Pediatrics, and the American Society of Anesthesiologists (ASA) have published clinical practice guidelines for its use.[13-15] Pediatric procedural sedation is currently used in emergency departments, radiology suites, dental offices, and hospital inpatient units for a myriad of therapeutic and diagnostic procedures, including but not limited to fracture reduction, burn debridement, dental extraction, laceration repair, imaging, and endoscopy.

THE NEED

These advances in procedural sedation and analgesia are limited almost exclusively to high-income countries (HIC). Although data are limited, pediatric procedural sedation appears to be virtually nonexistent in low- and middle-income countries (LMIC). This is not for lack of need. Whereas children constitute 15-20% of the population in HIC, they account for 45% of the population in LMIC, and it has been estimated that 85% of these children will require a surgical procedure by the age of 15 years.[16,17] Most of these surgical procedures are for the treatment of lacerations, burns, fractures, and infections, many of which could likely be performed using procedural sedation and analgesia rather than general anesthesia, reducing the risk profile of care.[18] A study conducted in Gambia found that 68% of the pediatric surgical procedures performed over the course of a year were classified as "minor"—conceivably minor enough that procedural sedation and analgesia would have been sufficient.[17] Procedural sedation is likely not being used in LMIC not only because providers have not been trained on its use but also because providers may not be aware that sedation is a cheaper, faster, and safer alternative to surgery.[19]

Multiple constraints limit the use of pediatric sedation in LMIC, chief among them a lack of skilled providers.[20] Currently, the only providers trained to provide procedural sedation for children in LMIC are anesthesiologists. Although the physician to population ratio in most LMIC is lower than the World Health Organization's target of 1 physician to 1000 people, formally trained anesthesiologists are even rarer. A survey of 78 district hospitals in 7 LMIC found fewer than 1 anesthesiologist per 10 000 people.[21,22] Among the anesthesiologists who work in LMIC, there is great reluctance to practice on children due to lack of training and/or appropriate equipment, with a survey of Ugandan anesthesiologists identifying that only 13% had the necessary equipment to care for children.[18,23] The training of specialized anesthesiologists takes time and local investment. While this long-term development strategy is under way, procedural sedation is uniquely situated to help address the current anesthesia gap.[19,24]

Consistently available equipment, reliable electricity, and essential medications also represent challenges to providing sedation in resource-limited settings. The advanced monitoring and resuscitation technology used in HIC settings, including end-tidal carbon dioxide monitoring, endotracheal intubation, and mechanical ventilation, are rarely available in LMIC. Similarly, the necessary sedative medications are not always available despite nitrous oxide, ketamine, propofol, lorazepam, diazepam, and midazolam being listed on the World Health Organization Essential Medicines List for Children.[19,25]

To increase the safe use of pediatric procedural sedation in LMIC, research, clinical guidelines, and educational initiatives are necessary. Although research on pediatric procedural sedation is currently scarce, it is growing: recent studies from Nepal, Pakistan, and Tanzania have shown that both propofol and ketamine are safe for use in children in limited-resource settings.[26-28] This appears to be true for nurse-administered ketamine sedation as well.[29,30] More research on the sedative medications used, types of procedures performed, and adverse events incurred is needed. Providers in LMIC must also have a national policy and/or clinical practice guideline from a local professional organization to use as a reference. Currently, there appears to be only 1 clinical guideline written specifically for use in LMIC, from South Africa.[31] Widespread, multidisciplinary training on pediatric procedural sedation and analgesia developed specifically for LMIC is also necessary. Guidelines and training for use in LMIC will not be the same as those developed in HIC because the patient population is different, with malaria and malnutrition as frequent comorbid conditions. The available sedative medications are different in LMIC, as well as the necessary resuscitation medications and techniques should an adverse event occur. Finally, indications for procedural sedation in LMIC must be clearly delineated, as an anesthesiologist or ventilator may not always be available should an adverse event occur.

THE INTERVENTION

With the limitations of an LMIC environment in mind, a novel pediatric procedural sedation

curriculum for providers was developed. Training methods were tailored specifically for a resource-limited setting by restricting the required teaching supplies to printed handouts, poster paper, markers, and low-fidelity simulation equipment. This eliminates the need for computers, projectors, presentation software, and electricity. The training package delivers educational content using adult learning techniques, including peer-to-peer teaching, group work, simulations, and literature review.

The curriculum focuses solely on the use of ketamine, which is cheap, is widely available in Africa, and has repeatedly been shown to be safe for use in children.[10] Ketamine was chosen for this training package for multiple reasons. Ketamine does not require refrigeration or any expensive equipment such as flow meters and scavenging systems necessary for nitrous oxide. Additionally, single-agent sedations are less likely to cause adverse events, and the multiple possible routes (per os, intravenous, intramuscular) of administration for ketamine are convenient when working with children.[32] The most common adverse events in ketamine sedations are tachycardia, hypertension, and nausea and vomiting which are temporary, relatively benign, and easy to manage. For the serious and life-threatening adverse event of laryngospasm, the curriculum teaches the use of the laryngospasm notch maneuver (applying painful anterior and inward pressure at the laryngospasm notch, or Larson's Point) and the administration of succinylcholine with bag-valve mask ventilation for laryngeal paralysis. Continuous positive pressure is not taught because that requires high-flow oxygen, which is not routinely available in resource-limited settings.

This curriculum allows for a single-practitioner method of procedural sedation. Several clinical practice guidelines from HIC promote a 2-practitioner method of having a sedationist and a proceduralist, but this may be impossible in resource-limited settings where practitioners are scarce. Where the procedure is simple enough that the provider may discontinue it abruptly without causing harm to the patient to provide resuscitation due to sedation-related adverse event, the single-practitioner method is acceptable. This is a realistic approach to staffing but does require evaluation of the patient's condition and intended procedure to determine appropriateness in advance.

The training package also includes presedation assessment forms, parental consent forms, and intra- and postsedation monitoring forms and equipment checklists, all of which can be photocopied and used in patient charts to facilitate proper documentation. The presedation assessment uses ASA guideline level to evaluate sedation risk and limits the use of procedural sedation to children older than 1 year who are rated ASA level 1 or 2 to decrease the likelihood of adverse events.[1] Sedation monitoring is restricted to blood pressure cuff, stethoscope, manual suction pump, self-inflating bag-valve mask, and a battery-operated pulse oximeter. This approach is taken to account for settings where electricity is inconsistent and expensive technology such as end-tidal carbon dioxide monitors and ventilators is not available. More expensive equipment like cardiac monitors and capnography is also usually not necessary for single-agent, moderate sedation.[19] The production and use of "Procedural Sedation Kits" or ready-made, locked boxes of all required equipment are recommended during the training phase to improve readiness and ease for procedural sedation and to ensure consistent sedation monitoring. Procedural Sedation Kits should be maintained and checked regularly to ensure that all equipment is present and functioning.

The training package recommends conducting stakeholder engagement meetings with hospital administrators, pharmacists, and supply chain staff before the implementation of procedural sedation at a facility to ensure system-wide engagement to allow procedural sedation to occur by nonanesthesiologists and consistent availability of medications and supplies.

COUNTRY EXAMPLE

This curriculum was piloted in June 2017 at John F. Kennedy (JFK) Hospital in Monrovia, Liberia. Liberia, a West African nation of 4.3 million people, has only 9 full-time board-certified pediatricians and 0 Liberian anesthesiologists. Monitoring equipment is scarce, as an assessment of the inpatient units at Liberian county hospitals in 2012 noted that only 18% had pulse oximeters.[21] There are currently no national guidelines for pediatric procedural sedation and analgesia in Liberia and no formalized training to teach providers how to safely perform this in children.

The curriculum was deployed in a training package conducted over 6 hours for 15 pediatric and surgical residents. It was developed and taught by the authors of this paper, Drs Schultz and Niescierenko, pediatric emergency physicians at Children's Hospital of Wisconsin and Boston Children's Hospital, respectively. The curriculum is divided into 3 units, each 2 hours long: (1) introduction to procedural sedation, (2)

TABLE 1. Curricular objectives.

By the end of this curriculum, participants will be able to:
- Describe the rationale for performing pediatric procedural sedation.
- Name at least 4 clinical indications for procedural sedation.
- List at least 4 risk factors associated with increased likelihood of adverse events during procedural sedation.
- Assign the correct ASA Level to a patient undergoing procedural sedation.
- Name the 5 absolute contraindications to procedural sedation.
- Perform a presedation screening for a patient undergoing procedural sedation.
- Identify and test the necessary monitoring and resuscitation equipment for a procedural sedation.
- Describe the potential adverse events that can occur during a procedural sedation.
- Demonstrate how to manage the potential adverse events during a procedural sedation.
- Complete sedation documentation, including the informed consent form, safety checklist, and sedation monitoring chart.
- Describe the components of postsedation monitoring.
- Demonstrate clinical decision making that decreases the likelihood of adverse events during procedural sedation based on individual patient scenarios.

resuscitation and management of adverse events, and (3) monitoring and conclusion. For the complete list of curricular objectives, see Table 1. For an example unit, see Figure 1. The 6-hour training was divided over 2 days to avoid disrupting the clinical service responsibilities of the residents. This curriculum is unique in that it was created with the specific goal in mind of actively engaging adult learners. As such, there are no prolonged facilitator presentations, lectures, or PowerPoint slides. Adult learners are typically more successful when they can draw on their previous experiences, engage actively with material, have open dialogue with their instructor, and learn from their peers. Some example teaching methods used in this curriculum to engage adult learners are:

- Reflection
- Large group discussion
- Peer teaching
- Role play
- Simulation
- Case study

During the first curricular activity, participants were asked to reflect on a pediatric procedure they had performed in the past. Participants shared prior experiences with an abscess incision and drainage where procedural accuracy and safety were jeopardized due to the patient's pain level and/or anxiety during the procedure, as well as a burn debridement that was exceptionally traumatic for the patient, the patient's parent, and the provider. The subsequent discussion regarding the benefits of procedural sedation and analgesia in decreasing patient pain and anxiety while increasing procedural efficiency and accuracy led to immediate and universal buy-in among participants on the importance of sedation and analgesia training.

Over the course of the training, participants were encouraged to voice their questions and concerns regarding the successful implementation of pediatric procedural sedation and analgesia as routine practice at JFK Hospital, thereby identifying areas for curricular and systemic improvement. For example, although ketamine was routinely available to surgeons and nurse anesthetists in the operating rooms of JFK Hospital, it was not stocked in the Accident and Emergency Department, where procedural sedation and analgesia could be frequently used. Ensuring the availability of ketamine to the residents required discussions with supply chain, pharmacy, and administrative officials at the hospital. In addition, residents shared that they did not have reliable access to pulse oximeters. As a result of this discussion, Lifebox (Lifebox, Brooklyn, NY) pulse oximeters were purchased for inclusion in the Procedural Sedation Kits. Lifebox is a pulse oximeter developed specifically for use in resource-limited settings. They are reusable, are highly durable, do not need recalibration, and use rechargeable batteries rather than electricity.[33] For a complete list of supplies included in the Procedural Sedation Kits, see Table 2. All supplies are sterilizable and reusable.

Rollout of safe and routine pediatric procedural sedation and analgesia practice is ongoing in Liberia. Next steps include the creation and maintenance of Procedural Sedation Kits, ongoing data collection from residents' procedure logs, and the development of Procedural Sedation Mentors among the newly trained Liberian pediatric faculty who will be able to provide supervision to newly trained sedation providers. Residents' procedure logs will provide data on the types of procedures being performed under sedation, adverse events incurred, and provider comfort level with sedation. These procedure logs are collected monthly on hard copy, as previous attempts at electronic versions were unsuccessful due to inconsistent Internet and computer access. A full-time research nurse will be

Unit 2: Resuscitation and Management of Adverse Events

Unit Objectives

By the end of this unit, participants will be able to:

- Identify and test the necessary monitoring and resuscitation equipment for a procedural sedation.
- Describe the potential adverse events that can occur during a procedural sedation.
- Demonstrate how to manage the potential adverse events during a procedural sedation.

Time Required: 2 hours

	Content	Suggested Time	Teaching Method	Actual Time
Session 1	Adverse Events	60 min	Demonstration; Peer Teaching	
Session 2	Resuscitation	60 min	Large Group Discussion; Simulation	

Supplies

- One large easel paper pad
- Markers
- Tape
- Simulation mannequin(s)

Figure 1. Unit 2 example.

employed by the Department of Pediatrics at JFK to review the procedure logs and enter all data into an electronic spreadsheet for review by pediatric administration and study staff. The training package will need to be delivered yearly to educate new residents and providers on the use of pediatric procedural sedation. There is also a need for collecting information regarding patient and family satisfaction levels with this practice.

The eventual long-term goal of this project is to formulate a clinical guideline specifically for resource-limited pediatric sedation and analgesia using best practices learned in Liberia. Although sedation guidelines should ideally be made at a regional or institutional level to be tailored to a specific setting's resources and needs, an example guideline may be useful to other resource-limited sites hoping to implement procedural sedation and analgesia in children.

IMPACT

This curriculum and training package is an initial step toward enabling pediatric procedural sedation in LMIC. This documented lack of widely available, safe pediatric procedural sedation and analgesia in LMIC is actively resulting in delays in care, increased pain, and unnecessary morbidity and mortality in children. Making procedural sedation available to children in all settings supports global movements toward improving care quality and health care for all as described in the United Nation's Sustainable Development Goals.[34,35] To increase the use of procedural sedation and analgesia in children living in resource-limited settings, further research is needed on the implementation of this practice through training and health systems-level interventions. This is necessary to understand the safety profile as well as effects on patient and parent satisfaction in LMIC. Formalized training

TABLE 2. Procedural sedation kits.

Supply	Cost (US $)
Lifebox pulse oximeter	250
Pediatric bag valve mask	30
Stethoscope	40
Pediatric adjustable blood pressure cuff	50
Manual suction pump	55
Lockable storage box	45
Total cost per kit	470

specifically tailored for multidisciplinary providers treating pediatric patients in resource-limited settings must be available. This includes but is not limited to clinical officers, general practitioners, nurses, pediatric specialists, and anesthesiologists. Most importantly, country-specific clinical guidelines for pediatric procedural sedation and analgesia must be developed to guide practitioners within the norms of their settings. Although the path to globally available sedation and analgesia for children may seem long, it is necessary to improve the health care and outcomes of children living in LMIC.

SUMMARY

The documented lack of widely available and safe pediatric procedural sedation in LMIC results in delays in care, increased pain, and unnecessary morbidity and mortality in children. Piloted in Liberia, this training package represents an initial step toward enabling safe procedural sedation in LMIC. It was implemented among pediatric and surgical residents, used multiple adult learner techniques, and was packaged with site-specific procedural sedation kits. Lessons learned may be adapted to other settings with similar resource constraints.

CONFLICTS OF INTEREST

None declared.

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