

A Safe-Anesthesia Innovation for Emergency and Life-Improving Surgeries When no Anesthetist is Available: A Descriptive Review of 193 Consecutive Surgeries

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Abstract

Background The worldwide human resource gap in anesthesia services often presents a barrier to accessing life-saving and life-improving surgeries. This paper assessed the impact of a ketamine anesthesia package, Every Second Matters-Ketamine (ESM-Ketamine)TM, for use in emergency and life-improving surgeries by non-anesthetist clinicians in a resource-limited setting when no anesthetist was available.

Methods We analyzed prospectively collected data from 193 surgeries constituting a pilot implementation of the ESM-Ketamine package, among three sub-district hospitals in Western Kenya. The study population comprises patients who required emergency or life-improving surgery when no anesthetist was available. Non-anesthetist clinicians in three sub-district hospitals underwent a 5-day training course in ESM-Ketamine complemented by checklists and an ESM-Ketamine Kit. Data were collected prospectively every time the ESM-Ketamine pathway was invoked. The training cases, although primarily tubal ligations, were included. The primary outcome measures centered on capturing the ability to safely support emergency and life-improving surgeries, when no anesthetist was available, through invoking the ESM-Ketamine pathway. The registry was critically examined using standard descriptive and frequency analysis.

Results 193 surgical procedures were supported using the ESM-Ketamine package by five ESM-Ketamine trained providers. Brief (<30 s) patient desaturation below 92 % and hallucinations occurred in 16 out of 186 (8.6 %) and 23 out of 190 patients (12.1 %), respectively. There were no reported major adverse events such as death, prolonged desaturations (over 30 s), or injury resulting from ketamine use.

Conclusion This study provides promising initial evidence that the ESM-Ketamine package can support emergency and life-improving surgeries in resource-limited settings when no anesthetist is available.

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Introduction

Death and disability is greatly reduced worldwide through timely surgical interventions such as cesarean section, burn and wound care, repair of open fractures, and a myriad of other emergent and urgent operative procedures [1]. Unfortunately, the worldwide human resource gap in anesthesia services often presents a barrier to accessing life-saving and life-improving surgeries. For example, through the lens of the most common world-wide operation, cesarean section, a recent study of 49 countries found that access to an estimated additional 2.8 million cesarean

deliveries would have prevented 59,100 cases of obstetric fistula and 16,800 maternal deaths [2, 3]. In the most recently published Kenya Demographic Health Survey, cesarean section rates across broad stretches of Western, Northern, and Northeastern Kenya were found to be below 1 %, despite the WHO recommendation of a minimum cesarean section rate of 10–15 % [4]. These same statistics undoubtedly hold true for many other surgeries, across Kenya and beyond.

A 2011 Kenya Ministry of Health study of the Nyanza region identified that, for a population of 5.8 million people, there were 34 operating theaters with associated doctors able to perform cesarean section and other basic surgical procedures. However, there were only 18 anesthesiologists in the region, and 15 of the 34 theaters (44.1 %) reported severely limited access to anesthesiologist services [5]. Our own recent assessment of all 30 health facilities with operating theaters and surgical capabilities in Siaya and Kisumu counties in Western Kenya found that 57 % of these facilities are without access to anesthesia services [6].

In early December 2013, the authors implemented a bounded pilot program in Kenya on the use of a ketamine anesthesia package for emergency cesarean section and other life-saving and life-improving surgical procedures, called Every Second Matters-Ketamine (ESM-Ketamine)TM. The goal of the program was to train non-anesthetist clinicians in the safe administration of ketamine, and to incorporate lessons learned in developing a best-evidence safe-anesthesia rescue package for when no anesthetist is available. Ketamine is an ultra-low-cost anesthetic agent that has been used worldwide for cesarean section and other operative procedures for over 40 years. While almost universally described as safe, it has been implemented in an unregulated and disorganized fashion [7–16]. Ketamine has an extremely attractive safety record even in circumstances with limited supporting equipment [9].

Since there have been few rigorous studies on the administration of ketamine by non-anesthetist clinicians for life-saving and life-improving surgeries, this study was designed with the goal of analyzing prospectively collected ESM-Ketamine data in order to determine the impact in a resource-limited setting.

Materials and methods

Study design

This was an analysis of data collected prospectively during pilot implementation of Massachusetts General Hospital's (MGH's) ESM-Ketamine package in Kenya. The ESM-Ketamine program implemented by faculty from MGH/Harvard Medical School (Boston, MA, USA) and Maseno

University Medical School (Kenya) focused on training non-anesthetist clinicians in the administration of ketamine for life-saving and life-improving surgical procedures when no anesthetist was available. ESM-Ketamine trainees underwent a 5-day training program that covered basic pharmacology, appropriate patient monitoring, and essential respiratory management of adults and newborns, including the American Academy of Pediatrics' "Helping Babies Breathe" program. The ESM-Ketamine providers were trained on the skills of appropriate airway positioning, suctioning, and bag-mask ventilation but received no training on airway adjuncts or other forms of advanced airway management. A special emphasis, via role-playing simulation case scenarios, was made on a high quality two person bag-mask ventilation technique in the rare event of ketamine-related laryngospasm. The majority of the training week was focused on hands-on, case-based learning through supervised ketamine administration during surgeries in the operating theater. In addition to the training, the ESM-Ketamine package provided to participating facilities included: ESM-Ketamine clinical pathway wall charts and pocket checklists, and a kit consisting of an adult bag-mask device, newborn bag-mask device, bulb suction, pulse oximeter, ketamine, syringes, tape, needles, alcohol wipes, and 2" × 2" gauze bandages [17]. The initial cost of each kit was USD \$150, with an estimated per patient cost of under USD \$1. This paper reports on data collected between the start of the pilot implementation (December 2, 2013) and approximately 16 months thereafter (March 27, 2015).

Ethical approvals

The study was approved by the Institutional Review Board at Maseno University as well as by the Institutional Review Board at Partners Healthcare, Boston.

Setting

The pilot program and data collection were implemented at three sub-district hospitals in Western Kenya. The initial roll out was focused on Sagam Community Hospital and took place during the first week of December 2013. The second roll out, which incorporated staff from the initial training and expanded the implementation to Maseno Mission and Yala Sub-District Hospitals, took place during the second week of January 2014. Selection criteria included facilities that have operating theaters and doctors who could perform surgical procedures, but with severely limited anesthetist services.

Fifteen healthcare providers selected by chief administrators from these three hospitals were trained on the ESM-Ketamine package. A total of six nurses, six clinical

officers, two medical officers (doctors), and one nurse's aide were trained on ESM-Ketamine.

According to the ESM-Ketamine protocol, when an emergent or life-improving case that required anesthesia services was identified at a participating facility, an immediate attempt was made to secure a trained anesthesiologist. If no anesthesia provider was available and the only other option was a delay that would potentially lead to suffering, death, or loss of opportunity to improve life, the ESM-Ketamine protocol was activated.

Patients were monitored with continuous pulse oximetry and administered supplemental oxygen beginning prior to ketamine administration. The ESM-Ketamine clinical pathway calls for the initial administration of 2 mg/kg of ketamine intravenously over 30–60 s, followed by 1–2 mg/kg intravenously every 10–15 min.

Selection of participants

The cases examined in this study were *all* of the surgeries and procedures performed and supported by the application of the ESM-Ketamine clinical pathway at the three participating sub-district hospitals in Western Kenya from December 2, 2013 to March 27, 2015. The ESM-Ketamine protocol was activated for all consecutive patients who required emergency cesarean section or other life-saving or life-improving surgeries when no anesthesiologist was available. Surgeries performed as part of the ESM-Ketamine training—primarily but not exclusively bilateral tubal ligations (BTLs)—as well as all those performed by ESM-Ketamine trained health providers after the completion of their training were included.

Data sources/measurement

Data were collected prospectively by the clinician administering ketamine in all cases of ESM-Ketamine use at study facilities using a standardized ESM-Ketamine Clinical Record form. The form included elements such as: patient age; patient weight; procedure performed; whether an anesthesiologist was called, and, if unavailable, details regarding why the anesthesiologist was unavailable; and complications directly attributable to the use of ketamine: patient desaturation below 92 % and occurrence of hallucinations. ESM-Ketamine quality assurance auditors collected completed ESM-Ketamine Clinical Record forms from the facilities on a weekly basis. Each facility CEO nominated a staff member who was responsible for providing all salient study data to the ESM-Ketamine auditors.

Variables

The primary study outcomes centered on capturing the program's ability to safely support emergency and life-

improving surgeries when no anesthesiologist was available through invoking the ESM-Ketamine pathway (e.g., number of surgeries and type of surgeries successfully supported by ESM-Ketamine without major adverse effects). Major adverse events were defined as death, prolonged oxygen desaturation (more than 30 s) below 92 %, or any anesthesia-related injury, and minor adverse events were defined as brief patient desaturation (<30 s) below 92 % and hallucinations. Occurrence of hallucinations were scored "yes" if hallucinations were observed by a health care provider or reported in the affirmative on questioning at discharge and on surgical clinic follow-up.

Data analysis

The registry was built using utilizing Microsoft Excel 2007 (Seattle, Washington, USA) and critically examined using standard descriptive and frequency analysis in STATA 13.1 (College Station, Texas, USA).

Results

Procedures performed using ESM-Ketamine

Between December 2, 2013 and March 27, 2015, 193 surgical procedures were supported using the ESM-Ketamine package at the participating facilities (Table 1) by five of the ESM-Ketamine trained providers (one medical officer, two clinical officers, and two nurses). None of the other ten ESM-Ketamine trained providers invoked the protocol.

The 193 cases included 40 cesarean sections (20.7 %), two of which included a ruptured uterus, 25 open BTLs (13.0 %), and nine emergency laparotomies (4.7 %) for acute bowel obstruction or perforation. Other key life-saving and life-improving surgical procedures for which the ESM-Ketamine protocol was activated included 34 orthopedic procedures and surgeries (17.6 %)—6 of which were open fracture repairs (3.1 %), 27 large wound and burn debridements (14.0 %) and 16 operative procedures addressing large abscesses and necrotizing fasciitis (8.3 %). Nine of the ESM-Ketamine cases (4.7 %) were from circumstances where the patient refused the recommended emergency surgery, and prepared to go home to die, due to being unable to afford the fees an anesthesiologist would have required.

Mean total ketamine dose per procedure

The mean dose of ketamine administered across the operative procedures was 4.6 mg/kg (Table 1). The mean length of the procedures was 49.9 min. Thirty-three

Table 1 Distribution of the procedures, ketamine dose per procedure and time per procedure (excluding the inadvertent overdose in a BTL case)

Operative procedure	Number (%)	Mean ketamine dose (mg/kg) ^a	Median dose (range) (mg/kg) ^a	Mean time of procedure (min) ^b	Median time of procedure (range) (min) ^b
Emergency cesarean section	40 (20.7)	7.1	7.0 (3.0–15.2)	80.6	74.5 (17.0–173.0)
Emergency laparotomy for bowel obstruction or perforation	9 (4.7)	9.5	7.3 (2.0–20.0)	101.3	104.0(40.0–150.0)
Open bilateral tubal ligation	25 (13.0)	5.6	4.9 (2.0–16.8)	46.2	35.0 (14.0–145.0)
Open orthopedic fracture repair	6 (3.1)	3.6	2.4 (2.0–8.3)	30.7	32.5 (5.0–60.0)
Closed orthopedic fracture/dislocation reduction	28(14.5)	2.1	2.0 (1.2–4.0)	24.3	20.0 (6.0–60.0)
Debridement and Irrigation of large burns and wounds	27 (14.0)	2.2	2.0 (0.5–10.0)	43.0	20.0 (7.0–180.0)
Drainage of large abscesses and necrotizing fasciitis	16 (8.3)	2.8	2.0 (1.9–5.0)	45.5	35.0 (15.0–142.0)
Complex exams, painful biopsies, and foreign body removal	20 (10.4)	2.9	2.0 (1.0–6.0)	28.6	24.5 (10.0–75.0)
Complex wound repair	8 (4.2)	5.4	4.8 (2.0–10.0)	60.1	60.0 (25.0–105.0)
Manual vacuum aspiration/D&C	6 (3.1)	2.3	2.0 (1.8–3.0)	29.6	25.0 (10.0–60.0)
Resection of tumor/large mass	8 (4.2)	10.1	10.0 (2.0–21.0)	75.9	62.5 (55.0–149.0)
Total	193	4.6	3.0 (0.5–21.0)	49.9	38.5 (5.0–180.0)

^a Ketamine doses were missing for two cases (one cesarean section and one case of complex exams, painful biopsies, and foreign body removal)

^b Time data points were missing for three cases (one complex exam, painful biopsies, and foreign body removal; one complex wound repair; and one drainage of large abscesses and necrotizing fasciitis)

(17.1 %) cases were dosed twice and 87 (45.0 %) cases were dosed three or more times.

Patient demographics

Patients who were administered ketamine ranged from one to 88 years old. Patients between 30 and 39 years (54/193, 28.0 %) comprised the largest age group for ketamine administration across the three facilities (Table 2).

Complications associated with ESM-Ketamine administration

Out of the 193 surgeries and procedures, pulse oximetry readings were recorded in the data sheet in 186 cases. Brief (<30 s) desaturations, below 92 %, occurred in 16 out of the 186 (8.6 %). Hallucinations during recovery or reported on follow-up occurred in 23 out of 190 patients (12.1 %), with information missing from three patients (Table 3). There were no reported major adverse events such as death due to ketamine, prolonged desaturations (over 30 s), or injury resulting from ketamine use.

Of note, the in-country research team queried the ESM-Ketamine providers about the pulse oximetry desaturations after the 72nd case in the patient series, and discovered that in each case of desaturation the patient had not been administered oxygen as required by the protocol (oxygen

Table 2 ESM-Ketamine patients by age group

Age group (years)	Number (%)
0–9	23 (11.9)
10–19	35 (18.1)
20–29	41 (21.2)
30–39	54 (28.0)
40–49	13(6.7)
50–59	12 (6.2)
60–69	9 (4.7)
70–79	3 (1.6)
80–89	2 (1.0)
Not available	1 (0.5)
Total	193 (100)

was then administered upon desaturation). This led to an immediate/emergency in-service meeting with all of the ESM-Ketamine providers during which the cases-to-date and the critical nature of checklist adherence were reviewed. We discovered through the discussions during that in-service meeting that very few of the ESM-Ketamine patients-to-date had been placed on oxygen prior to the administration of ketamine, and that the required 30–60 s of slow administration of ketamine had not been adhered to. Four further brief desaturations were recorded in the ensuing 121 cases and only two in the last 98 of this series (of 193)—the latter two occurred subsequent to near

Table 3 Patient complications and average ketamine dose per procedure (excluding the inadvertent overdose BTL case)

Patient Complication	Number (%)	Mean ketamine dose per procedure (mg/kg)
Hallucinations ^a	23 (12.1)	4.5
Desaturations below 92 % ^b	16 (8.6)	5.4
Neither	149 (77.2)	4.7

^a Side effect data regarding hallucinations were not recorded in three cases (two cases of complex exams, painful biopsies, and foreign body removal; one case of debridement and irrigation of large burns and wounds)

^b Side effect data regarding desaturations were not recorded in seven cases (four closed reductions, one debridement, one laparotomy and one case of drainage of large abscesses and necrotizing fasciitis)

simultaneous ketamine administration and loss of power and oxygen concentrator function.

A patient who was given ketamine on two consecutive days for debridement of an infected palmar wound eventually died due to tetanus. Additionally, a woman who presented in a very late stage of obstructed labor delivered an intrauterine fetal death via cesarean section. One woman undergoing a BTL was administered a total of 2000 mg of intravenous ketamine due to a labeling error. She briefly desaturated immediately after the initial ketamine administration, experienced a prolonged recovery from her anesthesia (awoke 6 h after surgery completion), and salivated remarkably during her recovery. Even with the mistakenly high dose, she was well and back to baseline very soon after awakening.

Discussion

Main findings

Between December 2, 2013 and March 27, 2015, 193 surgeries were successfully and safely supported using the ESM-Ketamine package in the three participating sub-district hospitals in Western Kenya. The 193 cases included 40 cesarean sections; 9 emergency laparotomies (4.7 %); 34 orthopedic surgeries and procedures (17.6 %)–6 (3.1 %) of which were open fracture repairs, 25 BTLs (13.0 %), 27 wound and burn debridements (14.0 %), and 16 surgeries addressing large abscesses and necrotizing fasciitis (8.3 %).

None of the uses of the ESM-Ketamine pathway resulted in a major adverse event. The incidence of minor adverse events such as brief desaturation (<30 s) below 92 % (8.6 %) and hallucinations (12.1 %) is comparable to other reports in the literature [9, 16, 18–20].

Strengths and limitations

This study's major strength is that it provides promising initial data regarding the impact of the application of the ESM-Ketamine package by non-anesthetist clinicians in

resource-limited settings. It addresses the dearth of rigorous studies on the administration of ketamine by non-anesthetist clinicians for life-saving and life-improving surgeries.

There are several study limitations. Along with a moderate sample size, which included the training cases that were primarily bilateral tubal ligations, a limitation of the study is that the data collected were harvested from manually completed records, a few of which were missing key data points. Confidence in the reported desaturation levels on the data forms would have been enhanced if the pulse oximeters could have been queried in a way that would have provided actual objective numbers for the lowest desaturation values. Because this innovative protocol was breaking new ground, hospital directors ultimately only allowed five of the fifteen ESM-Ketamine trained providers to administer the ESM-Ketamine protocol. Since only one of the facilities (Sagam Community Hospital) developed a call roster so that a provider could always be available to be called in for an emergency surgery if no anesthetist or safe transfer was available, the overall number of cases of ESM-Ketamine use likely does not capture all of the circumstances where the rescue anesthesia innovation might have been helpful.

Interpretation

The promising initial data from this study have several downstream implications for clinical practice in resource-limited settings. The potential for 24-h, 7-day-a-week availability of safe anesthesia services may not only save and improve lives but may also help create demand for health facility-based services in rural areas by improving the delivery of quality and compassionate care. For example, women will be more likely to seek facility-based care if they—and other members of the community—have a positive impression of health facilities, based on communities' experience with safe and effective anesthesia for emergency cesarean sections and other operative procedures.

It was illuminating to discover that adherence to pre-oxygenation was initially very low among providers, and to

observe that subsequent to in-service training the incidence of desaturations was considerably reduced. When combined with the fact that hospital directors only allowed five of the fifteen ESM-Ketamine trained providers to administer the ESM-Ketamine protocol, these findings indicate the need to further understand barriers to uptake and implementation of the ESM-Ketamine protocol at the facility level [21].

In Kenya, per invitation from the Ministry of Health, on November 11, 2014 in Nairobi, our team presented the quality assurance data up to that date to a broad and ultimately extremely supportive constituency of health leaders and stakeholders from across Kenya. However, the sustainability and success of an ESM-Ketamine scale-up will depend on buy-in by all salient health stakeholders including policymakers, professional societies, regulatory bodies, and local communities.

Our study provides promising initial evidence that non-anesthetist clinicians in sub-district hospitals can effectively provide safe anesthesia when no anesthetist is available, using ketamine in a protocol-driven fashion, subsequent to a 5-day training course complemented by checklists and an ESM-Ketamine Kit.

Further studies will need to examine the economic environment that surrounds the ESM-Ketamine package, further details regarding safety, the potential for surgical-demand creation, community, and provider experiences and perceptions, the policy landscape that emerges, barriers to uptake and implementation, and the best strategies for optimizing provider adherence to best practices.

Expanded prospective investigation is now underway; the results of which we hope will inform opportunities for widespread scaling.

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Conflict of interest None.

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