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# Pediatric Perioperative Mortality in Kenya

## A Prospective Cohort Study from 24 Hospitals

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## ABSTRACT

**Background:** The global surgery access imbalance will have a dramatic impact on the growing population of the world's children. In regions of the world with pediatric surgery and anesthesia manpower deficits and pediatric surgery–specific infrastructure and supply chain gaps, this expanding population will present new challenges. Perioperative mortality rate is an established indicator of the quality and safety of surgical care. To establish a baseline pediatric perioperative mortality rate and factors associated with mortality in Kenya, the authors designed a prospective cohort study and measured 24-h, 48-h, and 7-day perioperative mortality.

**Methods:** The authors trained anesthesia providers to electronically collect 132 data elements for pediatric surgical cases in 24 government and nongovernment facilities at primary, secondary, and tertiary hospitals from January 2014 to December 2016. Data assistants tracked all patients to 7 days postoperative, even if they had been discharged. Adjusted analyses were performed to compare mortality among different hospital levels after adjusting for prespecified risk factors.

**Results:** Of 6,005 cases analyzed, there were 46 (0.8%) 24-h, 62 (1.1%) 48-h, and 77 (1.7%) 7-day cumulative mortalities reported. In the adjusted analysis, factors associated with a statistically significant increase in 7-day mortality were American Society of Anesthesiologists Physical Status of III or more, night or weekend surgery, and not having the Safe Surgery Checklist performed. The 7-day perioperative mortality rate is less in the secondary (1.4%) and tertiary (2.4%) hospitals when compared with the primary (3.7%) hospitals.

**Conclusions:** The authors have established a baseline pediatric perioperative mortality rate that is greater than 100 times higher than in high-income countries. The authors have identified factors associated with an increased mortality, such as not using the Safe Surgery Checklist. This analysis may be helpful in establishing pediatric surgical care systems in low–middle income countries and develop research pathways addressing interventions that will assist in decreasing mortality rate.

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## EDITOR'S PERSPECTIVE

### What We Already Know about This Topic

- The pediatric surgical load in low- and middle-income countries is growing; more than 50% of the population are children and up to 85% may require surgery.
- Data on perioperative mortality rates are sparse and inconsistently collected, but some studies indicate high rates in Africa.

### What This Article Tells Us That Is New

- In a series of 24 Kenyan hospitals, an innovative, robust data tool for collecting more accurate mortality rates found cumulative rates of 0.8% at 24 h, 1.1% at 48 h, and 1.7% at 7 days postoperatively.
- In this sample, the 7-day mortality was more than 100 times higher than in high-resource settings and associated with American Society of Anesthesiologists Physical Status III or more, surgery at night or over the weekend, and not using the Safe Surgical Checklist. Mortality was also higher in primary hospitals compared to secondary or tertiary hospitals.

Children comprise more than 50% of the overall population in many low- and middle-income countries. Perhaps 85% of these children will require a surgical operation before their fifteenth birthday.[1] Surgical admissions account for 6 to 12% of all pediatric hospitalizations in Sub-Saharan Africa, although this may be even higher in urban settings or areas of conflict.[2,3] Surgical capacity in Sub-Saharan Africa is well below current goals. As such, pediatric surgical patients likely experience preventable morbidity and mortality. The lack of basic surgery infrastructure, shortages of pediatric surgeons and anesthesia providers, and absent or inadequate physiologic monitoring capability each degrade the safety of the pediatric surgery ecosystem while making access extremely difficult, or not affordable, for this large low- and middle-income country population.[4–9]

Against this backdrop, there has been a concerted effort by global health advocates to increase surgical capacity in low- and middle-income countries.[6] To measure the effectiveness of these capacity-building efforts, it is important to establish a baseline of performance for agreed-upon clinical

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outcomes and to monitor changes as interventions are made and capacity added. Perioperative mortality rate, defined as the number of all-cause deaths before discharge in patients who have undergone a procedure in an operating theater, divided by the total number of procedures, and presented as the percentage, is a credible quality and safety indicator of perioperative care.[6] Despite the apparent simplicity of the metric, there are multifactorial collection system deficits in low- and middle-income countries (an insufficient workforce; paper medical records; lack of appreciation for importance of data; and lack of resources) that make accurate assessments challenging.[10]

From very limited available data on pediatric perioperative mortality rate in Africa, mortality ranges from less than 3% in select procedures to more than 50% in emergency neonatal bowel obstruction cases.[10] A meta-analysis from the pediatric surgical literature reported an overall pediatric perioperative mortality rate in African countries from 2005 to 2014 as 29.4%.[11] Possible contributors to this high pediatric mortality rate were delayed presentation and inadequate facilities in 39 studies (77%), dearth of trained support personnel in 32 studies (63%), and insufficient or absent neonatal intensive care services in 29 studies (57%).[11] Almost all of these mortality estimates are based upon retrospective mortality reports obtained by review of hospital surgery log books, a limitation that makes the estimates subject to multiple potential biases.

We have previously described the creation and implementation of a laptop-based electronic data collection system in Kenya at a large nongovernmental hospital.[12] In that study, we noted that the prospectively collected perioperative mortality rate among all surgical patients was lower than estimates based on retrospective reviews. After this feasibility demonstration, we scaled our data collection capacity to include all levels (primary, secondary, tertiary) of government and nongovernment hospitals (24) in Kenya over a 3-yr period focusing on the pediatric surgical patient. Our primary aims in this study were to establish a pediatric perioperative mortality rate baseline in Kenya; determine if the mortality rate could be impacted by national hospital level structure; and identify risk factors (including use of the Safe Surgery Checklist) associated with mortality in this patient population.

## Materials and Methods

### Study Design

This prospective cohort study was approved by the Institutional Review Boards of Vanderbilt University Medical Center (Nashville, Tennessee) and Kenyatta National Hospital (Nairobi, Kenya), with the requirement for written informed consent waived by all hospitals. Owing to an extensive collaborative history between Kijabe Hospital (Kijabe, Kenya) and Vanderbilt University

**Table 1.** Hospital Size, Operative Volume, Operative Capacity, Number of Cases, Dates of Data Collection

| Hospital Level (Name of Hospital) | Hospital Beds (n) | Operating Theaters (n) | Type of Facility | Month Data Collection Was Initiated | No. of Cases |
|---|---|---|---|---|---|
| Tertiary | | | | | |
| Kenyatta National Hospital | 2,065 | 9 | Government | Oct 2015 | 586 |
| Secondary | | | | | |
| Coast General Hospital | 546 | 4 | Government | July 2014 | 9 |
| Embu Provincial General Hospital | 468 | 2 | Government | July 2014 | 19 |
| Kakamega County Referral Hospital | 448 | 4 | Government | Oct 2016 | 17 |
| Nyeri County Referral Hospital | 327 | 3 | Government | July 2014 | 49 |
| Africa Inland Church Kijabe Hospital | 320 | 8 | Faith-based | Jan 2014 | 4,248 |
| Meru Teaching and Referral Hospital | 306 | 3 | Government | July 2014 | 11 |
| Tenwek Hospital | 300 | 8 | Private | May 2015 | 220 |
| Naivasha County Referral Hospital | 143 | 2 | Government | July 2016 | 3 |
| Primary | | | | | |
| Isiolo District Hospital | 305 | 2 | Government | July 2014 | 11 |
| Busia County Hospital | 284 | 1 | Government | Oct 2016 | 16 |
| Maua Methodist Hospital | 275 | 4 | Faith-based | July 2014 | 223 |
| Yala Sub-District Hospital | 209 | 1 | Government | Oct 2015 | 5 |
| Kiambu District Hospital | 200 | 2 | Government | May 2016 | 10 |
| Siaya County Referral | 200 | 1 | Government | Oct 2015 | 18 |
| Kilifi County Hospital | 172 | 2 | Government | Sept 2016 | 11 |
| Christamarianne Hospital | 170 | 2 | Faith-based | July 2014 | 15 |
| Africa Inland Church Litein Hospital | 160 | 3 | Faith-based | Nov 2016 | 18 |
| Msambweni District Hospital | 155 | 2 | Government | July 2014 | 4 |
| Africa Inland Church Kapsowar Hospital | 126 | 3 | Faith-based | Jan 2015 | 107 |
| Mutomo Mission Hospital | 124 | 2 | Faith-based | July 2014 | 42 |
| Bondo District Hospital | 49 | 1 | Government | Oct 2015 | 11 |
| Nyambene District Hospital | 40 | 1 | Government | July 2014 | 2 |
| Africa Inland Church Cure Children's Hospital | 30 | 2 | Faith-based | July 2014 | 310 |

Medical Center, Kijabe Hospital was selected as the first center for implementation of the data collection tool, beginning in January 2014, with subsequent expansion to government, private, and faith-based hospitals throughout Kenya (table 1). This study is a subgroup analysis of pediatric cases from the collected surgical cases performed at these hospitals. Two-year data from Kijabe Hospital were previously published by our group.[12]

## Questionnaire

A total of 132 data elements were collected on each surgical case, with selection of data fields guided by two main principles. The first principle was to include all data fields that have been reported as clinically significant to understanding baseline characteristics of surgical care and outcomes in low- and middle-income countries. This also includes discrete data fields that have been reported to be associated with surgical outcomes (*e.g.*, use of Safe Surgery Checklist; weight; age). The second principle was to limit the number of data fields to an amount that could be completed by an anesthesia provider in near real-time during a typical case at Kijabe Hospital (average duration of anesthesia ≈ 90 ± 20 min [mean ± SD]). These design principles were applied through iterative cycles utilizing a modified Delphi technique with a team of experts from Vanderbilt University Medical Center (B.S., M.D.M., W.S.S.) and Kijabe Hospital (M.W.N., J.K.). Through this process, five sections of questions were developed, including Provider Information and Case Demographics, General Case Information, Details of Anesthetic Administration, Intraoperative Vital Signs, and Perioperative Complications and Follow-Up.

## Data Collection Tool

Initial data collection was performed using paper forms while the electronic data collection tool was being developed. The Research Electronic Data Capture group (REDCap) tool, developed and maintained at Vanderbilt University, is a customizable software platform and workflow methodology designed for electronic collection and management of research data.[13] Anesthetic providers, including Kenyan registered nurse anesthetists and student Kenyan registered nurse anesthetists at Kijabe Hospital, received training on principles of quality improvement, real-time data acquisition, data management, and professionalism. This included hands-on workshops concerning the proper use of the REDCap data collection tool.

## Morbidity and Mortality

Data assistants who were not involved in patient care followed patients prospectively from preoperative assessment until discharge from the hospital or 7 days into the postoperative period, whichever came later. Patients were followed postoperatively in order to record outcomes of death or any perioperative complications. In cases where patients were discharged before 7 days postoperative, a follow up phone call was made to the patient or designated family member to determine mortality status.

## Statistical Analysis

*A priori* statistical power calculation was not conducted. Instead, a convenient sample size was used, and the maximum amount of patients' data was collected during the study period. Patient demographics, hospital variables, clinical characteristics, and outcomes are summarized using the median (25th and 75th percentiles) and mean ± SD for continuous variables and percentage for categorical variables. In the unadjusted analysis, the Wilcoxon rank sum test for continuous data, the Pearson chi-square test for nominal data, and the proportional odds likelihood ratio test for ordinal data were used to study the associations between hospital type and clinical variables. In the adjusted analysis, wherein a logistic model was fitted to compare perioperative mortality rate among different types of hospitals after adjusting for the following prespecified risk factors, including patient age at admission, sex, weight, American Society of Anesthesiologists (ASA) classification, emergent status, surgery type, time of surgery, trauma, and Safe Surgery Checklist use. Effects are presented using the odds ratios (95% CI, *P* value). Missing data in independent variables were imputed with a multiple imputation method where 10 "complete" datasets were generated, and model parameters were estimated using each complete dataset, and then parameter estimates and their standard errors were combined into final model estimates using the Hmisc and rms packages in R. All analyses were performed using the R Programming Language 3.3.0 (R Foundation for Statistical Computing, Austria). A two-sided 0.05 significance level was applied for inference.

# Results

Data were collected on 6,005 pediatric surgery cases from 24 facilities in Kenya from January 2014 to December 2016. A majority of the cases collected (4,557, 76.5%) were from secondary hospitals, while the only tertiary hospital that participated in this study collected 586 (9.8%) of cases (table 2). Secondary hospitals performed a higher percentage of neurosurgical procedures (1,463, 32%), as compared to primary (10, 1%) and tertiary (46, 8%) hospitals, while a majority of cases performed at primary hospitals were orthopedic procedures (385, 47%), compared to 518 (11%) at secondary and 79 (13%) at tertiary hospitals (table 2).

A majority of the cases (5,631, 95.8%) were performed on healthy patients with ASA classification of I or II, while 244 (4.1%) had a score of III or higher. While a large number of the cases were performed on children older than 3 yr (3,342, 55.8%), some hospitals performed surgery on children that were less than 1 wk old (229, 3.8%). In addition, while most patients (5,490, 92.5%) weighed more than 3 kg, 442 (7.5%) weighed less than 3 kg (table 3). The number of observations (nonmissing data) for each variable is indicated in table 3 (column N).

Mortality was lower than previous estimates predicted. Forty-six (0.8%), 62 (1.1%), and 77 (1.7%) patients died within 24 h, 48 h, and 7 days of the surgery (table 4). Seven-day mortality data were available on 4,595 (76.5%) cases. In the unadjusted analysis, younger age ($P = 0.012$), weight less than 3 kg ($P = 0.003$), ASA status above III ($P < 0.001$), general surgery ($P < 0.001$), night/weekend surgery time ($P < 0.001$), emergency surgery ($P < 0.001$), primary hospital type ($P = 0.001$), and no Safe Surgery Checklist performed ($P < 0.001$) were associated with increased 7-day perioperative mortality rate. However, age and weight were not statistically significant risk factors for 24-h or 48-h perioperative mortality rate.

Compared to secondary hospitals, primary hospitals increased the odds of 7-day mortality by a factor of 3.09 (95% CI, 1.50 to 6.4, $P = 0.002$) after adjusting for other covariates. However, there was no statistically significant difference between tertiary and secondary hospitals (fig. 1). ASA status III or more, night or weekend surgery, not having safe checklist increased the odds of 7-day mortality by a factor of 5.76 (95% CI, 2.77 to 12.0, $P < 0.001$), 2.43 (95% CI, 1.02 to 5.8, $P = 0.045$), and 2.97 (95% CI, 1.26 to 7.0, $P = 0.013$), respectively, after adjusting for other risk factors. Patient age, sex, weight, emergency status, and trauma were not statistically significant risk factors for 7-day perioperative mortality rate after adjusting for other covariates (fig. 1). Compared to primary hospitals, secondary and tertiary hospitals were associated with 68 (95% CI, 34 to 85, $P = 0.002$) and 75 (95% CI, 29 to 91, $P = 0.009$) percent decrease in odds of 7-day mortality after adjusting for other covariates. There was no perioperative mortality rate difference between secondary and tertiary hospitals 0.80 (95% CI, 0.31 to 2.06, $P = 0.646$).

## Discussion

### Pediatric Surgery and Anesthesia in Low- and Middle-Income Countries

In the Lancet Commission's Global Surgery 2030, the estimation that 143 million additional surgical procedures are needed each year worldwide demonstrates the clinically significant burden on the pediatric population, which is part of this 143 million procedure deficit.[6] This imbalance, evidenced by a healthcare provider density in high income countries of 56.9 providers per 100,000 population compared to a low- and middle-income country density of 0.7 providers per 100,000, highlights the gravity of this heathcare crisis.[8] The obstacles to receiving safe, efficient surgical care in low- and middle-income countries are even more threatening in the pediatric population located in these rural areas of resource-poor countries.[9] The limited and urban-focused pediatric surgery capacity in Africa poses serious challenges to the surgical coverage of the rural masses, which account for more than 75% of the population.[9] In addition, the pediatric surgery patient with delayed presentation and advanced pathology presents an extremely difficult clinical and economic dilemma for this overstretched surgery provider context, which is prevalent in most African countries. Within this low- and



**Table 2.** Operative Case Mix and Volume by Hospital Classification

| | N | Primary Hospitals N = 816 | Secondary Hospitals N = 4,557 | Tertiary Hospital N = 586 | *P* Value |
|---|---|---|---|---|---|
| Type of surgery | 5,942 | | | | < 0.001 |
| Plastic or burns | | 52 (6%) | 388 (9%) | 32 (6%) | |
| Orthopedic | | 385 (47%) | 518 (11%) | 79 (13%) | |
| General | | 208 (25%) | 1,141 (25%) | 195 (33%) | |
| Neurosurgery | | 10 (1%) | 1,463 (32%) | 46 (8%) | |
| Ear, nose, throat | | 123 (15%) | 406 (9%) | 127 (22%) | |
| Urology | | 11 (1%) | 441 (10%) | 36 (6%) | |
| Cardiac/thoracic | | 4(0%) | 13 (0%) | 6 (1%) | |
| Gynecology | | 2 (0%) | 3 (0%) | 14 (2%) | |
| Endocrine | | 1 (0%) | 11 (0%) | 1 (0%) | |
| Endoscopy | | 1 (0%) | 40 (1%) | 1 (0%) | |
| Ophthalmology | | 0 (0%) | 3 (0%) | 24 (4%) | |
| Oral/maxillofacial | | 13 (2%) | 88 (2%) | 16 (3%) | |
| Emergent surgeries | 5,942 | 157 (19%) | 253 (6%) | 134 (23%) | < 0.001 |
| Trauma | 5,878 | 167 (21%) | 274 (6%) | 50 (9%) | < 0.001 |
| Time of surgery | 5,834 | | | | < 0.001 |
| Day (Mon to Fri, 7:00 AM to 5:00 PM) | | 705 (88%) | 4,232 (95%) | 565 (100%) | |
| Night (Mon to Fri, 5:00 PM to 7:00 AM) | | 69 (9%) | 114 (3%) | 1 (0%) | |
| Weekend | | 27 (3%) | 87 (2%) | 0 (0%) | |

Data are shown in n (%). The Pearson chi-square test was used for comparisons. Hospital classification data were available for n = 5,959 patients.

**Table 3.** Patient Demographics and Clinical Characteristics

| | N | Primary Hospitals | Secondary Hospitals | Tertiary Hospitals | *P* Value |
|---|---|---|---|---|---|
| Sex | 5,944 | | | | 0.009 |
| Male | | 464 (57%) | 2,834 (63%) | 364 (64%) | |
| Female | | 348 (43%) | 1,689 (37%) | 209 (36%) | |
| Weight, kg | 5,932 | | | | < 0.001 |
| < 2 | | 0 (0%) | 19 (0%) | 2 (0%) | |
| 2–3 | | 2 (0%) | 386 (9%) | 33 (6%) | |
| 4–10 | | 142 (18%) | 1,455 (32%) | 148 (26%) | |
| 11–50 | | 565 (70%) | 2,397 (53%) | 341 (59%) | |
| 51–70 | | 92 (11%) | 219 (5%) | 52 (9%) | |
| 71–100 | | 6 (1%) | 26 (1%) | 4 (1%) | |
| Age | 5,989 | | | | < 0.001 |
| < 1 wk | | 0 (0%) | 216 (5%) | 13 (2%) | |
| 1 wk to < 1 month | | 3 (0%) | 283 (6%) | 15 (3%) | |
| 1 month to < 3 months | | 14 (2%) | 332 (7%) | 24 (4%) | |
| 3 months to < 3 yr | | 164 (20%) | 1,309 (29%) | 229 (40%) | |
| 3 yr to < 12 yr | | 413 (51%) | 1,677 (37%) | 210 (36%) | |
| 12 yr to ≤ 18 yr | | 222 (27%) | 732 (16%) | 88 (15%) | |
| ASA | 5,875 | | | | < 0.001 |
| I | | 549 (68%) | 1,562 (35%) | 388 (70%) | |
| II | | 239 (30%) | 2,785 (62%) | 108 (19%) | |
| III | | 13 (2%) | 119 (3%) | 45 (8%) | |
| IV | | 6 (1%) | 6 (0%) | 15 (3%) | |
| V | | 1 (0%) | 4 (0%) | 1 (0%) | |
| Anesthesia type | 5,944 | | | | < 0.001 |
| General | | 580 (71%) | 4,165 (91%) | 530 (93%) | |
| Neuraxial | | 79 (10%) | 151 (3%) | 29 (5%) | |
| Sedation | | 145 (18%) | 172 (4%) | 9 (2%) | |
| Local anesthesia | | 6 (1%) | 22 (0%) | 3 (1%) | |
| Regional | | 4 (0%) | 9 (0%) | 1 (0%) | |
| Safe Surgery Checklist used | 5,899 | 740 (91%) | 4,423 (99%) | 374 (65%) | < 0.001 |

Data are shown in n (%). The Pearson chi-square test was used for comparisons. ASA, American Society of Anesthesiologists Physical Status.

middle-income country surgery ecosystem, we demonstrated the feasibility of prospectively collecting perioperative mortality rate over a 36-month period to use these data for the quantification of surgery and anesthesia risk. These were the main findings. First, the pediatric perioperative mortality rate that we report (1.7%) across the 24 Kenyan hospitals we studied is lower than previous estimates for larger groupings across Africa, but still 100 to 200 times more than pediatric perioperative mortality rate in high-resource settings.[9–11] Second, use of a Safe Surgery Checklist was associated with decreased mortality in the pediatric surgical population.

## Pediatric Perioperative Mortality Rate

Our study does not elucidate why perioperative mortality rate is lower in our Kenyan sample of hospitals, but we can hypothesize two potential reasons. First, large numbers of cases were done in centers that focus on pediatric surgery and anesthesia in Kenya. This lower perioperative mortality rate may result from the training of the perioperative team in the management of the pediatric surgical population. These centers tend to have anesthesia monitors and attachments, such as blood pressure cuffs and pulse oximeter probes, designed for children. In addition, these hospitals have a system that focuses on standardized care protocols along with monthly morbidity and mortality meetings. Second, the sample of 24 hospitals probably is biased toward the "willing and able" healthcare facilities in Kenya. If the facility is able to participate in a study of mortality rate, perhaps it is also more capable of maintaining higher standards of care than facilities that do not have the wherewithal to participate in quality improvement research. An approach that employs complete data capture rather than voluntary participation would help resolve these questions.

## Factors Associated with Pediatric Perioperative Mortality Rate

Multivariable logistic regression to model predictors of pediatric perioperative mortality rate in our study revealed that Safe Surgery Checklist use, ASA classification, and time of surgery were associated with an increased pediatric perioperative mortality rate in our patient population. The Safe Surgery Checklist implementation in many high-income countries is well established, with improved results in the reduction of perioperative complication rates.[14] While most high-income country operating rooms use the Safe

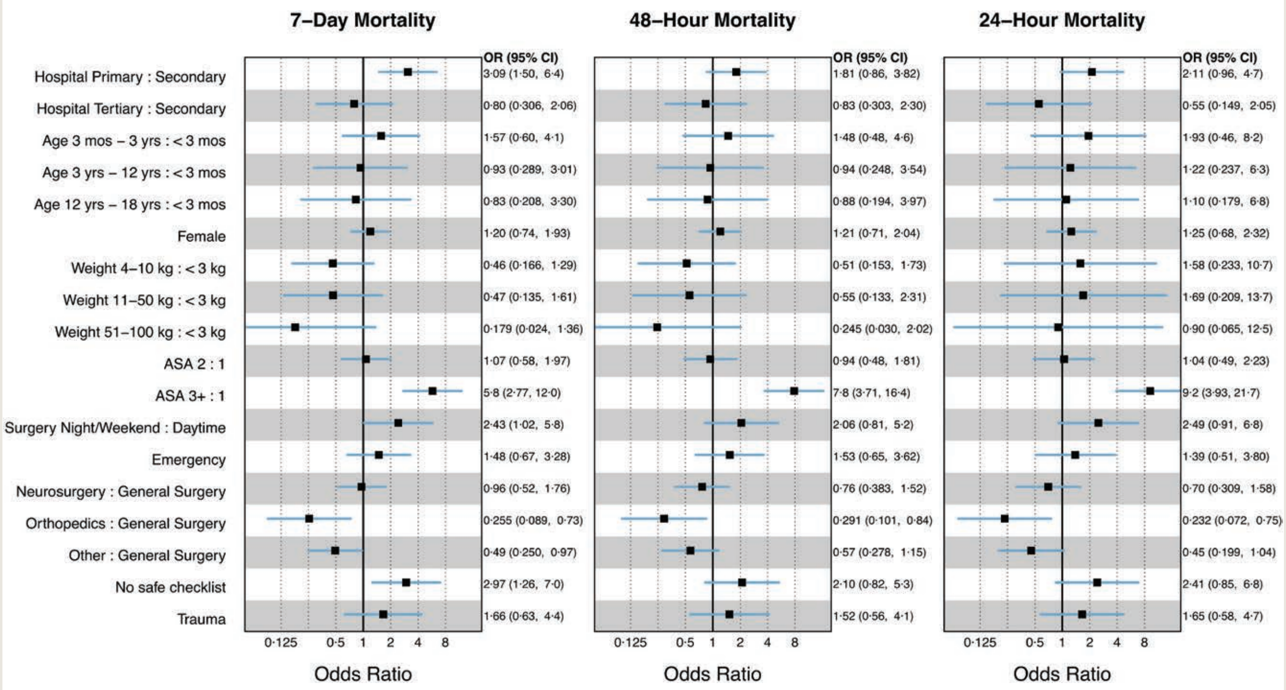

**Fig. 1.** Estimated odds ratio (95% CI) for mortality at 24 h, 48 h, and 7 days from the multiple logistic regression model. Missing data were imputed using the multiple imputation method. Number of cases included in each model: 24-h mortality (n = 5,804), 48-h mortality (n = 5,708), and 7-day mortality (n = 4,595). ASA, American Society of Anesthesiologists Physical Status; OR, odds ratio.

**Table 4.** Perioperative Mortality at 24 h, 48 h, and 7 Days

| | Overall* | Primary | Secondary | Tertiary | *P* Value |
|---|---|---|---|---|---|
| 24 h | 46/5,804 (0.8%) | 13/807 (1.6%) | 29/4,493 (0.7%) | 4/475 (0.8%) | 0.018 |
| 48 h | 62/5,708 (1.1%) | 13/790 (1.7%) | 41/4,434 (0.9%) | 8/458 (1.8%) | 0.074 |
| 7 days | 77/4,595 (1.7%) | 15/404 (3.7%) | 52/3,753 (1.4%) | 10/414 (2.4%) | 0.001 |

Data are shown in No. death/group size (%). *P* value was calculated using the Pearson chi-square test. *n = 201 patients had missing 24-h mortality data, n = 96 patients had missing 48-h mortality data, and n = 1,113 patients had missing 7-day mortality data.

Surgery Checklist in various formats, this is not the case in most low- and middle-income countries. A survey to determine the use of the Safe Surgery Checklist in the largest government referral hospitals in five East African countries (Uganda, Tanzania, Kenya, Rwanda, Burundi) has shown that although 58% of anesthesia providers who responded knew about the Safe Surgery Checklist, only 25% ever utilized the checklist in their obstetrical operating rooms, and that use was not necessarily routine.[15] The reasons for noncompliance in these settings are multifactorial and not fully understood, but this study highlights that significant work must be done to develop a safe surgery culture within a team model in these settings. Our study has shown that not using the Safe Surgery Checklist in the pediatric surgery population was associated with a 218% increase (95% CI, 25 to 705, $P = 0.015$) in the odds of 7-day perioperative mortality rate across all hospital levels. This is the first study we know of that has shown an association between the use of the Safe Surgery Checklist and a reduction of pediatric surgery mortality in a low–middle income country.

Additionally, our data have shown that an ASA status III or greater is associated with a 424% (95% CI, 154 to 983, $P < 0.001$) increase in odds of 7-day mortality. Similar to our study, the Pediatric Perioperative Cardiac Arrest Registry taken from high-income countries (United States, Canada) showed that ASA III to V was the highest predictor of death.[16] Studies from Africa directly linking ASA status to pediatric perioperative mortality are not available, but a meta-analysis has shown that mortality is higher in surgeries that would classify as ASA III cases, such as neonatal bowel perforation, congenital diaphragmatic hernia, ruptured omphalocele, and gastroschisis.[11] A study from Brazil, an upper middle–income country, has been able to link pediatric cardiac arrest in a large academic urban center with the following risk factors: age younger than 1 yr, ASA greater than III, and emergency surgery, with the most common causes of death related to the airway and medications.[17] To our knowledge, this study is the first to demonstrate a link between ASA status and pediatric perioperative mortality rate in the East Africa setting with prospectively collected data. We believe that these data support the idea that a country-specific roadmap for pediatric surgery and anesthesia should include referral protocols so that patients with ASA III or greater patients could be resuscitated and then transferred to designated surgical centers prepared to manage these patients at greater risk of perioperative mortality. As pediatric-specific Bellwether procedures are established, this appreciation of increased perioperative mortality rate and hospital level could help guide these discussions.

Interestingly, night/weekend surgery as an isolated factor substantially increased odds of 7-day mortality while emergency surgery alone did not. Although not able to be verified from our data, and a result that will require further investigation, off-hours surgery in an ecosystem that is stretched during normal hours will be substantially more limited, with less support, thus adding to the potential for a higher operative mortality. In these settings, the surgical team, understanding the reduced resources, may be forced to operate in these dire circumstances on these higher-acuity pediatric patients.

## Prospective, Electronic Pediatric Perioperative Mortality Rate Data Collection Model in Low- and Middle-Income Countries

Previous research has shown that data collection requires extensive training and reinforcement to capture the cases in a prospective, accurate fashion.[12] We have demonstrated the feasibility of prospective electronic data collection of the pediatric perioperative mortality rate at scale in Kenya. The data collection tool was able to be used in the operating room by both physician and nonphysician anesthesia providers in multiple regions (urban, rural) across the country. The vast majority of these cases were performed by anesthesia nurses who also entered the data. Indicators for the ability to perform safe pediatric surgery at all hospital levels must be determined to help guide policy leaders about the essential facility and human resource infrastructure requirements necessary to safely meet this growing population's surgical needs. Although this data collection tool is already being implemented in other low- and middle-income countries, additional sharing of tools and training methodologies we describe should be further encouraged to allow for the development of a standardized, feasible best practice for use within all low- and middle-income countries.

## Limitations

The current study does have several limitations. First, we were able to capture data at each hospital level, but a secondary hospital, Kijabe Hospital, with a pediatric surgery care team, including pediatric intensivists, had the busiest overall surgical volume, and this could have skewed the data. The data capture infrastructure was adapted for each hospital level, but the pediatric surgery case volumes were determined based upon local referral patterns. Second, we collected a low number of cases from the only tertiary hospital in the country (Kenyatta National Hospital). Unfortunately, we had a considerable number of cases missing at postoperative day 7, and it was not until we hired an additional data quality assurance technician that we improved the 7-day follow-up. For each of the mortality endpoints, we assume that the outcome is missing at random (*i.e.*, either with a constant missingness rate, or a rate that varies only as a function of the independent variables). In a similar previous study, a random sample of patients with missing mortality records was selected for intensive follow-up to ascertain mortality status. Using these data, we found no evidence to contradict the missing at random assumption.[12] We performed model validation and calibration, and did not see evidence of model overfit. The optimism-corrected slope index was 0.83 and 0.82 respectively for 7-day and 48-hour mortality. Nevertheless, because mortality is rare, there is still a potential for bias in estimating the postoperative mortality rate due to subtle systematic missingness. Thus, we caution the reader to consider this uncertainty in applying these findings to policy matters. Third, we had insufficient outcome data for complex models, but as we are continuously adding cases to the database, future analyses should allow for more complex statistical models. Fourth, any morbidity or mortality database with self-reporting could underreport, so this always needs to be considered. We spent a considerable amount of education time on this issue, but it is still a possible limitation due to the potential for error with data entry by human beings and reporting bias.

In conclusion, pediatric perioperative mortality rate can be prospectively captured electronically in a low–middle resource environment in both urban and rural settings. Perioperative mortality rates, not a standard of practice in most low-resource countries, represent a very important indicator for the quantification of risk for anesthesia. In addition, these data will help us direct future quality improvements and standard of care practices, specifically for the low- and middle-resource settings. Studies have shown that perioperative mortality rate will differ substantially between institutions, resource levels, and case distribution patterns when comparing hospitals from different countries, or even within the same country (urban *vs.* rural). Our focus should now be on establishing a standard, prospective approach to measurement and then reporting of perioperative mortality rate, adults and children, as a global surgery indicator that guides policy and education. We cannot use these pediatric perioperative mortality results and apply them to every low- and middle-income country hospital setting, but now we have a guide. However, we can verify that, with proper data entry training and point of care information technology support, the system required to obtain granular data is not only possible, but insightful.

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## Competing Interests

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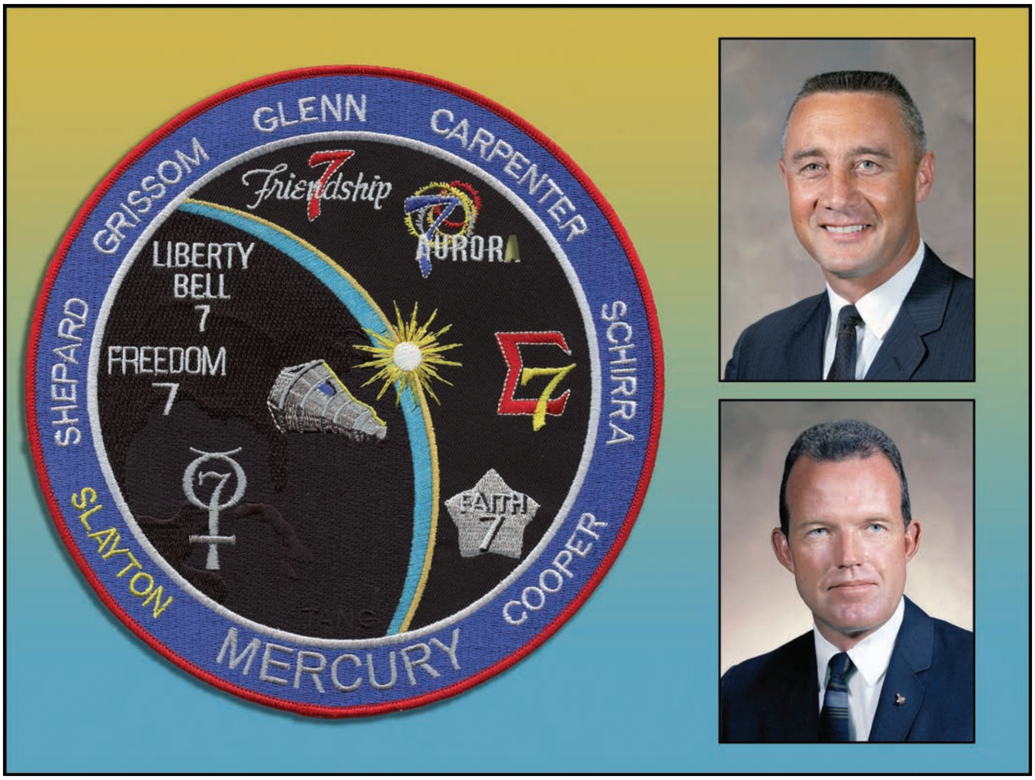
# Byline Backstory No. 2—Astronaut-ministering Launched Interest in Science for a Future Anesthesiologist and Curator




The Air Force assigned my father in 1961 to serve as a chaplain in Alaska for 1 year. His wife Suzanne and their youngsters, Brenda, Chris, and me, stayed behind in Pennsylvania. Dad's reports on "men in isolation"—those manning lonely radar sites—soon swayed the Air Force to station him next at Florida's Cape Canaveral, where he met or ministered to all six of the "Mercury 7" (astronauts Shepard through Cooper, *left*) who flew solo on America's first spaceflights. In turn, the sixth Mercury astronaut, Gordon Cooper (*lower right*) and then a future Gemini astronaut, Tom Stafford, ministered to me—as these former Scouts took turns handing me my Cub Scout awards. They also interested me in becoming an Eagle Scout and in pursuing a science career. After Mercury "solo" spaceflights ended, our family transferred to Morón Air Force Base in Spain. There in 1967, we learned the sad news that the second Mercury astronaut and our former church usher, "Gus" Grissom (*upper right*), had perished in a fire back in Florida during a prelaunch test of Apollo 1. (Copyright © the American Society of Anesthesiologists' Wood Library-Museum of Anesthesiology.)

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