Title
Developing a Surgical Risk-Adjustment Tool for Low- and Middle-Income Countries.

Author
Anderson, Jamie

Publication Date
2014

Developing a Surgical Risk-Adjustment Tool for Low- and Middle-Income Countries

Jamie Anderson, MPH
MD Candidate, June 2014
Independent Study Project

ISP Committee:
Chair: Stephen Bickler, MD; Department of Surgery
Members: David Chang, PhD, MPH, MBA; Department of Surgery
Steffanie Strathdee, PhD; Division of Global Public Health

I. ABSTRACT

Surgical conditions have been a largely neglected public health issue in low- and middle-income countries (LMICs). It is estimated that 11% of the global burden of disease can be treated surgically. While access maintains a barrier, more should be done to ensure quality surgical care. Developing a risk-adjustment tool to fairly measure surgical outcomes is one way in which we can begin to evaluate surgical quality. This requires that outcomes be adjusted based on the risk of the patient population. For example, a hospital with a high mortality rate but high-risk patients may provide "better" surgical care than a hospital with a similarly high mortality rate but low-risk patients.

Our research seeks to develop a risk-adjustment tool by collecting 17 preoperative variables from surgical patients at a district hospital in Mozambique. We will then perform a statistical analysis to find <10 variables that are most predictive of mortality.
This model can help establish a system to benchmark surgical outcomes in LMICs.

II. SUMMARY OF INDEPENDENT STUDY PROJECT PROPOSAL

What are the goals of this project?

The primary objective of this study is to develop a risk-adjustment tool for use in LMICs. In the process, this study will also achieve the following secondary objectives:

- Describe the burden of surgical disease in this setting
- Create a sustainable patient registry at each site
- Train healthcare officials and staff on risk-adjustment and outcomes research
- Create observed/expected ratios for each site in order to compare outcomes

We hypothesize that fewer than 10 preoperative variables are required to build a risk-adjustment tool with an area under the receiver operator characteristic curve (AUC) value of >80%.

Methods

This is a prospective study to collect certain demographic, preoperative, and postoperative variables on all surgical patients from a district hospital in Mozambique. We propose to collect data on at least 300 surgical patients. Because both preoperative and postoperative data is needed, data collection should be performed at time of admission and at time of discharge.

Data will be used to complete univariate and multivariate analyses, and analyze area under the receiver operator characteristic curve (AUC). The AUC helps evaluate a model's ability to predict outcomes by comparing the rate of true positives (sensitivity) with the rate of false positives (1-specificity). Based on AUC values, we will sequentially add variables to our model to create a model with high discrimination. We will complete this process for each outcome of interest: mortality, complication, and referral status. The final result of this study will be to calculate observed/expected ratios for each hospital.

An additional benefit of this data collection is that we can identify the types of procedures performed at these sites over a period of time. This is important in identifying the burden of surgical disease in this area, as well as the surgical capacity of each hospital.

Evaluation of Independent Study Project

This project will be deemed successful if I am able to implement the data collection and complete the data analysis. The final product is expected to be a publication for submission to a peer-reviewed journal.

However, there may be unforeseen events that prevent completion of this project. In that case, the project will be deemed satisfactory if a reasonable attempt is made and circumstances beyond my control prevent completion of data collection and/or analysis. I will then write an evaluation of the project with "lessons learned" to help ensure success in future research projects.

III. PROJECT UPDATE AND LESSONS LEARNED

The goal of our research is to develop a risk-adjustment model for use in resource-poor settings, such as in low- and middle-income countries (LMICs) to help establish a system to benchmark surgical outcomes. In the United States, the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) is the first nationally validated mechanism for comparing risk-adjusted surgical outcomes between U.S. medical centers, and measures over 130 variables and includes a 30-day patient follow-up. Using these data, NSQIP provides risk-adjusted analyses of each hospital to provide feedback as to how they stack up against competitors. Our hypothesis is that instead of 130 variables and a 30-day follow-up period, only a handful of variables are sufficient to develop an adequate risk-adjusted analysis for use in resource-limited settings, including LMICs. This model provides an opportunity to begin to evaluate and raise standards of surgical care to the next level, in conjunction with ongoing efforts to improve access to surgical care in developing countries.

PROJECT HISTORY

The first phase of my ISP, completed during summer 2011 (after my first year of medical school), consisted of a data analysis of NSQIP with validation in a U.S. community hospital. Based on NSQIP data from 2005-2009, our preliminary research found that a more concise tool based on 3-4 preoperative variables is adequate in performing a risk-adjustment analysis. We validated these findings using patient data from a non-rural hospital in the U.S. that serves a catchment area of 25,000 people and is two hours away from an urban area. This work was accepted for publication in the *Archives of Surgery* after a podium presentation at the Pacific Coast Surgical Association in February 2012. The final publication is attached in Appendix I.

The second phase of our research was to develop a similar tool for use in LMICs. Based on our findings from our preliminary research, we established data collection on variables of interest at our partner institution in rural Mozambique in southeastern Africa.

I first traveled to Mozambique in June 2012 to implement data collection at Chókwè Rural Hospital, a district hospital approximately 230 km northwest of the capital of Maputo. I worked with our key partner, Manuel Sipriano Santos, a non-physician surgeon who was the clinical director and primary surgeon of the hospital. I reviewed the project with him, showed him our preliminary research, and together, we decided on the key variables that we would collect. Most records are kept via paper logs in the hospital, but ultimately these data needed to be sent electronically to me in the U.S., as I expected approximately 6 months of data to be collected. We thus decided that the use of an Android-based tablet with the survey available on Opensource Data Kit (ODK), would allow for easy data collection and uploading. Data collection was well underway when I left. However, several unforeseen events occurred, resulting in the project's delay. First, the Android tablet was stolen. Second, Dr. Sipriano had an extended visit to the U.S., during which no data were collected. Third, a contract to compensate Dr. Sipriano for his time was never ensured. Fourth, a massive flood destroyed most of the city of Chókwè, leaving its citizens in camps outside the city and essentially closing the hospital for two months. Fifth, a nationwide strike of doctors put the project on hold for several more months.

CURRENT STATUS

After these initial setbacks, the project was rekindled and additional assistance provided by a UCSD surgery resident, Dr. John Rose, who was taking two years of time off to do research. Since he would have more dedicated time, he would be able to more closely monitor the data collection process. I returned to Mozambique in September 2013 to reinitiate the project along with Dr. Rose. Data collection on all surgery patients is now underway. Although I will not be able to complete the analysis before graduation, the process of setting up this extensive research project with local partners was very challenging and an important learning experience.

While working on this project, I also worked on a side project and published a paper describing the amount of surgical disease that presented to Chókwè Rural Hospital. This was published in the *World Journal of Surgery* and is attached in Appendix 2.

The following are some of the key points that I learned while working in this setting, along with specific ways in which these learning points influenced changes to this project.

LESSONS LEARNED

1. Partnership development and clear paths to communication is key.

Initially, I worked solely with Dr. Sipriano, the clinical director and only surgeon at Chókwè Hospital. As the surgeon, he would need to be in charge of data collection. Dr. Sipriano was very engaged in the project from the beginning, but the success of the project as a whole, and expansion to other sites outside of Chókwè, depended upon a higher level of involvement by those involved with the Eduardo Mondlane University – UCSD Medical Education Partnership Initiative (MEPI) grant. Thus, when retrying the data collection process, we first met with our MEPI partners in the capitol of Maputo to discuss the entire plan, including the specific variables we wished to collect. Second, once we set up the project in Chókwè, we also established a plan for regular phone calls with Dr. Sipriano to ensure that data collection was going smoothly and to provide ongoing support and troubleshooting.

2. When local partners participate in developing the research plan, they are more likely to support it.

During the initial set-up, I discussed the variables and plan with Dr. Sipriano, but when restarting data collect, we started from scratch and discussed all variables in detail with both our partner researchers at MEPI and Dr. Sipriano. Instead of using ODK survey collection data on an Android, we decided to utilize paper data collection sheets in conjunction with EpiInfo software to collect and send data electronically. The local partners were familiar with this software and having paper charts ensured that there was a back-up copy. Coming to consensus on both the data to be collected and the process of collection is an important factor for success.

3. Setting contracts can clarify expectations and formalize relationships.

Although Dr. Sipriano, staffed to oversee data collection at Chókwè Hospital, was promised a contract with a stipend for compensation, this did not come to fruition due to a variety of budgetary and logistic factors. Formalizing this relationship is not only important to compensate him for his work, but also to recognize him as a valuable and acknowledged partner in this initiative.

4. Identify incentives for participation by all key players.
The ultimate goal of this project was to improve surgical care in LMICs, but if the specific sites did not see any tangible benefit for themselves, the research was more a burden than a benefit for them. We brainstormed ways that this project could help the specific sites. We determined that by collecting baseline data, we could offer partner organizations a place to implement interventions that could prospectively study change in surgical outcomes as a result of this intervention.

5. Floods, strikes, thefts, etc. will happen: you can't completely prepare or prevent it all.
From my experience in the Peace Corps, I am well aware of some of these difficulties in working in a LMIC. While you can't plan for everything, developing alternatives and maintaining flexibility is critical to achieve any goal. Maintaining adequate lines of communication with partners is also necessary to develop local solutions.

6. Never underestimate the amount of knowledge you don't know – especially in a foreign setting.
It can be difficult enough to complete a research project in the U.S., but placed in a foreign setting, where you are unfamiliar with the language, culture, and the more nuanced challenges of navigating an unfamiliar medical and university system poses a plethora of challenges. Furthermore, it is impossible to even know some of the areas in which you are deficient. For example, the political context in a certain setting can have a major influence on the ways in which others may approach working with you, but these may not be readily apparent.

IV. RAISING THE QUALITY OF SURGICAL CARE IN LOW- AND MIDDLE-INCOME COUNTRIES: DEVELOPING A SURGICAL RISK-ADJUSTMENT TOOL IN MOZAMBIQUE

Note: Since data collection is still in process, the following is a draft of the introduction and methods of the paper that we ultimately hope to publish.

INTRODUCTION

Surgical conditions have been a largely neglected public health issue in low- and middle-income countries (LMICs). It is estimated that 11% of the global burden of disease can be treated surgically, with injuries (38%) and malignancies (19%) making up a high proportion of these conditions.[1] The highest disability-adjusted life years (DALYs) are found in LMICs; by region, the most surgical DALYs are in South-East Asia, while Africa has the highest ratio of surgical DALYs per 1000 people.[1] The current burden of surgical disease in LMIC is large and also growing with the shift of the global burden of disease to non-communicable diseases. Presently, 80% of deaths due to non-communicable diseases occur in low- and middle-income countries, and at least some of these conditions could be treated surgically.[1] The number of people affected by non-communicable diseases is only expected to rise, further exacerbating the need for quality surgical care in developing countries.

Despite the high burden of surgical disease in LMIC, these countries have a disproportionately low volume of surgery. In 2004, there were an estimated 187.2 to 281.2 million surgical cases throughout the world, translating to approximately one operation for every 25 human.[2] It is estimated that people in the poorest third of the world make up 34.8% of the world's population, but receive only 3.5% of global operations.[2] In contrast, an estimated 58.9% of all operations are performed in the world's richest countries, representing only 15.6% of the world's population.[2]

Surgical outcomes also vary widely between developed and developing countries. It is estimated that the mortality rate in surgery in developed countries is 0.4-0.8%, while the rates are estimated to be 5-10% in developing countries.[2] Other variables of postoperative morbidity and mortality are also likely to be higher in developing countries, but data is severely lacking to accurately assess these rates.[2]

Delivering quality surgical care in these settings will require more than training physicians and building operating rooms. Stronger data is needed to identify the prevalence and incidence of surgical conditions in these settings.[3] Data also need to be collected within individual medical centers to begin to monitor surgical outcomes. Incorporating appropriate and useful data collection and analysis into surgical systems is an important step to drive quality assurance programs.

The American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) is the first nationally validated mechanism for comparing risk-adjusted surgical outcomes between U.S. medical centers and measures over 130 variables and includes a 30-day patient follow-up. However, there is evidence that only a handful of variables may be all that is required for an adequate risk-adjustment analysis.[4-6] Our previous research found that a more concise tool based on 3-4 preoperative variables is adequate in to perform risk-adjustment analyses evaluating mortality or morbidity.[7-8]

This research seeks to develop a similar tool for use in resource-limited settings in LMICs. This model can help establish a system to benchmark surgical outcomes in developing countries and is an opportunity to begin to evaluate and raise standards of health care to the next level, in conjunction with ongoing efforts to improve the surgical capacity of developing countries.

METHODS

This is a prospective study to collect certain demographic, preoperative, and postoperative variables on all patients undergoing surgery requiring inpatient hospitalization from Chókwè Rural Hospital in Mozambique.

Setting

Mozambique is a country of approximately 25 million people located in southeastern Africa.[9] In 2012, it ranked 185 out of 187 countries in the world on the UNDP Human Development Index.[10] The average live expectancy is 50.7 years and nearly half (45%) of its population is aged less than 15 years.[10-11] On average, adults have had 1.2 years of schooling.[10] Over half of Mozambique's population must walk more than an hour to reach a health facility and there are only three doctors per 100,000 people.[12]

Chókwè District is predominantly a rural, agricultural area, approximately 230 km northwest from the capital of Maputo. Chókwè Hospital serves a catchment area of approximately 200,000 people, while roughly 53,000 live in the city of Chókwè.[13] Most people earn less than $2 per day and the district literacy rate is estimated at 57%.[14] Chókwè has the highest HIV rate in the country, estimated at 19.4%.[15]

Chókwè Hospital has 125 beds, which includes 28 beds designated for surgical patients and 38 beds for obstetrics/gynecology patients. Approximately 8,000 inpatients receive care at HRC annually. A non-physician surgeon (*técnico de cirurgia*) manages all operative and non-operative surgical care in the hospital. A separate *técnico* manages all obstetric care. For surgical procedures requiring a specialist, patients are transferred to tertiary hospitals in the provincial capital of Xai-Xai (127 km away) or in the country capital of Maputo (225 km away). The hospital also serves as a teaching hospital for medical students from the Universidade Eduardo Mondlane (UEM) in Maputo and houses a training center for nurses.

Data Collection

We collected data from all surgery inpatients beginning in September 13, 2013 at Chókwè Hospital. The primary surgeon oversaw data collection.

Variables were chosen through a multi-step collaborative process. Initial variables were based on results from our previous research. Using patient data from NSQIP from 2005-2009, we built a risk-adjusted model to measure inpatient mortality using 6 or fewer preoperative risk variables.[7] Subsequent research repeated the analysis with any adverse event, including mortality, as the outcome of interest (data not yet published).[8] Models were built based on the area under the receiver-operator characteristic (AUC) from logistic regressions that predicted inpatient mortality. Several different models reached a high AUC value. All top variables from these previous studies were initially considered (Table 1).

We discussed this initial list with physicians from the Mozambique Ministry of Health as well as the non-physician surgeons operating in Chókwè Hospital. The process of omitting or adding variables was based on consensus among all parties. The final list of variables collect on each surgery patient can be found in Table 2.

Several preoperative risk variables were omitted because they were not easily collected at this site. These include INR, disseminated cancer status, ascites, and weight loss. Surgeon specialty was also omitted as surgeons are not specialized in Chókwè; rather, a non-physician surgeon handles all general surgery cases while an additional non-physician surgeon oversees all obstetrics cases.[16]

We also added several variables based on the setting. Since none of the original preoperative laboratory values were easily collected, we added other laboratory values that could be easily obtained through a complete blood count (CBC) at this hospital that had an AUC>0.6 in the original mortality analysis. These include hematocrit (AUC=0.7184), white blood cell (WBC) count (AUC=0.6629), and platelet count (AUC=0.6182). Height and weight were added to calculate body mass index (BMI). Given that the HIV rate in Mozambique is estimated at 11.5%, we felt this was an important variable to consider and added it to the analysis.[17] Pregnancy status was also added given a fertility rate of 5.9 children per woman in Mozambique and the increased potential this may have on surgical outcomes.[15] Ketamine was also added to the three types of anesthesia described by NSQIP (general, spinal, and local), as this is a common option at these district hospitals that we did not feel was adequately captured by the existing choices. A large proportion of surgery patients are trauma patients at this district hospital; we thus captured whether the patient was a trauma patient and of what type.

For a descriptive analysis of this patient population, we also collected information on diagnosis and type of surgery. We chose a list of 11 commonly performed procedures at this hospital to choose from, in addition to an “other” category, in which the surgeon could write in a different operation.

We also collected intraoperative variables, including total anesthesia time and total operative time. To identify areas requiring intervention, we also asked whether there were any barriers to adequate surgical care, with possible options including: lack of electricity, lack of water, lack of antibiotics, lack of other materials, surgical staff unavailable, or other. Whether pre-operative antibiotics were given was also asked, as this could be another area for intervention. Intra-operative complications were also inquired.

Post-operative outcomes were recorded both at time of discharge and at time of follow-up visit. All patients were expected to return to at least one follow-up visit within two weeks after discharge, with some patients requiring additional follow-up. In addition to mortality, we collected a variety of post-operative outcomes, including dates (to estimate length of time to surgery and total length of stay), whether the patient was transferred to another hospital, and the following outcomes captured by NSQIP: death, surgical site infection (superficial, deep, or organ space), wound dehiscence, pneumonia, unplanned intubation, urinary tract infection, cerebrovascular accident with neurological deficits, coma >24 hours, peripheral nerve damage, cardiac arrest requiring cardiopulmonary resuscitation (CPR), bleeding requiring transfusion, deep vein thrombosis or thrombophlebitis, sepsis, septic shock, other. NSQIP also captures pulmonary embolism, ventilator >48 hours, progressive renal insufficiency, acute renal failure, and prosthesis or flap failure, but these were determined to be too difficult to diagnose or not applicable given available technology and equipment at each site.

Importantly, variables specific to obstetrics patients were also added. Cesarean sections are the most commonly performed operation at these sites and it is estimated that Cesarean sections comprise a large proportion, if not a majority of all surgeries in LMICs.[18] Although NSQIP only considers general surgery patients, we did not want to ignore this important aspect of surgery in LMICs. Additional pre-operative variables for these patients include: number of prior births, whether they had a prior Cesarean section, duration of labor (active phase) prior to Cesarean section, whether labor was induced prior to surgery, and whether there was use of instrumentation (suction, forceps, etc.) prior to surgery. We also asked whether the patient was hemorrhaging prior to surgery, and if so, the estimated amount (<500 mL, 500-1000 mL, or >1000 mL) and if she received a blood transfusion. Maternal diagnoses were also inquired and included uterine rupture, placental problems, obstruction, uterine/vaginal infection, atony, fetal macrosomia (>4 kg), pre-eclampsia, eclampsia, or other. Post-operatively, we asked if there was post-partum hemorrhage and whether there were any other outcomes, including fetal demise, fetal disability, maternal disability, infection, unplanned hysterectomy, or other.

Data Analysis

Once data were collected, we performed a six-step process to add each additional variable sequentially. For each step, a logistic regression was performed to predict any adverse event (complication or death). After each regression, the area under the receiver-operator characteristic curve (AUC) for each model was calculated**.** The AUC is a discriminative measure to identify how well a model separates two groups (i.e. patients with versus without adverse events). An AUC value of 0.5 indicates that the model separated the two groups no better than chance, whereas an AUC value of 1.0 indicates that the model completely separates the two groups. The AUC statistic is actually the percentage of randomly selected pairs that are correctly predicted by the model. Thus, the AUC allows us to determine which model can more accurately discriminate between the two groups of interest.[19-22]

In Step 1, a simple logistic regression was performed with each variable to predict in-hospital adverse events. The variable with the highest AUC was chosen and used as the basis for Step 2. In Step 2, all other variables were added to the top variable chosen from Step 1. Multivariate logistic regression with inpatient adverse event as the outcome was performed again for each variation of this two-variable model and AUC values were found. The models with the top five AUC values were chosen and used as the basis for Step 3. The method for Steps 3-6 was the same as in Step 2: each additional variable was added to the five models chosen from the previous step, multivariate logistic regression was performed, and the AUC value was found. The five models with the highest AUC value became the basis for the next step. This process was repeated until we created models with six variables each (Figure 1).

Statistical analysis was performed using STATA 64-bit Special Edition, version 11.2 (Stata Corp, College Station, Texas). The National Bioethics Committee of Mozambique and the Human Research Protection program at UC San Diego approved this study.

REFERENCES

[1] Ozgediz D, Jamison D, Cherian M, McQueen K. The burden of surgical conditions and access to surgical care in low- and middle-income countries. *Bulletin of the World Health Organization* 2008; 86(8): 646-647.

[2] Weiser TG, Regenbogen SE, Thompson KD, Haynes AB, Lipsitz SR, Berry WR, Gawande AA. An estimation of the global volume of surgery: a modeling strategy based on available data. *Lancet* 2008; 372:139-44.

[3] Bickler S, Ozgediz D, Gosselin R, Weiser T, Spiegel D, Hsia R, Dunbar P, McQueen K, Jamison D. Key concepts for estimating the burden of surgical conditions and the unmet need for surgical care. *World J Surg* 2010; 34:374-380.

[4] Dimick JB, Osborne NH, Hall BL, et al. Risk adjustment for comparing hospital quality with surgery: how many variables are needed? J Am Coll Surg 2010;210:503-508.

[5] Rubinfeld I, Farooq M, Velanovich V, Syed Z. Predicting surgical risk: how much data is enough? AMIA 2010 Symposium Proceedings: 777-781.

[6] Birkmeyer JD, Shahian DM, Dimick JB, et al. Blueprint for a new American College of Surgeons: National Surgical Quality Improvement Program. *J Am Coll Surg* 2008;207:777-782.

[7] Anderson JE, Lassiter R, Bickler SW, et al. Brief tool to measure risk-adjusted surgical outcomes in resource-limited hospitals. *Arch Surg* 2012;147:798-803.

[8] Anderson JE, Rose J, Noorbakhsh A, et al. An efficient risk-adjustment model to predict inpatient adverse events after surgery. *Under review.*

[9] World Bank , World DataBank: World Development Indicators, Mozambique. http://databank.worldbank.org/data/views/reports/tableview.aspx Accessed September 24, 2013.

[10] UNDP: Human Development Report 2012: Sustainability and Equity: A Better Future for All. New York, Palgrave Macmillan, 2012.

[11] Population Reference Bureau. PRB 2012 World Population Data Sheet. http://www.prb.org/DataFinder/Geography/Data.aspx?loc=284

[12] USAID, Mozambique Global Health. August 6, 2013. http://www.usaid.gov/mozambique/global-health

[13] Instituto Nacional de Estatistica, Portal de dados Mocambique. http://www.ine.gov.mz/ Accessed June 14, 2013.
[14] The Republic of Mozambique National Statistics Institute and Official Sector Statistics. Report on the Millennium Development Goals 2010. The Republic of Mozambique, Maputo, Mozambique.
[15] AllAfrica.com. Mozambique: Fertility rate remains extremely high. 7 May 2012. http://allafrica.com/stories/201205071402.html Accessed September 24, 2013.
[16] Pereira C, Cumbi A, Malalane R et al. Meeting the need for emergency obstetric care in Mozambique: work performance and histories of medical doctors and assistant medical officers trained for surgery. BJOG *2007;* 114:1530–1533
[17] Centers for Disease Control and Prevention, Global HIV/AIDS: Mozambique. http://www.cdc.gov/globalaids/Global-HIV-AIDS-at-CDC/countries/Mozambique/ Accessed September 24, 2013.
[18] Galukande M, von Schreeb J, Wladis A, et al. Essential surgery at the district hospital: a retrospective descriptive analysis in three African countries. *PLoS Medicine* 2010;7(3): e1000243.
[19] Healey C, Osler TM, Rogers FB, et al. Improving the Glasgow Coma Scale Score Model: Motor Score Alone Is a Better Predictor. *Journal of Trauma Injury, Infection, and Critical Care* 2003; 54(4):671-680.
[20] Beckwick V, Cheek L, Ball J. Statistics review 13: Receiver operator characteristic curves. *Critical Care* 2004;8(6):508-512.
[21] Meredith JW, Evans G, Kilgo PD, et al. A comparison of the abilities of nine scoring algorithms in predicting mortality. *J Trauma* 2002;53:621-629.
[22] Connell FA, Koepsell TD. Measures of gain in certainty from a diagnostic test. *Am J Epidemiology* 1985;121(5):744-753

Table 1. Initial variables considered for analysis, based on previous research from NSQIP

	Pre-operative Variables Predicting Inpatient Mortality*	**Pre-operative Variables Predicting Any Inpatient Adverse Event (Mortality or Morbidity)†**
Common to both models	Age Albumin ASA Classification Blood urea nitrogen (BUN) Emergent Functional Status Hematocrit INR Surgical specialty Weight loss Wound classification	Age Albumin ASA Classification Blood urea nitrogen (BUN) Emergent Functional Status Hematocrit INR Surgical specialty Weight loss Wound classification
Unique to each model	Ascites Cancer Sepsis	Alkaline phosphatase Body mass index (BMI) Principal anesthesia technique Sex

*Anderson JE, Lassiter R, Bickler SW, et al. Brief tool to measure risk-adjusted surgical outcomes in resource-limited hospitals. Arch Surg 2012;147:798-803.

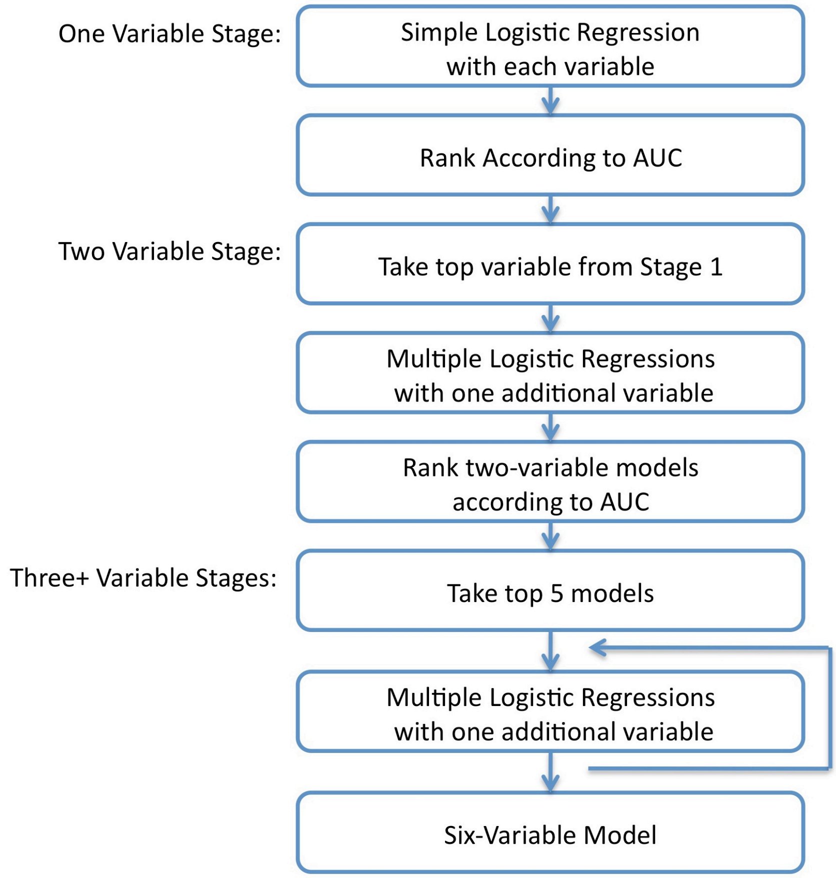
†Anderson JE, Rose J, Noorbakhsh A, et al. An efficient risk-adjustment model to predict inpatient adverse events after surgery. *Under review.*

Table 2. Description of variables collected

Variable	**Definition**
Preoperative Variables	
ID number	Hospital ID and study ID
Sex	
Age (years)	
Diagnosis	
Date admitted to the hospital	
Trauma patient	No; Car accident; Burn; Other
ASA classification	1) Healthy, normal; 2) Mild systemic disease; 3) Serious systemic disease; 4) Serious systemic disease that is a constant threat to life; 5) Not expected to survive without surgery
Sepsis status	None; SIRS; Sepsis; Septic shock
Functional status prior to surgery	Independent; Partially dependent; Totally dependent
HIV status	Positive; Negative; Unknown
Pregnant	Yes; No
Vitals: Weight; Height; Temperature; Heart rate; Blood pressure; Respiratory rate	
Laboratory values: WBC; Hematocrit; Platelets; Urea; Albumin	
Additional pre-operative variables for maternity patients	
Number of prior births	
Prior Cesarean sections	Yes; No
Duration of labor prior to Cesarean section (hours)	
Was labor induced prior to surgery (e.g. use of oxytocin or misoprostol)	Yes; No
Was there use of instrumentation prior to surgery (e.g. suction, forceps, etc.)	Yes; No
Was the patient hemorrhaging prior to surgery	Yes; No. If yes: 0-500 mL, 500-1000 mL, >1000 mL. If yes: did the patient receive a blood transfusion? Yes; No.
Maternal diagnosis	Uterine rupture; placental problems; obstruction; uterine/vaginal infection; atony; fetal macrosomia (>4 kg); pre-eclampsia; eclampsia; other
Peri-operative Variables	

Date of surgery	
Type of surgery	Cesarean section; herniorraphia; exploratory laparotomy; intestinal resection; salpingectomy; hysterectomy; split-thickness skin graft; wound debridement; appendectomy; hydrocoelectomy; limb amputation; other
Emergent	Yes; No
Antibiotics given preoperatively	Yes; No
Duration of operation (minutes)	
Duration of anesthesia (minutes)	
Type of anesthesia	General; Ketamine; Spinal; Local; None
Wound classification	Clean; Clean/contaminated; Contaminated; Dirty/Infected
Intra-operative complications	Yes; No. If yes, check one: required blood transfusion; CPR; myocardial infarction; unplanned intubation; other
Did any of the following interfere with patient care before, during, or after surgery	Lack of electricity; lack of water; lack of antibiotics; lack of other materials; surgical staff unavailable; other
Post-operative Variables (collected at time of discharge and at time of follow-up)	
Date of discharge / Date of follow-up visit	
Transferred to another hospital	Yes; No
Were there any post-operative complications	Yes; No. If yes: check below:
Surgical site infection	Superficial; deep; organ space
Other	Death; wound dehiscence; pneumonia; unplanned intubation; urinary tract infection; cerebrovascular accident with neurological deficits; coma>24 hours; peripheral nerve damage; cardiac arrest requiring CPR; blood transfusion; DVT/thrombophlebitis; sepsis; septic shock; other
Additional post-operative variables for maternity patients	
Post-partum hemorrhage after Cesarean section	Yes; No. If yes: 0-500 mL, 500-1000 mL, >1000 mL. If yes: did the patient receive a blood transfusion? Yes; No.
Other maternal outcomes	Fetal demise; fetal disability; maternal disability; infection; unplanned hysterectomy; other

Figure 1. Stepwise methods for creating a 6-variable model based on AUC values



ONLINE FIRST

Brief Tool to Measure Risk-Adjusted Surgical Outcomes in Resource-Limited Hospitals

Jamie E. Anderson, MPH; Randi Lassiter, BS; Stephen W. Bickler, MD; Mark A. Talamini, MD; David C. Chang, PhD, MPH, MBA

Objectives: To develop and validate a risk-adjusted tool with fewer than 10 variables to measure surgical outcomes in resource-limited hospitals.

Design: All National Surgical Quality Improvement Program (NSQIP) preoperative variables were used to develop models to predict inpatient mortality. The models were built by sequential addition of variables selected based on their area under the receiver operator characteristic curve (AUROC) and externally validated using data based on medical record reviews at 1 hospital outside the data set.

Setting: Model development was based on data from the NSQIP from 2005 to 2009. Validation was based on data from 1 nonurban hospital in the United States from 2009 to 2010.

Patients: A total of 631 449 patients in NSQIP and 239 patients from the validation hospital.

Main Outcome Measures: The AUROC value for each model.

Results: The AUROC values reached higher than 90% after only 3 variables (American Society of Anesthesiologists class, functional status at time of surgery, and age). The AUROC values increased to 91% with 4 variables but did not increase significantly with additional variables. On validation, the model with the highest AUROC was the same 3-variable model (0.9398).

Conclusions: Fewer than 6 variables may be necessary to develop a risk-adjusted tool to predict inpatient mortality, reducing the cost of collecting variables by 95%. These variables should be easily collectable in resource-poor settings, including low- and middle-income countries, thus creating the first standardized tool to measure surgical outcomes globally. Research is needed to determine which of these limited-variable models is most appropriate in a variety of clinical settings.

Arch Surg. 2012;147(9):798-803. Published online May 21, 2012. doi:10.1001/archsurg.2012.699

MANY EFFORTS HAVE BEEN made to define, measure, and evaluate quality surgical care, but these programs tend to focus on hospitals in urban areas, missing many suburban or rural hospitals and completely overlooking low- and middle-income countries (LMICs). In the United States, the most well known include the American College of Surgeons National Surgical Quality Improvement Program (NSQIP),[1] the Surgical Care Improvement Project,[2] and the Leapfrog Group's surgical care standards.[3] Many of these programs focus their research on data from urban and large suburban hospitals and target their programs toward these hospitals. For example, NSQIP collects data on more than 130 variables and includes a 30-day patient follow-up. The cost of participation in this quality improvement program is prohibitory for many small, rural medical centers. The NSQIP recently launched their small and rural program for hospitals that are designated rural by zip code or have fewer than 1680 "NSQIP eligible cases," but this may miss many medium-sized hospitals in nonurban areas that may be too large for this program or too small to feasibly participate in the original NSQIP.[1]

See Invited Critique at end of article

CME

CME available online at www.jamaarchivescme.com and questions on page 794

In addition, surgical quality improvement programs have largely been isolated in developed countries. To improve global surgery, quality measurement tools must be developed to be broadly and internationally applicable. Allowing hospi-

Author Affiliations: Department of Surgery, University of California, San Diego.

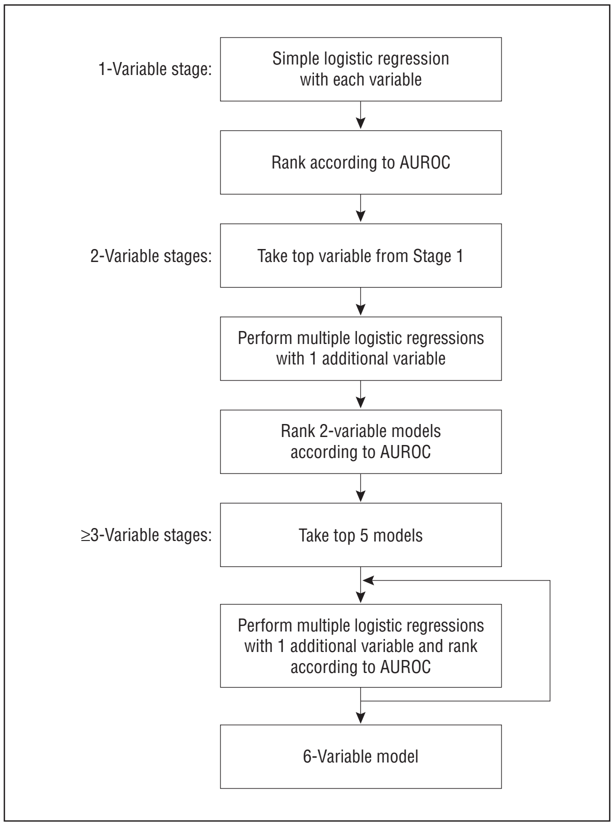


Figure 1. Stepwise methods for creating a 6-variable model based on area under the receiver operator characteristic curve (AUROC) values.

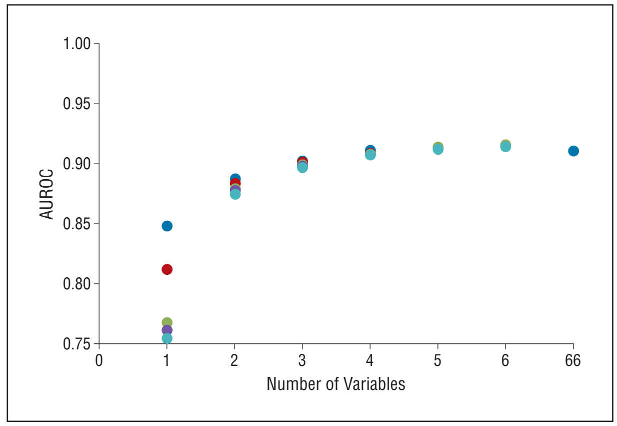


Figure 2. Diminishing returns of additional variables on area under the receiver operator characteristic curve (AUROC). The AUROC values for the top 5 ranked models within each stage are shown.

tals in resource-limited countries to participate in surgical quality improvement efforts through the development of a simplified tool to measure surgical outcomes is the next critical step to improving surgical outcomes globally.

This research seeks to develop and validate a risk-adjusted tool with a limited number of variables to expand risk-adjustment outcomes research to all of the world's surgical settings. This approach will provide the first step to compare risk-adjusted outcomes over time within a given nonurban hospital, between nonurban hospitals, and between urban and nonurban hospitals at a much lower cost. This research creates an important new model for quality improvement and will help establish a system to benchmark surgical outcomes in nonurban hospitals. Ultimately, this research seeks to create pathways to raise standards of health care of all hospitals to the next level.

METHODS

Patient data from NSQIP from 2005 to 2009 were used to build a tool with a limited number of variables to predict inpatient mortality. This nationally validated program measures more than 130 variables on each patient and includes a 30-day patient follow-up.[4] This data set was chosen for its breadth of variables available for each patient, both preoperatively and postoperatively.

A 6-variable tool was built using a list of all preoperative variables included in the NSQIP database, a total of 66 variables, to predict inpatient mortality. All continuous variables were kept as such except for age, which was grouped into 10-year categories.

We performed a 6-stage process to add each additional variable sequentially (**Figure 1**). For each stage, logistic regression was performed to predict inpatient death. After each regression, the area under the receiver operator characteristic curve (AUROC) for each model was calculated. The AUROC value is a discriminative measure to identify how well a model separates 2 groups (ie, survivors vs nonsurvivors). An AUROC value of 0.5 would indicate that the model separated the 2 groups no better than chance, whereas an AUROC value of 1.0 would indicate that the model completely separated the 2 groups. The AUROC statistic is actually the percentage of randomly selected pairs that are correctly predicted by the model. Thus, the AUROC value allows us to see which model can more accurately discriminate between the 2 groups of interest.[5-8]

In stage 1, simple logistic regression was performed with each variable to predict inpatient death. The variable with the highest AUROC value to predict inpatient death was chosen from this first stage and used as the basis for stage 2. In stage 2, all other variables were added to the top variable chosen from stage 1. Multivariate logistic regression with inpatient death as the outcome was performed again for each variation of this 2-variable model, and AUROC values were found. The models with the top 5 AUROC values were chosen and used as the basis for stage 3. The method for stages 3 through 6 was the same as in stage 2: each additional variable was added to the 5 models chosen from the previous stage, multivariate logistic regression was performed to predict inpatient death, and the AUROC value was found. The 5 models with the highest AUROC value would become the basis for the next stage. This process was repeated until we created 6-variable models.

The models with the highest AUROC value at each stage were plotted to observe the diminishing returns of AUROC by each additional variable added (**Figure 2**).

The models with the highest AUROC value were validated using patient data from a 110-bed hospital with a level IV trauma center that serves a community of approximately 25 000 people in California. A retrospective medical record review of 239 surgical patients from 2009 to 2010 was conducted to collect data on each variable of interest. Patients were chosen to represent a random sampling of common, low-mortality operations performed at this hospital (40 procedures on 153 patients) and less common, high-mortality procedures (18 procedures on 86 patients). Common procedures were found by ranking *International Classification of Diseases, Ninth Revision (ICD-9)* procedure codes. High-mortality procedures were found by ranking *ICD-9* procedures among patients who died. Endoscopic

Table 1. Characteristics of the Patient Population

Characteristic	NSQIP Database All (N = 631 449)	NSQIP Database Survived (n = 615 373)	NSQIP Database Died (n = 16 076)	NSQIP Database P Value	Validation Hospital All (N = 239)	Validation Hospital Survived (n = 236)	Validation Hospital Died (n = 3)	Validation Hospital P Value
Age, mean (SD), y[a]	57.4 (17.2)	57.1 (17.2)	71.2 (13.6)	<.001	50-54 (20)	50-54 (20)	60-64 (15)	.31
Race, No. (%)[b]								
White	460 085 (78.8)	448 003 (78.8)	12 082 (80.7)	<.001	49 (20.5)	49 (20.8)	0	.002
African American	65 071 (11.2)	63 217 (11.1)	1854 (12.4)		5 (2.1)	4 (1.7)	1 (33.3)	
Hispanic	41 165 (7.1)	40 493 (7.1)	672 (4.5)		179 (74.9)	177 (75.0)	2 (66.7)	
Asian or Pacific Islander	13 221 (2.3)	12 946 (2.3)	275 (1.8)		NA	NA	NA	
Other or unknown	4291 (0.7)	4199 (0.7)	92 (0.6)		6 (2.5)	6 (2.5)	0	
Female sex	356 475 (56.5)	348 808 (56.7)	7667 (47.7)	<.001	135 (56.5)	135 (57.2)	0	.047

Abbreviations: NA, not applicable; NSQIP, National Surgical Quality Improvement Program.
[a] Age was recorded within 5-year categories in the validation hospital and 10-year categories in the NSQIP database.
[b] Race was only reported for 583 833 of the 631 449 patients. Thus, the percentages are calculated from the total number of patients with a reported race (583 833).

procedures were excluded. A random number of patients from procedures in each group were chosen to obtain a representative sample of both common and high-mortality operations performed at this hospital.

Patient data from this hospital were used to validate the models by rerunning the original multivariate logistic regressions and calculating AUROC values. Pseudo-R^2 values were also found for these models. Some variables, such as albumin, international normalized ratio, blood urea nitrogen, cancer status, ascites status, and surgical specialty of the surgeon, were not identified from medical record reviews; models with these variables were not available to include in the validation.

Statistical analysis was performed with Stata statistical software, version 11.0 (StataCorp). Statistical significance was defined as $P<.05$. This study received approval from the University of California, San Diego, Institutional Review Board.

RESULTS

Data from 631 449 patients from 2005 to 2009 were considered from the NSQIP database to create the limited risk-adjustment model, and data from 239 patients from 2009 to 2010 from the validation hospital were used to assess the risk-adjustment model (**Table 1**). Mean age and sex distribution are similar between the 2 study populations. By race, Hispanics constitute most cases at the validation hospital, whereas whites constitute most cases in the NSQIP data set.

The American Society of Anesthesiologists (ASA) physical status classification had the highest AUROC value (0.8479) in a single-variable model to predict inpatient mortality (**Table 2**). The top variables were ASA classification, albumin, functional status, age, sepsis status, and preoperative hematocrit. Combinations of these variables made up the 2- and 3-variable models. In the 4-variable model, emergency status and wound classification were added as significant variables. In the 5-variable model, cancer status, surgeon specialty, and ascites emerged as significant variables. In the 6-variable model, weight loss also emerged as a significant variable, but it is possible this is a surrogate for cancer status.

Using patient data from the validation hospital, the model with the highest AUROC value was a 3-variable model with age, ASA classification, and functional status (AUROC value of 0.9398) (Table 2). The model with the next highest AUROC value was a 2-variable model with ASA classification and functional status (AUROC value of 0.9290).

The AUROC values greater than 90% were achieved after only 3 variables (Figure 2). The AUROC values increased to 91% with 4-variable models and almost 92% with 6-variable models. There is little additional gain in AUROC for a 5- or 6-variable model compared with a 3- or 4-variable model. Including all 66 preoperative variables resulted in an AUROC value of 0.9104 (pseudo-R^2=0.3342), approximately the same AUROC value achieved with only 4 variables.

COMMENT

We found that 3 or 4 variables may be sufficient for adequate risk adjustment to measure surgical outcomes. We achieved AUROC values of greater than 90% with only 3 variables. On a scale of 0.5 to 1.0, with an AUROC value of 0.5 indicating that the model cannot distinguish between 2 groups any better than change and an AUROC value of 1.0 indicating that the model completely discriminates between the 2 groups, an AUROC value of greater than 90% is substantial.

Our data provide several examples of risk-adjustment models that may be appropriate for hospitals in resource-limited settings. In particular, a 3-variable model with ASA class, functional status, and age was found to have high discrimination within our nonurban validation hospital. However, the data presented allow for a wide range of possible risk-adjustment models, allowing surgical systems to choose the most appropriate model given their unique resources. For example, although it may be possible for hospital systems in one area to collect preoperative laboratory values, such as albumin or hematocrit, other hospital systems may find it easier to collect information on ASA classification or functional status.

Other studies found that a model based on only a few variables may provide enough discrimination to measure surgical outcomes. Rubinfeld et al[9] found the AUROC value for mortality decreased only slightly from 0.907

Table 2. Stepwise Process for Creating the Limited Model to Predict Inpatient Mortality[a]

	NSQIP Database		Validation Hospital	
Model	AUROC	Pseudo-R^2	AUROC	Pseudo-R^2
1-Variable model				
ASA class	0.8479	0.2310	0.8217	0.2354
Albumin[b]	0.8119	0.1512	NA	NA
Functional status	0.7676	0.1933	0.9124	0.3025
INR[b]	0.7615	0.0366	NA	NA
BUN[b]	0.7540	0.0909	NA	NA
2-Variable model				
ASA class, albumin[b]	0.8870	0.2712	NA	NA
ASA class, functional status	0.8830	0.2868	0.9290	0.3562
ASA class, age (category)	0.8792	0.2465	0.8241	0.2320
ASA class, sepsis	0.8788	0.2841	0.6833	0.0916
ASA class, hematocrit	0.8744	0.2410	0.7079	0.2310
3-Varible model				
ASA class, age (category), sepsis	0.9019	0.3057	0.6333	0.0511
ASA class, functional status, age (category)	0.9015	0.3002	0.9398	0.4605
ASA class, albumin,[b] age (category)	0.8982	0.2883	NA	NA
ASA class, albumin,[b] functional status	0.8977	0.2964	NA	NA
ASA class, albumin,[b] sepsis	0.8963	0.2951	NA	NA
4-Variable model				
ASA class, age (category), sepsis, functional status	0.9103	0.3253	0.5000	0.0000
ASA class, functional status, age (category), emergency	0.9085	0.3207	0.5000	0.0000
ASA class, age (category), sepsis, albumin[b]	0.9079	0.3168	NA	NA
ASA class, functional status, age (category), wound class	0.9073	0.3105	Unable to calculate	Unable to calculate
ASA class, functional status, age (category), albumin[b]	0.9072	0.3120	NA	NA
5-Varible model				
ASA class, age (category), sepsis, functional status, cancer[b]	0.9133	0.3308	NA	NA
ASA class, functional status, age (category), emergency, sepsis	0.9131	0.3348	Unable to calculate	Unable to calculate
ASA class, age (category), sepsis, functional status, wound class	0.9130	0.3281	Unable to calculate	Unable to calculate
ASA class, age (category), sepsis, functional status, surgical specialty[b]	0.9129	0.3294	NA	NA
ASA class, age (category), sepsis, functional status, ascites[b]	0.9126	0.3305	NA	NA
6-Variable model				
ASA class, age (category), sepsis, functional status, cancer,[b] emergency	0.9159	0.3403	NA	NA
ASA class, age (category), sepsis, functional status, cancer,[b] wound class	0.9154	0.3330	NA	NA
ASA class, age (category), sepsis, functional status, cancer,[b] surgical specialty	0.9154	0.3344	NA	NA
ASA class, functional status, age (category), emergency, sepsis, wound class	0.9152	0.3370	Unable to calculate	Unable to calculate
ASA class, functional status, age (category), emergency, sepsis, weight loss[b]	0.9151	0.3380	NA	NA

Abbreviations: ASA, American Society of Anesthesiologists; AUROC, area under the receiver operator characteristic curve; BUN, blood urea nitrogen; INR, international normalized ratio; NA, not applicable; NSQIP, National Surgical Quality Improvement Program.

[a]The process used NSQIP data to create the model and data from a nonurban hospital for validation. Only the models with the 5 highest AUROC values for each stage are listed. The models are listed from high to low AUROC values at each stage.

[b]Variable not collected from validation hospital.

using all variables to 0.902 using 10 variables and argue that only a few variables are required for predictive accuracy. Dimick et al[10] found that limited models based on 5 or 12 variables had comparable discrimination to a 21-variable model using receiver operator characteristics. Birkmeyer et al[11] also found high correlation between a 5-variable and a 20-variable morbidity risk model and recommended that the new version of the NSQIP have no more than 5 to 10 core covariates.

There is some concern that ASA class and functional status are not reliable measures because they are more subjective. Some data suggest that there is a lack of interrater reliability in assigning ASA class.[12-14] Davenport et al[15] found that although ASA class was the strongest single predictor of outcomes, combinations of other risk variables without ASA class were better predictors than ASA class alone. However, ASA class was significantly correlated with 57 of 59 NSQIP preoperative risk factors.[15] In addition, Cohen et al[16] did not find evidence that ASA class and functional status were inconsistently classified and argue that they improve model quality and should be used in surgical risk-adjusted assessments. Dimick et al[10] also found that ASA class and functional status were the most important variables in all risk-adjustment models. Furthermore, ASA class and functional status were 2 of the most predictive preoperative risk variables of postoperative morbidity in the National Veterans Affairs Surgical Risk Study[17] and have been shown to predict operative outcomes in specific procedures.[18,19] Disagreement rates between ASA class and functional status, as well as other NSQIP variables, have also improved since implementation (functional status before operation: 11.38% in 2005 to 3.4% in 2008; ASA class: 2.65% in 2005 to 1.82% in 2008); the authors argue that this is possibly due to data collection training and ongoing support.[20]

This study is strengthened by the fact that we developed our model using data from a large multicenter database from multiple years. Another strength of this study is that it was validated using patient data from a smaller nonurban hospital, using data from both common procedures and less common, high-mortality procedures. Validating our study findings enabled us to judge the practicality of collecting such variables in a resource-limited setting and, in this case, in a setting that has not yet moved to electronic medical records. Our validation process also provided additional information as to which variables had the highest discrimination among this population. This study is also strengthened because we included data on all surgical patients. Some quality improvement programs focus specifically on certain surgical specialties. By using all patients in NSQIP and validating our models using a mix of surgical patients (including patients with the most common procedures performed and those with less common but higher-mortality procedures), our findings can be widely applicable to a variety of surgical fields.

One limitation of this study is that some of the top variables from our models created by the NSQIP data were unable to be collected from our validation hospital because they were not easily obtained through the paper medical record review. However, the 2- and 3-variable models using data from the validation hospital had very high AUROC values, indicating that the additional missing variables would be unlikely to significantly affect the results. Another limitation is that there are likely to be coding errors, both in the NSQIP data and in data from the validation hospital. However, these errors are likely to be evenly and randomly distributed and thus should not affect our conclusions. Furthermore, coding errors will also be a reality when this model is used, so any coding errors present in our current data are likely to be similar to those encountered by this model in practice.

Our study has global implications. Although participation in programs such as the NSQIP offers administrative support and comparison of outcomes among participating hospitals, the low-cost options reported can expand the number of hospitals that participate in risk-adjustment outcomes analysis and quality improvement programs. Our work also allows the expansion of risk-adjustment outcomes research to LMICs. With minimal training, 3 or 4 variables can be easily and efficiently collected by existing hospital personnel at small or resource-limited hospitals in both developed and LMICs with limited costs. From these variables, a hospital's observed-to-expected ratio can be calculated to make comparisons about outcomes. By offering a simplified risk-adjustment tool, we can compare surgical outcomes among hospitals on a global scale, regardless of the spectrum of surgical procedures offered or hospital resources.

The area of global surgery has focused primarily on issues of access, which are still problematic in many LMICs. However, we should also begin to examine the process and outcomes of a hospital's surgical system to develop more appropriate and cost-effective interventions. Evaluating surgical outcomes requires risk adjustment to take patient variability into account. Our study suggests that simple but sufficient risk adjustment can be achieved in these settings. Future validation in an LMIC setting would be valuable.

Future risk-adjustment models should also consider surgical complications and morbidity, in addition to mortality. Although in-hospital mortality is simple to collect and the ultimate outcome, other outcomes, such as complications and morbidity, should not be overlooked. Other important outcome indicators are disability-adjusted life-years, which can be used to measure reductions in premature death and disability as a result of an intervention.[21,22] Disability-adjusted life-years are commonly used in LMICs, particularly in public health efforts aimed at infectious diseases. By considering disability-adjusted life-years as an outcome measurement, we can begin to quantify surgical outcomes in terms of the amount of reduction of death or disability and have a better understanding of the cost-effectiveness of surgical interventions, which is particularly crucial information in resource-limited settings.[23]

Furthermore, surgical quality assessments must include considerations of structure, process, and outcomes to evaluate and improve the entire system of surgical care.[24] We encourage the World Health Organization to expand their Tool for Situational Analysis to Assess Emergency and Essential Surgical Care to include data collection on preoperative variables to perform adequate risk-adjustment analyses.[25] With these additional data, the situational analysis tool can help record and compare risk-adjusted surgical outcomes within and among hospitals in LMICs. In conclusion, we propose that future risk-adjustment tools be based on 6 or fewer variables to allow for surgical outcomes to be measured and compared within and among hospitals in resource-limited settings.

Accepted for Publication: March 9, 2012.
Published Online: May 21, 2012. doi:10.1001/archsurg.2012.699
Correspondence: Jamie E. Anderson, MPH, Department of Surgery, University of California, San Diego, 200 W Arbor Dr, Ste 8400, San Diego, CA 92103 (jaa002@ucsd.edu).
Author Contributions: *Study concept and design:* Anderson, Lassiter, Bickler, Talamini, and Chang. *Acquisition of data:* Anderson and Chang. *Analysis and interpretation of data:* Anderson, Lassiter, Bickler, and Chang. *Drafting of the manuscript:* Anderson, Bickler, and Chang. *Critical revision of the manuscript for important intellectual content:* Anderson, Lassiter, Bickler, Talamini, and Chang. *Statistical analysis:* Anderson, Lassiter, and Chang. *Obtained funding:* Anderson, Bickler, Chang, and Talamini. *Administrative, technical, and material support:* Bickler and Chang. *Study supervision:* Bickler and Chang.
Financial Disclosure: None reported.
Funding/Support: Ms Anderson was supported by award T35HL007491 from the National Heart, Lung, and Blood Institute. Dr Chang is partially supported by SCANNER grant R01 HS19913-01 awarded by the Agency for Healthcare Research and Quality. Drs Chang and Bickler are also partially supported by the Medical Education Partnership Initiative grant 1R24TW008910-01 awarded by the National Institutes of Health Fogarty International Center.
Previous Presentation: This paper was presented as a podium presentation at the 83rd Annual Meeting of the Pacific Coast Surgical Association; February 20, 2012; Napa

Valley, California, and is published after peer review and revision.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Heart, Lung, and Blood Institute or the National Institutes of Health.

Additional Contributions: The NSQIP and its participating hospitals are the source of data used in this research; they have not verified and are not responsible for the statistical validity of the data analysis or conclusions of the authors.

REFERENCES

1. American College of Surgeons National Surgical Quality Improvement Program website. http://site.acsnsqip.org/. Accessed August 26, 2011.
2. Surgical Care Improvement Project website. https://www.premierinc.com/safety/topics/scip/. Accessed August 26, 2011.
3. The Leapfrog Group website. http://www.leapfroggroup.org/. Accessed August 26, 2011.
4. American College of Surgeons National Surgical Quality Improvement Program. *User Guide for the 2009 Participant Use Data File*. Chicago, IL: American College of Surgeons; October 2010.
5. Healey C, Osler TM, Rogers FB, et al. Improving the Glasgow Coma Scale score model: motor score alone is a better predictor. *J Trauma*. 2003;54(4):671-680.
6. Bewick V, Cheek L, Ball J. Statistics review 13: receiver operating characteristic curves. *Crit Care*. 2004;8(6):508-512.
7. Meredith JW, Evans G, Kilgo PD, et al. A comparison of the abilities of nine scoring algorithms in predicting mortality. *J Trauma*. 2002;53(4):621-629.
8. Connell FA, Koepsell TD. Measures of gain in certainty from a diagnostic test. *Am J Epidemiol*. 1985;121(5):744-753.
9. Rubinfeld I, Farooq M, Velanovich V, Syed Z. Predicting surgical risk: how much data is enough? *AMIA Annu Symp Proc*. 2010;2010:777-781.
10. Dimick JB, Osborne NH, Hall BL, Ko CY, Birkmeyer JD. Risk adjustment for comparing hospital quality with surgery: how many variables are needed? *J Am Coll Surg*. 2010;210(4):503-508.
11. Birkmeyer JD, Shahian DM, Dimick JB, et al. Blueprint for a new American College of Surgeons: National Surgical Quality Improvement Program. *J Am Coll Surg*. 2008;207(5):777-782.
12. Aronson WL, McAuliffe MS, Miller K. Variability in the American Society of Anesthesiologists Physical Status Classification Scale. *AANA J*. 2003;71(4):265-274.
13. Haynes SR, Lawler PGP. An assessment of the consistency of ASA physical status classification allocation. *Anaesthesia*. 1995;50(3):195-199.
14. Burgoyne LL, Smeltzer MP, Pereiras LA, Norris AL, De Armendi AJ. How well do pediatric anesthesiologists agree when assigning ASA physical status classifications to their patients? *Paediatr Anaesth*. 2007;17(10):956-962.
15. Davenport DL, Bowe EA, Henderson WG, Khuri SF, Mentzer RM Jr. National Surgical Quality Improvement Program (NSQIP) risk factors can be used to validate American Society of Anesthesiologists Physical Status Classification (ASA PS) levels. *Ann Surg*. 2006;243(5):636-644.
16. Cohen ME, Bilimoria KY, Ko CY, Richards K, Hall BL. Effect of subjective preoperative variables on risk-adjusted assessment of hospital morbidity and mortality. *Ann Surg*. 2009;249(4):682-689.
17. Daley J, Khuri SF, Henderson W, et al. Risk adjustment of the postoperative morbidity rate for the comparative assessment of the quality of surgical care: results of the National Veterans Affairs Surgical Risk Study. *J Am Coll Surg*. 1997;185(4):328-340.
18. Crawford RS, Cambria RP, Abularrage CJ, et al. Preoperative functional status predicts perioperative outcomes after infrainguinal bypass surgery. *J Vasc Surg*. 2010;51(2):351-359.
19. Davenport DL, Ferraris VA, Hosokawa P, Henderson WG, Khuri SF, Mentzer RM Jr. Multivariable predictors of postoperative cardiac adverse events after general and vascular surgery: results from the Patient Safety In Surgery Study. *J Am Coll Surg*. 2007;204(6):1199-1210.
20. Shiloach M, Frencher SK Jr, Steeger JE, et al. Toward robust information: data quality and inter-rater reliability in the American College of Surgeons National Surgical Quality Improvement Program. *J Am Coll Surg*. 2010;210(1):6-16.
21. Debas HT, Gosselin R, McCord C, Thind A. Surgery. In: Jamison D, Breman J, Measham A, eds, et al. *Disease Control Priorities in Developing Countries*. 2nd ed. Washington, DC: Oxford University Press; 2006:1245-1259.
22. Shillcutt SD, Clarke MG, Kingsnorth AN. Cost-effectiveness of groin hernia surgery in the western region of Ghana. *Arch Surg*. 2010;145(10):954-961.
23. Farmer DL. Surgeon, do you know where your DALYs are?: (can *you* fix a hernia with a mosquito net?): comment on "Cost-effectiveness of groin hernia surgery in the western region of Ghana." *Arch Surg*. 2010;145(10):961 doi:10.1001/archsurg.2010.205.
24. Donabedian A. Evaluating the quality of medical care. *Milbank Mem Fund Q*. 1966;44(3):166-206.
25. World Health Organization. Tool for Situational Analysis to Assess Emergency and Essential Surgical Care. http://www.who.int/surgery/publications/WHOtoolSituationalAnalysisEESC.pdf. Accessed January 17, 2012.

INVITED CRITIQUE

ONLINE FIRST

NSQIP Lite

A Potential Tool for Global Comparative Effectiveness Evaluations

The need to compare outcomes across hospitals is of paramount importance to our patients, physicians, and payers. Administrative databases are inherently limited in scope as has been described in several recent articles in this and other journals.[1] To date, the National Surgical Quality Improvement Program (NSQIP) remains the most robust risk-adjusted and reliable tool available and, most important, the only tool that is readily accepted by most surgeons. A significant problem with NSQIP is that its expense limits the number of participating hospitals and excludes most of our smaller and rural hospitals—hospitals about which one might legitimately wish to ask certain quality and safety questions.

Anderson et al[2] present a compelling pilot model that suggests that as few as 3 simple NSQIP data points, obtainable at significantly lower cost, are all that may be needed to predict inpatient mortality in a risk-adjusted manner across a wide variety of clinical settings. Although the statistical methods are dense, one should not overlook the importance of this article. The development of a simple and inexpensive tool that could be used in the most resource-poor settings in this country and around the world is of enormous importance. For the first time, a tool would exist that would give researchers the ability to measure the effect of changes to the health care provision systems as they are being implemented in widely diverse settings. One would have a tool that gives teeth to the surgical compara-

World J Surg
DOI 10.1007/s00268-013-2366-1

World Journal of Surgery

Surgical Conditions Account for the Majority of Admissions to Three Primary Referral Hospitals in Rural Mozambique

Jamie E. Anderson · Anne Erickson · Carlos Funzamo · Peter Bendix · Americo Assane · John Rose · Fernando Vaz · Emilia Virginia Noormahomed · Stephen W. Bickler

Abstract

Background The World Health Organization has identified the primary referral hospital as its priority site for improving surgical care in low- and middle-income countries. Little is known about the relative burden surgical patients place on health care facilities at this level. This research estimates the fraction of admissions due to surgical conditions at three hospitals in rural Mozambique.

Methods Prospective data were collected on all inpatients at three primary referral hospitals in Mozambique during a 12-day period. We compared the number of surgical patients and their length of stay (LOS) to the patients admitted to the medicine, pediatric, and maternity wards. These findings were validated using retrospective data collected from one hospital from January to May 2012.

Results Patients with surgical conditions (i.e., patients admitted to the surgical or maternity ward) accounted for 57.5 % of admissions and 48.0 % of patient-days. The majority of patients were admitted to the maternity ward (32.3 %). The other admissions were evenly distributed to the pediatric (22.5 %), medical (20.0 %), and surgical (25.2 %) wards. Compared to patients from the three other wards, surgical patients had longer average LOS (8.7 vs. 1.9–7.7 days) and a higher number of total patient-days (891 vs. 252–703 days). The most prevalent procedures were cesarean section (33.3 %) and laceration repair/wound care (11.8 %).

Conclusions Surgical conditions are the most common reason for admissions at three primary referral hospitals in rural Mozambique. These data suggest that surgical care is a major component of health care delivered at primary referral hospitals in Mozambique and likely other sub-Saharan African countries.

J. E. Anderson (✉) · J. Rose · E. V. Noormahomed · S. W. Bickler
Department of Surgery, University of California, San Diego, 200 W. Arbor Drive, San Diego, CA 92103, USA
e-mail: jaa002@ucsd.edu

A. Erickson
Stanford University School of Medicine, Palo Alto, CA, USA

C. Funzamo · A. Assane · F. Vaz · E. V. Noormahomed
Univsersidade Eduardo Mondlane, Maputo, Mozambique

P. Bendix
Department of Surgery, Dartmouth-Hitchcock Memorial Hospital, Lebanon, NH, USA

E. V. Noormahomed
Department of Medicine, University of California, San Diego, CA, USA

Introduction

Surgical conditions have been a largely neglected public health issue in low- and middle-income countries (LMICs). Globally, surgical disease has been estimated as among the top 15 causes of disability [1, 2]. It has been estimated that there is approximately one operation performed for every 25 people—double the annual world volume of childbirth [3]. An estimated 11 % of the global burden of disease can be treated by surgery, which includes injuries (38 %), malignancies (19 %), congenital anomalies (9 %), complications of pregnancy (6 %), cataracts (5 %), and perinatal conditions (4 %) [1, 4]. Surgical conditions have also been estimated to account for up to 15 % of total disability-adjusted life years (DALYs) lost worldwide, estimated at

Published online: 18 December 2013

Fig. 1 Map of Mozambique shows the location of the three primary referral hospitals

38 DALYs lost per 1,000 people [1, 5]. Untreated surgical conditions contribute to an estimated 10 % of all deaths and 20 % of deaths in young adults [6].

This article examines the relative burden of surgical diseases at three primary referral hospitals in rural Mozambique. This information could be useful when planning surgical services for population living in rural areas of LMICs.

Methods

Data were collected from three primary referral hospitals (Chókwè, Nhamatanda, Ribaue) in the southern, central, and northeastern regions of Mozambique, respectively (Fig. 1; Table 1). Mozambique is a country of approximately 24 million people located in southeastern Africa. It ranks 184 of 187 countries in the world on the United Nations

Table 1 Study sites

Parameter	Chókwè hospital	Nhamatanda hospital	Ribaue hospital
Catchment population	259,000	281,000	228,000
No. of beds	125	128	57
No. of doctors	2	3	4
No. of high-level nurses	9	3	1
No. of mid- and basic-level nurses	64	110	89
Distance to referral center (km)	125	110	150

Development Programme (UNDP) Human Development Index [7]. The average life expectancy is 50 years, and nearly half (43.9 %) of its population is aged <15 years [8].

Less than half of Mozambique's population lives within 5 km of a public health facility. There is an estimated one physician for every 23,000 people [9, 10]. Each hospital serves a catchment area of roughly 230,000–280,000 people and is located approximately 110–150 km from the nearest referral center. Chókwè and Nhamatanda Rural Hospitals have 125 and 128 beds, respectively. Ribaue Rural Hospital is somewhat smaller with 57 beds. Each hospital employs two to four doctors and has a total of 75–116 medical staff. Each hospital is equipped with an emergency room, an operating room, and an ambulance.

Prospective data were collected from all inpatients at Chókwè Rural Hospital from June 18–29, 2012, from Nhamatanda Rural Hospital from June 23–29, 2012, and from Ribaue Rural Hospital from July 5–12, 2012. Data included demographics, diagnosis, dates of admission and discharge, type of operation performed (if applicable), and human immunodeficiency virus (HIV) status (if available). To identify the proportion of surgical disease within these hospitals, the proportion of patients, patient-days, and average length of stay (LOS) of surgical patients were compared to those of the three other hospital wards: medicine, pediatrics, and maternity.

Selection bias from the limited period of prospective data collection was accounted for by reviewing retrospective data from all inpatients at Chókwè Rural Hospital from January 2012 to May 2012. These data included the number of patients in each ward, total patient-days (number of patients multiplied by their LOS), summary statistics of diagnoses and operations performed, and deaths. Although retrospective data offered a larger sample size and time period that was not possible during the prospective data collection, the prospective data allowed for a more detailed analysis.

Surgical conditions were defined as a disease state requiring the expertise of a surgically trained provider [11].

Table 2 Summary statistics of all inpatients, prospective study period

Parameter	Chókwè (n = 173)				Nhamatanda (n = 153)				Ribaue (n = 79)			
	Maternity	Medicine	Pediatrics	Surgery	Maternity	Medicine	Pediatrics	Surgery	Maternity	Medicine	Pediatrics	Surgery
No. of patients	48 (27.8 %)	45 (26.0 %)	27 (15.6 %)	53 (30.6 %)	43 (27.7 %)	26 (18.1 %)	53 (34.2 %)	31 (20.0 %)	40 (50.6 %)	10 (12.7 %)	11 (13.9 %)	18 (22.8 %)
Total patient-days	107	245	211	422	59	228	450	322	86	63	42	147
Female (%)	100 %	57.8 %	22.2 %	67.9 %	100 %	34.6 %	54.7 %	51.6 %	100.0 %	60.0 %	54.5 %	55.6 %
Age (years)[a]	25 (16–39)	35 (23–63)	2 (0–7)	29 (1–70)	22 (16–32)	35.5 (20–60)	2 (0–7)	21 (7–64)	23 (15–38.5)	32 (17–70)	1 (0–12)	23 (4–62)
LOS[a]	1 (0–8)	5 (1–10)	4 (2–21)	6 (1–28)	1 (0–2)	6.5 (1–22)	5 (1–1)	10 (1–26)	2 (0–5)	5 (3–16)	5 (1-8)	7 (2–26)
Average capacity[b]	20.0 %	64.4 %	45.8 %	72.6 %	43.7 %	51.3 %	100.0 %	128.6 %	51.9 %	29.4 %	45.0 %	111.3 %

LOS length of hospital stay

[a] Median (95 % CI). Bartlett's test for equal variance $p < 0.001$ between wards for each hospital, respectively

[b] Median (95 % CI). Calculated by (total number of patient days)/(beds × days in study period)

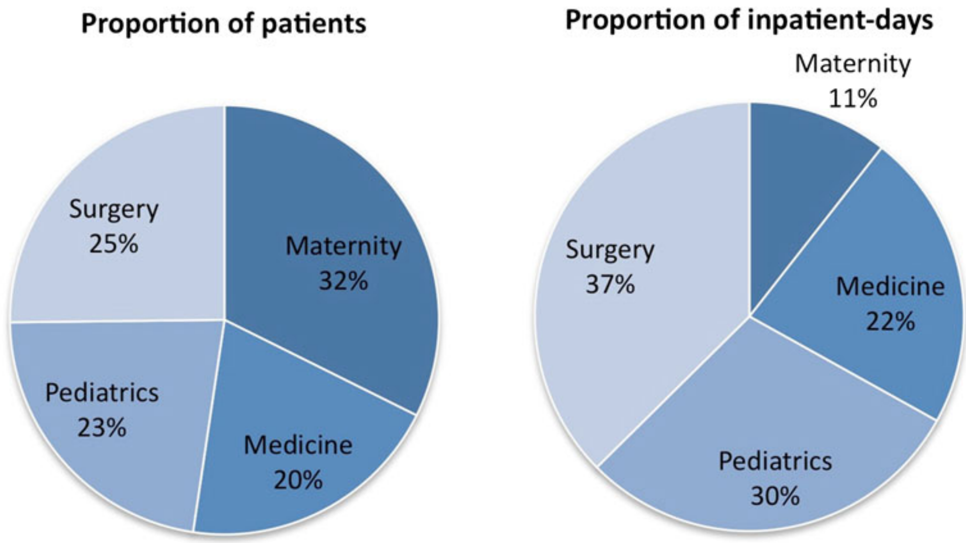


Fig. 2 Proportion of the total number of patients and total inpatient days by hospital ward. Data shown represent combined patients from all three hospitals

Thus, surgical patients were defined as those admitted to the surgical ward and any patient admitted to the maternity ward who underwent an operation. Not all patients admitted to the surgical ward had an operation. For example, some patients may have had nonoperative management of burns, wounds, lacerations, or fractures, but these patients were still cared for by the surgical team.

Statistical analysis was performed using STATA 64-bit Special Edition, version 11.2 (Stata Corp., College Station, TX, USA). The National Bioethics Committee of Mozambique and the Human Research Protection program at University of California, San Diego approved this study.

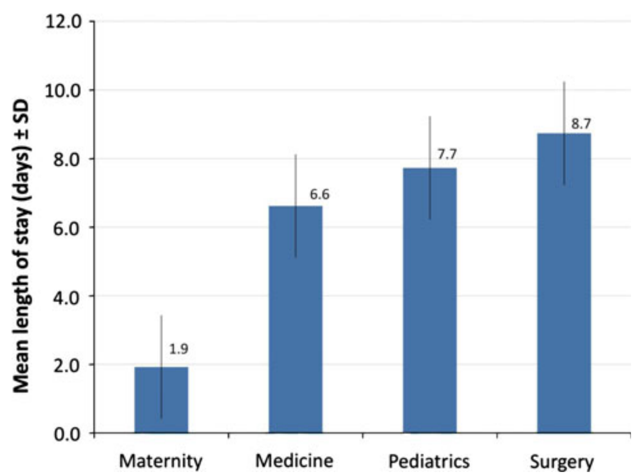


Fig. 3 Average length of stay by hospital ward (number of days, mean ± SD). Data shown represent combined patients from all three hospitals

Results

The number of patients in each ward was not equally distributed among the hospitals (Table 2). At Chókwè, the surgical ward had the highest proportion of patients (30.6 %), whereas pediatrics had the highest proportion of patients at Nhamatanda (34.2 %) and maternity had the highest proportion at Ribaue (50.6 %). Total patient-days had similar distributions, except surgical patients had more patient-days in Ribaue than maternity patients (147 vs. 86 days). Women made up a majority of patients in all wards except pediatrics at Chókwè (22.2 %) and medicine at Nhamatanda (34.6 %). The surgical ward had the most patients per available beds, exceeding 100 % at Nhamatanda (128.6 %) and Ribaue (111.3 %). The average LOS was longest for surgical patients at all hospitals (6–10 days, $p < 0.001$). Overall, the maternity wards had the highest number of patients, but the surgical wards had the most total patient-days (Fig. 2). Combined, surgical patients had a longer average LOS ($p < 0.001$) (Fig. 3).

Table 3 summarizes the surgical patients during the prospective study period at all hospitals. Cesarean sections made up the highest proportion of surgeries (49.3 %), followed by inguinal herniorrhaphies (15.9 %). Among patients who underwent a procedure, the median age was highest in patients with inguinal herniorrhaphies (50 years) and lowest in patients with cesarean sections (19.5 years). Average LOS was longest both preoperatively and postoperatively for patients with amputations (5.0 and 11.7 days, respectively). Patients who underwent a cesarean section or other obstetric and gynecologic surgeries had the shortest average preoperative LOS (0.5 and 0.4 days, respectively). Among patients who did not have an operation, lacerations/wounds made up the largest proportion of all surgical conditions (36.4 %). The average LOS was highest among burn patients (14.6 days).

Table 3 Summary of surgery patients, prospective study period

Parameter	No. of patients	% Female	Age (years)[a]	Average LOS, preoperatively (days)	Average LOS, postoperatively (days)	Overall LOS, average (days)
Procedure performed						
Cesarean section	34	100	19.5 ± 2.0	0.5	8.1	8.5
Other obstetric/gynecologic surgery	5	100	30.0 ± 17.3	0.4	3.4	6.4
Amputation	3	0	24.0 ± 13.9	5.0	11.7	16.7
Inguinal herniorrhaphy	11	9.0	50.0 ± 5.7	1.1	7.5	8.5
Epigastric herniorrhaphy	3	100	26.0 ± 15.0	1.3	6.0	7.3
Hydrocele	5	0.0	26.0 ± 25.4	1.2	6.0	7.2
Other	8	37.5	28.5 ± 5.1	2.4	10.4	12.8
Total	69	66.7	24.0 ± 18.0	1.0	54.5	61.5
No procedure performed						
Fracture	5	25.0	29.0 ± 16.6	N/A	N/A	7.4
Burn	5	40.0	7.0 ± 5.6			14.6
Laceration/wound	12	58.3	34.5 ± 14.6			5.8
Other	11	45.5	32.0 ± 17.0			11.0
Total	33	45.5	29.0 ± 16.7			9.1

Data shown represent combined patients from all three hospitals

[a] Median ± SD

Table 4 summarizes diagnoses and mortality by inpatient ward at the Chókwè Rural Hospital retrospectively from January to May 2012. Cesarean section and nonoperative surgical patients comprised the largest proportion of patients in the surgical ward (39.7 and 31.1 %, respectively). Among pediatric cases, malaria and malnutrition contributed to a majority of disease (23.9 and 23.1 %, respectively), whereas most deaths were a result of malnutrition (13.3 %). Among medical cases, HIV/acquired immunodeficiency disease (AIDS) made up the largest proportion of all diseases and cerebrovascular accidents had the highest mortality rate (39.4 and 43.8 %, respectively).

Table 5 summarizes retrospective data from Chókwè Rural Hospital from January to May 2012. Most patients were admitted to the maternity ward (53.6 %), which also had the highest percentage of occupied beds (30.0 %). The medical ward had the highest mortality rate (22.4 %), and the maternity and surgical wards had the lowest mortality rates (0.2 and 1.8 %, respectively).

Discussion

Surgical conditions represent a significant proportion of admissions to three primary referral hospitals in rural Mozambique. Although maternity patients made up the largest proportion of patients overall (32.3 % compared to 25.2 % of surgical patients), surgical patients accounted for the largest proportion of total patient-days (37.4 %) and had the longest average LOS (8.7 days). Together, patients with surgical conditions (i.e., patients admitted to the surgical and maternity wards) accounted for 57.5 % of admissions and 48.0 % of patient-days. Examining retrospective data over a five-month period at one hospital, the number of surgical patients was about equal to the number of medical and pediatric patients, whereas maternity patients made up the majority of the patient population (53.6 %). Mortality was lowest among the surgical and maternity patients (1.8 and 0.2 %, respectively)—far below the mortality rates for the medical and pediatric patients (22.4 and 7.2 %, respectively).

This study suggests that the provision of surgical services plays a key role, rather than a peripheral one, in delivering health care at the district level. In settings where medical management is unavailable or fails, resources for adequate surgical management are of even greater importance. For example, in the absence of appropriate antibiotics, higher rates of serious infections may lead to more amputations. In settings of already limited medical resources, surgical care offers a vital last resort when medical management fails.

Other studies suggest that surgical care at the district level has not adequately met patients' needs. At hospitals in Tanzania, Uganda, and Mozambique, a majority of nonobstetric surgery was emergent rather than elective, suggesting a lack of access to surgical care for common conditions such as hernias [12, 13]. In a survey of 132 facilities in eight countries, most facilities reported the capacity to perform

Table 4 Diagnoses and mortality by hospital ward at Chókwè Rural Hospital, January to May 2012

Diagnosis	No. of patients	No. of deaths	Mortality rate (%)
Pediatrics			
Diarrhea	21 (5.8 %)	2	9.5
Tuberculosis	13 (3.6 %)	1	7.7
Malaria	86 (23.9 %)	2	2.3
Anemia	36 (10.0 %)	5	13.9
Pneumonia	67 (18.6 %)	0	0.0
HIV/AIDS	6 (1.7 %)	3	50.0
Meningitis	5 (1.4 %)	1	0.0
Malnutrition	83 (23.1 %)	11	13.3
Other	43 (11.9 %)	1	2.3
Total	**360 (100 %)**	**26**	**7.2**
Medicine			
Diarrhea	7 (1.7 %)	0	0.0
Tuberculosis	17 (4.1 %)	2	11.8
Malaria	16 (3.9 %)	0	0.0
Anemia	20 (4.9 %)	5	25.0
Pneumonia	18 (4.4 %)	5	27.8
HIV/AIDS	162 (39.4 %)	43	26.5
Meningitis	11 (2.7 %)	4	36.4
CVA (stroke)	16 (3.9 %)	7	43.8
Hypertension	44 (10.7 %)	14	31.8
Psychosis	21 (5.1 %)	0	0.0
Diabetes	9 (2.2 %)	1	11.1
Cardiac	4 (1.0 %)	0	0.0
Asthma	0	0	0.0
Other	66 (16.1 %)	11	0.0
Total	**411 (100 %)**	**92**	**22.4**
Surgery			
Herniorrhaphy			
Elective	21 (5.5 %)	0	0.0
Urgent	9 (2.3 %)	0	0.0
Laparotomy	33 (8.6 %)	1	3.0
Cesarean section	152 (39.7 %)		
Hysterectomy	2 (0.5 %)	0	0.0
Other surgery	47 (12.2 %)	0	0.0
Nonoperative	119 (31.1 %)	6	5.0
Total	**383 (100 %)**	**7**	**1.8**
Maternity			
Births (not including cesarean sections)	1,045		
Maternal deaths		2	
Live births	1,100	–	
Low birth weight	50	–	
Stillbirths	–	47	
Other	136	0	
Total	**1,333**	**2**	**0.2**

HIV human immunodeficiency virus, *AIDS* acquired immunodeficiency disease syndrome, *CVA* cerebrovascular accident

Table 5 Total patients, days of occupied beds, and mortality by hospital ward at Chókwè Rural Hospital, January to May 2012

Department	No. of patients	Inpatient days of occupied beds	No. of deaths	Mortality rate (%)
Pediatrics	360 (14.5 %)	1,866 (19.4 %)	26	7.2
Medicine	411 (16.5 %)	2,649 (27.5 %)	92	22.4
Surgery	383 (15.4 %)	2,224 (23.1 %)	7	1.8
Maternity	1,333 (53.6 %)	2,894 (30.0 %)	2	0.2
Total	**2,487 (100 %)**	**9,633 (100 %)**	**127**	**5.1**

minor procedures, such as incision and drainage of abscesses, wound suturing, and management of acute burns. The capacity to perform more complex procedures, however, such as appendectomies, hernia repairs, and laparotomies, ranged from 6 to 92 % [10]. Only 44 % of facilities were able to offer cesarean sections [14].

Increased attention to improve surgical capacity in LMICs is also necessary as these countries have a disproportionate lack of access to surgical care. Countries with per-capita health expenditures of less than $100 account for one-third (34.5 %) of the world's population but only undertake 3.5 % of the world's surgical procedures [3]. Outcomes in these settings are also worse. Surgical mortality is estimated to be 5–10 % in LMICs, compared to <1 % in high-income countries [3]. Furthermore, in many LMICs, surgical care is disproportionately available to patients who can afford services and live in urban areas [5].

It is estimated that surgical conditions will contribute to an even larger proportion of morbidity and mortality in the future, further increasing demand for adequate surgical care at the district hospital. Mathers and Loncar estimated that road-traffic accidents will move from being the tenth leading cause of death in 2002 to being the eighth leading cause of death globally in 2030 [2]. Changing public health priorities, such as promoting circumcisions in an effort to reduce HIV transmission, may further increase demand for minor procedures in LMICs [15].

Surgical care has been shown to be cost-effective when delivered at the district hospital level. In such settings, the cost per surgical DALY averted is estimated at US$19–102 compared to immunizations (US$10/DALY averted), malaria prevention and treatment (US$2–24/DALY averted), oral rehydration therapy (US$1062/DALY averted), and antiretroviral therapy for HIV in sub-Saharan Africa (US$350–1494/DALY averted) [1, 16, 17]. The cost-effectiveness of providing surgical care is yet another reason to increase its availability at the district level.

This study has several limitations. The analysis assumes that data collected over the relatively short time period from these three hospitals is representative of diseases treated throughout the year. Our analysis was performed during winter, when burns are more prevalent and other diseases such as malaria are less prevalent. Birthing patterns also vary throughout the year.

These data should not be interpreted as a measure of the burden of disease in the community, as they include only patients admitted to the hospital [11]. The study also underestimated the number of surgical procedures performed, as it only counted major procedures performed in the operating room. It did not include minor procedures performed with local anesthesia, such as circumcisions or abscess drainage, which can represent a large proportion of all procedures performed. In addition, these results may not be representative of other LMICs. For example, the HIV/AIDS rate in Mozambique was estimated to be 11.5 % in 2009, which may contribute to different disease distribution and health care services than are seen in other countries [18].

Conclusions

These data show that surgical patients accounted for the majority of admissions and inpatient days at three primary referral hospitals in rural Mozambique. Together, patients with surgical conditions (i.e., patients admitted to the surgical and maternity wards) accounted for 57.5 % of admissions and 48.0 % of patient-days. Future research is needed to quantify the ability of the health care system to meet the total surgical needs of the community and to identify interventions that could close this gap.

Acknowledgments The research was supported by Grant No. R24TW 008910 from the Fogarty International Center. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Fogarty International Center or the National Institutes of Health. The NIH Common Fund supports the first award.

Conflict of interest None.

References

1. Debas HT, Gosselin R, McCord C et al (2006) Surgery. In: Jamison DT, Breman JG, Measham AR et al (eds) Disease control priorities in developing countries, 2nd edn. The International Bank for Reconstruction and Development/The World Bank Group, Washington
2. Mathers CD, Loncar D (2006) Projections of global mortality and burden of disease from 2002 to 2030. PLoS Med 3:e442
3. Weiser TG, Regenbogen SE, Thompson KD et al (2008) An estimation of the global volume of surgery: a modelling strategy based on available data. Lancet 372:139–144
4. Ozgediz D, Jamison D, Cherian M et al (2008) The burden of surgical conditions and access to surgical care in low- and middle-income countries. Bull World Health Organ 86:646–647
5. Farmer PE, Kim JY (2008) Surgery and global health: a view from beyond the OR. World J Surg 32:533–536. doi:10.1007/s00268-008-9525-9
6. Atiyeh BS, Gunn SW, Hayek SN (2010) Provision of essential surgery in remote and rural areas of developed as well as low and middle income countries. Int J Surg 8:581–585
7. UNDP (2011) Human development report 2011: sustainability and equity—a better future for all. Palgrave Macmillan, New York
8. The World Bank (2011) World development indicators. The World Bank, Washington
9. USAID (2006) Health sector (SO8) overview: briefing book. http://transition.usaid.gov/mz/doc/misc/health%20overview_nov2006.pdf. Accessed 1 May 2013
10. Lindelow M (2002) Health care demand in rural Mozambique: evidence from the 1996/97 household survey. http://www.ifpri.org/publication/health-care-demand-rural-mozambique-0. Accessed 1 May 2013
11. Bickler S, Ozgediz D, Gosselin R et al (2010) Key concepts for estimating the burden of surgical conditions and the unmet need for surgical care. World J Surg 34:374–380. doi:10.1007/s00268-009-0261-6
12. Galukande M, von Schreeb J, Wladis A et al (2010) Essential surgery at the district hospital: a retrospective descriptive analysis in three African countries. PLoS Med 7:e1000243
13. Notrica MR, Evans FM, Knowlton LM et al (2011) Rwandan surgical and anesthesia infrastructure: a survey of district hospitals. World J Surg 35:1770–1780. doi:10.1007/s00268-011-1125-4
14. Kushner AL, Cherian MN, Noel L et al (2010) Addressing the millennium development goals from a surgical perspective: essential surgery and anesthesia in 8 low- and middle-income countries. Arch Surg 145:154–159
15. Williams BG, Lloyd-Smith JO, Gouws E et al (2006) The potential impact of male circumcision on HIV in sub-Saharan Africa. PLoS Med 3:e262
16. Laxminarayan R, Chow J, Shahid-Salles SA (2006) Intervention cost-effectiveness: overview of main messages. In: Jamison DT, Breman JG, Measham AR (eds) Disease control priorities in developing countries, 2nd edn. The International Bank for Reconstruction and Development/The World Bank Group, Washington
17. Luboga S, Macfarlane SB, von Schreeb J et al (2009) Increasing access to surgical services in sub-saharan Africa: priorities for national and international agencies recommended by the Bellagio Essential Surgery Group. PLoS Med 6:e1000200
18. UNAIDS (2012) Global report: UNAIDS report on the global AIDS epidemic. http://www.unaids.org/globalreport/global_report.htm. Accessed 1 May 2013