# Perioperative patient outcomes in the African Surgical Outcomes Study: a 7-day prospective observational cohort study

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## Summary

**Background** **There is a need to increase access to surgical treatments in African countries, but perioperative complications represent a major global health-care burden. There are few studies describing surgical outcomes in Africa.**

**Methods** **We did a 7-day, international, prospective, observational cohort study of patients aged 18 years and older undergoing any inpatient surgery in 25 countries in Africa (the African Surgical Outcomes Study). We aimed to recruit as many hospitals as possible using a convenience sampling survey, and required data from at least ten hospitals per country (or half the surgical centres if there were fewer than ten hospitals) and data for at least 90% of eligible patients from each site. Each country selected one recruitment week between February and May, 2016. The primary outcome was in-hospital postoperative complications, assessed according to predefined criteria and graded as mild, moderate, or severe. Data were presented as median (IQR), mean (SD), or n (%), and compared using *t* tests. This study is registered on the South African National Health Research Database (KZ_2015RP7_22) and ClinicalTrials.gov (NCT03044899).**

**Findings** **We recruited 11 422 patients (median 29 [IQR 10–70]) from 247 hospitals during the national cohort weeks. Hospitals served a median population of 810 000 people (IQR 200 000–2 000 000), with a combined number of specialist surgeons, obstetricians, and anaesthetists totalling 0·7 (0·2–1·9) per 100 000 population. Hospitals did a median of 212 (IQR 65–578) surgical procedures per 100 000 population each year. Patients were younger (mean age 38·5 years [SD 16·1]), with a lower risk profile (American Society of Anesthesiologists median score 1 [IQR 1–2]) than reported in high-income countries. 1253 (11%) patients were infected with HIV, 6504 procedures (57%) were urgent or emergent, and the most common procedure was caesarean delivery (3792 patients, 33%). Postoperative complications occurred in 1977 (18·2%, 95% CI 17·4–18·9]) of 10 885 patients. 239 (2·1%) of 11 193 patients died, 225 (94·1%) after the day of surgery. Infection was the most common complication (1156 [10·2%] of 10 970 patients), of whom 112 (9·7%) died.**

**Interpretation** **Despite a low-risk profile and few postoperative complications, patients in Africa were twice as likely to die after surgery when compared with the global average for postoperative deaths. Initiatives to increase access to surgical treatments in Africa therefore should be coupled with improved surveillance for deteriorating physiology in patients who develop postoperative complications, and the resources necessary to achieve this objective.**

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## Introduction

The surgical population represents a major global health burden, with more than 300 million surgical procedures done annually[1] and an early postoperative mortality rate of up to 4%.[2,3] However, it has been estimated that 5 billion people are unable to access safe surgical treatments,[4] 94% of whom live in low-income and middle-income countries (LMICs).[4] Globally, an estimated additional 143 million surgical procedures are required each year, many of which are in Africa.[4] Surgery is a cost-effective and core component of universal health coverage,[5–7] but it needs to be safe.[4] Known barriers to the provision of safe surgical treatment in Africa include low hospital procedural volumes,[8] few hospital beds,[9] and a scarce number of operating theatres,[10] all of which are compounded by the geographical remoteness of many surgical hospitals and an absence of adequately trained staff.[11,12] The *Lancet* Commission on Global Surgery[13] was established to develop strategies for safe, accessible, and affordable surgical care, but implementation of this strategy requires robust epidemiological data describing patterns of surgical activity and subsequent patient outcomes.[7,13]

Data describing surgical outcomes in Africa are scarce, and the findings of international studies are dominated by activity in high-income countries, with little participation from African countries.[9,14] Furthermore, only a few African countries have national registries or audit systems to

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## Research in context

### Evidence before this study

Safe, accessible, and affordable surgery is a global health priority. An estimated 5 billion people do not have access to safe and affordable surgery, and an additional 143 million surgeries each year are needed in low-income and middle-income countries (LMICs) to address this need. However, there are few surgical outcome data from LMICs, and particularly few data from Africa. Two observational cohort studies only included a few African countries, with a small range of surgeries reported. Increasing access to surgery is a priority in Africa; however, it is essential to ensure that the surgery is safe, and that unnecessary perioperative morbidity and mortality are prevented. Because of the scarcity of surgical outcomes data in Africa, there is an urgent need for a robust epidemiological study of perioperative patient outcomes to inform the global surgery initiative.

### Added value of this study

The African Surgical Outcomes Study provided data from 25 African countries for all in-patient surgeries. Our findings showed that one in five surgical patients in Africa developed a perioperative complication, following which, one in ten patients died. Our findings also showed that, despite being younger with a low-risk profile, and lower occurrences of complications, patients in Africa were twice as likely to die after surgery when compared with outcomes at a global level. African surgical hospitals are under-resourced with a median combined total of specialist surgeons, obstetricians, and anaesthesiologists of 0·7 (IQR 0·2–1·9) per 100 000 population, far below the recommended number identified by the *Lancet* Commission on Global Surgery. The number of surgical procedures in Africa was also very low at 212 (65–578) per 100 000 population each year. Most surgical procedures were done on an urgent or emergency basis, and a third were caesarean deliveries. Importantly, 95% of deaths occurred after surgery, indicating the need to improve the safety of perioperative care.

### Implications of all the available evidence

Previous studies have presented only few data on surgical outcomes in Africa, because of limited country participation and inclusion of selected surgical procedures. The African Surgical Outcomes Study provided a detailed insight into this problem. Our findings suggest a high incidence of potentially avoidable deaths among low-risk patients after surgery, largely caused by a failure to identify and treat life-threatening complications in the perioperative period. Limited availability of human and hospital resources might be a key factor in this problem. Despite the positive effect of the global safe surgery campaign, our findings showed that surgical outcomes will remain poor in Africa unless the perioperative care of patients with deteriorating physiological function is addressed and sufficient resources are available to provide this care. A continent-wide quality improvement strategy to promote effective perioperative care might save many lives after surgery in Africa.

monitor surgical procedures and subsequent outcomes. Low human-development index countries, many of which are African, are believed to have significantly higher perioperative mortality but this is unconfirmed.[14,15] The effect of population disease burden on the pattern of surgical outcomes in Africa is also unknown. Compared with high-income countries, there is a preponderance of communicable diseases and injuries in Africa,[14,16–18] of which HIV is the leading cause of life-years lost.[18]

To improve both the provision and quality of surgical treatments in Africa, a detailed understanding is needed about the number of surgical treatments being undertaken, the surgical resources available, and the associated patient outcomes.[4] The objective of our African Surgical Outcomes Study (ASOS) was to provide robust epidemiological data describing the volume of surgical activity, perioperative outcomes, and surgical workforce density in Africa, which are similar to published international surgical outcomes data.[9]

## Methods

### Study design, setting, and participants

We did a 7-day, international, multicentre, prospective observational cohort study of patients aged 18 years and older undergoing any form of inpatient surgery in hospitals in 25 African countries. Our findings are reported in accordance with the STROBE statement.[19] A collaborative network of more than 1000 health-care professionals was established across Africa through personal invitations to colleagues, invitations to surgical and anaesthesia societies, a website and a Twitter feed. BMB made country visits where possible to meet with local study investigators. A website provided investigator support, in the form of a regularly updated page of frequently asked questions, the protocol, case report forms, and an outcomes definitions document in English and French.

In each country, we aimed to recruit as many hospitals as possible using a convenience sampling strategy. For inclusion of country data in the study we required data from at least ten hospitals or at least half the surgical centres if fewer than ten hospitals in the country, submission of the total number of eligible patients during recruitment week, and provision of data describing at least 90% of the eligible patients from each site. Each country selected a single recruitment week between February and May, 2016. All patients undergoing elective and non-elective surgery with a planned overnight hospital stay following surgery during the study week were eligible for inclusion. Patients undergoing planned day surgery or radiological procedures not requiring anaesthesia were excluded. Regulatory approval varied between countries, with some requiring ethics approval and others only data

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governance approval. The primary ethics approval was from the Biomedical Research Ethics Committee of the University of KwaZulu-Natal, South Africa (BE306/15). All sites approved a waiver of consent, except the University of the Witwatersrand (South Africa), which required informed consent from all patients with deferred consent for patients who could not give consent before surgery.

## Variables and data

Hospital-specific data included the number of hospital beds, number of operating rooms, number of critical care beds, and the numbers of anaesthetists, surgeons, and obstetricians working in each hospital. We replicated the design of a global study[9,20] with an almost identical patient dataset to allow a direct comparison of surgical outcomes data from Africa with surgical outcomes at a global level. Complications were assessed according to predefined criteria[20] and were graded as mild, moderate, or severe.[20] Data describing consecutive patients were collected on paper case-record forms until hospital discharge and censored at 30 days following surgery for patients who remained in hospital. Data were anonymised during the transcription process using Research Electronic Data Capture (REDCap) tools hosted by Safe Surgery South Africa. REDCap is a secure, web-based application designed to support data capture for research studies.[21] Soft limits were set for data entry, prompting investigators when data were entered outside these limits. In countries with poor internet access, mobile phones were used for data entry, or paper case-record forms were forwarded to BMB, for entry by Safe Surgery South Africa. National lead investigators confirmed the face validity of the unadjusted outcome data for their countries, and hospital-level data were assessed statistically to confirm plausibility.

## Outcomes

The primary outcome measure was in-hospital post-operative complications defined according to consensus definitions.[20] The secondary outcome measure was in-hospital mortality. All outcomes were censored at 30 days for patients who remained in hospital. Outcomes data were measured for national, regional (central, eastern, northern, southern, and western African, and the Indian Ocean Islands), and continental levels. The outcomes definitions document is in the appendix.

## Statistical analysis

There was no prespecified sample size in our study because our aim was to recruit as many hospitals as possible, and ideally, every eligible patient from recruited hospitals. We anticipated that a minimum sample size of 10 000 patients would provide a sufficient number of events for construction of a robust continental logistic regression model.[22] Although this study could provide an estimate of continental mortality, it was not powered to detect differences in mortality or complications between countries. During the process of hospital recruitment and data collection, we realised that our predefined criteria for including a national patient sample were too strict for many countries, despite formal acceptance by the national leaders of these requirements before the study began. Before analysis, we therefore decided to present the data describing the full cohort, and include a per-protocol analysis of the predefined representative sample for comparison.

We describe categorical variables as proportions and compared them using Fisher's exact test. Continuous variables are presented as mean (SD), or median (IQR), and compared using *t* tests. For country-specific mortality comparisons, we constructed a multivariable logistic model that included all potential risk factors associated with in-hospital mortality. These included age, smoker status, sex, American Society of Anesthesiologists (ASA) category, preoperative chronic comorbid conditions (coronary artery disease, congestive heart failure, diabetes, cirrhosis, metastatic cancer, hypertension, stroke, chronic obstructive pulmonary disease, HIV, or chronic renal disease), the type of surgery, urgency of surgery (elective, urgent, or emergency) and the severity of surgery (minor, intermediate, or major). To avoid collinearity of potential risk factors, variables with a variance-inflation factor greater than 2 were excluded. National co-ordinators confirmed the face validity of their raw data before analysis.

We did a complete case analysis for all analyses, excluding patients with missing data. South Africa was the

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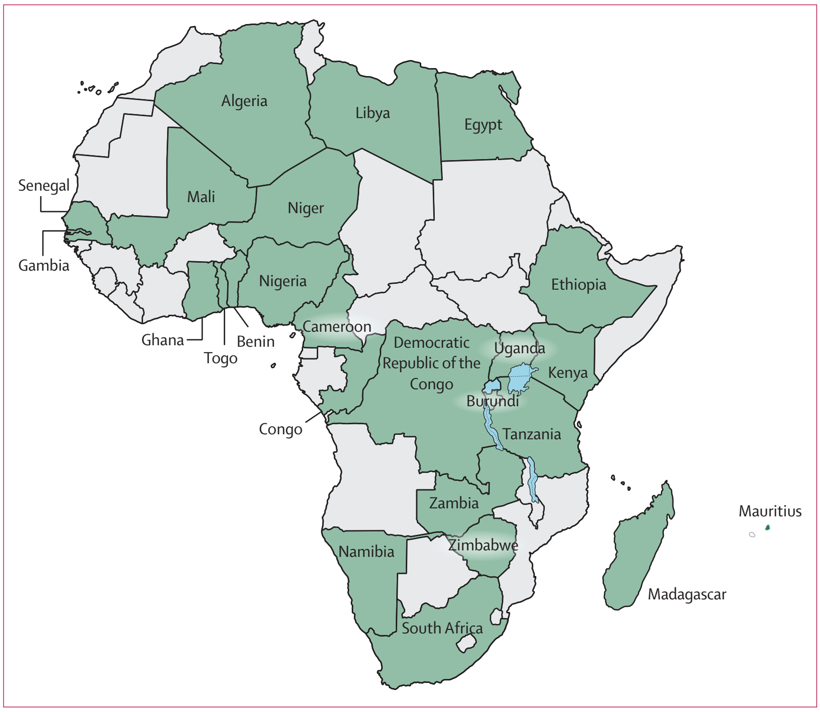


*Figure 1:* **Participating countries in the African Surgical Outcomes Study**
Participating countries shown in green.

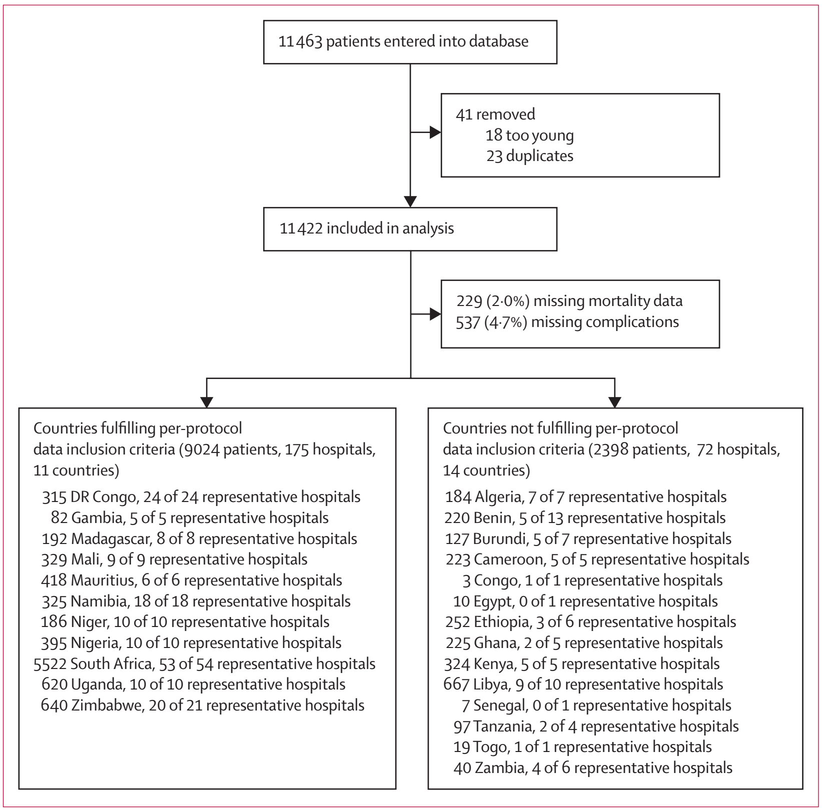


***Figure 2:*** **African Surgical Outcomes Study country, hospital, and patient recruitment**
Representative hospitals provided data for the number of eligible patients for the study, and recruited more than 90% of the eligible patients into the study

See Online for appendix

country with the largest number of observed events, and was therefore used as the reference country. Orthopaedic surgery—the largest non-cardiac, non-obstetric, surgical category—was used as the surgical reference category. We used restricted cubic splines to fit continuous variables.[23] Model performances were assessed using the calibration and discrimination of the model. We created a smooth, non-parametric calibration line with a locally weighted scatterplot smoothing algorithm to estimate the observed probabilities of in-hospital mortality in relation to the predicted probabilities. Discrimination was quantified by calculating the concordance statistic (c statistic) completed with optimism,[24] which relates to both model coefficients estimation and over-fitting (eg, selection of predictors and categorisation of continuous predictors). We did four sensitivity analyses of the association between preoperative risk factors and mortality. These were a per-protocol sensitivity analysis of only patients from the hospitals that provided hospital facility data, a full case-sensitivity analysis with multiple imputation of missing data to test for potential bias associated with missing variables,[25] and two further analyses that explored the effect of the hospital-facility level or university affiliation on mortality. In the two further analyses, we forced either hospital-facility level data or university affiliation data into the model. We did the statistical analyses with the Statistical Package for the Social Sciences version 24 and R statistical software package version 3.4. This study is registered on the South African National Health Research Database (KZ_2015RP7_22) and ClinicalTrials.gov (NCT03044899).

## Role of the funding source

The funder of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the paper. The corresponding author (BMB), YLM, and TME had full access to all the data in the study. BMB and RMP had final responsibility for the decision to submit for publication.

## Results

We recruited 11 422 patients (median 29, IQR 10–70) from 247 hospitals in 25 African countries during the national cohort weeks (figures 1, 2). These countries included 14 low-income countries (Benin, Burundi, Congo, Democratic Republic of the Congo, Ethiopia, The Gambia, Madagascar, Mali, Niger, Senegal, Tanzania, Togo, Uganda, and Zimbabwe) and 11 middle-income countries (Algeria, Cameroon, Egypt, Ghana, Kenya, Libya, Mauritius, Namibia, Nigeria, South Africa, and Zambia). Hospital-level data were submitted for 216 (87%) of the 247 participating hospitals. 173 (80%) of 216 were government-funded hospitals, 28 (12%) were privately funded, and 15 (7%) were jointly funded. 103 (49%) of 212 were university-affiliated hospitals. 45 (21%) of 216 were primary-level hospitals (defined as mainly obstetrics and gynaecology, and general surgery), 68 (31%) were secondary-level (defined as highly differentiated by function with five to ten clinical specialities), and 103 (48%) were tertiary-level (defined as specialised staff or technical support).[26] Each hospital served a median population of 810 000 people (IQR 200 000–2 000 000), with a median of 300 beds (140–545), four operating rooms (2–7), and three critical care beds (0–7) providing invasive ventilation. 0·9% of hospital beds (IQR 0–2·0) were critical care beds. Hospitals were staffed by a median of three specialist surgeons (IQR 1–8), one specialist anaesthetist (0–5), and two specialist obstetricians (0–5), with a median of 0·7 (0·2–1·9) of any specialist per 100 000 population. The median number of surgical procedures per hospital for the study week was 29 (10–71).

Most patients had a low perioperative risk profile (table 1). They were mainly young with a low ASA physical status score. The most common comorbidities were hypertension and HIV/AIDS. Most surgeries were urgent or emergent, and the most common procedure was caesarean delivery (3792 [33·3%] of 11 393 procedures). The WHO Safe Surgery Checklist or a similar surgical checklist was used in 6183 (57·1%) of 10 836 surgeries.

Postoperative complications occurred in 1977 (18·2%, 95% CI 17·4–18·9) of 10 885 patients. Of 1970 patients with postoperative complications, 188 died (9·5%, 8·2–10·8; table 2). Around 16·3% of patients with

| | All patients (n=11 422) | Patients with complications (n=1977) | Patients with no complications (n=8908) | Patients who died (n=239) | Patients who survived (n=10 954) |
|---|---|---|---|---|---|
| Age (years) | 38·5 (16·1); 34·0 (24·0–48·0) | 40·7 (17·5) 36·0 (27·0–53·0) | 38·0 (15·8); 33·0 (26·0–47·0) | 49·5 (19·1); 51·0 (32·0–64·0) | 38·3 (16·0); 34·0 (26·0–47·0) |
| Sex | | | | | |
| Male | 3833/11 418 (33·6%) | 819/1977 (41·4%) | 2832/8908 (31·8%) | 121/239 (50·6%) | 3656/10 953 (33·4%) |
| Female | 7585/11 418 (66·4%) | 1158/1977 (58·6%) | 6076/8909 (68·2%) | 118/239 (49·4%) | 7297/10 953 (66·6%) |
| Current smoker | 1520/11 367 (16·8%) | 315/1972 (16·0%) | 1351/8881 (15·2%) | 38/235 (16·2%) | 1688/10 924 (15·5%) |
| ASA category | | | | | |
| 1 | 5713/11 352 (50·3%) | 781/1962 (39·8%) | 4675/8887 (52·6%) | 45/239 (18·8%) | 5552/10 899 (50·9%) |
| 2 | 4199/11 352 (37·0%) | 705/1962 (35·9%) | 3309/8887 (37·2%) | 62/239 (25·9%) | 4050/10 899 (37·2%) |
| 3 | 1197/11 352 (10·5%) | 354/1962 (18·0%) | 804/8887 (9·0%) | 79/239 (33·1%) | 1111/10 899 (10·2%) |
| 4 | 234/11 352 (2·1%) | 117/1962 (6·0%) | 96/8887 (1·1%) | 47/239 (19·7%) | 184/10 899 (1·7%) |
| 5 | 9/11 352 (0·1%) | 5/1962 (0·3%) | 3/8887 (0%) | 6/239 (2·5%) | 2/10 899 (0%) |
| Grade of surgery | | | | | |
| Minor | 2459/11 341 (21·7%) | 277/1972 (14·0%) | 2064/8888 (23·2%) | 28/238 (11·8%) | 2392/10 920 (21·9%) |
| Intermediate | 5487/11 341 (48·4%) | 852/1972 (48·5%) | 4415/8888 (49·7%) | 96/238 (40·3%) | 5322/10 920 (48·7%) |
| Major | 3395/11 341 (29·7%) | 843/1972 (42·7%) | 2409/8888 (27·1%) | 114/238 (47·9%) | 3206/10 920 (29·4%) |
| Urgency of surgery | | | | | |
| Elective | 4874/11 378 (42·8%) | 624/1970 (31·7%) | 4034/8896 (45·3%) | 48/239 (20·1%) | 4744/10 928 (43·4%) |
| Urgent | 2700/11 378 (23·7%) | 519/1970 (26·3%) | 2036/8896 (22·9%) | 77/239 (32·2%) | 2562/10 928 (23·4%) |
| Emergency | 3804/11 378 (33·4%) | 827/1970 (42·0%) | 2826/8896 (31·8%) | 114/239 (47·7%) | 3622/10 928 (33·1%) |
| Surgical speciality | | | | | |
| Orthopaedic | 1770/11 393 (15·5%) | 292/1977 (14·8%) | 1372/8902 (15·4%) | 27/239 (11·3%) | 1710/11 179 (15·6%) |
| Breast | 229/11 393 (2·0%) | 31/1977 (1·6%) | 192/8902 (2·2%) | 2/239 (0·8%) | 227/11 179 (2·1%) |
| Obstetrics (caesarean delivery) | 3792/11 393 (33·3%) | 531/1977 (26·9%) | 3074/8902 (34·5%) | 20/239 (8·4%) | 3664/11 179 (33·5%) |
| Gynaecology | 1305/11 393 (11·5%) | 153/1977 (7·7%) | 1102/8902 (12·4%) | 7/239 (2·9%) | 1285/11 179 (11·7%) |
| Upper GIT | 301/11 393 (2·6%) | 102/1977 (5·2%) | 191/8902 (2·1%) | 29/239 (12·1%) | 268/11 179 (2·4%) |
| Lower GIT | 940/11 393 (8·3%) | 228/1977 (11·5%) | 670/8902 (7·5%) | 46/239 (19·2%) | 872/11 179 (8·0%) |
| Hepatobiliary | 172/11 393 (1·5%) | 28/1977 (1·4%) | 139/8902 (1·6%) | 4/239 (1·7%) | 168/11 179 (1·5%) |
| Urology and kidney | 560/11 393 (4·9%) | 108/1977 (5·5%) | 430/8902 (4·8%) | 13/239 (5·4%) | 541/11 179 (4·9%) |
| Vascular | 237/11 393 (2·1%) | 72/1977 (3·6%) | 153/8902 (1·7%) | 16/239 (6·7%) | 219/11 179 (2·0%) |
| Head and neck | 453/11 393 (4·0%) | 68/1977 (3·4%) | 356/8902 (4·0%) | 13/239 (5·4%) | 431/11 179 (3·9%) |
| Cardiac surgery | 58/11 393 (0·5%) | 21/1977 (1·1%) | 35/8902 (0·4%) | 6/239 (2·5%) | 52/11 179 (0·5%) |
| Thoracic (lung and other) | 130/11 393 (1·1%) | 37/1977 (1·9%) | 92/8902 (1·0%) | 8/239 (3·3%) | 122/11 179 (1·1%) |
| Thoracic (gut) | 23/11 393 (0·2%) | 9/1977 (0·5%) | 14/8902 (0·2%) | 2/239 (0·8%) | 21/11 179 (0·2%) |
| Neurosurgery | 253/11 393 (2·2%) | 85/1977 (4·3%) | 156/8902 (1·8%) | 21/239 (8·8%) | 230/11 179 (2·1%) |
| Other | 555/11 393 (4·9%) | 79/1977 (4·0%) | 471/8902 (5·3%) | 11/239 (4·6%) | 541/11 179 (4·9%) |
| Surgical checklist | 6183/10 836 (57·1%) | 1082/1971 (54·9%) | 5101/8865 (57·5%) | 145/239 (60·7%) | 6188/10 894 (56·8%) |
| Comorbidity | | | | | |
| Coronary artery disease | 178/11 422 (1·6%) | 53/1977 (2·7%) | 119/8908 (1·3%) | 11/239 (4·6%) | 166/10 954 (1·5%) |
| Congestive heart failure | 92/11 422 (0·8%) | 30/1977 (1·5%) | 58/8908 (0·7%) | 11/239 (4·6%) | 80/10 954 (0·7%) |
| Diabetes mellitus | 776/11 422 (6·8%) | 201/1977 (10·20%) | 547/8908 (6·1%) | 46/239 (19·2%) | 722/10 954 (6·6%) |
| Cirrhosis | 12/11 422 (0·1%) | 5/1977 (0·3%) | 5/8908 (0·1%) | 0/239 (0%) | 11/10 954 (0·1%) |
| Metastatic cancer | 142/11 422 (1·2%) | 32/1977 (1·6%) | 103/8908 (1·2%) | 11/239 (4·6%) | 129/10 954 (1·2%) |
| Hypertension | 1863/11 422 (16·3%) | 377/1977 (19·1%) | 1406/8908 (15·8%) | 77/239 (32·2%) | 1767/10 954 (16·1%) |
| Stroke or transient ischaemic attack | 91/11 422 (0·8%) | 36/1977 (1·8%) | 48/8908 (0·5%) | 8/239 (3·3%) | 82/10 954 (0·7%) |
| COPD or asthma | 375/11 422 (3·3%) | 75/1977 (3·8%) | 274/8908 (3·1%) | 13/239 (5·4%) | 357/10 954 (3·3%) |
| HIV-positive/AIDS | 1253/11 422 (11·0%) | 222/1977 (11·2%) | 986/8908 (11·1%) | 18/239 (7·5%) | 1224/10 954 (11·2%) |
| Chronic renal disease | 171/11 422 (1·5%) | 46/1977 (2·3%) | 111/8908 (1·2%) | 14/239 (5·9%) | 154/10 954 (1·4%) |

Data are mean (SD), median (IQR), or n/N (%). Denominators vary with the completeness of the data. ASA=American Society of Anesthesiologists. GIT=gastrointestinal tract. COPD=chronic obstructive pulmonary disease.

***Table 1:*·Baseline characteristics of the African Surgical Outcomes Study patient cohort**

| | Number of patients | Patients admitted to critical care immediately after surgery | Patients not admitted to critical care immediately after surgery |
|---|---|---|---|
| **All surgeries** | | | |
| Complications | 1977/10 885 (18·2%) | 495/1971 (25·1%) | 1476/9705 (15·2%) |
| Mortality | 239/11 193 (2·1%) | 108/1198 (9·0%) | 130/9960 (1·3%) |
| Critical care admission to treat complications | 321/1972 (16·3%) | 255/493* (51·7%) | 64/1473† (4·3%) |
| Death following a postoperative complication | 188/1970 (9·5%) | 96/493* (19·5%) | 92/1472† (6·3%) |
| **Elective surgery only** | | | |
| Complications | 624/4658 (13·4%) | 140/367 (38·1%) | 482/4282 (11·3%) |
| Mortality | 48/4792 (1·0%) | 12/376 (3·2%) | 35/4403 (0·8%) |
| Critical care admission to treat complications | 86/622 (13·8%) | 68/140* (48·6%) | 17/480† (3·5%) |
| Death following a postoperative complication | 30/620 (4·8%) | 10/139* (7·2%) | 20/480† (4·2%) |

Data are n/N (%). Denominators vary with the completeness of the data. *Total number admitted to critical care immediately following surgery. †Total number not admitted to critical care immediately after surgery

*Table 2:* **Postoperative outcomes in the African Surgical Outcomes Study**

postoperative complications were admitted to critical care to treat these complications, of whom approximately 79% were admitted to critical care immediately after surgery. Complications were associated with prolonged hospital stay (median 3 days [IQR 2–5] without complications *vs* 6 days [4–13] with complications; p<0·0001). Infection was the most common postoperative complication (table 3).

239 (2·1%) of 11 193 patients died after surgery, 14 (5·9%) of whom died on the day of surgery. Median time of death was 5 days (IQR 2–11) postoperatively. Cardiovascular complications were associated with the highest mortality, mostly cardiac arrest. Non-communicable diseases were the most common indication for surgery (table 4); however, significantly more postoperative complications and death followed surgery for infection and trauma.

The model to describe mortality had poor discrimination for mortality (c statistic corrected for optimism of 0·53, Brier of 0·0222 for mortality) when based on the countries alone (appendix). However, the adjusted model for country-specific mortality showed good discrimination for mortality (c statistic corrected for optimism of 0·83, Brier of 0·0222; appendix). After adjustment for risks, most countries had a similar risk of in-hospital mortality (appendix). Postoperative mortality was strongly associated with increasing ASA grade, urgency of surgery, and grade of surgery (intermediate and major). Gastrointestinal, hepatobiliary, and neurosurgery were associated with increased mortality.

When compared with a global epidemiological study of elective surgery (the International Surgical Outcomes Study [ISOS]),[9] the elective surgical patients in the ASOS cohort were younger, had a lower risk profile, and underwent more minor surgery. Patients in ASOS had fewer postoperative complications (appendix). Mortality in surgical patients in Africa was twice the global average represented by the ISOS cohort (figure 3; appendix).

The per-protocol analysis of the hospital data, patient data, patient outcomes, postoperative complications, the primary indication for surgery, regional country participation, and the African regional outcomes are in the appendix. 14 countries did not provide per-protocol data samples.

The sensitivity analyses provided similar results to the primary multivariable analysis (appendix). Hospitals of a higher facility level were independently associated with increased mortality but university affiliation was not. None of the sensitivity analyses changed our overall findings.

## Discussion

The main finding of this study was that patients receiving surgery in Africa are younger than the global average, with a lower-risk profile and lower complication rates, and yet are twice as likely to die. Approximately one in five surgical patients in our African cohort developed a postoperative complication, and one in ten of these patients died. It is likely that many of these deaths were preventable. This large prospective cohort of surgery in 247 hospitals in 25 African countries revealed the scarce workforce resources available to provide safe surgical treatment. Although increased access to surgery is important for the people of Africa, it is essential that that these surgical treatments are safe and effective.[27] Importantly, 95% of deaths in our study occurred in the postoperative period, suggesting that many lives could be saved by effective surveillance for physiological deterioration in patients who have developed complications and increasing the resources necessary to achieve this objective. Surgical outcomes will remain poor in Africa[15] until the problem of under-resourcing is addressed.

Our results indicated that postoperative mortality following surgery is significantly higher in Africa, when compared with other international cohorts, despite the African patients having a lower patient-risk profile with lower occurrences of postoperative complications.[9] Improving the quality of surgery is a function of structures, processes, and outcomes as defined by The *Lancet* Commission on Global Surgery.[4] Our results provide important insights into some of the processes and outcomes that need to be addressed in Africa. Most of the deaths in our study occurred on the days following surgery, and many were probably preventable. There are few published reports of postoperative outcomes in Africa, but our interpretation is consistent with the findings from smaller epidemiological studies exploring postoperative mortality in African countries, with described mortality rates that were similar to,[14,28] or higher than those in our study.[29,30] In a global study of mortality after emergency abdominal surgery, most of the deaths in that study also occurred more than 24 h after surgery.[14] Our observations are also consistent with reports of intraoperative or anaesthetic-related mortality rates in low-income countries.[15,31] The findings of our study and previous investigations might be partly due to scarce workforce resources, and poor early warning systems to detect the physiological deterioration of patients who developed complications.[32] The median number of 0·7 specialists (a combined total of surgeons, obstetricians, and anaesthesiologists) per 100 000 population in this study is well below the inflection point of 20–40 specialists per 100 000 thought necessary to decrease perioperative mortality.[4] Furthermore, there are fewer hospital and critical-care bed resources in Africa than reported globally.[9] Consequently, the risk of death following perioperative complications is significantly greater in Africa.

The problem of unrecognised postoperative physiological deterioration on the surgical ward has been well

| | Number of patients | Complication severity | | | Number of deaths for all patients who developed complications | Number of deaths for patients after elective surgery who developed complications |
|---|---|---|---|---|---|---|
| | | Mild | Moderate | Severe | | |
| **Infectious complications** | | | | | | |
| Superficial surgical site | 10 968 | 402 (3·5%) | 303 (2·7%) | 82 (0·7%) | 41/787 (5·2%) | 5/245 (2·0%) |
| Deep surgical site | 10 969 | 77 (0·7%) | 141 (1·2%) | 110 (1·0%) | 43/328 (13·1%) | 3/78 (3·8%) |
| Body cavity | 10 968 | 25 (0·2%) | 55 (0·5%) | 45 (0·4%) | 28/125 (22·4%) | 1/21 (4·8%) |
| Pneumonia | 10 968 | 51 (0·5%) | 85 (1·2%) | 49 (0·4%) | 56/185 (30·3%) | 5/50 (10·0%) |
| Urinary tract | 10 967 | 64 (0·6%) | 29 (0·3%) | 19 (0·2%) | 20/112 (17·9%) | 2/38 (6·3%) |
| Bloodstream | 10 970 | 27 (0·2%) | 50 (0·5%) | 64 (0·6%) | 58/141 (41·1%) | 6/32 (18·8%) |
| Total | .. | .. | .. | .. | 112/1156 (9·7%) | 12/354 (3·4%) |
| **Cardiovascular complications** | | | | | | |
| Myocardial infarction | 10 969 | 7 (0·1%) | 1 (0·0%) | 3 (0·0%) | 3/11 (27·3%) | 0/2 |
| Arrhythmia | 10 969 | 16 (0·1%) | 14 (0·1%) | 10 (0·1%) | 11/40 (27·5%) | 1/14 (7·1%) |
| Pulmonary oedema | 10 969 | 17 (0·1%) | 13 (0·1%) | 8 (0·1%) | 17/38 (44·7%) | 1/7 (14·3%) |
| Pulmonary embolism | 10 969 | 3 (<0·1%) | 1 (<0·1%) | 11 (0·1%) | 11/15 (73·3%) | 5/8 (62·5%) |
| Stroke | 10 921 | 6 (0·1%) | 6 (0·1%) | 8 (0·1%) | 6/20 (30·0%) | 1/7 (14·3%) |
| Cardiac arrest | 10 945 | NA | NA | 113 (1·0%) | 101/113 (89·4%) | 13/19 (68·4%) |
| Total | .. | .. | .. | .. | 110/190 (57·9%) | 15/48 (31·3%) |
| **Other complications** | | | | | | |
| Gastrointestinal bleed | 10 966 | 20 (0·2%) | 12 (0·1%) | 7 (0·1%) | 13/39 (33·3%) | 1/11 (9·1%) |
| Acute kidney injury | 10 967 | 50 (0·4%) | 54 (0·5%) | 42 (0·4%) | 51/146 (34·9%) | 4/31 (12·9%) |
| Postoperative bleed | 10 968 | 98 (0·9%) | 404 (3·5%) | 59 (0·5%) | 39/561 (7·0%) | 5/159 (3·1%) |
| ARDS | 10 966 | 14 (0·1%) | 19 (0·2%) | 19 (0·2%) | 26/52 (50·0%) | 4/14 (28·6%) |
| Anastomotic leak | 10 961 | 9 (0·1%) | 14 (0·1%) | 23 (0·2%) | 16/46 (34·8%) | 3/19 (15·8%) |
| All others | 10 936 | 151 (1·3%) | 147 (1·3%) | 83 (0·7%) | 40/381 (10·5%) | 5/131 (3·8%) |
| Total | .. | .. | .. | .. | 112/1044 (10·7%) | 14/314 (4·5%) |
| Total number of patients with complications | .. | .. | .. | .. | 188/1970 (9·5%) | 30/620 (4·8%) |

Data are n/N (%). Denominators vary with the completeness of the data. NA=not applicable. ARDS=acute respiratory distress syndrome

***Table 3:* Postoperative complications in the African Surgical Outcomes Study**

| | All patients (n=10 842) | Complications (n=1973) | No complications (n=8869) | | | Died (n=238) | Survived (n=10 876) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | n (%) | Odds ratio (95% CI) | p value | | n (%) | Odds ratio (95% CI) | p value |
| Non-communicable disease | 4577 (42·2%) | 736 (37·3%) | 4577 (42·2%) | Ref | NA | 96 (40·3%) | 4607 (42·4%) | Ref | NA |
| Acute infection | 1380 (12·7%) | 398 (20·2%) | 982 (12·7%) | 2·12 (1·84–2·44) | <0·0001 | 63 (26·5%) | 1352 (12·4%) | 2·24 (1·62–3·09) | <0·0001 |
| Trauma | 1929 (17·8%) | 405 (20·5%) | 1524 (17·8%) | 1·39 (1·21–1·59) | <0·0001 | 61 (25·6%) | 1947 (17·9%) | 1·50 (1·09–2·08) | 0·0140 |
| Caesarean section | 2956 (27·3%) | 434 (22·0%) | 2522 (28·4%) | 0·90 (0·79–1·02) | 0·10 | 18 (7·6%) | 2970 (27·3%) | 0·29 (0·18–0·48) | <0·0001 |

Data presented as n (%) unless stated otherwise. Odds ratios were constructed for in-hospital complications and mortality with univariate binary logistic regression analysis. NA=not applicable.

***Table 4:* Association between the primary indication for surgery and postoperative complications and in-hospital mortality.**

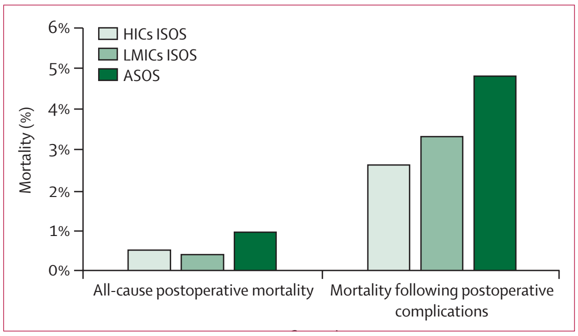


***Figure 3:*** **Surgical mortality following elective surgery in HICs, LMICs, and African countries**

HICs=high-income countries. ISOS=International Surgical Outcomes Study. LMICs=low–middle income countries. ASOS=African Surgical Outcomes Study.

described.[32] Interventions such as early warning scores, critical-care outreach, medical emergency teams, and critical-care skills training for junior surgeons are now standard in most high-income countries. Failure to rescue and similar metrics have been successfully used to support data-driven quality improvement projects.[33] Our findings suggest that the drivers of perioperative death might be broadly consistent across Africa, although further prospective audits are required to understand the site-specific drivers in individual hospitals and countries. Findings from some studies have highlighted the feasibility of surgical outcomes audit in low-income countries.[28,34] A pragmatic continent-wide quality improvement programme might improve the allocation of resources towards the postoperative surveillance of patients who are most at risk, and a simple surgical-risk calculator could facilitate this approach.

To our knowledge, this is the most comprehensive assessment of surgical workforce density and patient outcomes following surgery done so far in Africa. Although our study was not designed to inform detailed health-care policy decisions in individual countries, the data are likely to have a substantial effect throughout Africa. The drivers of morbidity and mortality are probably similar across the different countries in Africa. Some of the country-level data presented might provide the outcomes information required to power future country-specific studies of postoperative morbidity and mortality. Assuming a mortality rate of 2% and a postoperative complication rate of 18%, an individual country-level surgical outcomes audit would require a sample of 3000 patients to provide a reliable mortality estimate with a 95% CI of 1%, and a sample of 1400 patients to provide a reliable complication rate with a 95% CI of 4%. We used a simple dataset mainly of categorical variables to minimise the amount of missing data. Patient-level variables were selected on the basis that they were objective, routinely collected for clinical reasons, could be accurately transcribed with a low rate of missing data, and would be relevant to a risk-adjustment model that included a variety of surgical procedures.

Our study also had some weaknesses. The 7-day cohort design was chosen as a pragmatic approach to tackling the paucity of epidemiological data describing this population. However, care should be taken in applying our findings to individual hospitals and countries. Variation in factors such as seasonal weather, industrial action, available health-care workforce, armed conflict, surgical workload, and the health-care seeking behaviour of patients might all affect our results. Furthermore, these factors might also affect direct comparisons of surgical outcomes with high-income countries. 14 countries did not provide per-protocol data samples, which might compromise the generalisability of the findings to these countries. However, those hospitals unable to meet our protocol requirements might possibly face even greater difficulties in ensuring good patient outcomes. Indeed, more than half the countries in our study could not fulfil the protocol requirements for an included sample, and in hindsight these rules were inappropriately strict. Although 25 African countries participated, this was fewer than half the countries in Africa, and several low-income countries did not take part. Generalisation of our findings to those unrepresented countries must therefore be cautious, although they too might have difficulties in delivering good surgical outcomes. Nearly half the hospitals included in this study were university-affiliated, and our findings might underestimate the poor patient outcomes in smaller, more remote hospitals.

We defined complications according to the published criteria that were also used in the ISOS study.[9] These definitions were developed in high-income countries, and it is possible that some complications were under-reported because of little access to diagnostic tests, for example in the case of myocardial infarction. Additionally, the assessment of some other complications can be subjective, particularly surgical site infection. Although few of our investigators were experienced researchers, it was beyond the scope of this project to train them in a standardised approach to assessing individual complications. This might have resulted in variability in the findings between hospitals. However, our primary focus was on all complications, rather than a specific individual complication. We carefully replicated the design of the previous ISOS study to enable comparisons with the current global standard, but this comparison was not fully contemporaneous as ISOS data were collected in 2014 whereas ASOS was undertaken in 2016.

Surgical patients in Africa are younger, with a lower risk profile and low complication rates, but twice as likely to die when compared with the global average. Most deaths occur after surgery, suggesting a need to improve the safety through postoperative surveillance for deteriorating patients on the ward. Contributory factors include few specialists, poor hospital infrastructure, and low procedural volumes. The *Lancet* Commission on Global Surgery[13] advocates improving access to safe, accessible, and affordable surgical care. Our study highlights the

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additional importance of effective perioperative care to achieving this objective in Africa. A pragmatic continent-wide quality improvement programme, including prospective audits, might reduce the number of preventable deaths following surgery in Africa.

**Contributors**

All authors were involved in the design and conduct of the study. Data collection and collation were done by the ASOS local investigators. Data analysis was done by BMB, TME, and YLM. The first draft of the paper was written by BMB. The paper was redrafted by BMB after critical review by all authors.

**Declaration of interests**

RMP has received research grants from Edwards Lifesciences, Nestle Health Sciences, and Intersurgical, and has given lectures or performed consultancy work for Nestlē Health Sciences, Medtronic, Edwards Lifesciences, BBraun, and GlaxoSmithKline. All other authors declare no competing interests.

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