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The ASOS Surgical Risk Calculator: development and validation of a tool for identifying African surgical patients at risk of severe postoperative complications

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Abstract

Background: The African Surgical Outcomes Study (ASOS) showed that surgical patients in Africa have a mortality twice the global average. Existing risk assessment tools are not valid for use in this population because the pattern of risk for poor outcomes differs from high-income countries. The objective of this study was to derive and validate a simple, preoperative risk stratification tool to identify African surgical patients at risk for in-hospital postoperative mortality and severe complications.

Methods: ASOS was a 7-day prospective cohort study of adult patients undergoing surgery in Africa. The ASOS Surgical Risk Calculator was constructed with a multivariable logistic regression model for the outcome of in-hospital mortality and severe postoperative complications. The following preoperative risk factors were entered into the model; age, sex, smoking status, ASA physical status, preoperative chronic comorbid conditions, indication for surgery, urgency, severity, and type of surgery.

Results: The model was derived from 8799 patients from 168 African hospitals. The composite outcome of severe postoperative complications and death occurred in 423/8799 (4.8%) patients. The ASOS Surgical Risk Calculator includes the following risk factors: age, ASA physical status, indication for surgery, urgency, severity, and type of surgery. The model showed good discrimination with an area under the receiver operating characteristic curve of 0.805 and good calibration with c-statistic corrected for optimism of 0.784.

Conclusions: This simple preoperative risk calculator could be used to identify high-risk surgical patients in African hospitals and facilitate increased postoperative surveillance.

Clinical trial registration: NCT03044899.

Keywords: mortality; preoperative; risk assessment; risk stratification; surgery

Editor's key points

- Surgical patients in Africa have a mortality twice the global average.
- A simple preoperative risk assessment tool could facilitate identification and targeted resource allocation to improve postoperative outcomes.
- A simple preoperative risk calculator was developed using data from 8799 patients involving 168 African hospitals from 25 countries included in the African Surgical Outcomes Study.
- This tool could be used to identify high-risk surgical patients in African hospitals and facilitate increased postoperative surveillance.

The African Surgical Outcomes Study (ASOS)[1] was designed to provide robust surgical outcomes data from Africa to help inform the Commission on Global Surgery.[2] The main findings of ASOS were that surgical patients in Africa are younger and mainly ASA physical status 1 or 2 patients, and yet are twice as likely to die after postoperative complications compared with the global average. The study suggested that postoperative care might be severely compromised by limited surgical resources, in terms of both personnel and facilities, to provide a safe postoperative environment for surgical patients in Africa.[1]

The limited variation in postoperative morbidity and mortality across the African countries in ASOS[1] suggests that a continent-wide strategy to provide safer postoperative care could decrease surgical mortality in Africa. However, with limited resources available for postoperative care, a strategy is needed to focus care on those patients at greatest risk of severe complications and death. A simple, preoperative risk assessment tool might allow targeted postoperative surveillance in resource limited environments. For several reasons, existing simple risk scores have not been validated in an African context. The pattern of risk is very different for patients undergoing surgery in Africa. Compared with patients in high-income countries, the indication for and type of surgery are stronger risk factors, whilst age and ASA physical status are weaker risk factors.[1,3,4] Limited resources preclude the widespread use of biochemical and radiological tests, and even stable internet access limits the utility of some technologies for risk prediction. Furthermore, the African surgical population is much less diverse, perhaps enabling the use of a simpler, more pragmatic solution to risk prediction.[1,3] There is a need for a simple African-specific bedside tool to assess perioperative risk amongst patients in African hospitals. The objective of this study was to derive and validate a simple, preoperative risk assessment tool to identify African surgical patients at risk of in-hospital severe complications and death.

Methods

This study is presented in accordance with the Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD) recommendations for the derivation and validation of risk prediction models.[5]

Source of data and participants

The source of data was from ASOS.[1] The study design and patient recruitment have previously been described.[1] In summary, it was a 7-day, international, multicentre, prospective cohort study of patients ≥18 yr undergoing surgery in hospitals in African countries, and was registered on ClinicalTrials.gov (NCT03044899). The primary ethics approval was from the Biomedical Research Ethics Committee of the University of KwaZulu-Natal, South Africa (BE306/15), with participation by 247 hospitals from 25 African countries between February and May 2016. All patients

undergoing elective and non-elective surgery with at least one planned postoperative overnight hospital stay were included during the recruitment week. We only included data that we considered representative of both country and hospital in order to limit bias. A representative country population sample was defined as participation from at least 10 hospitals (or at least 50% of the surgical centres, if less than 10 surgical centres in the country). From these countries, we only included data from representative hospitals that were defined as providing data on at least 90% of eligible patients during the study week. Data that fulfilled these criteria for a representative sample were used as the population and source data for the derivation model.

Outcome

The primary outcome of the main study was in-hospital complications, which was censored at 30-days for patients who were still in-hospital.[1] Complications were assessed according to predefined criteria and graded as mild, moderate, or severe.[6] The outcome for the model derivation was severe in-hospital postoperative complications. The outcome of severe in-hospital complications was defined as a composite of mortality or complications defined as severe by Jammer and colleagues.[6] Definitions are shown in Supplementary Appendix 1.

Predictors

We included all available potential preoperative predictors of severe postoperative complications and death to develop the predictive model (Supplementary Appendix 2). Intraoperative and postoperative variables were not included as potential predictors, as the objective of this paper was to build a preoperative predictive model of postoperative outcomes.

Sample size and missing data

For all analyses, we performed a complete case analysis, excluding patients with missing data from the analysis. No imputation was performed. This was deemed acceptable because of the limited number of missing variables (<3%).[7,8] The anticipated number of primary outcome events in this cohort exceeded the usual limitations related to overfitting[9] and warranted development of an appropriate predictive model using all preoperative predictors.[5]

Statistical analysis

We conducted a multivariable logistic regression analysis that included all the preoperative variables. Collinearity was evaluated by identification of a variance inflation factor; variables with a variance inflation factor >2 were excluded. Orthopaedic surgery was defined as the surgical reference category, as it included the largest number of patients. Age was first entered in the predictive model as a continuous variable using restricted cubic splines to fit a non-linear functional relationship with the primary outcome, and then as categorised ordinal variables (<30 yr, 30–49 yr, 50–69 yr, and ≥70 yr). As categorisation of age resulted in a mild decrease in the predictive performance (data not shown), but a simpler calculation for a preoperative risk calculator, age was subsequently entered as a categorical variable into the model. To further simplify the model and keep with the principles of a parsimonious model,[8,10] types of surgery with similar predicted risk were aggregated into groups, and these groups were entered as risk predictors into the model.

To develop the ASOS Surgical Risk Calculator, we rounded the regression coefficients to build an additive user-friendly score using methods previously described.[11,12] To optimise the clinical relevance of the ASOS Surgical Risk Calculator, we defined that a one point increase in the score will represent an increase in risk of 30% (an odds ratio increase of 0.25) for the development of severe postoperative complications and death. We created risk groups of increasing severity based on an approximate doubling of risk per group by using an increase of three points per category (i.e. a 90% increase in risk, and an odds ratio increase of 0.75).

The performance of the predictive model was evaluated by discrimination and calibration. Discrimination was reported by the concordance statistic or c-statistic, where a value of 1 suggests perfect discrimination and a value of 0.5 suggests no discrimination. Calibration was assessed graphically by plotting the observed outcome against the predicted probability. A smooth, non-parametric calibration line was created with the locally weighted scatterplot smoothing (LOESS) algorithm to estimate the observed probabilities in relation to the predicted probabilities.[5,7] We then plotted: i) ideal calibration (a hypothetical perfect predictive model with the diagonal crossing the origin of the plot (0;0) with a slope of 1); ii) apparent calibration (the comparison between the predicted probabilities from the derived model, with that observed in the study population); and iii) bias corrected calibration (or bootstrapped calibration), on the same figure to provide a qualitative evaluation of the model calibration. To internally validate the model, optimism corrected performances were calculated. To calculate the optimism corrected performances, 400 bootstrap samples of the study population were conducted, and the difference between the performances in each bootstrap sample and those observed in the original full study population

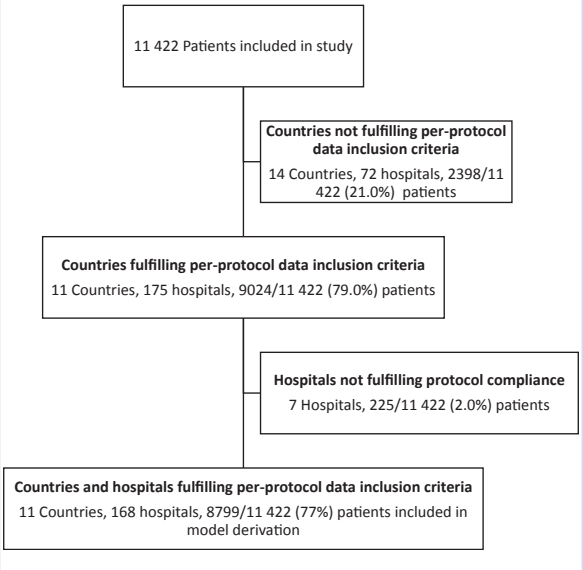

Fig 1. The African Surgical Outcomes Study (ASOS) flow diagram of patient recruitment for model derivation.

were calculated. The average of the differences, known as the optimism, was then subtracted from the performances observed in the full study population to create optimism corrected performance estimate.

When necessary, categorical variables were compared using Fisher's exact test. Continuous variables were tested and confirmed for normality, and therefore summarised using mean (standard deviation) and compared using *t*-tests. Statistical analyses were performed using SPSS version 24 (SPSS Inc., Chicago, IL, USA) and R statistical software package version 3.4 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Participants

From the 11 422 patients recruited in ASOS, 8799 (77.0%) met the predefined representative criteria from 168 hospitals in 11

Table 1 Description of patient cohort and associated severe complications and death. Data are mean (standard deviation) or *n* (proportion). Odds ratios (unadjusted) were constructed for in-hospital severe complications and death with univariable binary logistic regression analysis. The denominator for each group is shown. AIDS, acquired immunodeficiency syndrome; CI, confidence interval; COPD, chronic obstructive pulmonary disease; GIT, gastrointestinal; HIV, human immunodeficiency virus

	All patients (*n*=8799) (%)	Patients with severe complications and death (*n*=423) (%)	Patients without severe complications and death (*n*=8195) (%)	Odds ratio (95% CI)	*P*-value
Age (yr)	39.0 (18–106)	46.3 (18–97)	38.6 (18–106)	1.025 (1.020–1.031)	<0.001
Female	5837/8799 (66.3)	220/423 (52)	5528/8195 (67.5)	Reference	
Male	2962/8799 (33.7)	203/423 (48.0)	2667/8195 (32.5)	1.913 (1.572–2.327)	<0.001
Current smoker	1501/8771 (17.1)	69/420 (16.4)	1386/8171 (17.0)	0.962 (0.739–1.254)	0.776
ASA physical status					
1	4082/8799 (46.4)	88/423 (20.8)	3910/8195 (47.7)	Reference	
2	3422/8799 (38.9)	130/423 (30.7)	3225/8195 (39.4)	1.791 (1.361–2.357)	<0.001
3	1076/8799 (12.2)	136/423 (32.2)	917/8195 (11.2)	6.590 (4.992–8.698)	<0.001
4 and 5	219/8799 (2.5)	69/423 (16.3)	143/8195 (1.7)	21.439 (15.008–30.625)	<0.001
Grade of surgery					
Minor	1999/8786 (22.8)	56/423 (13.2)	1886/8182 (23.1)	Reference	
Intermediate	4428/8786 (50.4)	181/423 (42.8)	4159/8182 (50.8)	1.466 (1.081–1.988)	0.014
Major	2359/8786 (26.8)	186/423 (44.0)	2137/8182 (26.1)	2.931 (2.161–3.977)	<0.001
Urgency of surgery					
Elective	3793/8799 (43.2)	106/422 (25.1)	3611/8186 (44.1)	Reference	
Urgent	2033/8799 (23.1)	127/422 (30.1)	1850/8186 (22.6)	2.339 (1.796–3.045)	<0.001
Emergency	2963/8799 (33.7)	189/422 (44.8)	2725/8186 (33.3)	2.363 (1.853–3.013)	<0.001
Surgical speciality					
Orthopaedic	1354/8616 (15.7)	60/423 (14.2)	1294/8193 (15.8)	Reference	
Breast	180/8616 (2.1)	5/423 (1.2)	175/8193 (2.1)	0.616 (0.244–1.555)	0.305
Obstetrics	2762/8616 (32.1)	50/423 (11.8)	2712/8193 (33.1)	0.398 (0.272–0.582)	<0.001
Gynaecology	1085/8616 (12.6)	28/423 (6.6)	1057/8193 (12.9)	0.571 (0.362–0.901)	0.016
Upper GIT	219/8616 (2.5)	30/423 (7.1)	189/8193 (2.3)	3.423 (2.152–5.445)	<0.001
Lower GIT	689/8616 (8.0)	72/423 (17.0)	617/8193 (7.5)	2.517 (1.763–3.592)	<0.001
Hepatobiliary	118/8616 (1.4)	10/423 (2.4)	108/8193 (1.3)	1.997 (0.994–4.012)	0.052
Urology and kidney	466/8616 (5.4)	25/423 (5.9)	441/8193 (5.4)	1.223 (0.757–1.974)	0.411
Vascular	183/8616 (2.1)	29/423 (6.9)	154/8193 (1.9)	4.061 (2.529–6.522)	<0.001
Head and neck	308/8616 (3.6)	21/423 (5.0)	287/8193 (3.5)	1.578 (0.945–2.636)	0.081
Plastics/cutaneous	432/8616 (5.0)	23/423 (5.4)	409/8193 (5.0)	1.213 (0.740–1.986)	0.443
Cardiac surgery	52/8616 (0.6)	9/423 (2.1)	43/8193 (0.5)	4.514 (2.103–9.687)	<0.001
Thoracic (lung and other)	113/8616 (1.3)	12/423 (2.8)	101/8193 (1.2)	2.562 (1.335–4.918)	0.005
Thoracic (gut)	18/8616 (0.2)	3/423 (0.7)	15/8193 (0.2)	4.313 (1.216–15.303)	0.024
Neurosurgery	182/8616 (2.1)	30/423 (7.1)	152/8193 (1.9)	4.257 (2.662–6.806)	<0.001
Other	455/8616 (5.3)	16/423 (3.8)	439/8193 (5.4)	0.786 (0.448–1.379)	0.401
Indication for surgery					
Non-communicable disease	3657/8758 (41.8)	167/423 (39.5)	3425/8169 (41.9)	Reference	
Infection	1142/8758 (13.0)	123/423 (29.1)	993/8169 (12.2)	2.540 (1.992–3.240)	<0.001
Trauma	1602/8758 (18.3)	93/423 (22.0)	1447/8169 (17.7)	1.318 (1.015–1.711)	0.038
Caesarean section	2357/8758 (26.9)	40/423 (9.5)	2304/8160 (28.2)	0.356 (0.251–0.505)	<0.001
Preoperative comorbidity					
Coronary artery disease	150/8618 (1.7)	19/423 (4.5)	131/8195 (1.6)	2.895 (1.771–4.732)	<0.001
Congestive heart failure	73/8618 (0.8)	13/423 (3.1)	60/8195 (0.7)	4.299 (2.341–7.894)	<0.001
Diabetes mellitus	631/8618 (7.3)	70/423 (16.5)	561/8195 (6.8)	2.698 (2.059–3.536)	<0.001
Cirrhosis	7/8618 (0.1)	0/423 (0.0)	7/8195 (0.1)	–	–
Metastatic cancer	120/8618 (1.4)	18/423 (4.3)	102/8195 (1.2)	3.526 (2.116–5.878)	<0.001
Hypertension	1590/8618 (18.4)	122/423 (28.8)	1468/8195 (17.9)	1.857 (1.494–2.309)	<0.001
Stroke or transient ischaemic attack	78/8618 (0.9)	15/423 (3.5)	63/8195 (0.8)	4.746 (2.679–8.407)	<0.001
COPD/asthma	323/8618 (3.7)	21/423 (5.0)	302/8195 (3.7)	1.365 (0.867–2.149)	0.178
HIV positive/AIDS	1131/8618 (13.1)	37/423 (8.7)	1094/8195 (13.3)	0.622 (0.441–0.877)	0.007
Chronic renal disease	141/8618 (1.6)	27/423 (6.4)	114/8195 (1.4)	4.833 (3.139–7.441)	<0.001

countries: Democratic Republic of the Congo (DRC), Gambia, Madagascar, Mali, Mauritius, Namibia, Niger, Nigeria, South Africa, Uganda, and Zimbabwe. Seven of these countries are low-income countries (DRC, Gambia, Madagascar, Mali, Niger, Uganda, and Zimbabwe), and seven (DRC, Gambia, Madagascar, Mali, Mauritius, Namibia, and Zimbabwe) provided data on >95% of adult surgical patients performed during the recruitment week. Patients included in the model derivation are shown in Figure 1.

Patient characteristics and outcomes

Patient characteristics and their unadjusted association with the primary outcome of in-hospital severe complications and death are shown in Table 1. Most of the patients had a low-risk profile, with 7504/8799 (85.3%) being ASA physical status 1 or 2. Some 4996/8799 (56.8%) of the surgical procedures were urgent or emergent, and 6787/8799 (77.1%) were classified as of intermediate or major severity. Severe postoperative complications occurred in 423 patients [4.8%, 95% confidence interval (CI) 4.4–5.3], including 204 cases of in-hospital mortality (2.3%, 95% CI 2.0–2.6). The unadjusted association with in-hospital postoperative mortality is reported in Supplementary Table 1.

Model development, specification, and performance

Two hundred and thirteen (2.4%) of the patients had missing data and were not included in the model derivation. Of the 8785 patients included in the model derivation, 422 patients developed the primary outcome of in-hospital severe complications and death. Variables were selected for the model by initially analysing all variables including sex, smoking status, and comorbidities (coronary artery disease, congestive heart failure, diabetes mellitus, cirrhosis, metastatic cancer, hypertension, stroke or transient ischaemic attack, chronic obstructive pulmonary disease/asthma, human immunodeficiency virus/acquired immunodeficiency syndrome, and chronic renal disease) during regression with the primary outcome. Of these variables, only smoking status was independently associated with outcome. The addition of smoking status did not however improve the model and it was excluded in the interests of developing a parsimonious model.[8] The variables retained in the model are shown in Supplementary Appendix 3. The full regression coefficients and intercept of the final risk-adjusted model for in-hospital severe complications are shown in Supplementary Table 2. The risk-adjusted model showed good discrimination for severe postoperative complications and death with a c-statistic of 0.805 and good calibration with c-statistic corrected for optimism of 0.784. The LOESS plot of observed *vs* expected outcomes is shown in Figure 2.

The ASOS Surgical Risk Calculator for severe postoperative complications is shown in Table 2 with the observed outcomes per risk group and the points for each risk factor present. A single point increase represents an increase in relative risk of 30% (relative risk 1.3 or an odds ratio increase of 0.25). The observed outcomes for each individual risk score observed in the derivation population are shown in Supplementary Table 3. The frequencies of the ASOS Surgical Risk Calculator scores and their observed severe complications and death are shown in Supplementary Figure 1. The receiver operating characteristic curve for the internal validation is shown in Supplementary Figure 2. The ASOS Surgical Risk Calculator and observed outcomes based upon three-point risk groups

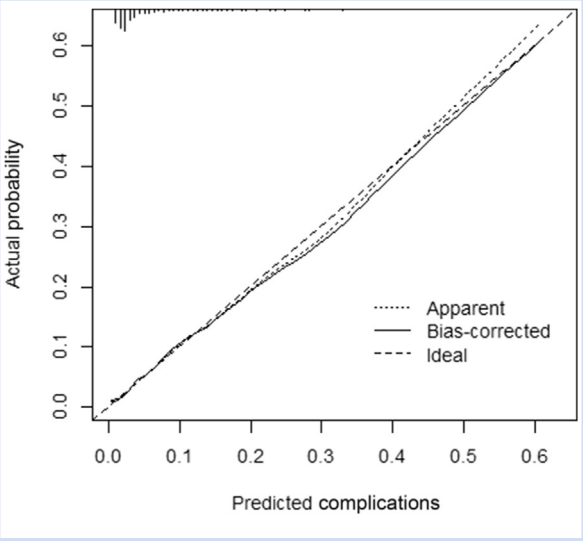

Fig 2. Calibration plot of the African Surgical Outcomes Study (ASOS) Surgical Risk Calculator. The rug plot along the top of the figure demonstrates the distribution of patients' risks observed in the study population.

Table 2 The African Surgical Outcomes Study (ASOS) Surgical Risk Calculator for preoperative risk prediction of severe postoperative complications and death. A single point represents a standard increase in risk, defined as a 0.25 increase in the logistic regression coefficient, equivalent to a 30% increase in the risk of the outcome being present. Total score possible: from −3 to 25. ASA, American Society of Anesthesiologists

Age (yr)	
18–29	0
30–69	+1
≥70	+3
ASA physical status	
ASA 1	0
ASA 2	+2
ASA 3	+5
ASA 4 and more	+8
Surgery timing	
Elective surgery	0
Urgent surgery	+3
Emergent surgery	+4
Surgery severity	
Minor	0
Intermediate	+2
Major	+4
Indication for surgery	
Non-communicable disease	0
Caesarean section	-2
Trauma	+1
Infection	+2
Surgery type	
Gynaecology/obstetrics	-1
Plastics and breast	+1
Urology	+2
Ear, nose and throat, gastro-intestinal, hepato-biliary, cardiothoracic, vascular	+3
Neurosurgery	+4
All other types of surgery	0

are shown in Table 3. The ASOS Surgical Risk Calculator can be accessed at https://www.asos.org.za/index.php.

Discussion

The ASOS Surgical Risk Calculator is a simple preoperative risk stratification tool that provides good discrimination and calibration for prediction of in-hospital mortality and severe postoperative complications. Because of the low-risk profile of surgical patients in Africa,[1] the predictors of major postoperative morbidity are driven predominantly by surgical risk factors (indication, urgency, severity, and type). The risk calculator does not require any special investigations, and so can be applied to every adult surgical patient. Finally, the score can be calculated and presented simply on a card, and therefore does not require a computer or internet access to implement. This risk assessment model could be used in preoperative clinical decision-making in order to identify patients at increased postoperative risk. This would allow for informed decisions concerning appropriate postoperative care and human resource allocation.

Limitations

Fourteen countries did not provide representative data in ASOS, and so were not used as source data for this derivation model. This could compromise the generalisability of the ASOS Surgical Risk Calculator in those countries. Furthermore, although there was participation of 25 African countries, this is still less than half of the countries in Africa, and therefore generalisability of this model to those unrepresented countries might be inappropriate. However, as the risk-adjusted analyses conducted on the ASOS cohort suggested that the poor surgical outcomes were fairly consistent across African countries,[1] we believe that use of the source data that were considered to be 'representative' in ASOS would have less selection bias than use of the entire cohort, and would therefore provide a more reliable risk prediction model for Africa. A further limitation is that South Africa contributed 5318 (60.4%) of cases to the derivation model.

The model has strong internal validation, through bootstrapping and cross-validation. Unfortunately, no appropriate dataset for the primary outcome was available for external validation. We are confident, however, that there is little overfitting in this model. Model overfitting could arise when the number of events is small when compared with the number of predictors in the risk model, which was not the case in the development of the ASOS Surgical Risk Calculator.[9] Therefore, we do not expect this model to demonstrate the characteristics of overfitted models, where the probability of an event tends to be underestimated in low-risk patients and overestimated in high-risk patients.[7] Furthermore, the limited data collected in ASOS did not allow us to validate established risk scores, such as the Surgical Outcome Risk Tool (SORT), in this African surgical population.[4]

Interpretation

ASOS provided an insight into the difference in predictors of postoperative morbidity and mortality in Africa when compared with other cohorts.[1,3] The low-risk profile of the African patients would suggest that both the patient characteristics included as predictors in a model and the risk associated with these predictors should be lower in the African cohort. Furthermore, because of the limited human resources to provide care, it is likely that surgical procedures that carry higher risk for postoperative complications might be disproportionately associated with increased mortality because of increased 'failure to rescue'. These hypotheses are supported when comparing the ASOS Surgical Risk Calculator with the SORT.[4] Although the risk predictors are similar in the two models, because of the lower morbidity of the African surgical patients, cancer is not independently associated with risk in Africa, as it is in SORT.[4] Secondly, when comparing the relative risk for surgical risk factors against the risk associated with the ASA categories for both models, patients in the African cohort carry a relatively higher risk associated with major surgery and higher risk surgical types. It is not surprising, therefore, that the performance of the ASOS Surgical Risk Calculator appears to be at least equivalent or better than the SORT model for predicting severe postoperative complications in the African cohort.[13] This provides some justification to consider adoption of the African Surgical Risk Calculator in Africa.

Implications

The ASOS Surgical Risk Calculator might be used to identify high-risk patients at greatest need of enhanced postoperative surveillance. The use of the ASOS Surgical Risk Calculator in further studies will be needed to provide external validation. There is also the need to conduct an

Table 3 Severe postoperative complications for each risk group of the African Surgical Outcomes Study (ASOS) Surgical Risk Calculator observed in the derivation cohort. Data presented as *n* (%). Severe postoperative complications were defined as a composite of in-hospital mortality and all postoperative complications defined as severe in the consensus statement by Jammer and colleagues.[6] The incidence of severe complications in the full cohort was 423/8799 (4.8%, 95% confidence interval 4.4–5.3)

ASOS surgical risk calculator score	Number of patients (*n*)	Severe complications (*n*)	Severe complications [%, 95% confidence interval (CI)]
≤3	1835	22	1.20, 0.70–1.69
4–6	2888	40	1.39, 0.96–1.81
7–9	1971	81	4.11, 3.25–4.97
10–12	970	80	8.25, 6.58–9.91
13–15	470	84	17.87, 14.68–21.06
16–18	177	62	35.03, 28.98–41.08
≥19	65	54	83.08, 76.34–89.81

impact analysis of whether its use ensures appropriate allocation of the current limited resources available for the care of surgical patients at risk in Africa.[14] It is important to realise that resource allocation thresholds based on the ASOS Surgical Risk Calculator score could vary between African countries based upon the patient profile and the available resources for care.

Conclusions

Morbidity and mortality after surgery are significant in Africa, and these poor outcomes appear to be consistent across many African countries.[1] The difference in the patient profile and the resources available for care of the surgical patient in Africa suggests that a specific African risk prediction tool is warranted. The ASOS Surgical Risk Calculator is simple and potentially universally applicable for adult surgery in Africa. It is hoped that this tool might help identify patients at risk of severe postoperative complications in this limited resource environment.

Authors' contributions

Design and conduct of the study: all authors.
Data collection and collation: the ASOS local investigators.
Data analysis: B.M.B., Y.L.M.
Writing the first draft of the paper: H.L.K., B.M.B.
Redrafting of the paper: H.L.K., B.M.B.
Critical review: all authors.

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Declarations of interest

R.P. holds research grants and has given lectures, performed consultancy work for Nestle Health Sciences, BBraun, Medtronic, Glaxo Smithkline, Intersurgical, and Edwards Lifesciences, or both, and is a member of the associate editorial board of the *British Journal of Anaesthesia*. All other authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.bja.2018.08.005.

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