Supplementary material

Salvage surgery outcomes following circumcision mishaps in Southeastern Ghana: development, internal validation and external validation of a prognosticating model

Frank Obeng *et al.*

Corresponding author: Frank Obeng

Email: fobeng@uhas.edu.gh

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Annex 1: development, validation and deployment of the logistic regression model predicting successful salvage surgery following circumcision-related complications			
Domain	**Parameter**	**Result**	**Clinical interpretation/remarks**
Model development	Statistical model	Multivariable logistic regression	Logistic regression was used to estimate the probability of successful salvage surgery following circumcision-related complications.
	Development cohort	23 patients	Consecutive cases managed at Ho Teaching Hospital, Ghana.
	Outcome variable	Successful salvage surgery (yes/no)	Binary dependent variable.
	Predictor variables	Occupation, religion, ethnicity, nationality, referral status, circumciser, education, facility, hypospadias	Variables selected based on clinical relevance and available data.
Final logistic regression model	Intercept	β = 0.488	Baseline log-odds of successful salvage surgery.
	Occupation	β = –0.054	Slight negative contribution to the probability of successful salvage.
	Religion	β = +0.048	Minimal positive contribution.
	Ethnicity	β = +0.032	Minimal positive contribution.
	Nationality	β = –0.186	Foreign nationality reduced the predicted probability of successful salvage.
	Referral promptness	β = +0.121	Earlier referral increased the probability of successful salvage.
	Circumciser	β = –0.201	Provider category demonstrated an inverse association within the fitted model.
	Education	β = –0.061	Small inverse contribution.
	Facility	β = +0.013	Minimal positive contribution.
	Hypospadias present	β = –1.037	Largest negative predictor of successful salvage surgery.
Prediction Equation	Linear predictor	Logit(P) = 0.488 – 0.054(Occupation) + 0.048(Religion) + 0.032(Ethnicity) – 0.186(Nationality) + 0.121(Referral) – 0.201(Circumciser) – 0.061(Education) + 0.013(Facility) – 1.037(Hypospadias)	Linear predictor generated from the fitted logistic regression model.
	Estimated probability	P = e^(Logit(P)) / [1 + e^(Logit(P))]	Converts the linear predictor into an individual's estimated probability of successful salvage surgery.
Variable coding	Occupation	1 = Informal; 2 = Skilled; 3 = Middle level; 4 = Senior; 5 = Executive	Ordinal categorical variable.

	Religion	1 = Christian; 2 = Muslim; 3 = Other	Nominal categorical variable.
	Ethnicity	1 = Akan; 2 = Ewe; 3 = Ga; 4 = Guan; 5 = Northern; 6 = Foreigner	Nominal categorical variable.
	Nationality	1 = Local; 2 = Foreign	Binary categorical variable.
	Referral status	0 = Early; 1 = Late	Earlier referral associated with improved outcomes.
	Circumciser	1 = Wanzam; 2 = Nurse; 3 = Midwife; 4 = Doctor	Ordinal provider category.
	Education	1 = None; 2 = Primary; 3 = Secondary; 4 = Tertiary; 5 = Postgraduate	Increasing educational attainment.
	Facility	0 = Home; 1 = Rural; 2 = District; 3 = Teaching Hospital	Higher values correspond to increasing level of healthcare facility.
	Hypospadias	0 = Absent; 1 = Present	Presence of congenital anomaly.
Model performance	Accuracy	68.2%	Overall proportion of correctly classified patients.
	Precision (Positive predictive value)	72.4%	Probability that predicted successful salvage cases were truly successful.
	Sensitivity	73.1%	Ability of the model to correctly identify successful salvage cases.
	F1-score	72.7%	Harmonic mean of precision and sensitivity.
	Area Under the ROC Curve (AUC)	0.70	Acceptable discrimination between successful and unsuccessful outcomes.
	Hosmer–Lemeshow goodness-of-fit	$\chi^2 = 5.67$; $p = 0.684$	Indicates good calibration (no evidence of poor model fit).
	McFadden pseudo-R^2	0.263	Moderate explanatory performance.
	Nagelkerke R^2	0.475	Reasonable proportion of explained variation.
Internal validation	Validation method	Bootstrap resampling (1,000 iterations)	Used to assess model stability and potential overfitting.
	Development dataset	n = 23	Internal validation cohort.
	Confusion matrix	TP = 11; FN = 4; FP = 3; TN = 5	Classification summary.
	Accuracy	69.6%	Stable predictive performance within the development dataset.
	Sensitivity	73.3%	Good detection of successful salvage cases.
	Specificity	62.5%	Moderate detection of unsuccessful salvage cases.
External validation	Validation cohort	n = 22	Independent cases from Ghana, Nigeria, Burkina Faso, Israel, and the United States.
	Accuracy	72.7%	Comparable performance in external data.

	Sensitivity	78.6%	Good external discrimination.
	Specificity	62.5%	Moderate specificity maintained.
	Area under the ROC curve (AUC)	0.69	External discriminatory ability remained acceptable.
Combined validation	Total validated cohort	n = 45	Combined development and external validation datasets.
	Accuracy	71.1%	Stable overall classification performance.
	Sensitivity	75.9%	Good identification of successful salvage cases.
	Specificity	62.5%	Moderate identification of unsuccessful cases.
	Precision (PPV)	78.6%	High probability that predicted successes were true successes.
	F1-score	77.2%	Balanced predictive performance.
	Area under the ROC curve (AUC)	0.705	Acceptable discrimination following combined validation.
	Hosmer–Lemeshow goodness-of-fit	$\chi^2 = 6.03$; $p = 0.641$	Calibration remained satisfactory after validation.
	Nagelkerke R^2	+0.480	Overall model explanatory power remained 7
The CDSOS2 (Clinical Decision Support on salvage-surgery-Outcomes' Scoring-system)			
THE BEDSIDE TOOL: CDSOS1: The Circumcision Disaster Salvage Outcomes' Score Derivation: The model coefficients were converted into a scoring system by rounding β-values and assigning point weights to each variable. The variable HY (presence of hypospadias or congenital anomalies) had the highest negative weight (-3). Other variables were weighted proportionally based on their contribution.	Variable	Categories (Coding)	Score assigned
	Parental occupation	1 = Informal (0), 2 = Skilled (+0.5), 3 = Mid (+1), 4 = Senior (+1.5), 5 = Exec (+2)	0–2 pts
	Parental religion	1 = Christian (0), 2 = Muslim (+1), 3 = Traditional/Other (+0.5)	0–1 pt
	Ethnicity	1 = Akan (0), 2 = Ewe (+0.5), 3 = Others (+1)	0–1 pt
	Nationality	1 = Local (0), 2 = Foreign (–1)	–1 to 0 pt
	Referral status	0 = Early (+1), 1 = Late (0)	0–1 pt
	Circumciser type	1 = Wanzam (–1), 2 = Nurse (0), 3 = Midwife (+1), 4 = Doctor (+2)	–1 to +2 pts
	Parental education level	1 = None (0), 2 = Primary (+0.5), 3 = Secondary (+1), 4 = Tertiary (+1.5), 5 = Postgrad (+2)	0–2 pts
	Facility where circumcision done	0 = Home (–1), 1 = Rural (0), 2 = District (+1), 3 = Teaching (+2)	–1 to +2 pts
	Hypospadias / Anomaly (HY)	0 = Absent (0), 1 = Present (–3)	–3 to 0 pts
Risk stratification: Total score range = –4 to +13	Score range	Estimated probability of success	Clinical interpretation
	≤ 2	< 30%	High risk of failure; refer urgently
	3–5	30–50%	Consider specialist involvement
	6–8	50–70%	Moderate outcome with proper support
	≥ 9	> 80%	High confidence in favorable outcome

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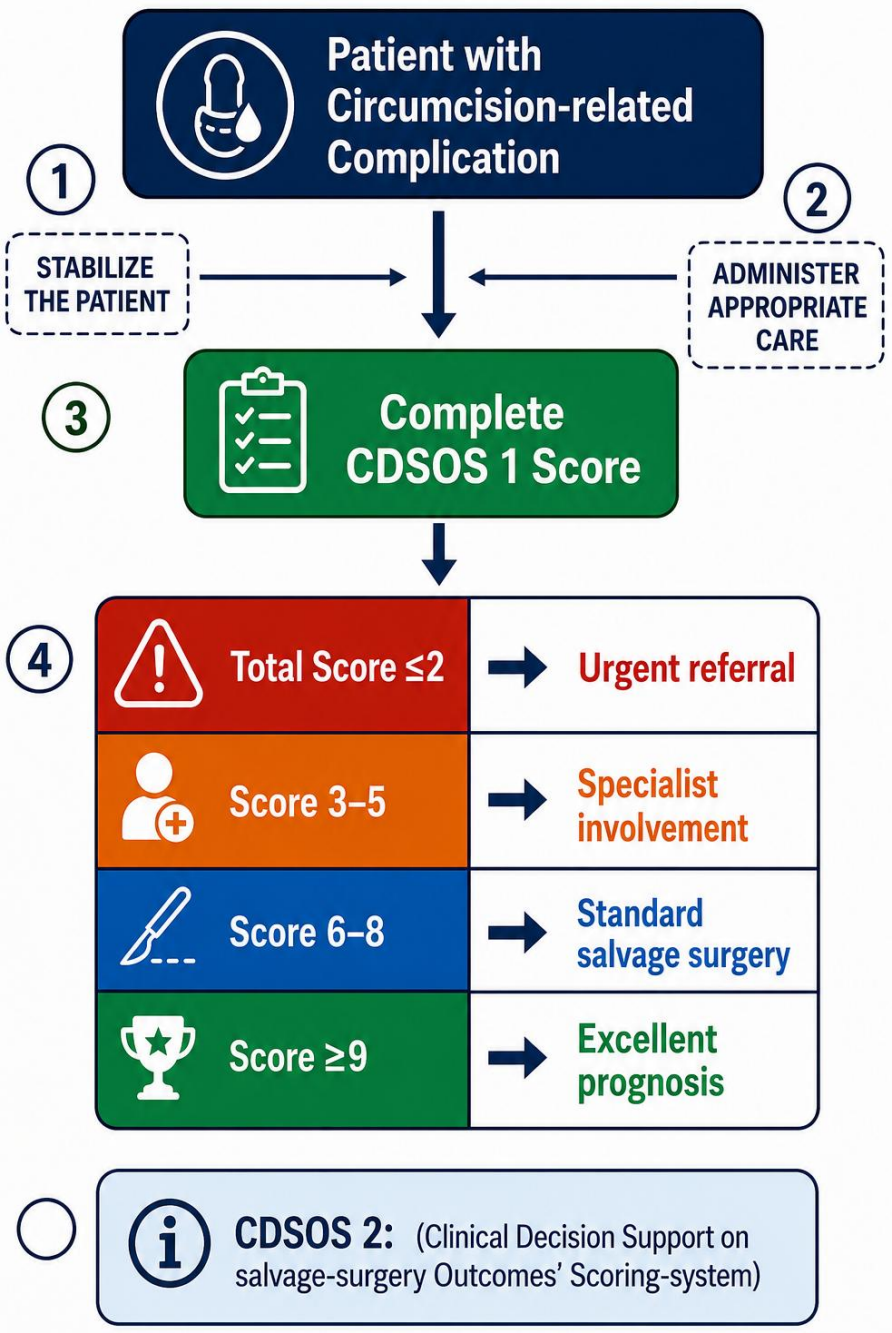
PATIENT CDSOS1&2 WORKSHEET (To be completed at the bedside)				
Patient score = _____ /13	Probability (refer to score band above)	Risk category = _____	Management plan = _____	Review date = _____



Annex 2: CDSOS2 (Clinical Decision Support on Salvage Surgery Outcomes Scoring System) decision tree: showing the algorithm for the final clinical decision-making based on the CDSOS1. (source: authors' construct, 2026)