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Factors Associated with Complications and in-Hospital Mortality among Patients with Congenital Heart Disease Evacuated from Gabon for Cardiac Surgery

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ABSTRACT

Background: *Congenital heart disease (CHD) carries substantial morbidity and mortality in sub-Saharan Africa, where delayed diagnosis and the absence of local cardiac surgery compound adverse outcomes. In Gabon, patients requiring surgical repair must be evacuated abroad. This study aimed to identify clinical and biological factors independently associated with complications and in-hospital mortality in this population.*

Methods: *Retrospective multicentre analytical cohort study (2021-2023), N = 72 CHD patients evacuated from Gabon for cardiac surgery. Complications (n = 22/69; 31.9%) and death (n = 11/70; 15.7%) were the primary outcomes. Univariate associations were assessed by chi-square or Fisher's exact test. Binary logistic regression identified independent predictors of complications (rule of ten events per variable).*

Results: *On univariate analysis, significant predictors of complications included: cyanotic CHD (OR 3.09; 95% CI 1.09-8.75; p = 0.031), pulmonary atresia (OR 10.89; p = 0.028), respiratory distress (OR 13.06; 3.10-54.97; p < 0.001), oxygen desaturation (OR 4.80; p = 0.003), pre-operative cardiac failure (OR 3.80; p = 0.011), and polycythaemia (OR 8.95; p = 0.002). VSD was protective (OR 0.17; p = 0.006). On multivariate analysis, independent predictors of complications were respiratory distress (adjusted OR 16.42; 3.46-78.00; p < 0.001) and pre-operative cardiac failure (adjusted OR 4.99; 1.43-17.40; p = 0.012). All 11 deaths occurred in infants (≤ 24 months); univariate predictors of mortality included respiratory distress (OR 9.26; p = 0.003), pulmonary atresia (OR 11.06; p = 0.023), fever (OR 11.06; p = 0.023), and oxygen desaturation (OR 5.37; p = 0.028).*

Conclusion: *Respiratory distress and pre-operative cardiac failure independently predict complications in CHD patients evacuated from Gabon. In-hospital mortality is restricted to infants and is associated with markers of severe haemodynamic compromise. These findings support early referral, systematic pre-operative haemodynamic optimisation, and the urgent development of local paediatric cardiac surgical capacity.*

Keywords

Congenital heart disease, Complications, Mortality, Prognostic factors, Logistic regression, Sub-Saharan Africa, Gabon.

Introduction

Congenital heart disease (CHD) represents the most common group of structural birth defects, affecting 5 to 15 per 1,000 live births worldwide [1]. According to Global Burden of Disease data, infants under 12 months account for approximately 75% of CHD-related deaths in low-sociodemographic-index regions, with the highest mortality and disability-adjusted life-year burden concentrated in sub-Saharan Africa and South Asia [2]. Despite significant advances in paediatric cardiology, cardiac surgery, and critical care in high-income countries, which have progressively

reduced CHD mortality over recent decades, the situation in low- and middle-income countries (LMICs) remains strikingly inequitable.

In sub-Saharan Africa, CHD mortality has increased by 38.1% and 40.3% in Central and Western Africa respectively over the past decade, a trend attributed to persistent poverty, limited diagnostic infrastructure, and the near-universal absence of paediatric cardiac surgery facilities [3]. Access to corrective cardiac surgery within the first two years of life is estimated at less than 1% of affected children in the region [4], a figure that starkly contrasts with correction rates exceeding 85% in comparable age groups in high-income countries. The consequences are predictable: prolonged haemodynamic overload, progressive pulmonary vascular remodelling, and accumulation of complications, cardiac failure, pulmonary arterial hypertension (PAH), recurrent bronchopulmonary infections, and growth retardation, before any surgical correction becomes possible [5,6]. Series from West and Central Africa consistently document complication rates of 30-40% and in-hospital mortality of 15-25% in surgically managed CHD cohorts [7,8], compared with 2-5% in established North American and European paediatric cardiac surgery centres.

Pulmonary arterial hypertension deserves particular emphasis in the African context. Namuyonga and Mocumbi reported that PAH mortality in African children with CHD reaches 18-21%, with most deaths occurring within six months of diagnosis, and that unoperated post-tricuspid shunt lesions, ventricular septal defect (VSD), atrioventricular canal defect (AVCD), patent ductus arteriosus (PDA), are the primary drivers of irreversible pulmonary vascular disease in this population [9]. The window for reversible pulmonary vascular remodelling is narrow: for high-risk shunt lesions, surgical repair must be achieved before 6-12 months of age to prevent permanent vascular damage, a timeline that is rarely met in sub-Saharan Africa given current infrastructure and referral pathways.

In Gabon, the management of CHD has historically relied on medical evacuation through the national health insurance system (Caisse Nationale d'Assurance Maladie et de Garantie Sociale, CNAMGS), as no paediatric cardiac surgery unit is currently available in the country. A recent descriptive study from our group characterised the clinical and evolutionary profile of 72 CHD patients evacuated for cardiac surgery between 2021 and 2023: the leading CHD types were VSD (37.5%), tetralogy of Fallot (22.2%), and AVCD (19.4%), with an overall complication rate of 31.9% and in-hospital mortality of 15.7% [10]. While this work described the clinical burden of CHD in Gabon, the determinants of these adverse outcomes, which predictors drive complications and death, were not investigated.

Identifying independent clinical and biological risk factors for complications and death is essential for several practical purposes: (i) risk stratification and prioritisation of the most vulnerable patients for urgent surgical referral; (ii) targeted pre-operative optimisation before evacuation; and (iii) informing the design of a dedicated pre-surgical care pathway for infants and children awaiting evacuation in Gabon. The present analytical study therefore aims to investigate the factors independently associated with peri-operative complications and in-hospital mortality in this evacuated CHD cohort, using multivariate logistic regression on the same dataset as Ndoume Obiang et al. [10].

Patients and Methods

Study design and setting

This retrospective multicentre analytical cohort study used the same dataset as Ndoume Obiang et al. [10], collected from the cardiology and paediatrics departments of the main public and private hospitals in Libreville, Gabon (Centre Hospitalier Universitaire de Libreville, Centre Hospitalier Universitaire Mère-Enfant Jeanne Ebori, Centre Hospitalier Universitaire d'Owendo, and Polyclinique Chambrier). The study period covered January 2021 to January 2023.

Population and eligibility

Inclusion criteria: all patients with a confirmed CHD diagnosis for whom medical evacuation for cardiac surgery abroad was approved by CNAMGS, with a complete medical record including clinical, paraclinical, surgical, and outcome data. Patients with incomplete records and those with acquired heart disease were excluded. The final cohort comprised 72 patients; three with missing paraclinical data were excluded from specific analyses (N = 69 for most variables).

Outcome variables

Two binary outcomes were defined: (i) occurrence of any peri-operative complication (composite: PAH crisis, cardiac failure, bronchopneumopathy, anoxic crisis, complete atrioventricular block requiring pacemaker, haemodynamic failure, acute renal failure, Eisenmenger syndrome, sepsis, tamponade, or other), yes/no; and (ii) in-hospital death, yes/no. Post-operative outcomes were assessed within 30 days of surgery or during the evacuation period.

Predictor variables

Potential predictors included: sex, age group (infant ≤ 24 months / child / adult), CHD type (cyanotic vs acyanotic), number of defects (isolated vs associated), all available clinical signs (dyspnoea, respiratory distress, cyanosis, oxygen desaturation, cardiac failure, hepatomegaly, growth retardation, fever), ECG findings (right/left ventricular hypertrophy, atrial enlargement, RBBB, tachycardia), radiological findings (cardiomegaly, PAH, pulmonary hypervascularisation), and biological/comorbidity data (anaemia, polycythaemia, trisomy 21, sickle cell disease, repeated bronchitis, bronchopneumopathy).

Statistical analysis

Categorical variables are expressed as frequencies and percentages. Univariate associations between each predictor and each outcome were assessed by Pearson's chi-square test when all expected cell counts were ≥ 5, or by Fisher's exact test otherwise. Crude odds ratios (OR) with 95% confidence intervals (CI) were calculated

using the Woolf method. Variables with $p < 0.20$ on univariate analysis were selected for inclusion in binary logistic regression. Given 22 events for the complication outcome, a maximum of two predictors was included in the final model (rule of ten events per variable). The model with the lowest Akaike Information Criterion (AIC) was selected. For mortality, the presence of complete separation (all deaths occurring in infants) precluded logistic regression; univariate ORs with Fisher's exact p-values are reported. Statistical significance was set at $p < 0.05$. Analyses were performed using Python (SciPy 1.13, statsmodels 0.14).

Results

Study population

Seventy-two patients were included. There were 38 females (52.8%) and 34 males (47.2%), sex-ratio 0.89. The mean age was 5.6 ± 9.6 years (range: 0.17-60). Infants accounted for 55.6% (n = 40), children for 37.5% (n = 27), and adults for 6.9% (n = 5). Isolated CHD was present in 72.2% (n = 52). The main CHD types were VSD (n = 27; 37.5%), tetralogy of Fallot (ToF; n = 16; 22.2%), and AVCD (n = 14; 19.4%). Cyanotic CHD accounted for 34.7% (n = 25) and acyanotic shunt lesions for 62.5% (n = 45). The full clinical, biological, and paraclinical profile is presented in Table 1.

Outcomes

Of 72 patients, 70 (97.2%) underwent cardiac surgery. Complications occurred in 22 of 69 patients (31.9%). Eleven patients died (15.7%); all deaths occurred in infants aged ≤ 24 months. Causes of death were: severe PAH crisis (n = 4; 36.4%), haemodynamic failure (n = 2; 18.2%), cardiac arrhythmia (n = 2; 18.2%), sepsis (n = 1; 9.1%), tamponade (n = 1; 9.1%), and acute renal failure (n = 1; 9.1%). Five patients did not undergo surgery: one was deemed inoperable (Eisenmenger syndrome) and four had surgery deferred. The post-operative course was favourable in 55 of 71 patients (77.5%).

Table 1: Clinical, biological, ECG, and radiological characteristics of the study population (N = 69-72).

Characteristic	n	% (N)
Sex (male)	34	47.2% (72)
Age group: infant (≤ 24 months)	40	55.6% (72)
Age group: child (2-18 years)	27	37.5% (72)
Age group: adult (> 18 years)	5	6.9% (72)
Cyanotic CHD (ToF, TGA, atresias, truncus)	25	34.7% (72)
Acyanotic CHD (VSD, ASD, AVCD, PDA)	45	62.5% (72)
Associated CHD (≥ 2 defects)	20	27.8% (72)
Cardiac murmur	60	87.0% (69)
Dyspnoea	52	75.4% (69)
Growth retardation	27	39.1% (69)
Pre-operative cardiac failure	24	34.8% (69)
Cyanosis	22	31.9% (69)
Oxygen desaturation	22	31.9% (69)
Hepatomegaly	17	24.6% (69)
Respiratory distress	13	18.8% (69)
Fever	5	7.2% (69)
Right ventricular hypertrophy (RVH, ECG)	45	65.2% (69)
Left ventricular hypertrophy (LVH, ECG)	28	40.6% (69)
Cardiomegaly (CXR)	57	82.6% (69)
PAH signs (CXR)	42	60.9% (69)
Anaemia	23	33.3% (69)
Polycythaemia	11	15.9% (69)
Trisomy 21	9	13.0% (69)
Repeated bronchitis	19	27.5% (69)

Factors associated with complications, Univariate analysis

Table 2 presents the univariate analysis for complications. Eight variables were significantly associated ($p < 0.05$): cyanotic CHD, pulmonary atresia, respiratory distress, dyspnoea, oxygen desaturation, pre-operative cardiac failure, polycythaemia, and VSD (protective). Five additional variables showed $p < 0.20$: male sex, infant age group, fever, hepatomegaly, and repeated bronchitis.

Table 2: Factors associated with complications.

Variable	Complications. n/N (%)	No Complications n/N (%)	Crude OR	95% CI	p-value
✦ **Respiratory distress**	10/13 (76.9)	12/59 (20.3)	13.06	3.10-54.97	< 0.001
✦ **Polycythaemia**	8/11 (72.7)	14/61 (23.0)	8.95	2.09-38.35	0.002
✦ **Oxygen desaturation**	12/22 (54.5)	10/50 (20.0)	4.80	1.62-14.25	0.003
✦ **Pulmonary atresia**	4/5 (80.0)	18/67 (26.9)	10.89	1.14-104.03	0.028
✦ **Cyanotic CHD**	12/26 (46.2)	10/46 (21.7)	3.09	1.09-8.75	0.031
✦ **Dyspnoea**	20/52 (38.5)	2/20 (10.0)	5.62	1.18-26.88	0.019
✦ **Pre-op. cardiac failure**	12/24 (50.0)	10/48 (20.8)	3.80	1.32-10.98	0.011
✦**VSD (protective)**	3/27 (11.1)	19/45 (42.2)	0.17	0.04-0.65	0.006
Hepatomegaly	8/17 (47.1)	14/55 (25.5)	2.60	0.84-8.05	0.091
Repeated bronchitis	3/19 (15.8)	19/53 (35.8)	0.34	0.09-1.30	0.103
Male sex	7/34 (20.6)	15/38 (39.5)	0.40	0.14-1.14	0.082
Infant age group	16/40 (40.0)	6/32 (18.8)	2.89	0.97-8.59	0.052
Fever	3/5 (60.0)	19/67 (28.4)	3.79	0.59-24.50	0.163
Cardiomegaly (CXR)	19/57 (33.3)	3/15 (20.0)	2.00	0.50-7.95	0.529
PAH signs (CXR)	15/42 (35.7)	7/30 (23.3)	1.83	0.64-5.25	0.261
Trisomy 21	3/9 (33.3)	19/63 (30.2)	1.16	0.26-5.12	1.000
Anaemia	8/23 (34.8)	14/49 (28.6)	1.33	0.46-3.84	0.594

✦ Statistically significant at $p < 0.05$. OR: odds ratio; CI: confidence interval; VSD: ventricular septal defect; CXR: chest radiograph.

Multivariate analysis, independent predictors of complications

Among variables with $p < 0.20$ on univariate analysis, respiratory distress and pre-operative cardiac failure were selected for the final logistic regression model. The model correctly classified 74.6% of patients. Two variables were identified as independent predictors (Table 3).

Table 3: Binary logistic regression, independent predictors of complications.

Variable	Adjusted OR	95% CI	p-value
Respiratory distress	16.42	3.46-78.00	< 0.001
Pre-operative cardiac failure	4.99	1.43-17.40	0.012

Factors associated with in-hospital mortality, Univariate analysis

All 11 deaths occurred in infants (n = 11/40; 27.5% of infants), while no death was observed in children or adults ($p = 0.0008$). Given this perfect separation, logistic regression for the mortality outcome was not performed. Univariate ORs are reported in Table 4.

Discussion

To our knowledge, this is the first analytical study to investigate the independent predictors of complications and in-hospital mortality in a cohort of Gabonese CHD patients evacuated for surgical correction. Building on the descriptive data previously reported [10], our results identify respiratory distress and pre-operative cardiac failure as independent predictors of complications, and confirm that in-hospital mortality is exclusively restricted to infants with specific markers of severe haemodynamic compromise.

The management of CHD in sub-Saharan Africa remains profoundly inequitable. CHD mortality has increased by 38.1% and 40.3% in Central and Western sub-Saharan Africa respectively over the past decade, in stark contrast with a 20.1% decline in Southern Africa [3]. Access to corrective surgery within two years of birth is estimated at less than 1% in six key sub-Saharan countries, which together account for more than 50% of the regional CHD burden [4]. The absence of paediatric cardiac surgery in Gabon situates our cohort firmly within this paradigm: the mean diagnostic delay in our series exceeded 30 months, a delay that fundamentally shapes the clinical severity and outcome profile we document [10].

Respiratory distress was the most powerful independent predictor of complications in multivariate analysis (adjusted OR 16.42; 95% CI 3.46-78.00; $p < 0.001$) and a significant predictor of mortality on univariate analysis (OR 9.26; 95% CI 2.23-38.46; $p = 0.003$). This finding is consistent with the broader literature on CHD in resource-limited settings.

In a large-sample cohort from Ethiopia (N = 583 neonates with CHD), Ayfokru et al. identified CHD type and associated congenital malformations as the principal determinants of neonatal mortality [5], with severe clinical compromise at presentation as a central mediating factor. Mechanistically, respiratory distress in CHD reflects two converging pathways: pulmonary congestion from elevated pulmonary venous pressure in large left-to-right shunts, and systemic hypoxaemia from right-to-left shunting in cyanotic lesions. Lacroix et al. demonstrated that prolonged post-operative mechanical ventilation (> 48 hours), a surrogate for peri-operative respiratory failure, carried a mortality rate of 15.7% versus 4.6% in children ventilated less than 48 hours after CHD repair [11].

In the African context, respiratory distress further signals the consequences of delayed surgical referral. Dib et al. showed that late repair of ToF leads to progressive right ventricular dysfunction and chronic hypoxia-related complications that respiratory distress signals clinically [6]. Khainza et al. reported that lower pre-operative oxygen saturation was significantly associated with 30-day mortality in a 10-year review of ToF repair at the Uganda Heart Institute (overall 30-day mortality: 8%) [12]. These data establish a consistent evidence base across Central and East Africa confirming that respiratory compromise at presentation is the key modifiable pre-operative risk signal.

Pre-operative cardiac failure independently increased the odds of complications by nearly fivefold (adjusted OR 4.99; 95% CI 1.43-17.40; $p = 0.012$). In children with CHD, congestive cardiac failure reflects sustained haemodynamic overload, volume overload in large shunt lesions (VSD, AVCD, PDA) or pressure overload in obstructive and cyanotic defects, that impairs myocardial reserve

Table 4: Univariate analysis, factors associated with in-hospital mortality (N = 70; 11 deaths).

Variable	Deaths n/N (%)	Survivors n/N (%)	Crude OR	95% CI	p-value
✦ **Infant age (≤ 24 months)**	11/40 (27.5)	0/32 (0.0)	∞	—	0.0008
✦ **Respiratory distress**	6/13 (46.2)	5/59 (8.5)	9.26	2.23-38.46	0.003
✦ **Pulmonary atresia**	3/5 (60.0)	8/67 (11.9)	11.06	1.60-76.65	0.023
✦ **Fever**	3/5 (60.0)	8/67 (11.9)	11.06	1.60-76.65	0.023
✦ **Oxygen desaturation**	7/22 (31.8)	4/50 (8.0)	5.37	1.38-20.90	0.028
✦ **VSD (protective)**	1/27 (3.7)	10/45 (22.2)	0.13	0.02-1.12	0.044
Cyanotic CHD	7/26 (26.9)	4/46 (8.7)	3.87	1.01-14.81	0.084
Polycythaemia	4/11 (36.4)	7/61 (11.5)	4.41	1.02-18.97	0.057
Bronchopneumopathy	4/12 (33.3)	7/60 (11.7)	3.79	0.90-15.91	0.078
Trisomy 21	3/9 (33.3)	8/63 (12.7)	3.44	0.71-16.55	0.134
Pre-op. cardiac failure	6/24 (25.0)	5/48 (10.4)	2.87	0.77-10.61	0.163

✦ Statistically significant at $p < 0.05$.

and reduces tolerance to cardiopulmonary bypass [13].

Murni et al. demonstrated that pre-operative nutritional and cardiac status were independently associated with post-operative adverse events in children with CHD [13]. In a systematic review and meta-analysis of 13 studies, Yang et al. showed that elevated pre-operative NT-proBNP, a direct biochemical marker of ventricular wall stress and cardiac failure, was associated with higher post-operative mortality (OR 0.23 for lower post-operative values; 95% CI 0.08-0.68) and longer mechanical ventilation time [14]. These findings collectively support systematic pharmacological pre-operative stabilisation, diuretics, afterload reduction, nutritional optimisation, before cardiac surgical evacuation. In the Gabonese context, where pre-operative cardiac failure was documented in 34.8% of patients, its identification at referral should trigger optimisation before evacuation and close coordination with the receiving surgical team.

All 11 deaths occurred exclusively in infants aged ≤ 24 months (mortality 27.5% vs 0% in children and adults; Fisher exact $p = 0.0008$). This restriction reflects the unique physiological vulnerability of the immature heart: the neonatal and infant myocardium exhibits reduced contractile reserve, impaired calcium handling, and greater sensitivity to ischaemia-reperfusion injury during cardiopulmonary bypass [15]. Pulmonary vascular reactivity in infants further predisposes to hypertensive crises, directly implicated in 4 of the 11 deaths in our cohort (severe PAH crisis; 36.4% of fatal cases).

The concentration of deaths in infants is consistent with the findings of Toure et al. from the CHNEAR, Senegal, who identified young infant age, malnutrition, and cyanosis as principal predictors of in-hospital mortality in CHD patients under 3 months [16]. Global burden of disease data confirm that infants under 12 months account for approximately 75% of CHD-related deaths in low-sociodemographic-index regions [2]. In the Ugandan ToF series, Khainza et al. found that lower pre-operative oxygen saturation was significantly associated with mortality, underlining the compounding effect of chronic hypoxia and infant physiology [12]. These data argue for a specific high-dependency pre-operative pathway for CHD infants awaiting evacuation: systematic haemodynamic optimisation, prevention of respiratory infections, nutritional support, and early PAH identification.

Polycythaemia was significantly associated with complications on univariate analysis (OR 8.95; 95% CI 2.09-38.35; $p = 0.002$), though not retained in the multivariate model (collinearity with cyanosis markers). This finding reflects the complex haematological alterations of chronic hypoxaemia in cyanotic CHD. Zabala and Galan-Moya described how secondary erythrocytosis increases whole blood viscosity, precipitates subclinical vascular sludging, and, through concurrent reductions in plasma von Willebrand factor, fibrinogen, and platelets, creates a simultaneous thrombotic and haemorrhagic predisposition [17]. Haematocrit values above 65% represent the threshold above which pre-operative haemodilution is indicated [18]. Systematic haematological assessment before evacuation, haematocrit, coagulation profile, platelet count, should be part of the pre-operative workup for all cyanotic CHD patients in our setting.

PAH was documented in 60.9% of our cohort, reflecting the progressive pulmonary vascular remodelling that results from sustained untreated cardiac shunting. Namuyonga and Mocumbi reported that PAH mortality in African children with CHD reaches 18-21%, with unoperated post-tricuspid shunt lesions as the primary driver [9]. PAH crises accounted for 4 of 11 deaths in our series (36.4%). Severe post-operative PAH complicates approximately 2% of paediatric cardiac procedures globally, but this proportion rises substantially in patients with pre-existing elevated pulmonary vascular resistance, the situation in most of our evacuated infants [19]. Reversal of pulmonary vascular disease requires timely surgical closure before irreversible remodelling, ideally before 6-12 months for high-risk lesions (large VSD, AVCD, truncus arteriosus) [19,20]. The single Eisenmenger case, the most advanced form of this process, illustrates the irreversibility of late presentation.

VSD was protective against both complications (OR 0.17; $p = 0.006$) and mortality (OR 0.13; $p = 0.044$). This reflects the favourable surgical prognosis of isolated VSD in established centres: West and Central African series report post-operative mortality of 3-6% for isolated VSD closure [21,22], substantially lower than the 15.7% overall mortality in our heterogeneous cohort. The protective effect of VSD should be interpreted as a relative advantage over complex cyanotic defects and atresias, not as intrinsic haemodynamic protection. Practically, pulmonary atresia, associated with OR 10.89 for complications and OR 11.06 for mortality, requires the highest level of pre-operative preparation and should be referred exclusively to centres with documented experience in complex cyanotic CHD repair.

The retrospective design carries inherent selection bias: only patients deemed operable and insured by CNAMGS were included, potentially underrepresenting the most severely ill. The modest number of fatal events (n = 11) limited statistical power and precluded multivariate logistic regression for mortality; univariate ORs should be interpreted with caution. Post-operative follow-up was restricted to the evacuation period, and delayed mortality after repatriation could not be captured. The absence of echocardiographic pulmonary vascular resistance measurements precluded formal haemodynamic classification of PAH severity. Despite these limitations, the consistency of associations across multiple variables and their alignment with the international literature support the clinical validity of our conclusions.

Conclusion

Respiratory distress and pre-operative cardiac failure are independent predictors of peri-operative complications in CHD patients evacuated from Gabon. In-hospital mortality is restricted to infants aged ≤ 24 months and is associated with markers of severe haemodynamic compromise, respiratory distress, oxygen desaturation, fever, and pulmonary atresia. These results support

systematic pre-operative haemodynamic optimisation before evacuation, the establishment of a dedicated high-dependency care pathway for CHD infants, and the urgent development of a local paediatric cardiac surgery unit in Gabon to reduce the peri-operative risk attributable to diagnostic and surgical delay.

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