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Modeling Time-to-Recurrence of Chronic Rhinosinusitis Following Endoscopic Sinus Surgery Using Cox Proportional Hazards Regression at Abubakar Tafawa Balewa University Teaching Hospital, Bauchi State, Nigeria

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ABSTRACT

This retrospective cohort study examined CRS recurrence following endoscopic sinus surgery (ESS) in 46 patients at ATBUTH, Bauchi State, Nigeria, over five years. Recurrence occurred in 13 patients (28.26%; 95% CI 17.32%–42.55%). Among 41 patients with complete survival data, recurrence-free survival declined from 100% at 6 months to 65.36% at 36 months and remained at that level through 60 months; median recurrence-free survival was not reached. No demographic, clinical, radiological, or laboratory factor was a statistically significant predictor of recurrence in univariate or multivariable Cox models (all $p > 0.05$). AERD (adjusted HR 2.497), smoking (adjusted HR 2.239), and IgE (adjusted HR 2.257; $p = 0.059$ in the parametric model) showed non-significant elevated hazard estimates. With 10 covariates and only 13 events (~1.3 events per variable), the model was substantially underpowered, so the null findings reflect limited statistical precision rather than evidence of no effect. The Cox model performed marginally better than the flexible parametric model (MSE 0.1791 vs 0.2004; lower AIC and BIC), and the proportional hazards assumption was not violated. The authors conclude that ESS yields favourable outcomes for most patients but recurrence affects roughly three in ten, and that AERD, smoking, and IgE warrant investigation in larger, adequately powered multicentre studies.

Keywords: Chronic Rhinosinusitis, Endoscopic Sinus Surgery, Recurrence, Survival Analysis, Cox Proportional Hazards

1. Introduction

Chronic rhinosinusitis (CRS) is a persistent inflammatory disorder of the nasal and paranasal sinuses marked by symptoms such as nasal obstruction, purulent discharge, facial pressure or pain, and olfactory disturbances lasting longer than 12 weeks. Endoscopic sinus surgery (ESS) has become the standard surgical management for patients with medically refractory CRS. Existing research has identified numerous potential predictors of CRS recurrence, including high preoperative Lund-Mackay scores, elevated eosinophil counts, comorbid asthma, and poor compliance with postoperative medical therapy (Chen et al., 2025). In addition, most studies on CRS recurrence and predictors originate from non-African populations with potentially different environmental exposures, healthcare access, and disease profiles compared to low-resource settings such as Nigeria. There is a relative dearth of locally derived evidence on ESS outcomes in Nigerian tertiary hospitals, including the incidence and timing of postoperative recurrence.

Available studies in Nigerian on rhinosinusitis have primarily focused on symptom patterns and general outcomes following ESS, reporting recurrence rates but without robust survival-based analysis or extensive follow-up (Mbaye et al., 2026; Omer et al., 2025; Kikuhe et al., 2025). This evidence gap limits the ability of clinicians in Nigeria to make precise prognostic assessments and tailor postoperative management to the local patient population.

Endoscopic sinus surgery (ESS) remains the standard surgical intervention for patients who do not respond adequately to medical therapy; however, postoperative recurrence of CRS continues to pose a significant clinical challenge. As a result, there is limited empirical evidence in Nigeria and Bauchi State in particular regarding the incidence, timing, and determinants of CRS recurrence following ESS. The lack of locally generated data and appropriate survival-based statistical modeling constrains clinicians' ability to make accurate prognostic assessments and to implement evidence-based postoperative management strategies. This study is therefore designed to bridge these gaps by employing a Cox proportional hazards regression model to analyze time-to-recurrence of CRS following ESS in Bauchi State, Nigeria.

Modeling recurrence as a time-dependent event, this study aims to identify independent predictors of recurrence while accounting for varying follow-up durations, censoring, and temporal risk patterns. In doing so, the study seeks to extend and improve upon the methodological limitations of (Ma *et al.*, 2025) and to provide context-specific evidence that can inform clinical practice and health policy in the Nigerian setting. A critical synthesis of the global and local literature reveals significant, interconnected gaps that limit a comprehensive understanding of Chronic Rhinosinusitis (CRS) recurrence, particularly in underrepresented populations. These deficiencies span methodological approaches, the integration of predictive domains, and geographical

representation, collectively justifying a novel and rigorous investigation. The existing literature is predominantly composed of retrospective case series reporting simple recurrence proportions, devoid of Kaplan-Meier survival estimates or Cox proportional hazards models (Ma *et al*., 2025; Saleh et al., 2026).

Consequently, the instantaneous hazard of recurrence over time and its key drivers in the Nigerian population are entirely unknown. Moreover, the available studies are largely from tertiary centers in southern Nigeria and do not account for the unique socio-economic, environmental, and healthcare access challenges prevalent in regions like Bauchi State in northeastern Nigeria (Nuhu et al., 2025; Idris et al., 2026). This constitutes a critical evidence void for clinicians managing CRS in low-resource, high-burden settings where patient phenotypes and management constraints may differ substantially. These gaps collectively justify the need for a Cox regression study in the Nigerian context, specifically in ATBUTH. A study designed to collect and integrate comprehensive clinical (e.g., asthma, prior surgery), radiological (Lund-Mackay score, osteitis), and laboratory (blood eosinophil count) data would create a first-of-its-kind predictive model for this population (Tomassen et al., 2016; DeConde et al., 2017). This model would identify which factors are most potent in the local context information vital for risk stratification, prioritizing limited resources for high-risk patients, and setting realistic postoperative expectations.

2. Methodology

A retrospective cohort research design was adopted to investigate the determinants of time to recurrence among patients diagnosed with chronic rhinosinusitis (CRS) who underwent endoscopic sinus surgery (ESS) at Abubakar Tafawa Balewa University Teaching Hospital (ATBUTH), Bauchi State, Nigeria, over a five-year period. The study population comprised patients with CRS with nasal polyps (CRSwNP) and CRS without nasal polyps (CRSsNP). A total enumeration approach was employed to identify all eligible cases from existing hospital records, subject to the availability of relevant clinical, radiological, laboratory and follow-up information. Data were extracted using a structured data extraction form covering demographic characteristics, CRS phenotype, asthma status, previous sinus surgery, smoking status, SNOT-22 score, Lund–Mackay CT score, osteitis, blood eosinophil count, serum IgE level, recurrence status and time to recurrence. Patients with incomplete records, no meaningful postoperative follow-up or coexisting major nasal malignancies were excluded. The primary outcome was time from ESS to documented CRS recurrence, while patients without recurrence by the end of their available follow-up were treated as censored observations. Kaplan–Meier estimation was used to describe recurrence-free survival, while the log-rank test was employed for preliminary comparisons between groups.

The Cox proportional hazards regression model was used to examine the association between selected demographic and clinical characteristics and the hazard of CRS recurrence. The model was specified as $(h(t/X_i) = h_0(t)exp(X_i^T\beta)$, where $h_0(t)$ represents the unspecified baseline hazard, X_i is the vector of explanatory variables and β is the vector of regression coefficients. The parameters were estimated by maximising the Cox partial likelihood, with the variance–covariance matrix obtained from the inverse of the observed information matrix. Hazard ratios (HRs), calculated as $exp(\hat{\beta}_j)$, and their corresponding 95% confidence intervals were used to quantify the direction and magnitude of associations. Statistical significance was assessed using Wald tests at the 5% level. The proportional hazards assumption was evaluated by examining whether hazard ratios remained constant over time; this assumption implies that the hazard ratio between two individuals, $exp\ [(X_A - X_B)^T\beta]$, does not vary with follow-up time. All statistical analyses were interpreted with consideration of the number of recurrence events and the adequacy of the fitted model.

3. Result

3.1 Incidence of CRS Recurrence among Patients Following Endoscopic Sinus Surgery

Outcome	Frequency	Percentage (%)
CRS recurrence	13	28.26
No CRS recurrence	33	71.74
Total	46	100.00

95% CI for recurrence proportion: 17.32% – 42.55%.

Out of the 46 patients studied, 13 (28.26%) experienced CRS recurrence following endoscopic sinus surgery, while 33 (71.74%) remained recurrence-free. This indicates that most patients had favourable postoperative outcomes, although recurrence affected approximately three out of every ten patients. The 95% confidence interval for recurrence was 17.32%–42.55%.

3.2 Survival Analysis: Kaplan–Meier Estimates of Recurrence-Free Survival at Selected Follow-up Times

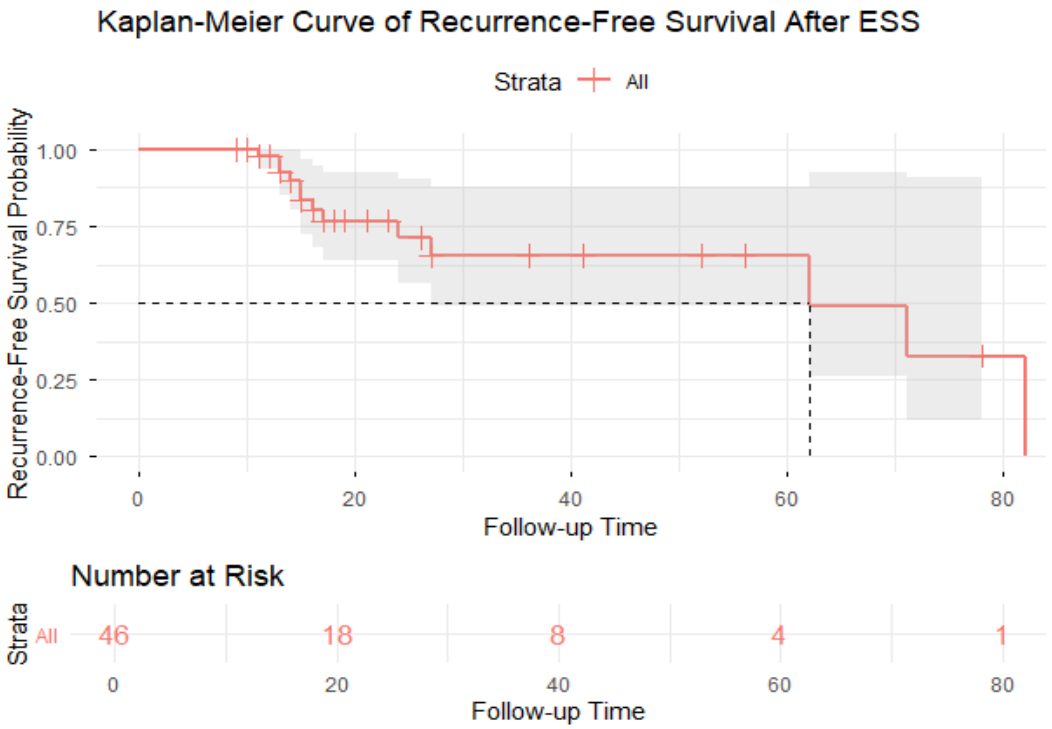
The survival analysis was reported for 41 patients. Five of the 46 eligible records were excluded because survival-time information was incomplete or unavailable. The reason for each exclusion and the recurrence status of these patients should be documented in the final study flow.

Time	*Patients at Risk*	*Recurrence Events*	*Recurrence-Free Survival (%)*	*Lower 95% CI (%)*	*Upper 95% CI (%)*
6	41	0	100.00	100.00	100.00
12	40	1	97.67	93.27	100.00
24	14	8	71.31	56.28	90.34
36	10	1	65.36	48.82	87.50
48	6	0	65.36	48.82	87.50
60	4	0	65.36	48.82	87.50

Median recurrence-free survival = 62; 95% CI = 27 to NA.

The Kaplan–Meier estimates indicate that recurrence-free survival declined from 100.00% at six months to 97.67% at 12 months, 71.31% at 24 months, and 65.36% at 36 months. The estimate remained at 65.36% at 48 and 60 months. The unchanged estimates at 48 and 60 months indicate that no additional recurrence event altered the Kaplan–Meier estimate at those selected time points; they do not mean that no patients were censored. Because the survival estimate remained above 50% throughout the observed follow-up, the median recurrence-free survival was not reached during the study period. The confidence intervals widen at later follow-up times, consistent with increasing uncertainty as the number of patients remaining under observation decreases.

Kaplan–Meier Curve



The Kaplan–Meier survival curve depicts the estimated recurrence-free survival probability over follow-up time following surgical intervention. The curve shows a gradual decline in the proportion of patients remaining recurrence-free as time progresses, with confidence intervals widening toward later follow-up intervals. The accompanying risk table indicates that 41 patients were initially at risk, decreasing in agreement with the tabulated numbers at risk (40 at 12 months, 14 at 24 months, 10 at 36 months, 6 at 48 months, and 4 at 60 months).

3.3 Univariate Cox Proportional Hazards Regression Analysis of Factors Associated with CRS Recurrence

Variable	***Hazard Ratio***	***Lower 95% CI***	***Upper 95% CI***	***P-value***
Age	0.9999	0.9987	1.001	0.835
Sex (Male)	0.8458	0.2535	2.822	0.785
Asthma (Yes)	0.8005	0.2146	2.986	0.740

Variable	*Hazard Ratio*	*Lower 95% CI*	*Upper 95% CI*	*P-value*
AERD (Yes)	1.3530	0.3188	5.741	0.682
Smoking (Yes)	1.7425	0.5067	5.993	0.378
IgE	1.3888	0.8271	2.332	0.214
Eosinophil	0.9256	0.7041	1.217	0.580
Lund–Mackay	0.9265	0.8012	1.071	0.304
Sleeping-Time	0.9105	0.4451	1.862	0.797
Allergy (Yes)	0.7551	0.1904	2.995	0.690

None of the variables examined in the univariate Cox regression analysis was statistically significantly associated with time to CRS recurrence at the 5% level; all reported p-values exceeded 0.05, and all corresponding 95% confidence intervals included one. Smoking (HR = 1.7425), AERD (HR = 1.3530), and IgE (HR = 1.3888) had point estimates above one, indicating higher estimated recurrence hazards in the relevant comparison or per unit increase. These estimates were not statistically significant and were imprecise. This does not establish that the examined factors have no association with recurrence; rather, the available data did not provide sufficient statistical evidence of an association. Formal assessment using Schoenfeld residuals and a global test of proportionality did not reveal evidence of violation of the proportional hazards assumption (global test $p > 0.05$). However, given the small number of events, this test has limited power, and the possibility of time-varying effects cannot be excluded.

3.4 Multivariable Cox Proportional Hazards Model for Factors Associated with CRS Recurrence

Variable	**Hazard Ratio**	**Lower 95% CI**	**Upper 95% CI**	**P-value**
Age	1.020	0.966	1.08	0.477
Sex	0.131	0.010	1.72	0.122
Asthma	0.708	0.111	4.51	0.715
AERD	2.497	0.317	19.68	0.385
Smoking	2.239	0.358	14.00	0.389
IgE	2.257	0.834	6.10	0.109
Eosinophil	0.842	0.576	1.23	0.376
Lund–Mackay	0.870	0.716	1.06	0.161
Sleeping-Time	0.861	0.338	2.19	0.753
Allergy	1.133	0.112	11.45	0.916

None of the variables in the reported multivariable model was statistically significant at the 5% level. The adjusted hazard ratios for AERD (2.497), smoking (2.239) and IgE (2.257) were greater than one, but their confidence intervals were wide and included one. The estimates therefore indicate possible higher hazards but do not establish statistically significant independent associations. The model included 10 explanatory variables despite only 13 recurrence events, corresponding to approximately 1.3 events per predictor parameter. This shows the estimated hazard ratios may be unstable.

3.5 Parameter Estimates from the Flexible Parametric Survival Model (df = 2)

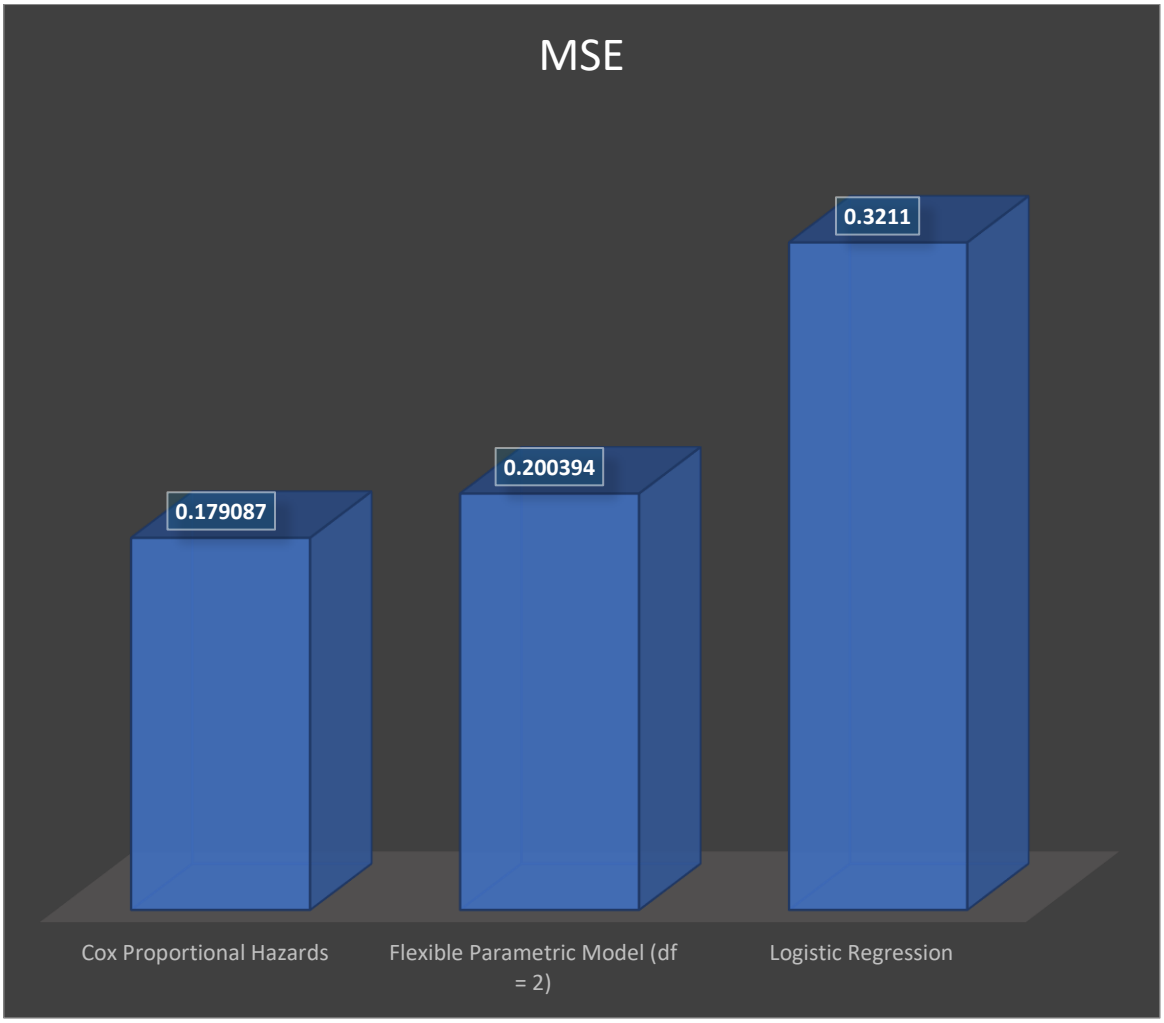
Parameter	*Estimate*	*Standard Error*	*P-value*
(Intercept)	-12.6300	7.2545	0.082
Age	0.0193	0.0255	0.450
Sex	-1.7127	1.1002	0.120
Asthma	-0.5625	0.8730	0.519
AERD	1.2422	0.9649	0.198

Parameter	*Estimate*	*Standard Error*	*P-value*
Smoking	0.4974	0.9221	0.590
IgE	0.8903	0.4722	0.059
Eosinophil	-0.1927	0.1900	0.310
Lund–Mackay	-0.1395	0.0955	0.144
Sleeping-Time	-0.2245	0.5156	0.663
Allergy	-0.1520	1.1018	0.890
Spline term 1	5.4975	1.3464	<0.001
Spline term 2	3.3728	0.8146	<0.001

The model was fitted on the log cumulative hazard scale. None of the patient-related covariates in the flexible parametric model was statistically significant at the 5% level. IgE had a positive coefficient (0.8903) with p = 0.059, which is close to, but above, the prespecified significance threshold. AERD and smoking also had positive coefficient estimates, but neither was statistically significant. The two spline terms were statistically significant; they represent components of the model's flexible baseline time function and should not be interpreted as clinical risk factors.

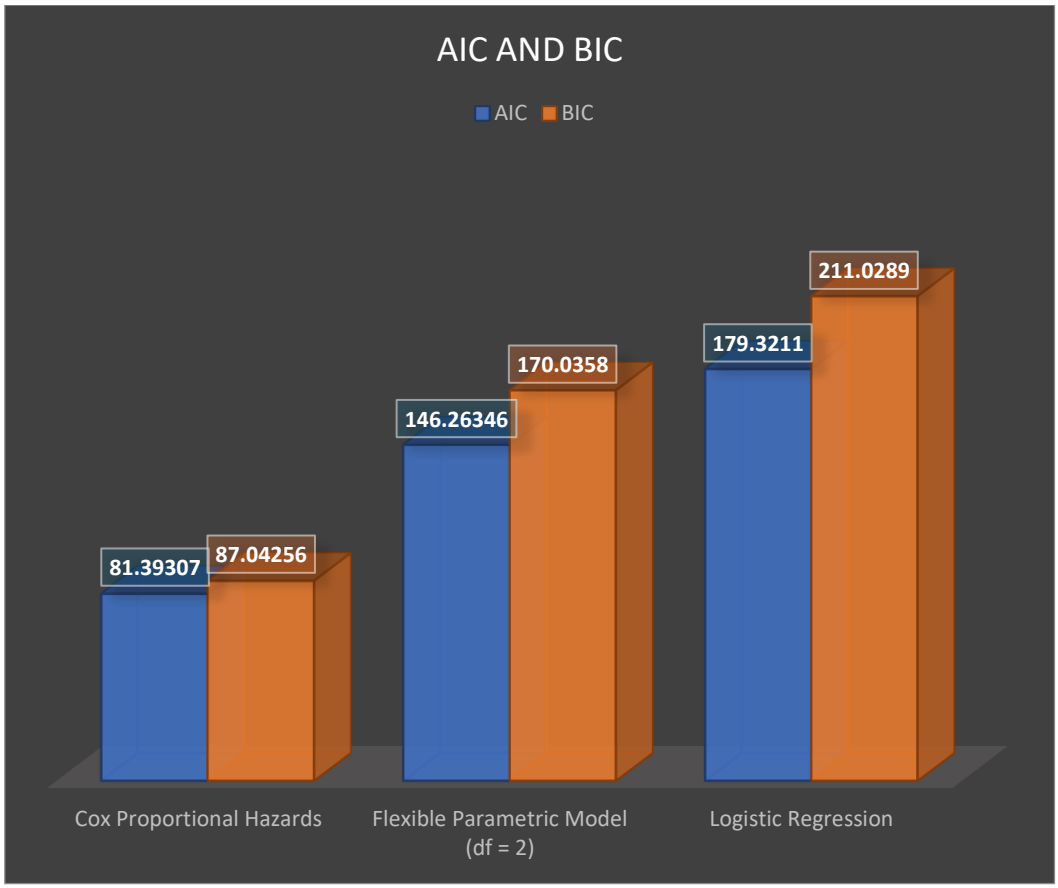
3.6 Comparison of Cox Proportional Hazards and Flexible Parametric Survival Models Based on Performance Measures

(i) Mean Square Error (MSE)



The bar chart compares the predictive performance of the survival models using mean squared error metrics. The Cox proportional hazards model achieved a mean squared error of 0.1791, whereas the flexible parametric model recorded a slightly higher mean squared error of 0.2004.

(ii) Comparison of AIC and BIC



The bar graph illustrates the relative model fit and complexity trade-offs using the Akaike Information Criterion and Bayesian Information Criterion for both modeling approaches. The Cox proportional hazards model yielded lower Akaike Information Criterion and Bayesian Information Criterion values compared to the higher information criterion values observed for the flexible parametric model.

4. Conclusion

Most patients (71.74%) remained recurrence-free after ESS, but 28.26% experienced recurrence. Recurrence-free survival declined from 100% at six months to 65.36% at 36 months, remained above 50% throughout follow-up (median not reached), and supports the need for continued postoperative monitoring. Neither the Cox nor the flexible parametric model identified any statistically significant predictor of recurrence. However, with only 13 events and 10 covariates (~1.3 events per variable), the analysis was substantially underpowered, and the wide confidence intervals reflect uncertainty rather than evidence of no effect. AERD, smoking, and IgE (the latter approaching significance, $p = 0.059$) warrant further investigation in adequately powered studies. The Cox model performed marginally better than the parametric model (MSE 0.1791 vs 0.2004; lower AIC/BIC), though this difference is modest and should be interpreted cautiously. The proportional hazards assumption was formally tested and not violated, though the test has limited power with few events.

Limitations and directions for future research. This study is a single-centre retrospective cohort with a small sample and few events, which fundamentally limits the precision of all hazard estimates and precludes robust multivariable adjustment. The five records excluded from survival analysis for incomplete time data may introduce selection bias. Future research should prioritize a larger, multicentre prospective cohort with adequate event counts to support multivariable modeling (at least 10 events per variable), prespecified variable selection, formal proportional hazards testing, and external validation of any predictive model.

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