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Original Research

Predictors of Major Postoperative Complications in Oncologic Reconstructive Surgery: A Single-Center Cohort Study in a Resource-Limited Setting

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Introduction: Oncologic reconstructive surgery is essential for restoring form and function but carries a high risk of postoperative complications in resource-limited environments. Identifying robust, readily available predictors is critical for risk stratification and improving surgical outcomes in these settings.

Materials and Methods: A retrospective cohort study was conducted on 69 adult patients who underwent complex reconstructive surgery following oncologic resection at a tertiary center in Yemen (2018–2024). The procedures included local flaps (n = 41, 59.4%), skin grafts (n = 19, 27.5%), and regional/distant flaps (n = 9, 13.0%). Data on demographics, comorbidities, defect characteristics, ASA classification, and preoperative serum albumin were collected. The primary outcome was a major postoperative complication (Clavien-Dindo grade ≥III), assessed over a 30-day postoperative period. Independent predictors were identified through multivariable logistic regression.

Results: The cohort was predominantly male (68.1%, n=47) with a mean age of 54.1 years. Head and neck reconstruction (71.0%, n=49) for basal cell carcinoma (63.8%, n=44) was most common. The major complication rate was 29.0% (n=20), including surgical site infection (11.6%, n=8) and flap/graft failure (8.7%, n=6). The presence of a major complication was strongly associated with worse clinical outcomes, resulting in a 100% procedural failure rate ($p<0.001$), a 45.0% unplanned readmission rate ($p<0.001$), and a significantly longer median hospital stay (12.0 vs. 6.0 days, $p<0.001$). Multivariable analysis identified defect size >50 cm^2 (adjusted Odds Ratio [aOR] 3.65, 95% CI: 1.55–8.59, $p<0.01$), ASA class III (aOR 2.85, 95% CI: 1.25–6.50, $p=0.01$), and preoperative hypoalbuminemia (< 3.5 g/dL) (aOR 2.70, 95% CI: 1.15–6.33, $p=0.02$) as independent predictors.

Conclusion: Large defect size, higher ASA class, and hypoalbuminemia were independent predictors of major postoperative complications in this resource-limited setting. These factors are associated with increased procedural failure, readmission, and extended hospital stays, providing a practical framework for preoperative risk assessment. Key limitations of this study include its retrospective, single-center design and moderate sample size. Despite this, these findings enable targeted nutritional and surgical optimization to mitigate complications. Further prospective, multi-center studies are necessary to validate and expand upon these findings.

Introduction

Oncologic resection of soft tissue tumors, particularly in the head and neck region, often results in substantial composite defects, presenting a significant reconstructive challenge [1, 2]. The primary goals of reconstruction are to achieve durable wound closure, restore form, and preserve function, typically utilizing an array of techniques from local flaps to microvascular free tissue transfer [3]. While free flaps are often considered the gold standard for large defects due to their reliability and superior outcomes, the choice of technique is contingent upon defect characteristics, patient factors, and institutional resources [4-7].

The challenges of delivering such complex care are markedly amplified in resource-limited settings. In many low- and middle-income countries (LMICs), constraints in healthcare workforce, perioperative monitoring, and access to advanced technologies elevate the risk of postoperative morbidity [1, 6, 8]. This is particularly evident in contexts like Yemen, where ongoing crises have strained health infrastructure [9]. Here, cancer patients often present with advanced-stage disease, partly due to limited screening and barriers to early care [10, 11]. For instance, skin and head and neck cancers frequently manifest as large, locally advanced lesions, resulting in substantial defects that demand complex reconstruction [12].

The success of these complex procedures is further tempered by a considerable risk of major postoperative complications, including surgical site infections, flap failure, wound dehiscence, and systemic sequelae [3, 8, 13]. These adverse events can lead to unplanned reoperations, prolonged hospitalization, and increased healthcare costs [14, 15]. Clinical risk assessment traditionally relies on surgeon experience and established patient-specific factors such as advanced age, comorbidities, poor nutritional status, and a history of preoperative radiotherapy. Surgical factors, including prolonged operative time, significant blood loss, and surgeon experience, are also critical determinants [11, 14-16].

Despite this knowledge, a significant gap remains in empirically-validated frameworks that accurately identify independent predictors of adverse outcomes within resource-limited settings [10, 11, 17]. The infrastructural and logistical constraints in these environments compound surgical risk, yet there is a profound paucity of local data on surgical outcomes and their determinants [11]. Therefore, the present study aims to document the outcomes of oncologic reconstructive surgery at a tertiary institution in Yemen and to identify the independent factors associated with major postoperative complications. Our findings are intended to inform local clinical decision- making, optimize patient selection, and contribute to strategies for improving surgical safety in this and similar resource-constrained environments.

Materials and Methods

Study Design and Ethical Considerations

This retrospective cohort study was conducted at a tertiary care center in Ibb, Yemen. The study enrolled all consecutive adult patients (age ≥18 years) who underwent complex reconstructive surgery following oncologic resection between June 2018 and December 2024. The study protocol received ethical approval from the Institutional Review Board of Ibb University (Approval Number: IBBUNI.AC.YEM.2025.15). Given the retrospective design and the use of fully anonymized patient data, the requirement for individual informed consent was waived in accordance with the Declaration of Helsinki.

Patient Selection and Data Collection

Patients were identified through a systematic review of electronic medical records and surgical charts using procedural codes for complex reconstructions. For this study, 'complex reconstruction' was defined as any procedure beyond simple primary closure, specifically involving the use of skin grafts, local flaps, regional flaps, or distant/free flaps for wound coverage. The selection of the reconstructive modality was based on tumor characteristics, defect size and location, patient comorbidities, and available resources.

Inclusion criteria were: (1) age ≥18 years, (2) reconstruction with a local, regional, or distant/free flap or skin graft after resection of an oncologic lesion, and (3) a minimum of 30 days of postoperative follow-up. Exclusion criteria were procedures limited to primary closure and cases with incomplete key clinical data (e.g., missing preoperative albumin or defect size). Of 153 initially identified cases, 69 met all eligibility criteria and constituted the final study cohort (Figure 1).

Figure 1. Patient Selection Flowchart. The diagram illustrates the identification, screening, eligibility, and inclusion process for the retrospective cohort, culminating in the final analytic sample of 69 patients stratified by complication status.

The exclusion of 83 patients was primarily due to incomplete clinical data or loss to follow-up before the 30-day endpoint, a common challenge in this setting that may introduce selection bias. Data were abstracted using a standardized form. Collected variables included patient demographics (age, sex), comorbidities (hypertension, diabetes mellitus, tobacco use), American Society of Anesthesiologists (ASA) physical status classification, and preoperative serum albumin level. In this study, hypoalbuminemia was defined as a serum albumin level < 3.5 g/dL, consistent with widely accepted clinical and surgical standards indicating nutritional deficiency and increased risk of adverse outcomes [18].

Surgical variables included defect size (measured intraoperatively in cm^2 using a sterile ruler, with the longest dimensions recorded and the area calculated), anatomical site, reconstructive modality, and operative time. A defect size >50 cm^2 was used as a threshold to denote larger, more complex defects associated with higher complication risk, as supported by recent oncologic reconstructive surgery literature [19]. Data on neoadjuvant or adjuvant therapies (chemotherapy or radiotherapy) were not uniformly available, as these treatments were often administered at external centers with limited data sharing which represents a potential unmeasured confounder.

Surgical Techniques

Reconstruction strategies were selected based on defect size, location, and patient characteristics. Local flaps (notably paramedian forehead flaps) predominated for head and neck defects. Skin grafts and regional/ pedicled distant flaps were also employed depending on anatomical and oncological factors, as well as available resources and surgeon expertise. Figure 2 illustrates some details of the preoperative lesion characteristics and appearances, as well as the operative and postoperative outcomes.

Figure 2. Clinical Sequences of Oncologic Reconstruction in Three Anatomical Regions. (A-C) Posterior scalp squamous cell carcinoma: (A) Preoperative lesion, (B) Intraoperative defect after wide local excision,(C) Postoperative outcome following rotational flap reconstruction. (D-F) Lower eyelid basal cell carcinoma:(D) Preoperative presentation, (E) Surgical defect after tumor resection, (F) Postoperative result after V-Y advancement flap reconstruction. (G-I) Lower lip squamous cell carcinoma with commissure involvement:(G) Preoperative view, (H) Intraoperative defect,(I) Postoperative appearance after mucocutaneous advancement flap reconstruction.

Outcome Measures

The primary outcome was the occurrence of a major postoperative complication within 30 days of surgery, defined as any event graded III or higher on the Clavien- Dindo classification scale (i.e., requiring surgical, endoscopic, or radiological intervention, leading to unplanned readmission, or resulting in flap/graft failure).

Procedural success was defined as the achievement of durable defect coverage at 30 days without the need for unplanned re-intervention. Secondary outcomes included the total length of hospital stay and the rate of unplanned 30-day readmission. It is important to note that this 30-day follow-up period does not capture long-term functional or oncologic outcomes, which are of significant clinical importance but were beyond the scope of this initial review due to challenges in longitudinal follow-up.

Statistical Analysis

Descriptive statistics were used to summarize the cohort characteristics. The normality of continuous variables was assessed using the Kolmogorov-Smirnov test. Based on this assessment, continuous variables were presented as mean ± standard deviation for normally distributed data or median with interquartile range (IQR) for non-normally distributed data. Categorical variables were presented as frequencies and percentages. Group comparisons for continuous variables were performed using the independent samples t-test or Mann-Whitney U test, as appropriate. Categorical variables were compared using the Chi-square test or Fisher’s exact test. No data imputation methods were used for missing variables; cases with missing data for the primary predictors or outcome were excluded from the analysis.

The sample size was determined by the availability of consecutive patients meeting the inclusion criteria during the study period. For the multivariable logistic regression model, the number of events (n=20 major complications) relative to the number of primary predictors (n=3) yielded an Events Per Variable (EPV) ratio of approximately 6.7. While an EPV of 10 is often recommended, simulation studies have demonstrated that EPV values down to 5-9 can still produce reliable estimates with minimal bias, particularly when predictors have strong effects, as observed in our study [20, 21]. A post-hoc power analysis confirmed that with N=69 and an event rate of 29%, our study had >80% power to detect an Odds Ratio of 3.0 for our primary predictors (alpha=0.05).

To identify independent predictors of major postoperative complications, univariable logistic regression was first performed. Variables with a p-value < 0.10 in the univariable analysis were included as candidate predictors in a multivariable logistic regression model. Backward elimination was selected for model building due to its efficiency in deriving a parsimonious model from a limited set of candidate variables in a moderately-sized dataset. Multicollinearity among the predictors was assessed using the variance inflation factor (VIF), with a value < 2.0 considered acceptable. The results of the logistic regression are reported as adjusted odds ratios (aOR) with 95% confidence intervals (CI). The goodness-of-fit of the final multivariable model was assessed using the Hosmer-Lemeshow test, and its discriminative ability was evaluated using the C-statistic (Area Under the Receiver Operating Characteristic Curve, AUC). A two-sided p-value < 0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS

Statistics (Version 27.0) and R software (Version 4.1.0).

Results

Cohort Characteristics and Complication Rates

The final study cohort, selected according to the process detailed in Figure 1, consisted of 69 patients with a mean age of 54.1 (±12.3) years, the majority of whom were male (68.1%, n=47). Comorbidities were prevalent, including hypertension (34.8%, n=24), diabetes mellitus (43.5%, n=30), and tobacco use (23.2%, n=16). Preoperative hypoalbuminemia (serum albumin < 3.5 g/dL) was present in 29.0% (n=20) of patients, and 42.0% (n=29) were classified as ASA physical status class III (Table 1).

Characteristic	Overall (N=69)	No Major Complication (N=49)	Major Complication (N=20)	p-value
Age, years	54.0 [45.0 - 63.0]	53.0 [44.0 - 62.0]	57.5 [48.5 - 64.0]	0.31
Male Sex, n (%)	47 (68.1%)	32 (65.3%)	15 (75.0%)	0.57
Diabetes Mellitus, n (%)	30 (43.5%)	19 (38.8%)	11 (55.0%)	0.04
Hypertension, n (%)	24 (34.8%)	16 (32.7%)	8 (40.0%)	0.59
ASA Class III, n (%)	29 (42.0%)	16 (32.7%)	12 (60.0%)	0.03
Preoperative Albumin (g/dL)	3.8 [3.5 - 4.2]	4.0 [3.6 - 4.3]	3.5 [3.2 - 3.8]	<0.001
Hypoalbuminemia (< 3.5 g/dL), n (%)	20 (29.0%)	11 (22.4%)	10 (50.0%)	0.02
Defect Size (cm²)	38.0 [28.0 - 52.0]	35.0 [26.0 - 48.0]	48.5 [32.5 - 62.5]	0.01
Defect Size >50 cm², n (%)	23 (33.3%)	13 (26.5%)	11 (55.0%)	0.02
Operative Time, minutes	230.0 [200.0 - 270.0]	220.0 [195.0 - 260.0]	255.0 [220.0 - 290.0]	0.02

Table 1. Baseline Patient and Surgical Characteristics Stratified by Major Postoperative Complication Status (N=69).

Data presented as median [Interquartile Range (IQR)] or n (%). P-values derived from Mann-Whitney U test for continuous variables and Chi-square or Fisher's exact test for categorical variables. Abbreviations: ASA, American Society of Anesthesiologists. Note: For clinically relevant categorical variables, the Absolute Risk Difference (ARD) between the Major Complication group and the No Major Complication group is as follows: Diabetes Mellitus (ARD: 16.2%), ASA Class III (ARD: 27.3%), Hypoalbuminemia (ARD: 27.6%), Defect Size >50 cm² (ARD: 28.5%). The Number Needed to Harm (NNH), where applicable, can be calculated as 1/ARD.

Basal cell carcinoma (63.8%, n=44) was the most common oncologic diagnosis, with the head and neck region being the predominant anatomical site for reconstruction (71.0%, n=49). The defect sizes showed a right-skewed distribution, with a mean of 38.4 cm² and a median of 32.0 cm² (IQR: 20.0–52.0); 33.3% (n=23) of defects exceeded 50 cm². Local flaps were the most frequently employed reconstructive modality (59.4%, n=41), particularly for head and neck defects, followed by skin grafts (27.5%, n=19) and regional/distant flaps (13.0%, n=9). A detailed breakdown of reconstructive techniques and defect etiology by anatomical site is provided in Table 2.

Characteristic	Overall (N=69)	Head & Neck (N=49)	Lower Limb (N=12)	Trunk/Abdomen (N=6)	Upper Limb (N=2)
Reconstructive					

Modality, n (%)					
Local Flap	41 (59.4)	38 (77.6)	1 (8.3)	2 (33.3)	0 (0.0)
Paramedian Forehead Flap	25 (36.2)	25 (51.0)	0 (0.0)	0 (0.0)	0 (0.0)
Other Local Flaps	16 (23.2)	13 (26.5)	1 (8.3)	2 (33.3)	0 (0.0)
Skin Graft	19 (27.5)	9 (18.4)	7 (58.3)	2 (33.3)	1 (50.0)
Regional/Distant Flap	9 (13.0)	2 (4.1)	4 (33.3)	2 (33.3)	1 (50.0)
Defect Etiology, n (%)					
Basal Cell Carcinoma	44 (63.8)	40 (81.6)	2 (16.7)	2 (33.3)	0 (0.0)
Squamous Cell Carcinoma	11 (15.9)	6 (12.2)	3 (25.0)	1 (16.7)	1 (50.0)
Sarcoma	8 (11.6)	2 (4.1)	4 (33.3)	2 (33.3)	0 (0.0)
Melanoma	4 (5.8)	1 (2.0)	2 (16.7)	1 (16.7)	0 (0.0)
Other Malignancy	2 (2.9)	0 (0.0)	1 (8.3)	0 (0.0)	1 (50.0)

Table 2. Reconstructive Modalities and Defect Etiology by Anatomic Region.

Data presented as n (%). Percentages are calculated by column total for each anatomic region.

The analysis was conducted as a complete-case analysis, with no missing data for the primary outcome or the key predictor variables included in the final model.

Major postoperative complications (Clavien-Dindo Grade ≥III) occurred in 29.0% (n=20) of the cohort. The most frequent major complications were surgical site infections requiring intervention (11.6%, n=8), flap or graft failure (8.7%, n=6), and wound dehiscence necessitating reoperation (5.8%, n=4). A comparison of baseline characteristics stratified by complication status is presented in Table 1. Patients who experienced a major complication had a significantly higher prevalence of diabetes mellitus (55.0% vs. 38.8%, absolute risk difference [ARD]: 16.2%), ASA Class III (60.0% vs. 32.7%, ARD: 27.3%), hypoalbuminemia (50.0% vs. 22.4%, ARD: 27.6%), and defect size >50 cm² (55.0% vs. 26.5%, ARD: 28.5%). The p-values for these comparisons were 0.04, 0.03, 0.02, and 0.02, respectively.

Management of Major Complications

Among the 20 patients with major complications, surgical site infections (SSIs) were the most common (55%, n=11), managed effectively with culture-directed antibiotics and surgical debridement, including negative pressure wound therapy in select cases. Wound dehiscence (25%, n=5) was treated primarily via surgical re-closure or negative pressure therapy followed by delayed closure. Flap and graft failures (15%, n=3) necessitated prompt surgical revision or secondary reconstruction. Functional complications such as eyelid retraction (20%, n=4) initially received conservative management with lubricants and massage, with half eventually requiring surgical correction. This targeted, complication-specific management resulted in successful resolution in 95% of cases (19/20), though often requiring prolonged treatment and increased healthcare resources.

Impact of Major Complications on Secondary Outcomes

The occurrence of a major complication had a profound impact on all secondary postoperative outcomes (Table 3).

Outcome	Overall (N=69)	No Major Complication (N=49)	Major Complication (N=20)	p-value
Procedural Success†, n (%)	49 (71.0)	49 (100.0)	0 (0.0)	<0.001
30-day Unplanned Readmission, n (%)	9 (13.0)	0 (0.0)	9 (45.0)	<0.001
Hospital Stay, days (Median [IQR])	7.0 [5.0-10.0]	6.0 [4.0-8.0]	12.0 [9.0-16.0]	<0.001

Table 3. Impact of Major Complications on Secondary Postoperative Outcomes.

†Procedural success defined as complete defect closure without unplanned reoperation.

Procedural failure, defined as a lack of durable defect coverage requiring unplanned re-intervention, was universal in the complication group (100.0%, n=20) compared to none in the uncomplicated group (0.0%, n=49; p<0.001). The unplanned 30-day readmission rate was 45.0% (n=9) for patients with major complications versus 0.0% (n=0) for those without (p<0.001). Furthermore, the median hospital stay was significantly longer for patients with complications (12.0 days, IQR: 9.0–16.0) compared to those without (6.0 days, IQR: 4.0–8.0; p<0.001).

Predictors of Major Postoperative Complications

Univariable logistic regression identified defect size >50 cm², ASA Class III, and preoperative hypoalbuminemia as significant candidate predictors (p<0.10). These variables, along with diabetes mellitus which showed a trend (p=0.20), were included in the initial multivariable model.

The final multivariable logistic regression analysis, derived via backward elimination, revealed that defect size >50 cm² (aOR 3.65, 95% CI: 1.55–8.59, p<0.01), ASA Physical Status Class III (aOR 2.85, 95% CI: 1.25–6.50, p=0.01), and preoperative hypoalbuminemia (< 3.5 g/dL) (aOR 2.70, 95% CI: 1.15–6.33, p=0.02)

were independent predictors of major postoperative complications (Table 4). Diabetes mellitus was not retained as a significant independent predictor in the final model (aOR 2.25, 95% CI: 0.95–5.32, p=0.07).

Predictor	Univariable OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Defect Size >50 cm²	3.35 (1.18 – 9.50)	0.02	3.65 (1.55 – 8.59)	<0.01
ASA Physical Status Class III	3.09 (1.11 – 8.58)	0.03	2.85 (1.25 – 6.50)	0.01
Hypoalbuminemia (< 3.5 g/dL)	3.50 (1.21 – 10.11)	0.02	2.70 (1.15 – 6.33)	0.02
Diabetes Mellitus	1.92 (0.71 – 5.20)	0.2	2.25 (0.95 – 5.32)	0.07
Operative Time (per minute)	1.01 (1.00 – 1.02)	0.06	1.01 (1.00 – 1.02)	0.11
Age (per year increase)	1.03 (0.98 – 1.07)	0.29	---	---
Male Sex	1.60 (0.52 – 4.94)	0.41	---	---
Hypertension	1.45 (0.54 – 3.91)	0.46	---	---
Tobacco Use	1.35 (0.45 – 4.02)	0.59	---	---
Reconstructive Modality	1.24 (0.65 – 2.36)	0.51	---	---

Table 4. Univariable and Multivariable Logistic Regression Analysis of Predictors for Major Postoperative Complications.

Abbreviations: OR, Odds Ratio; CI, Confidence Interval; ASA, American Society of Anesthesiologists. Notes: The multivariable model was constructed using variables with $p<0.10$ in univariable analysis (shown in bold). The final model demonstrated good fit (Hosmer-Lemeshow test p = 0.51) and good discriminative ability, with an Area Under the Receiver Operating Characteristic Curve (AUC) of 0.78 (95% CI: 0.67–0.89). A dash (---) indicates the variable was not included in the multivariable model. The analysis was a complete-case analysis with no missing data for the variables included in this model.

The model demonstrated a good fit (Hosmer-Lemeshow test p = 0.51), no significant multicollinearity was detected (VIF < 2.0 for all predictors), and it exhibited good discriminative ability (C-statistic = 0.78, 95% CI: 0.67–0.89). However, given the modest sample size, the potential for overfitting cannot be entirely ruled out, and the effect estimates should be interpreted with appropriate caution.

Discussion

This retrospective cohort study, conducted in a resource-limited tertiary center in Yemen, identified large defect size, high ASA physical status, and preoperative hypoalbuminemia as robust, independent predictors of major complications following oncologic reconstructive surgery. The high prevalence of major complications (29.0%) and their significant impact on procedural failure, readmission, and hospital stay underscore the critical need for context-specific risk stratification in such challenging environments. To our knowledge, this study represents one of the few investigations to systematically establish a pragmatic predictive model for this patient population in Yemen, offering an important framework for improving perioperative care where resources are scarce.

In our resource-limited setting, the observed major complication rate was 29.0%, highlighting significant challenges in managing oncologic reconstructive surgeries. Although most of our cases involved head and neck reconstructions, our findings are relevant to general oncologic reconstructive procedures. Numerous studies have examined complications associated with free flap reconstruction across different healthcare environments. In high-income countries such as Canada, Le Nobel et al. reported an overall complication rate of 32.6%, with a perioperative mortality rate of 0.3%. The flap loss rate was 2.0%, and the partial flap necrosis rate was 1.0% [22]. Similarly, Frederick et al. highlighted favorable outcomes with low mortality rates, attributable to advanced surgical techniques and comprehensive perioperative care [23]. Conversely, in low-income countries, Suyama et al. documented higher complication rates, often exceeding 20%, which they attributed to resource limitations, delayed presentations, and limited access to advanced surgical equipment [24]. A study from Sub-Saharan Africa by Adebayo et al. further emphasized the challenges faced in these settings, including higher incidences of wound infections and flap failures [25]. Our findings contribute to the growing body of literature confirming that complication types are universal, but their frequency and severity are amplified in resource-constrained environments, underscoring the critical need for and limited direct applicability of risk models derived from well-resourced healthcare systems.

The clinical profile of our cohort, dominated by head and neck reconstructions for advanced basal cell carcinoma (BCC), is a hallmark of the surgical landscape in many LMICs. This aligns with global data identifying head and neck cancer as a significant burden in regions like South Asia, where cultural factors and diagnostic barriers lead to advanced disease [12, 26]. Furthermore, local environmental and lifestyle factors, such as khat use and nutritional deficiencies, may contribute to both disease aggressiveness and postoperative vulnerability, though this requires further study [12]. Faced with such advanced tumors and infrastructural constraints including a scarcity of microsurgeons and limited postoperative monitoring reconstructive strategy necessarily prioritizes reliability. Our reliance on local flaps, particularly the paramedian forehead flap, represents a pragmatic adaptation to this environment, a approach consistently observed in other LMIC settings [27, 28]. This finding also underscores the importance of training programs in LMICs that emphasize mastery of versatile local and regional flaps as a critical component of surgical capacity-building.

Predictive factors for major postoperative complications following complex reconstructive surgery have been extensively categorized in the literature. These factors broadly encompass patient-related variables such as advanced age, hypertension, diabetes, poor nutritional status, smoking history, and bleeding diathesis, all of which have been shown to elevate complication risks [2, 16]. Tumor-related characteristics, including advanced stage, tumor burden, and anatomical location, further influence postoperative outcomes negatively. Surgeon experience is also a critical determinant; lower specialty-specific experience correlates with increased rates of flap complications and adverse events. Treatment-related variables, including prolonged operative duration, significant intraoperative blood loss, flap size, and prior radiotherapy or chemotherapy, have likewise been implicated in heightened complication risk [6, 8, 9, 16, 29, 30]. Emerging predictive models that integrate these factors through logistic regression and machine learning approaches offer promise for personalized risk stratification and prevention strategies.

Our study corroborates and refines this framework by identifying defect size exceeding 50 cm^2 as the strongest predictor of poor outcomes, consistent with extant literature linking larger wounds to augmented technical complexity and susceptibility to infection and mechanical failures [31, 32]. The significant association of ASA Class III with complication risk further highlights the influence of systemic comorbidities and underscores the necessity for meticulous preoperative assessment [33]. Additionally, hypoalbuminemia (< 3.5 g/dL), prevalent in 41.3% of our cohort and conferring a 2.7-fold increased risk of major complications, aligns with broader surgical evidence emphasizing its role as a modifiable risk factor indicative of malnutrition and systemic inflammation [34]. A comprehensive meta-analysis of orthopaedic patients found that hypoalbuminemia (< 3.5 g/dL) carried a 2.39- fold increased risk of surgical site infection [34].

However, certain tumor-related factors, as well as data on chemotherapy, radiotherapy, and adjunct treatments, were not captured in our study due to these therapies being administered in other centers, and consequently, results should be interpreted with caution. Surgeon experience, while recognized as important, is nuanced in our context given the absence of a dedicated microvascular reconstructive surgeon; rather, procedures were conducted by a general surgeon with notable experience in such cases. Lastly, some factors commonly reported elsewhere such as gender and individual comorbidities (diabetes) did not reach statistical significance in our cohort, likely reflecting the limitations imposed by sample size. Future multicenter studies with comprehensive data collection are warranted to validate and expand upon our findings. The management of major complications in our cohort (n=20) was guided by established surgical protocols and performed by a general surgeon with specialized experience. In this setting, with limited formal multidisciplinary support, all decision-making was centralized. This protocol-driven strategy, which included debridement and antibiotics for infections (55%, n=11) and prompt surgical revision for dehiscence (25%, n=5) and flap failure (15%, n=3), resulted in successful resolution in 95% of cases (19/20). This demonstrates that standard outcomes can be achieved by an experiencergeon adhering to fundamental principles [35].

Clinical Implications

The clinical implications of our findings are immediate and actionable. They provide a validated, tripartite risk stratification framework based on readily available clinical data. Patients flagged as high-risk by these criteria those with large defects, significant comorbidities, or poor nutritional status warrant intensified preoperative optimization. This includes, wherever feasible, nutritional supplementation, which is critically supported by studies showing malnourished surgical patients have significantly higher rates of postoperative infections, mortality, and hospital stays [36], with hypoalbuminemia being a powerful independent predictor of poor outcomes [37]. Furthermore, the medical management of comorbidities is essential, as evidenced by research demonstrating a 31% reduction in postoperative complications when patients were optimized by a nonsurgical clinician before surgery. At a systems level, these data argue for policy interventions aimed at improving early cancer detection to reduce defect sizes, a strategy supported by data linking early-stage diagnosis to higher rates of curative surgery and long-term survival, and strengthening nutritional support services within surgical pathways.

Study strengths and limitations

Our study has several strengths, including its focused design, the use of standardized outcome definitions (Clavien-Dindo), and a robust multivariate analysis that controlled for key confounders. However, its limitations must be acknowledged. The modest sample size and single-center, retrospective design inherently limit the generalizability of our findings and preclude definitive causal inferences. The lack of complete data on neoadjuvant or adjuvant therapies, a common challenge in LMICs where patient care is fragmented, represents a potential source of unmeasured confounding. Furthermore, we were unable to capture long-term functional or oncologic outcomes. Future research should aim for larger, prospective, multi-center cohorts in similar settings to validate this risk model. Such studies should incorporate detailed data on adjuvant treatments and investigate the impact of targeted interventions, such as preoperative nutritional support, on mitigating complication risks.

In conclusion, in this single-center cohort study of patients undergoing oncologic reconstructive surgery in a Yemeni tertiary center, large defect size, higher ASA class, and preoperative hypoalbuminemia emerged as robust, independent predictors of major postoperative complications. These factors are strongly associated with adverse outcomes, including procedural failure, unplanned readmission, and prolonged hospitalization. Our findings provide a pragmatic, evidence-based framework for risk stratification, utilizing variables that are readily accessible in challenging environments. Integrating these predictors into routine preoperative checklists or risk scores could significantly enhance clinical decision-making.

For clinical practice, this underscores the imperative of integrating focused preoperative optimization particularly nutritional supplementation and comorbidity management, within the constraints of institutional capacity and clinical urgency into surgical pathways for high-risk patients. Furthermore, these results can help inform hospital policy and resource allocation in low-resource surgical programs by identifying patients who may require more intensive perioperative care. While the single-center, retrospective design suggests a need for broader validation, these results offer a foundational step toward improving surgical safety and outcomes. Future research should focus on prospectively validating this model across diverse LMIC settings and evaluating the specific impact of targeted preoperative interventions on mitigating complication risks.

Acknowledgments

None.

Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Authors' Contributions

Saleh Al-wageeh: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. Saif Ghabisha: Data curation, Investigation, Writing – review & editing. Qasem Alyhari: Data curation, Investigation, Writing – review & editing. Ahmed Ateik Ateik: Data curation, Investigation, Writing – review & editing. Abdulfattah Altam: Data curation, Investigation, Writing – review & editing. Hanan Mohammed: Data curation, Writing – review & editing. Azhar Al-Yafrosi: Writing – review & editing. Faisal Ahmed: Conceptualization, Supervision, Writing – review & editing, Corresponding author. All authors have read and approved the final manuscript.

Competing Interests

The authors declare no competing interests related to this work.

Ethics Approval and Consent to Participate

This retrospective study was approved by the Institutional Review Board of Ibb University, Ibb, Yemen (Approval Number: IBBUNI.AC.YEM.2025.15) on June 2, 2025. The requirement for informed consent was waived due to the study's retrospective nature. All procedures were conducted in accordance with institutional ethical standards, national regulations, and the Declaration of Helsinki.

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Originality Declaration for Figures

All figures included in this manuscript are original and have been created by the authors specifically for the purposes of this study. No previously published or copyrighted images have been used. The authors confirm that all graphical elements, illustrations, and visual materials were generated from the data obtained in the course of this research or designed uniquely for this manuscript.

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