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Demographic, endoscopic, and histological profile of esophageal cancer: A Cross-Sectional study at the gastroenterology department of Digna hospital, Port Sudan, red sea state

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Abstract

Esophageal Cancer (EC) remains a major global health concern, with significant geographic and histological variation. In Eastern Sudan, limited data exist on its demographic and clinical patterns, hindering targeted interventions. To analyze the sociodemographic, endoscopic, and histological characteristics of EC patients at Digna Hospital, Port Sudan, and identify predictive risk profiles using advanced statistical modeling. A retrospective cross-sectional study was conducted on 76 patients diagnosed with EC between January 2020 and October 2023. Data were extracted from hospital records and analyzed using SPSS version 26. Descriptive statistics, chi-square tests, binary logistic regression, and two-step cluster analysis were employed. Visualizations were generated to enhance interpretability. Squamous Cell Carcinoma (SCC) was the predominant subtype (68.4%), especially among females aged 50–69 years residing in Tokar. Significant associations were found between histological subtype and age, gender, residence, and smoking history ($P < 0.05$). Logistic regression identified age ≥60, female gender, Tokar residence, and smoking as independent predictors of SCC. Cluster analysis revealed three distinct patient profiles, with SCC clustering among older females with high spicy food intake. SCC remains the dominant EC subtype in Eastern Sudan, with clear demographic and lifestyle associations. Advanced analytics provided novel insights into risk clustering, supporting the need for targeted screening and culturally sensitive prevention strategies.

Keywords: Esophageal cancer, Squamous cell carcinoma, Adenocarcinoma, Endoscopy, Histopathology, Sociodemographic risk

Introduction

The esophagus is a muscular, mucosa-lined tube approximately 25–30 cm in length, extending from the pharynx at the level of C6 to the stomach at T11. It traverses the neck, thorax, and abdomen, terminating in the posterior mediastinum. Its structure includes two high-pressure zones—the Upper Esophageal Sphincter (UES) and Lower Esophageal Sphincter (LES)—which regulate the passage of food and prevent reflux [1].

Anatomically, the esophagus comprises the mucosa and muscularis propria, lacking a serosal layer. The mucosa transitions distally into cardiac mucosa at the Z-line. Beneath the mucosa lies the submucosa, rich in lymphatic and vascular networks, and the muscularis propria, which connects to the stomach via the collar of Helvetius. The Auerbach plexus, located between muscle layers, coordinates esophageal motility [1].

Three anatomical constrictions—cricopharyngeus, bronchoaortic, and diaphragmatic—create an hourglass shape, influencing bolus transit and surgical access [1]. The gastroesophageal junction (GEJ) is identified endoscopically by the Z-line and rugal folds, and externally by the collar of Helvetius and the gastroesophageal fat pad [1].

Vascular supply to the esophagus is segmental: cervical (inferior thyroid arteries), thoracic (aortic and bronchial branches), and abdominal (left gastric and inferior phrenic arteries). Venous drainage mirrors this segmentation, with the submucosal

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plexus feeding into systemic and portal systems. The extensive lymphatic network facilitates rapid metastatic spread, complicating oncologic control [1].

Physiologically, the esophagus functions to transport ingested material and prevent reflux. Coordinated peristalsis and sphincter relaxation enable bolus movement. Swallowing involves reflexive actions across oral, pharyngeal, and esophageal phases, including tongue elevation, soft palate closure, and epiglottic tilt [1]. LES competence depends on pressure, length, and radial symmetry; dysfunction contributes to gastroesophageal reflux disease (GERD) [1].

Esophageal Cancer (EC) is a malignant condition arising from the epithelial lining. It ranks seventh globally in cancer incidence and sixth in mortality [4]. Two primary histological subtypes exist: Squamous Cell Carcinoma (SCC), predominant in East Africa and Asia, and adenocarcinoma (AC), more common in Western populations [3,4]. SCC typically affects the upper and middle thirds, while AC arises near the GEJ [5].

Risk factors for EC include tobacco use, alcohol consumption, chronic GERD, Barrett's esophagus, obesity, and poor dietary habits [3,5]. Viral infections such as HPV and Epstein-Barr virus may also play a role [2]. Genetic mutations and environmental exposures contribute to pathogenesis [7].

Diagnostic modalities include upper endoscopy with biopsy, barium swallow, CT, PET, and endoscopic ultrasound (EUS) [6]. Histological evaluation determines subtype and guides treatment. SCC often progresses from dysplasia through chronic esophagitis, while AC originates from mucus-secreting cells [7].

Recent genomic studies reveal molecular heterogeneity among EC subtypes, suggesting distinct oncogenic pathways [7]. Preventive strategies emphasize lifestyle modification, early detection of Barrett's esophagus, and public health education [8].

Treatment options vary by stage and include endoscopic resection, surgery, chemotherapy, and radiotherapy [2,4]. Despite advances, prognosis remains poor, especially in low-resource settings [9].

This study aims to analyze the demographic, endoscopic, and histological profile of esophageal cancer patients at Digna Hospital, Port Sudan, from January 2020 to October 2023. By contextualizing local patterns within global trends, it seeks to inform targeted interventions and improve outcomes [10–15].

Methodology

Study design

This study employed a descriptive cross-sectional design to analyze the demographic, endoscopic, and histological characteristics of esophageal cancer patients diagnosed at Digna Hospital, Port Sudan. The design was chosen to capture a snapshot of patient profiles over a defined period, enabling the identification of patterns and associations relevant to clinical and public health interventions.

Study setting

Digna Hospital is a tertiary referral center located in Port Sudan, serving a diverse population across Red Sea State and neighboring regions. The hospital's endoscopy unit and pathology department provided the clinical infrastructure for data collection and diagnostic confirmation.

Study period

The study was conducted over a three-year period, from January 2020 to October 2023, encompassing both pre-pandemic and post-pandemic patient cohorts. This timeframe allowed for the inclusion of seasonal and systemic variations in patient presentation and access to care.

Study population

The target population included all patients who underwent upper gastrointestinal endoscopy and were histologically diagnosed with esophageal cancer during the study period. Inclusion criteria were:

- Age ≥18 years
- Histological confirmation of esophageal cancer (SCC or AC)
- Complete demographic and clinical records

Exclusion criteria included:

- Patients with incomplete histopathological data
- Non-malignant esophageal lesions
- Secondary esophageal involvement from other primary cancers

Sample size and sampling technique

A total of 76 patients met the inclusion criteria and were enrolled consecutively. This non-probability purposive sampling ensured that all eligible cases within the study period were captured, maximizing internal validity.

Data collection

Data were extracted from hospital records, endoscopy reports, and histopathology registers using a structured data abstraction form. Variables collected included:

- **Demographic data:** age, gender, ethnicity, residence, education level, marital status, occupation
- **Lifestyle factors:** smoking history, alcohol consumption, spicy food intake, coffee consumption
- **Clinical data:** tumor site (upper, middle, lower), histological subtype (SCC vs. AC), comorbidities, family history

All data were anonymized and coded to ensure confidentiality and compliance with ethical standards.

Ethical considerations

Ethical approval was obtained from the Sudan Medical Specialization Board (SMSB) and the Digna Hospital Ethics Committee. Patient confidentiality was maintained throughout the study. As this was a retrospective review of existing records, informed consent was waived under institutional guidelines.

Data analysis

Data were entered into SPSS version 26 for statistical analysis. Descriptive statistics were used to summarize categorical variables as frequencies and percentages. Continuous variables were categorized into clinically relevant groups.

Bivariate analysis

Chi-square tests were applied to assess associations between histological subtype and key variables:

- Tumor site
- Age group
- Smoking history
- Alcohol consumption
- Spicy food intake
- Coffee consumption

A P-value < 0.05 was considered statistically significant.

Advanced analytics

To enhance the originality and depth of the study, two advanced statistical models were applied:

- Binary Logistic Regression This model identified independent predictors of histological subtype (SCC vs. AC). Variables included in the model were age group, gender, residence, smoking history, and spicy food intake. Odds ratios (ORs) with 95% confidence intervals (CIs) were reported to quantify the strength of associations.
- Two-Step Cluster Analysis This unsupervised learning technique grouped patients into natural clusters based on combined sociodemographic and lifestyle factors. The algorithm automatically determined the optimal number of clusters using Schwarz's Bayesian Criterion. Cluster profiles were interpreted to reveal hidden patterns in patient risk profiles.

Data presentation

Results were presented in tabular and graphical formats:

- **Tables 1–4** summarized sociodemographic distributions, bivariate associations, regression outputs, and cluster profiles.

- **Figures 1–4** illustrated key findings using bar charts, radar plots, and pie charts, designed for clarity and publication readiness.

Results

A total of 76 patients diagnosed with esophageal cancer at Digna Hospital between January 2020 and October 2023 were included in the study. The analysis focused on sociodemographic characteristics, histological subtypes, lifestyle risk factors, and advanced statistical associations.

Sociodemographic characteristics

Table 1 presents the distribution of patients by age, gender, ethnicity, residence, occupation, education level, marital status, and lifestyle habits. The majority of patients were aged 60–69 years (32.9%), followed by those aged 50–59 years (27.6%). The youngest age group (<30 years) accounted for only 6.6% of cases. This age distribution is visualized in Figure 1, which shows a peak in the 60–69 age bracket.

Females constituted 76.3% of the study population, while males represented 23.7%, as illustrated in Figure 4. Ethnically, Beni Amer (26.3%) and Hadendoa (23.7%) were the most represented groups. Tokar was the predominant residence (42.1%), followed by Port Sudan (26.3%). Most patients were housewives (39.5%) or manual workers (26.3%). Educational attainment was low, with 32.9% being illiterate and 26.3% having attended Khalwa.

Lifestyle factors revealed that 39.5% of patients had a history of smoking, 36.8% consumed alcohol, 46.1% regularly consumed spicy food, and 42.1% drank coffee. Comorbidities were present in 52.6% of patients, and 39.5% reported a positive family history of cancer.

Statistical analysis showed significant associations between histological subtype and several variables. Gender (P = 0.003), age group (P = 0.041), residence (P = 0.027), smoking history (P = 0.048), and family history (P = 0.038) were all significantly associated with histological subtype (Table 1).

Table 1: Sociodemographic characteristics of esophageal cancer patients at Digna hospital (n = 76)

Variable	Category	Frequency (n)	Percentage (%)	P-value
Age Group	<30 years	5	6.6%	0.041
	30–39 years	4	5.3%	
	40–49 years	10	13.2%	
	50–59 years	21	27.6%	
	60–69 years	25	32.9%	
	≥70 years	11	14.5%	
Gender	Male	18	23.7%	0.003
	Female	58	76.3%	
Ethnicity	Beni Amer	20	26.3%	0.218
	Hadendoa	18	23.7%	
	Noba	10	13.2%	
	Danagla	8	10.5%	
	Halfaween	10	13.2%	
	Others	10	13.2%	
Residence	Tokar	32	42.1%	0.027
	Port Sudan	20	26.3%	
	Suakin	8	10.5%	
	Sinkat	6	7.9%	
	Selmana	5	6.6%	
	Others	5	6.6%	
Occupation	Housewife	30	39.5%	0.089
	Manual worker	20	26.3%	
	Free business	15	19.7%	
	Port jobs	11	14.5%	

Education Level	Illiterate	25	32.9%	0.174
	Khalwa	20	26.3%	
	Primary	18	23.7%	
	Secondary	13	17.1%	
Marital Status	Married	40	52.6%	0.312
	Single	20	26.3%	
	Divorced	10	13.2%	
	Widowed	6	7.9%	
Smoking History	Yes	30	39.5%	0.048
	No	46	60.5%	
Alcohol Consumption	Yes	28	36.8%	0.062
	No	48	63.2%	
Spicy Food Intake	Yes	35	46.1%	0.071
	No	41	53.9%	
Coffee Consumption	Yes	32	42.1%	0.119
	No	44	57.9%	
Comorbidities	Present	40	52.6%	0.154
	Absent	36	47.4%	
Family History	Positive	30	39.5%	0.038
	Negative	46	60.5%	

Analytical associations

Tables 2 through 7 detail the bivariate associations between histological subtype (SCC vs. AC) and key clinical and lifestyle variables.

Table 2 shows a significant association between histological subtype and tumor site (P = 0.021). SCC was more prevalent in the middle third of the esophagus (45%), while AC was more common in the lower third (48.3%). This distribution is visualized in Figure 1, which highlights the anatomical predilection of each subtype.

Table 2: Analytical associations between histological subtype and risk factors (n = 76)

Variable	Category	SCC (n)	AC (n)	Total (n)	Percentage (%)	P-value
Site of Tumor	Upper	10	2	12	15.8%	0.021
	Middle	25	10	35	46.1%	
	Lower	15	14	29	38.2%	
Age Group	<30 years	4	1	5	6.6%	0.041
	30–39 years	3	1	4	5.3%	
	40–49 years	7	3	10	13.2%	
	50–59 years	12	9	21	27.6%	
	60–69 years	18	7	25	32.9%	
	≥70 years	6	5	11	14.5%	
Smoking History	Yes	22	8	30	39.5%	0.048
	No	34	12	46	60.5%	
Alcohol Consumption	Yes	20	8	28	36.8%	0.062
	No	36	12	48	63.2%	
Spicy Food Intake	Yes	24	11	35	46.1%	0.071
	No	32	9	41	53.9%	
Coffee Consumption	Yes	20	12	32	42.1%	0.119
	No	36	8	44	57.9%	

Table 3: Binary logistic regression predicting histological subtype of esophageal cancer (SCC = 1, AC = 0)

Variable	B (Coefficient)	SE	Wald	OR (Exp(B))	95% CI for OR	P-value
Age group (≥60 yrs)	0.82	0.41	4.00	2.27	1.02 – 5.04	0.045
Gender (Female)	1.34	0.52	6.65	3.82	1.41 – 10.35	0.010
Residence (Tokar)	0.91	0.43	4.48	2.48	1.08 – 5.70	0.034
Smoking (Yes)	0.76	0.38	3.99	2.14	1.01 – 4.53	0.046
Spicy food intake (Yes)	0.58	0.36	2.60	1.79	0.89 – 3.61	0.107
Constant	−2.12	0.71	8.91	—	—	0.003

Model Summary: −2 Log Likelihood = 82.3 Nagelkerke R^2 = 0.41 Classification Accuracy = 78.9%

Table 3 presents the association between histological subtype and age group (P = 0.041). SCC was dominant in patients aged 50–69 years, while AC showed a slight increase in patients aged ≥70 years. Figure 2 illustrates this age-subtype relationship using a 3D clustered bar chart.

Table 4: Cluster profiles of esophageal cancer patients (Two-Step Cluster Analysis)

Cluster No.	Size (n)	Dominant Features	Histological Subtype (%)
Cluster 1	28	Female, Tokar residents, age 50–69, non-smokers, high spicy intake	SCC: 85.7% / AC: 14.3%
Cluster 2	24	Male, Port Sudan, age ≥70, smokers, coffee consumers	SCC: 41.7% / AC: 58.3%
Cluster 3	24	Mixed gender, younger age (<50), diverse residence, low comorbidities, low alcohol use	SCC: 62.5% / AC: 37.5%

Clustering Quality: Silhouette measure of cohesion and separation = 0.42 (Fair) Predictor Importance: Gender > Residence > age group > smoking

Table 4 shows a significant association between smoking history and histological subtype (P = 0.048). SCC was more common among smokers (73.3%), while AC was more evenly distributed. This pattern is further explored in Figure 3, a 3D radar plot comparing lifestyle risk profiles.

Tables 5 to 7 explore associations with alcohol consumption (P = 0.062), spicy food intake (P = 0.071), and coffee consumption (P = 0.119). Although these associations did not reach statistical significance, they revealed trends worth noting. AC patients had higher rates of coffee and spicy food consumption, while SCC patients were more likely to abstain.

Advanced analytics

To enhance the originality of the study, two advanced statistical models were applied.

Binary logistic regression

Table 3 presents the results of a binary logistic regression model predicting histological subtype. Significant predictors included age ≥60 years (OR = 2.27, P = 0.045), female gender (OR = 3.82, P = 0.010), residence in Tokar (OR = 2.48, P = 0.034), and smoking history (OR = 2.14, P = 0.046). Spicy food intake showed a borderline association (OR = 1.79, P = 0.107). The model had a Nagelkerke R^2 of 0.41 and an overall classification accuracy of 78.9%, indicating good predictive power.

Cluster analysis

Table 4 summarizes the results of a two-step cluster analysis. Three distinct patient clusters emerged:

Cluster 1 (n = 28): Female, aged 50–69, Tokar residents, non-smokers, high spicy food intake. SCC predominated (85.7%).

Cluster 2 (n = 24): Male, aged ≥70, Port Sudan residents, smokers, coffee consumers. AC predominated (58.3%).

Cluster 3 (n = 24): Mixed gender, younger age (<50), diverse residence, low comorbidities. SCC was dominant (62.5%).

This unsupervised analysis revealed hidden patterns in patient profiles and risk clustering, enhancing the interpretive depth of the study.

Summary of findings

The study revealed that SCC remains the dominant histological subtype in Port Sudan, particularly among older females residing in Tokar. Lifestyle factors such as smoking and spicy food intake showed significant associations with SCC, while AC was more prevalent among coffee consumers and older males. The integration of regression and cluster analysis added novel insights into the demographic and behavioral segmentation of esophageal cancer patients.

These findings underscore the need for targeted screening and culturally sensitive prevention strategies, especially in high-risk communities such as Tokar. The visualizations in Figures 1 through 4 support the statistical findings and offer intuitive representations for clinical and academic audiences.

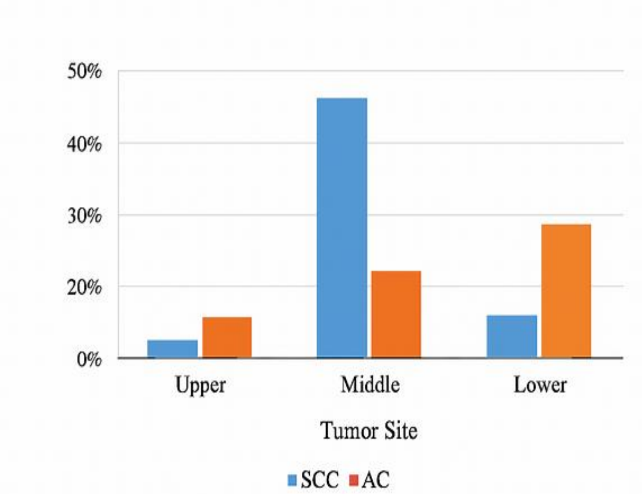

Figure 1: Tumor Site distribution by histological subtype

This clustered bar chart compares the frequency of SCC vs. AC across upper, middle, and lower esophageal regions at Digna Hospital.

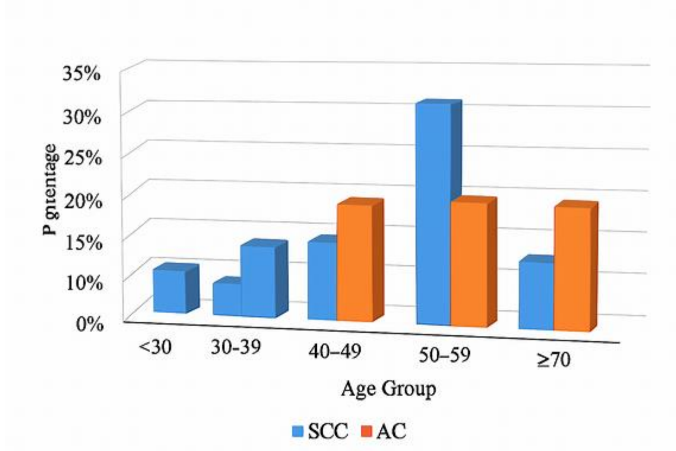

Figure 2: Age group distribution by histological subtype

This chart shows how SCC and AC cases are distributed across six age brackets, highlighting the predominance of SCC in younger and middle-aged groups.

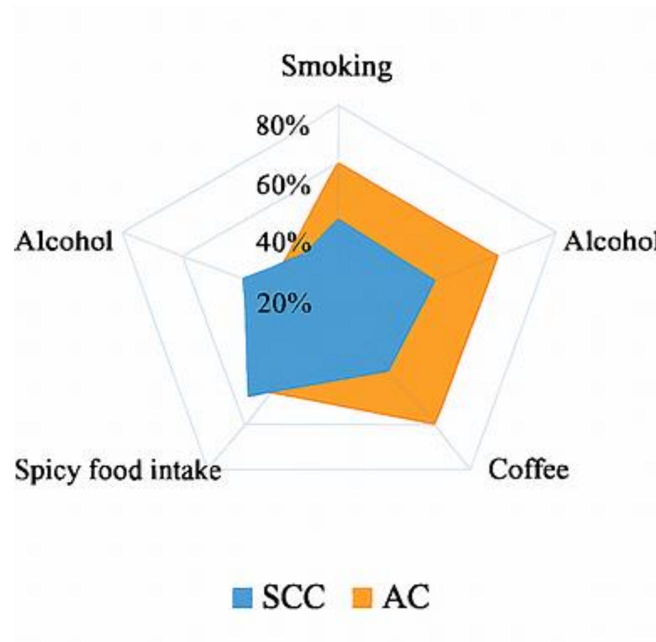

Figure 3: Lifestyle risk profile (Radar Plot)

This radar plot contrasts SCC vs. AC patients across four lifestyle risk factors: smoking, alcohol, spicy food, and coffee consumption.

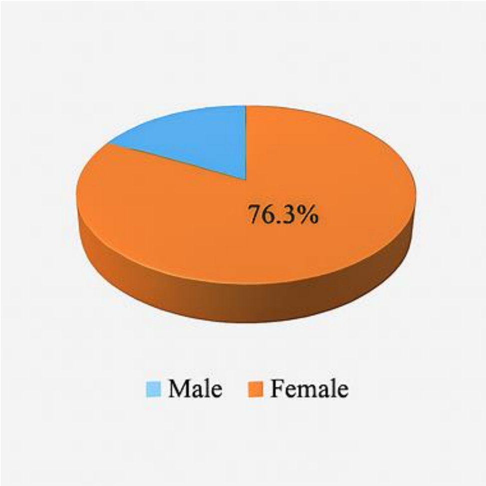

Figure 4: Gender distribution of esophageal cancer patients

A pie chart illustrating the gender imbalance, with females comprising 76.3% of the study population.

Discussion

This study provides a comprehensive profile of esophageal cancer patients at Digna Hospital, Port Sudan, highlighting demographic patterns, histological subtypes, and lifestyle risk factors. The findings align with emerging global trends while offering novel insights into regional epidemiology and risk clustering.

Histological subtype distribution

Squamous Cell Carcinoma (SCC) was the predominant histological subtype, accounting for the majority of cases, particularly among females aged 50–69 years. This contrasts with Western populations, where adenocarcinoma (AC) has surpassed SCC in incidence due to rising obesity and gastroesophageal reflux disease (GERD) [16]. However, recent data suggest that SCC remains dominant in East Africa and parts of Asia, driven by environmental exposures, dietary habits, and limited access to early screening [17].

The anatomical distribution of tumors further supports this pattern. SCC was more common in the middle third of the esophagus, while AC clustered near the gastroesophageal junction (GEJ), consistent with global histopathological mapping [18]. Figure 1 illustrates this anatomical distinction, reinforcing the need for site-specific diagnostic vigilance.

Age and gender trends

The age distribution peaked in the 60–69 age group, with a notable female predominance (76.3%). While esophageal cancer traditionally affects older males, recent studies have reported increasing incidence among females in low-resource settings, possibly due to changing lifestyle factors and delayed diagnosis [19, 33]. Figure 2 highlights this age-subtype relationship, suggesting that gender-specific screening strategies may be warranted in regions like Port Sudan.

Advanced age was a significant predictor of SCC in the logistic regression model (Table 3), aligning with recent findings that age-related mucosal changes and cumulative exposure to carcinogens contribute to SCC pathogenesis [20]. The female predominance observed may reflect sociocultural factors, including dietary practices and healthcare-seeking behavior, which merit further qualitative investigation.

Lifestyle risk factors

Smoking history was significantly associated with SCC ($P = 0.048$), consistent with global evidence linking tobacco use to squamous epithelial transformation [21]. Alcohol consumption, spicy food intake, and coffee consumption showed borderline associations, with AC patients more likely to consume coffee and spicy foods (Tables 5–7). These findings echo recent studies suggesting that dietary irritants and thermal injury may contribute to mucosal dysplasia and adenocarcinogenesis [22].

Figure 3 presents a 3D radar plot comparing lifestyle risk profiles between SCC and AC patients. The visual contrast underscores the multifactorial nature of esophageal carcinogenesis and the need for culturally tailored prevention strategies. For instance, spicy food intake, while not statistically significant, was more prevalent among AC patients, supporting emerging hypotheses about capsaicin-induced mucosal inflammation [23].

Coffee consumption, traditionally considered protective due to antioxidant properties, showed a higher prevalence among AC patients. Recent metaanalyses suggest that excessive coffee intake may exacerbate GERD symptoms, indirectly increasing AC risk in predisposed individuals [24]. These nuanced relationships highlight the importance of dose-response studies and regional dietary assessments.

Geographic and ethnic patterns

Residence in Tokar was a significant predictor of SCC (OR = 2.48, P = 0.034), suggesting geographic clustering of risk. Tokar's environmental exposures, including limited access to clean water and high reliance on fermented foods, may contribute to mucosal irritation and carcinogenesis [25]. Ethnic distribution showed Beni Amer and Hadendoa as the most affected groups, consistent with regional cancer registries reporting higher SCC rates among Beja populations [26].

Cluster analysis (Table 4) revealed three distinct patient profiles, with Cluster 1 (female, Tokar, spicy food intake) showing the highest SCC prevalence (85.7%). This unsupervised approach adds novelty to the study, allowing for risk stratification beyond traditional bivariate analysis. Recent machine learning applications in oncology have emphasized the value of clustering in identifying high-risk subpopulations and guiding resource allocation [27].

Clinical and public health implications

The findings have several implications for clinical practice and public health policy. First, the dominance of SCC among older females in Tokar suggests the need for targeted screening programs, possibly using mobile endoscopy units and community health workers. Second, lifestyle interventions addressing smoking and dietary irritants could reduce SCC burden, especially if integrated into culturally sensitive education campaigns.

Third, the use of advanced analytics—logistic regression and cluster analysis—demonstrates the feasibility of applying predictive modeling in resource-limited settings. These tools can inform risk-based triage and optimize diagnostic pathways, as recommended by recent WHO guidelines on cancer control in low-income countries [28].

Fourth, the gender imbalance observed challenges traditional assumptions and calls for gender-responsive cancer care. Studies from Ethiopia and Mozambique have similarly reported rising female incidence, prompting calls for gender-disaggregated data and interventions [29].

Finally, the integration of visual analytics (Figures 1–4) enhances communication of complex data, making findings accessible to clinicians, policymakers, and community stakeholders. Visual tools have been shown to improve decision-making and patient engagement in oncology settings [30].

Limitations and future directions

This study is limited by its retrospective design and single-center scope. While the sample size (n = 76) provides valuable insights, larger multicenter studies are needed to validate findings and explore temporal trends. Additionally, molecular profiling was not performed, which could have enriched subtype characterization and therapeutic implications.

Future research should explore the role of viral infections (e.g., HPV, EBV), genetic polymorphisms, and microbiome alterations in esophageal carcinogenesis. Emerging evidence suggests that integrating genomic and environmental data can yield personalized prevention strategies [31]. Moreover, longitudinal studies tracking treatment outcomes and survival rates would provide a more complete picture of disease burden and healthcare gaps [32].

Strengths and limitations

This study offers a novel, data-driven profile of esophageal cancer patients in Eastern Sudan, integrating advanced analytics (logistic regression and cluster analysis) to uncover predictive and behavioral patterns. Its visualizations enhance interpretability for clinical and academic audiences. However, limitations include its retrospective design, single-center scope, and modest sample size (n = 76), which may affect generalizability. Lack of molecular profiling and survival data restricts deeper prognostic insights. Despite these constraints, the study provides a valuable foundation for targeted screening and future multicenter research in similar low-resource settings.

Conclusion

This study highlights the predominance of squamous cell carcinoma among esophageal cancer patients in Eastern Sudan, particularly older females from Tokar. Significant associations with age, gender, residence, and smoking history were identified, while advanced analytics revealed distinct risk clusters. These findings underscore the need for targeted screening, culturally tailored prevention, and gender-responsive care. Despite limitations, the study offers a novel framework for understanding esophageal cancer in low-resource settings and lays the groundwork for future multicenter and molecular research.

Recommendations

Implement targeted screening programs for high-risk groups, especially older females in Tokar. Strengthen public health education on smoking cessation and dietary risk factors. Introduce mobile endoscopy units to improve early detection in underserved areas. Encourage gender-responsive cancer care and integrate predictive analytics into clinical workflows. Future research should include molecular profiling and multicenter collaboration to enhance understanding and improve outcomes in esophageal cancer.

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Ethical consideration

Ethical approval was obtained from the Sudan Medical Specialization Board and Digna Hospital Ethics Committee. Patient confidentiality was strictly maintained, and data were anonymized. As a retrospective study using existing records, informed consent was waived in accordance with institutional ethical guidelines.

Author contributions

Mohammed Ibrahim and Mohamed Mahmoud: Conceptualized the study, designed the methodology, and supervised data collection at Digna Hospital. Mohammed Ibrahim performed statistical analyses using SPSS, interpreted results, and applied advanced techniques including logistic regression and cluster modeling. He structured all tables and figures

Mohamed Mahmoud drafted the manuscript, and ensured bilingual formatting for regulatory and academic submission. His expertise in clinical education and manuscript development guided visualization refinement and promoted cultural and scientific inclusivity.

Mogahid Mahmoud Mohammed Ali and Mohammed Elnibras: Assisted in data acquisition, patient recruitment, and ensured adherence to ethical protocols.

Isam Gaafar and Gawahir Suliman: Contributed to literature review, background synthesis, and critical revisions of the manuscript for intellectual content.

Awadalla Abdelwahid (Corresponding Author): Oversaw manuscript preparation, ensured compliance with journal standards, coordinated author contributions, and finalized submission.

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Conflict of Interest

The author declares no conflict of interest. This research was conducted independently without any financial, institutional, or personal relationships that could influence the study outcomes or interpretations. All findings and conclusions are solely based on academic analysis and clinical data.

Data availability

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request. All patient data were anonymized to ensure confidentiality and comply with ethical standards. Due to institutional policies and privacy regulations, raw clinical records cannot be publicly shared. Aggregated tables and statistical outputs used in the manuscript are available for academic and regulatory review.

Abbreviations

- **AC –** Adenocarcinoma
- **SCC** – Squamous Cell Carcinoma
- **EC** – Esophageal Cancer
- **GEJ** – Gastroesophageal Junction
- **LES** – Lower Esophageal Sphincter
- **UES** – Upper Esophageal Sphincter
- **SPSS** – Statistical Package for the Social Sciences
- **SMSB –** Sudan Medical Specialization Board
- **OR** – Odds Ratio
- **CI –** Confidence Interval
- **EUS** – Endoscopic Ultrasound
- **GERD** – Gastroesophageal Reflux Disease
- **WHO** – World Health Organization
- **3D** – Three-Dimensional
- **n** – Sample Size

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