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Haematological Profile in Pre-Surgery Hernia Patients: A Case-Control Study in Ghana

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Abstract

Introduction: The burden of hernia is disproportionately high in low-to-middle-income countries, due to the lack of fundamental resources needed to effectively diagnose and manage cases. The patterns of hernia, the haematological profile, and the predictive ability of blood cell indices were all investigated in this study. *Methods:* Fifty-four subjects: 27 hernia patients and 27 healthy controls were included in this single-centre, unmatched case-control study. Hernia was diagnosed using physical examination and ultrasound scan. Haematological indices of each subject were measured with an automated blood cell counter. *Results:* Herniae recorded were 92.59% inguinal, and 3.27% each epigastric and uterine prolapse. Hernia was prevalent in males (85.2%, p=0.008) and older subjects ≥53 years (48.1%, p=0.004). HgB (p=0.006), MCHC ($p \leq 0.001$), and RDW-CV (p=0.042) levels were significantly elevated in strangulated than non-strangulated hernia and controls respectively, while Abs GRAN (p=0.024) was decreased in non-strangulated than strangulated hernia and control groups respectively. MCHC (AUC=0.947 [0.895-0.999], $p \leq 0.001$) was the most sensitive predictor for herniation followed by age (AUC=0.750 [0.610-0.889], p=0.002); HgB (AUC=0.718 [0.580-0.857], p=0.006); and RDW-CV (AUC=0.700 [0.559-0.840], p=0.012). Also, MCHC (AUC=0.831 [0.723-0.938], $p \leq 0.001$); HgB (AUC=0.738 [0.590-0.887], p=0.005); and RBC (AUC=0.671 [0.502-0.840], p=0.045) respectively, were significant predictors of strangulation. *Conclusion:* Gender and age were significantly associated with hernias. Inguinal hernia and strangulation were common in the study setting, especially, among males. Also, there were significant variations in erythrocyte- and leucocyte indices across the groups, but not platelets. Erythrocyte indices were significant predictive biomarkers for hernia and strangulation. The CBC is a useful test for the early detection of herniation and strangulation.

Keywords: Blood Cell Indices; Haematological Profile; Hernia; Pre-Surgery; Strangulation.

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1. Introduction

A hernia is a bulge of an organ or part of an organ through an opening [1] in the muscle wall of its surrounding cavity [2]. Hernia presents as a potential source of discomfort and may constitute a clinical emergency that requires immediate surgical attention. The aetiology of hernia may be inherited due to the inability of some structures to close after delivery, or acquired from underlying comorbidities like muscular weakness, obesity, or surgery [2]. Herniae have the propensity of occurring at several body sites, and the frequently affected areas are the groin, diaphragm, linea alba, umbilicus, surgical incisions, and spieghel [2].

Globally, herniorrhaphy is the most commonly performed surgical procedure [3], with over twenty million hernia repairs performed each year [4]. Of this, abdominal wall hernia repair is among the most frequently performed surgical operations [5] and constitutes about 15% to 18% of all surgeries [4]. Currently, there is no known global prevalence for hernia [6], and the available data is sparse across different hernia types. For instance, although the exact prevalence of abdominal wall hernias remains elusive [5], inguinal hernia alone affects more than 220 million individuals worldwide and causes the death of more than 40,000 people due to hernia-associated sequelae [7]. This makes inguinal hernia the most frequently reported condition requiring surgical intervention worldwide [7–10]. In Africa, the rate of occurrence of inguinal hernias ranges from 60 to 175 cases per 100,000 people [4]. Also, in sub-Saharan Africa, the burden of hernia and resulting deaths is huge [11], and the prevalence could exceed 30% in some parts of Africa, whereas in Ghana, the prevalence of hernia is about 7.7% [3].

The impact of hernia is disproportionately high in sub-Saharan African countries [7], largely because they lack fundamental resources, including the capacity to diagnose; human resources [12], including surgeons [7], and other materials needed to effectively treat patients diagnosed with hernia. This may result in delays in treatment, and could further culminate in complications like strangulation, incarceration, and bowel obstruction in affected persons [4]. Therefore, early detection of a hernia could be useful to avert such complications. The effect of several diseases on haematologic indices has been studied worldwide, however, there is limited data on the effect of hernia on these diagnostic biomarkers, although they are readily available. Presently, only a few studies [13, 14] conducted in Turkey have determined the derangements in blood cell indices among hernia patients. For instance, the studies conducted by Peksöz et al. [13] and Akturk et al. [14] evaluated blood cell indices among patients with only complicated hernias, while no attention was accorded to patients with uncomplicated hernias. Therefore, the studies failed to provide information on the ability of the biomarkers to predict uncomplicated hernias. Additionally, the study by Peksöz et al. [13] focused on total white blood cells (WBC) and neutrophils with a complete disregard for the other differential complete blood count (CBC) indices. Conversely, Akturk et al. [14] evaluated blood cell markers in hernia patients with an emphasis on only RDW, the study was therefore limited by its inability to consider the CBC results in their entirety. Presently, in Ghana, there is no standard laboratory workup for patients with a hernia, therefore, the diagnostic value of these blood cell indices for hernia and its associated complications remains unknown.

In this study, we explored the patterns of hernia, haematological profile, and the predictive ability of blood cell indices in pre-surgery hernia patients. This sought to establish the usefulness of the CBC, a routine and easily accessible blood test, for clinically predicting hernia and its associated complications at the early stages of the disease.

2. Materials and Methods

2.1. Study Design/Study Site

This single-centre unmatched case-control study was conducted between August and December 2019 among pre-surgery hernia patients seeking healthcare at the Mankranso District Hospital, Ghana. The hospital is located at Mankranso, the capital town of Ahafo-Ano South-West district in the Ashanti Region, Ghana. Mankranso is geographically located at these coordinates: longitude 1°45'W 2°20'W and latitude 6°42'N 7°10'N.

The hospital is an 88-bed capacity facility that serves as the major referral hospital for inhabitants within the South-West and South-East districts of the Ahafo-Ano electoral constituency. It operates both outpatient and inpatient services which include: separate wards for paediatrics, males, females, psychiatric, and pregnant mothers. Also, the hospital offers surgeries, clinical laboratory, and medical imaging (x-ray and ultrasound scan) services, and special outpatient clinics for patients seeking antenatal care, antiretroviral therapy (ART), diabetes and hypertensive care, ophthalmic, and ear-nose-and-throat services.

2.2. Study Population

Figure 1 displays the selection and exclusion flow diagram of study subjects. Fifty-four subjects aged between 13 and 67 years were recruited into the study using non-randomized purposive sampling: 27 hernia cases and 27 healthy control subjects. The ratio of cases to controls was 1:1, and the cases were recruited from patients diagnosed with various forms of hernia while controls were selected from apparently healthy non-hernia subjects. All the hernia cases were diagnosed by a qualified physician following physical examinations and subsequent review of abdominal ultrasound scan reports. Criteria for recruiting cases into the study were based on confirmation of hernia in the subjects, whereas in the control group, there was no evidence of hernia on examination. In addition, both groups were screened for other infections like malaria, human immunodeficiency virus (HIV), viral hepatitis B and C, and haemoglobinopathies to rule out diseases which can cause confounding effects. Subjects with negative tests for all these tests were then included. However, subjects with positive tests or presenting with other forms of swellings like hydroceles were excluded with the aid of an ultrasound scan. Information on the type of hernia, presence of strangulation, age and gender were extracted from subjects' folders.

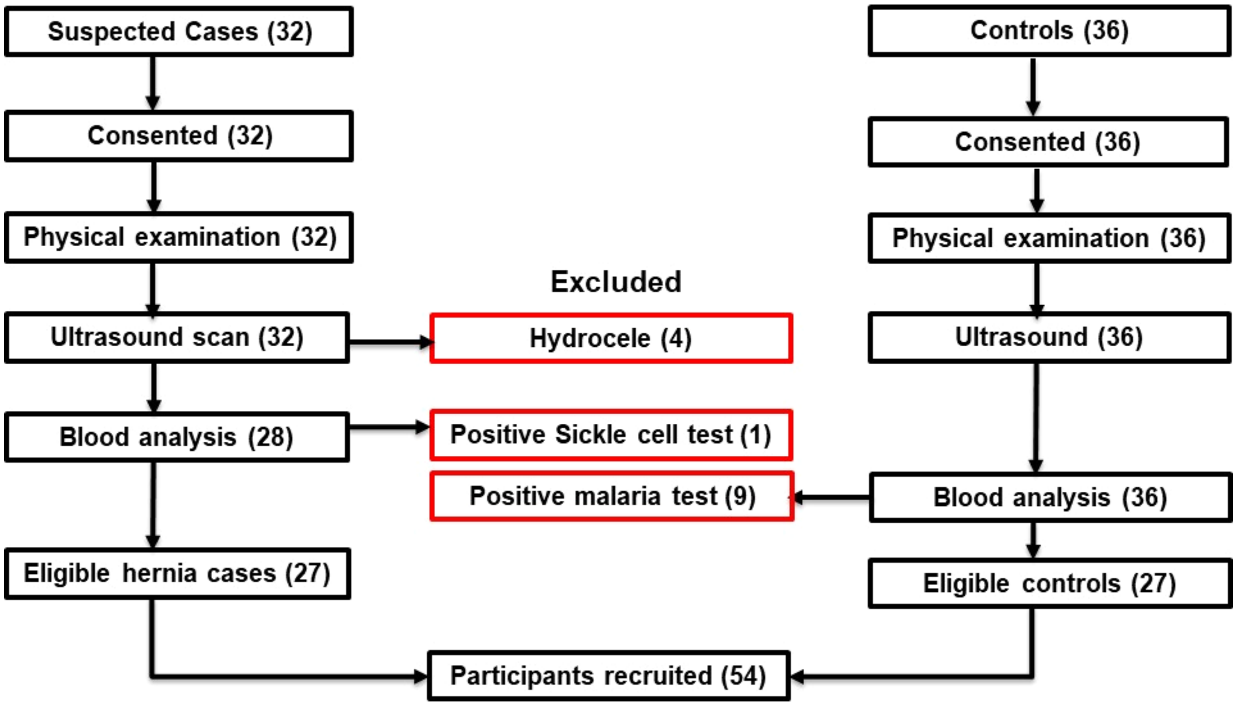

Figure 1. Flow chart of participant recruitment and exclusion at the Mankranso District Hospital, Ghana

2.3. Physical Examination and Ultrasound

The patients were palpated to see if there were a visible and palpable hernia, a palpable impulse, or a previous surgical scar. Prominently visible bulge herniae were detected by the use of visible lumps. The form of physical examination was solely dependent on the type of hernia, for instance, for a patient with a suspected inguinal hernia, a palpable hernia was identified if its neck was continuous with the inguinal canal or oriented rearward into the belly. Unless no apparent lump was seen, the scrotum was invaginated with the little finger to reach the external ring, and the individual was requested to cough to assess whether there was a palpable impulse.

Ultrasound evaluation on the patient was then performed using a 7MHz linear array transducer of a Toshiba Nemio XG SSA-580A Diagnostic Ultrasound machine (Toshiba Medical Systems Corporation, Japan). A patient with an inguinal hernia was laid in a supine position for the ultrasound. Using the pelvic vessels as landmarks, patients were asked to cough or perform a Valsalva manoeuvre for possible lump identification. With the location of the hernia identified, patients were again asked to cough and produce another Valsalva manoeuvre as the inguinal floors were being visualised to identify the spermatic cord movement and determine whether the hernia was direct or indirect. In males, sonographic assessment of indirect hernia included an evaluation of the scrotum to assess for inguinoscrotal hernia and to rule out hydrocele. In the case of epigastric hernia, scanning was done along the midline abdomen to determine anterior abdominal wall defect with or without omental fat herniation. In all cases of hernia, the compression technique was used to assess reducibility or evidence of tenderness which are associated with strangulation.

2.4. Blood Specimen Collection, Processing, and Analysis

Five millilitres of venous blood were drawn by venesection from all study subjects with tri-potassium ethylenediaminetetraacetic acid (K_3EDTA) anticoagulated vacutainer multi-sample blood collection tubes and needles (Venoject, Terumo Medical Corporation, Japan). Specimen from each subject was separated into 2 tubes: 3 mL in one tube and 2 mL in another. The blood specimen tubes were immediately labelled, inverted about 8 times, and placed on a blood tube roller mixer (Wincom KJMR-II, China) for 10 minutes to prevent the clotting of the blood. The 2 mL blood specimen was then spun at 3000 revolutions per minute for 5 minutes (HERMLE Z300K, Hermle LaborTechnik GmbH, Germany) and the plasma was used to test for HIV, and hepatitis B and C using rapid test kits. The other (3 mL) specimen was used to test for malaria parasites, sickle cells, and complete blood count (CBC). Details of each subject were logged into the ABX Micros ES60 automated three-part differential blood cell counter (Horiba ABX, France) which was then used to analyse each specimen for CBC indices. Parameters measured included indices of erythrocyte: haemoglobin (HgB), red blood cell (RBC), haematocrit (HCT), mean cell volume (MCV), red cell distribution width coefficient of variation (RDW-CV), mean cell haemoglobin (MCH), and mean cell haemoglobin concentration (MCHC); leucocyte: total white blood cell (TWBC), absolute granulocyte (Abs GRAN), absolute lymphocyte (Abs LYM), and absolute monocyte (Abs MON); and thrombocyte: platelet count (PLT), plateletcrit (PCT), mean platelet volume (MPV), and platelet distribution width (PDW).

2.5. Statistical Data Analysis

The data were entered into a Microsoft Excel spreadsheet, recoded and analysed using the IBM SPSS Statistics for Windows, Version 23.0 (Armonk, NY: IBM Corp.). The data were then visualised using both IBM SPSS Statistics and GraphPad Prism for Windows, Version 8.4.3 (GraphPad Software, San Diego, California USA). Test for normality of all continuous data was performed using the Shapiro-Wilk test. Age (in years), plateletcrit, total white blood cell, absolute granulocyte, red cell distribution width coefficient of variation, and absolute monocyte showed non-parametric distributions and were presented as medians (25^{th}-75^{th} percentiles). The Mann-Whitney U test was used to compare differences in age between hernia and control subjects. Age was further transformed into three groups using visual binning, whereas the biomarkers were grouped as either “Low”, “Normal”, or “High” using analyzer-specific reference limits. All other indices were normally distributed and presented as means and standard deviation (SD). Differences in proportions of two-by-two contingency data were determined using Fisher’s Exact test, whereas, for larger contingency data the Pearson Chi-square test was used. One-Way Analysis of Variance (ANOVA) with Tukey post hoc and Kruskal-Wallis tests with multiple pairwise comparisons were used to compare parametric and non-parametric distributions respectively, between strangulated and non-strangulated hernia and control groups. A receiver operating characteristic (ROC) curve was used to visualise the predictive accuracy of the biomarkers. P-values ≤0.05 were considered significant for all statistical analyses.

3. Results

3.1. Sociodemographic Characteristics of the Study Subjects

Table 1 presents the frequency and proportions of sociodemographic characteristics of study subjects stratified by healthy controls and hernia cases. Overall, the median age of the study subjects was 39.00 (21.75-54.00) years, with the median age significantly higher in the hernia cases than in controls (52.00 [37.00-56.00] vs 27.00 [20.00-42.00]; *p*=0.002). Of the 54 subjects recruited, the majority 66.7% (36) were males and 38.9% (21) were within the 27-52-year group. When stratified by hernia cases and controls, the hernia was more prevalent among subjects of ages ≥53 years (48.1% [13/27]) followed by (37.0% [10/27]) in the 27-52-year range, and 14.8% (4/27) in the ≤26-year group. However, in the controls, the majority (48.1% [13/27]) were ≤26 years and declined along with the groups 27-52 years to ≥53 years (40.7% [11/27] vs. 11.1% [3/27], respectively) (*p*=0.004). A vast majority (85.2% [23/27]) of the hernia cases were observed among the male population (*p*=0.008). The data showed a significant association between the occurrence of hernia and the sociodemographic variables, gender and age (Table 1).

Table 1. Sociodemographic characteristics of the subjects stratified by hernia and control groups, at the Mankranso Hospital, Ghana

Variables	Total (*n*=54)	Control (*n*=27)	Hernia (*n*=27)	*p*-value
Age (years)	**39.00 (21.75 - 54.00)**	**27.00 (20.00 - 42.00)**	**52.00 (37.00 - 56.00)**	**0.002**
Age group				**0.004**
≤26	17 (31.5)	13 (48.1)	4 (14.8)	
27-52	21 (38.9)	11 (40.7)	10 (37.0)	
≥53	16 (29.6)	3 (11.1)	13 (48.1)	
Gender				**0.008**
Male	36 (66.7)	13 (48.1)	23 (85.2)	
Female	18 (33.3)	14 (51.9)	4 (14.8)	

Age group and Gender are presented as frequencies with corresponding proportions in parentheses; Age (years) as Median with Interquartile ranges in parentheses; Pearson Chi-Square and Fisher’s Exact tests were used appropriately to compare proportions between control and hernia groups; Mann-Whitney U test was used to compare the distribution of Age (in years) between hernia and control groups; p≤0.05 was considered significant.

3.2. Frequency of Hernia and Associated Complications among the Study Subject

Figure 2 descriptively presents the frequency distribution of the type of hernia detected and also, the proportion of the hernias that were complicated (strangulated) in the subjects. Of the 27 hernia cases diagnosed, 92.59% (25) were inguinal, and 3.70% (1) each of epigastric hernia and uterine prolapse were recorded. Hundred per cent (23/23) of the male patients presented with inguinal hernia. In females, however, the inguinal hernia was observed in 50.0% (2/4) of patients, and epigastric hernia and uterine prolapse were detected in 25.0% (1/4) of each of the female patients. Concerning age, 100% (4/4) of patients between 0-26 years were diagnosed with inguinal hernia. Of the 10 patients aged 27-52 years, the inguinal hernia was present in 90.0% (9), and epigastric hernia in 10.0% (1). In the ≥53-year group inguinal hernia was present in 92.3% (12/13), and uterine prolapse in 7.7% (1/13) (p=0.590) (Figures 2-a to 2-c).

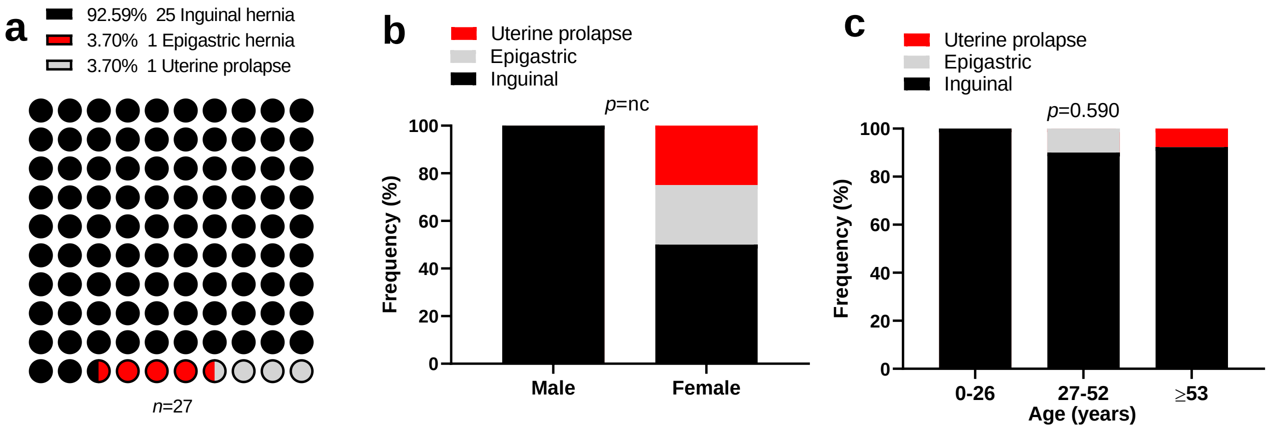

Figure 2. Frequency of the [a] various types of hernia, stratified by [b] gender and [c] age of the study subjects at Mankranso District Hospital, Ghana. ***Pearson Chi-Square and Fisher's Exact tests were used appropriately to compare the differences in proportions of clinical characteristics between gender and age groups; nc: Not computed; p≤0.05 was considered significant.***

Figure 3 shows the frequency of hernia-associated clinical complications among the study subjects stratified by the type of hernia, gender, and age. Of the 25 patients observed with inguinal hernia, the majority 68.0% (17) were strangulated and the remaining 32.0% (8) were non-strangulated hernia. However, for epigastric hernia, and uterine prolapse groups 100.0% (1/1) of non-strangulated forms of hernia were observed. The diagnosis of hernia complication (strangulated or non-strangulated) was not significantly associated with the type of hernia (p=0.159). Of the 23 male hernia patients studied, the majority 73.9% (17) presented with strangulation, and 26.1% (6) with a non-strangulated hernia. In females, however, 100.0% (4/4) of the hernia detected were of the non-strangulated type (p=0.012). Strangulation was detected in 75.0% (3/4), 70.0% (7/10), and 53.8% (7/13) of subjects aged between 0-26 years, 27-52 years, and ≥53 years, respectively (p=0.630) (Figures 3-a to 3-c).

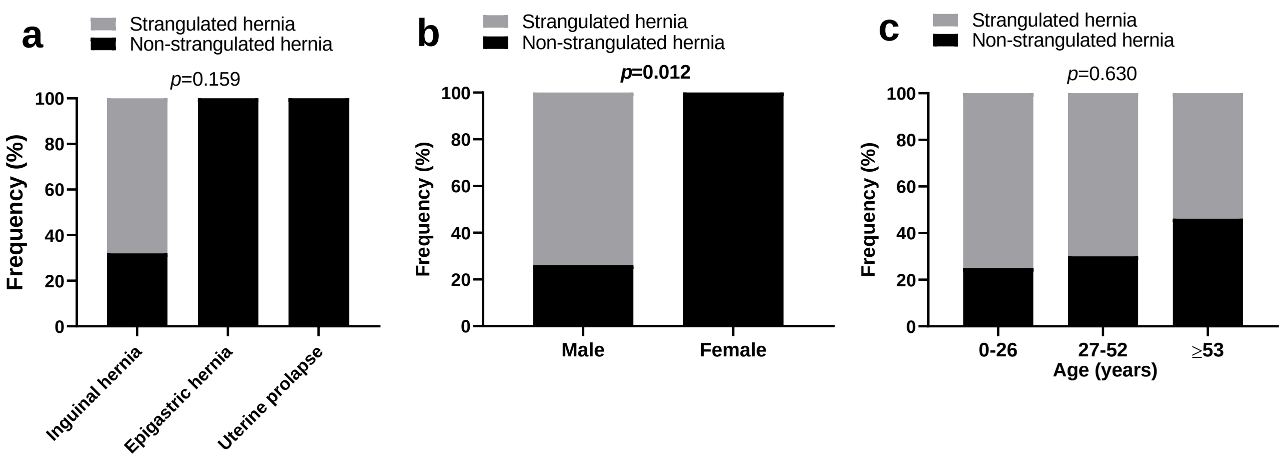

Figure 3. Frequency of hernia-associated clinical complications (strangulated and non-strangulated) stratified by [a] diagnosis, [b] gender, and [c] age group of the study subjects at Mankranso District Hospital, Ghana. ***Pearson Chi-Square and Fisher's exact tests were used appropriately to compare difference in proportions of clinical characteristics between gender and age groups; p≤0.05 was considered significant.***

3.3. Haematological Profile of the Study Subjects

Table 2 compares the mean and median haematological indices of strangulated and non-strangulated hernia groups with healthy controls. Mean HgB and MCHC values were significantly higher in the strangulated hernia group than in the non-strangulated hernia and control groups: HgB (13.65±1.68 vs. 12.68±1.97 vs. 11.89±1.60, p=0.006), and MCHC (31.62±1.41 vs. 31.41±1.03 vs. 29.03±0.96, $p\leq 0.001$). The difference in mean HgB was between the strangulated hernia and control groups, while the differences in mean MCHC were between strangulated hernia and controls, and also, between non-strangulated hernia and controls. The median RDW-CV was significantly increased in the strangulated hernia subjects than in the non-strangulated hernia and control groups, respectively (RDW-CV: 13.70 [13.40-14.20] vs. 13.65 [13.25-14.68] vs. 13.10 [12.20-13.80], p=0.042). However, the non-strangulated hernia subjects had significantly lower median Abs GRAN than the strangulated hernia and control groups, respectively (Abs GRAN: 2.95 [1.95-4.50] vs. 3.10 [2.40-3.65] vs. 4.30 [2.70-7.70]; p=0.024). The post-hoc analysis for both RDW-CV and Abs GRAN showed significant differences between strangulated hernia and control subjects, and also, between non-strangulated hernia and control subjects. However, the remaining blood cell indices (RBC, HCT, MCV, MCH, Abs LYM, PLT, MPV, PDW, PCT, TWBC, and Abs MON) did not significantly differ across the three groups (strangulated and non-strangulated hernia and controls) (Table 2).

Table 2. Haematological profile of participants stratified by hernia-associated complications (strangulated and non-strangulated) and control groups

Variables	Status of Hernia complication			*p*-value (Significant pairs)
	Strangulated [a] (*n*=17)	Non-strangulated [b] (*n*=10)	Healthy Control [c] (*n*=27)	
RBC ($10^6/\mu L$)	5.14 ± 0.82	4.72 ± 0.35	4.69 ± 0.62	0.079
HgB (g/dL)	13.65 ± 1.68	12.68 ± 1.97	11.89 ± 1.60	**0.006** (a & c)
HCT (%)	43.18 ± 4.97	40.31 ± 5.73	40.92 ± 5.46	0.299
MCV (fL)	84.94 ± 9.79	85.20 ± 8.22	87.44 ± 6.74	0.551
MCH (Pg)	26.93 ± 3.67	26.74 ± 2.81	25.46 ± 2.51	0.229
MCHC (g/dL)	31.62 ± 1.41	31.41 ± 1.03	29.03 ± 0.96	**≤0.001** (a & c, b & c)
Abs LYM ($10^3/\mu L$)	2.43 ± 0.93	2.20 ± 0.99	1.94 ± 0.87	0.233
PLT ($10^3/\mu L$)	261.80 ± 72.96	213.10 ± 71.87	252.10 ± 72.06	0.229
MPV (fL)	6.77 ± 0.69	7.02 ± 0.92	7.12 ± 0.81	0.367
PDW (fL)	13.76 ± 1.87	14.61 ± 1.75	15.10 ± 1.83	0.068
PCT (%)	0.18 (0.14 - 0.22)	0.15 (0.12 - 0.23)	0.18 (0.14 - 0.20)	0.850
TWBC ($10^3/\mu L$)	5.50 (4.60 - 7.60)	5.80 (4.50 - 6.70)	7.00 (5.80 - 10.70)	0.053
Abs GRAN ($10^3/\mu L$)	3.10 (2.40 - 3.65)	2.95 (1.95 - 4.50)	4.30 (2.70 - 7.70)	**0.024** (a & c, b & c)
RDW-CV (%)	13.70 (13.40 - 14.20)	13.65 (13.25 - 14.68)	13.10 (12.20 - 13.80)	**0.042** (a & c, b & c)
Abs MON ($10^3/\mu L$)	0.50 (0.40 - 0.70)	0.40 (0.28 - 0.70)	0.50 (0.40 - 0.70)	0.263

RBC: Red blood cell; HgB: Haemoglobin; HCT: Haematocrit; MCV: Mean cell volume; MCH: Mean cell haemoglobin; MCHC: Mean cell haemoglobin concentration; Abs LYM: Absolute lymphocyte; PLT: Platelet; MPV: Mean platelet volume; PDW: Platelet distribution width; PCT: Plateletcrit; TWBC: Total white blood cell; Abs GRAN: Absolute granulocyte; RDW-CV: Red cell distribution width coefficient of variation; Abs MON: Absolute monocyte; One-Way Analysis of Variance (ANOVA) with Tukey post hoc analysis and Kruskal-Wallis tests with multiple pairwise comparisons were used to compare parametric and non-parametric distributions respectively, between strangulated and non-strangulated hernia and control groups; $p\leq 0.05$ was considered significant.

3.4. Frequency of Derangements in Blood Cell Indices among the Study Subjects

Figure 4 displays frequencies of derangements in blood cell indices among hernia cases compared with healthy controls. An increased proportion of the controls than hernia cases had erythrocytopenia (44.4% [12/27] vs. 29.6% [8/27], p=0.355); anaemia (70.4% [19/27] vs. 33.3% [9/27], p=0.013); low red cell mass (55.6% [15/27] vs. 33.3% [9/27], p=0.170), low red cell haemoglobinization (70.4% [14/27] vs. 51.9% [14/27], p=0.278); and low MCHC (100.0% [27/27] vs. 63.0% [17/27], p=0.001). The proportions of subjects that showed anaemia and low MCHC were significantly different for cases and controls. In both controls and cases, respectively the following indices were mostly normal: abs MON (100.0% [27/27] vs. 100.0% [27/27]); RDW-CV (96.3% [26/27] vs. 96.3% [26/27], p=1.000); and abs LYM (88.9% [24/27] vs. 100.0% [27/27], p=0.236).

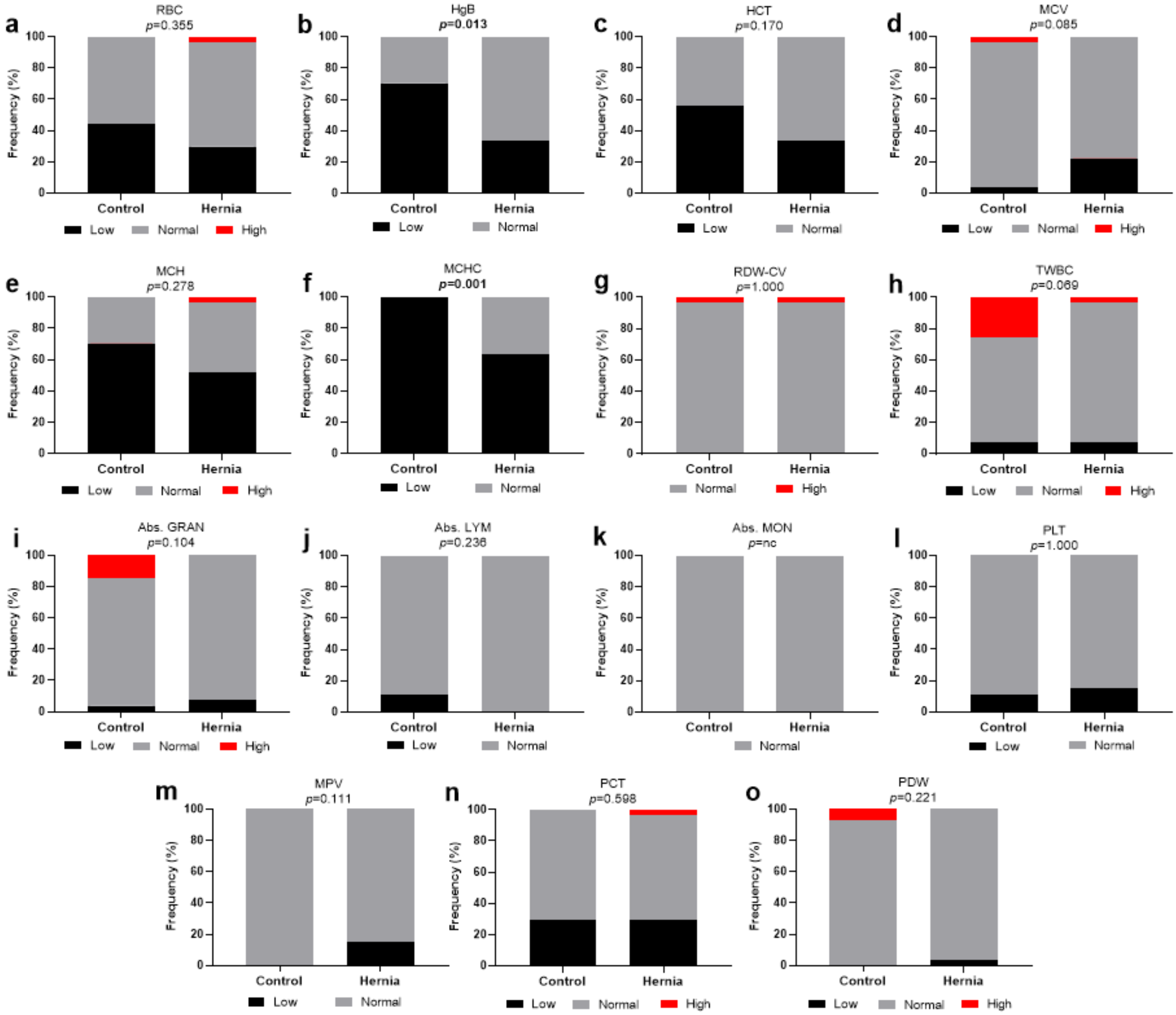

Figure 4. Frequency of derangements in blood cell indices among the study subjects at Mankranso District Hospital, Ghana stratified by control and hernia groups. ***Pearson Chi-Square and Fisher's Exact tests were used appropriately to compare the difference in proportions between control and hernia groups; (a) RBC: Red blood cell, 4.50-6.50 ×10^6/µL; (b) HgB: Haemoglobin, M=13-17, F=12-16g/dL; (c) HCT: Haematocrit, 40.0-54.0%; (d) MCV: Mean cell volume, 80-100fL; (e) MCH: Mean cell haemoglobin, 27-32Pg; (f) MCHC: Mean cell haemoglobin concentration, 32.0-36.0g/dL; (g) RDW: Red cell distribution width, 11.0-16.0%; (h) TWBC: Total white blood cell, 4.0-10.0 ×10^3/µL; (i) Abs GRAN: Absolute granulocyte, 2.00-9.00 ×10^3/µL; (j) Abs LYM: Absolute lymphocyte, 1.00-5.00 ×10^3/µL; (k) Abs MON: Absolute monocyte, 0.20-1.50 ×10^3/µL; (l) PLT: Platelet, 150-500 ×10^3/µL; (m) MPV: Mean platelet volume, 6.0-110fL; (n) PCT: Plateletcrit, 0.150-0.500%; (o) PDW: Platelet distribution width, 11.0-18.0%; nc: Not computed; p≤0.05 was considered significant.***

An increased proportion of the controls than hernia cases showed leucocytosis (25.9% [7/27] vs. 3.7% [1/27], *p*=0.069). An increased percentage of the hernia cases than controls had granulocytopenia (7.4% [2/27] vs. 3.7% [1/27], *p*=0.104), thrombocytopenia (14.8% [4/27] vs. 11.1% [3/27], *p*=1.000) and microcytosis (22.2% [6/27] vs. 3.7% [1/27], *p*=0.085). A greater proportion of the cases than controls showed low MPV (14.8% [4/27] vs. 0.0% [0/27], *p*=0.111) and PCT (3.7% [1/27] vs. 0.0% [0/27], *p*=0.598). In both hernia cases and controls, PDW was mostly normal with (3.7% [1/27]) of cases showing low values, whereas in the controls (7.4% [2/27], *p*=0.221) showed high values, although not significant (Figures 4-a to 4-o).

3.5. Predictive Ability of Blood Cell Indices and Age among the Study Subjects

Figure 5 displays the ability of blood cell indices and age to predict the occurrence of hernia and strangulation. The blood cell parameter, MCHC (AUC=0.947 [0.895-0.999], *p*≤0.001) was the most sensitive predictor for herniation, followed by age (AUC=0.750 [0.610-0.889], *p*=0.002); HgB (AUC=0.718 [0.580-0.857], *p*=0.006); and RDW-CV (AUC=0.700 [0.559-0.840], *p*=0.012) (Figure 5). Also, MCHC (AUC=0.831 [0.723-0.938], *p*≤0.001); HgB (AUC=0.738 [0.590-0.887], *p*=0.005); and RBC (AUC=0.671 [0.502-0.840], *p*=0.045) respectively, were significant predictors of strangulation in the hernia subjects (Figure 6).

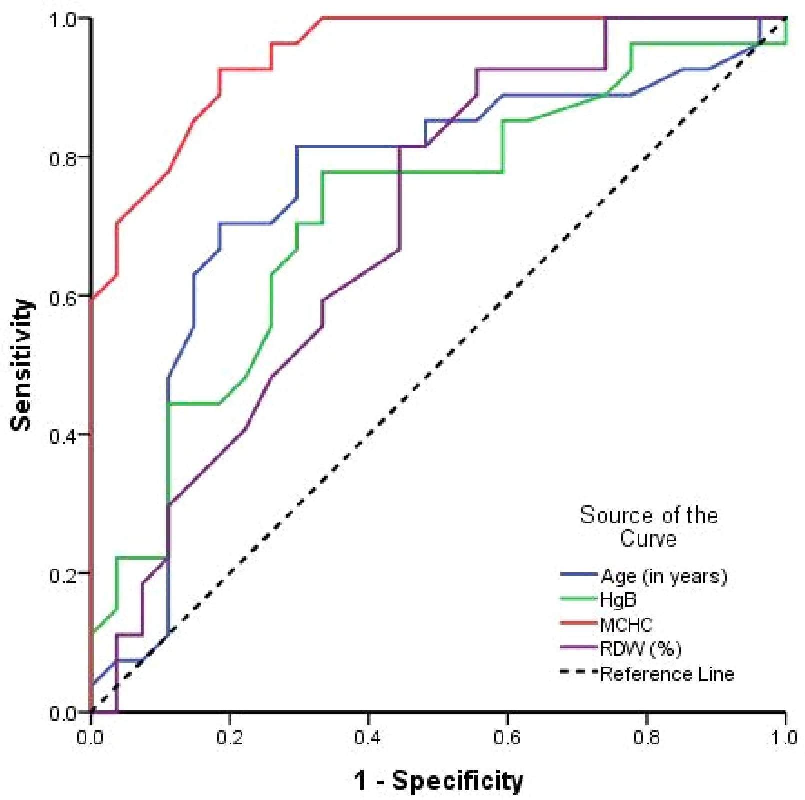

Figure 5. Predictive accuracy of blood cell indices and age for the occurrence of hernia. ***A receiver operating curve (ROC) with an area under a curve (AUC) was used to determine the predictive accuracy of blood cell indices for hernia and strangulation. HgB: Haemoglobin; MCHC: Mean cell haemoglobin concentration; RBC: Red blood cell; RDW: Red cell distribution width. p≤0.05 was considered significant.***

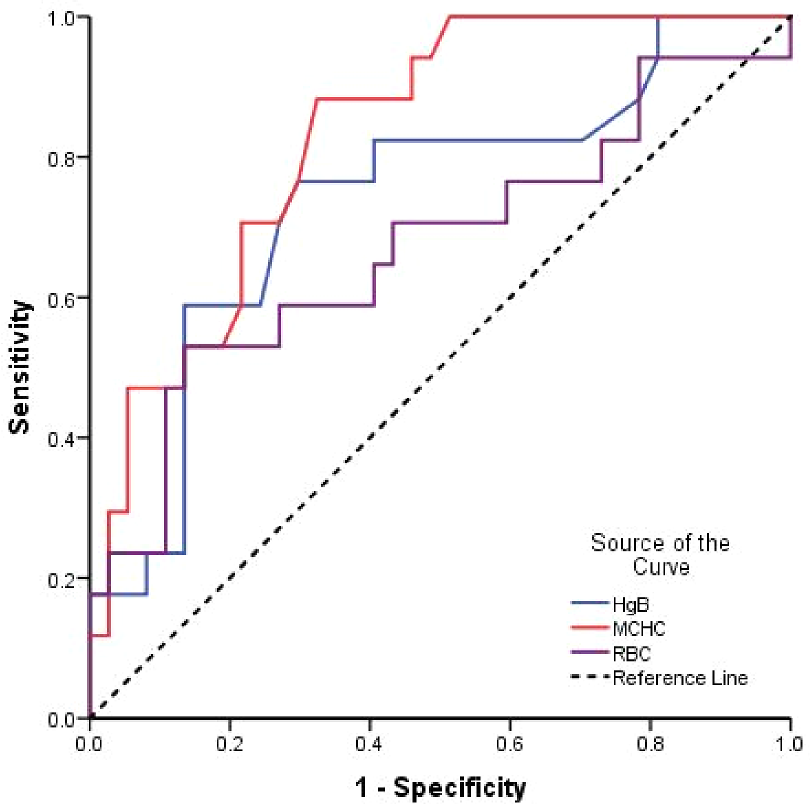

Figure 6. Predictive accuracy of blood cell indices for the occurrence of strangulation in hernia. ***A receiver operating curve (ROC) with an area under a curve (AUC) was used to determine the predictive accuracy of blood cell indices for strangulation. HgB: Haemoglobin; MCHC: Mean cell haemoglobin concentration; RBC: Red blood cell; p≤0.05 was considered significant.***

4. Discussions

This hospital-based case-control study determined the patterns of hernia and the usefulness of routine haematological indices in predicting herniation and strangulation in pre-surgery patients in a district hospital in Ghana. Our findings show that hernia was more prevalent (48.1%) among older subjects of ages ≥53 years and its occurrence significantly increased with increasing age. This was consistent with other works of literature that suggest similar trends in other forms of hernia [15]. To further buttress this age-associated vulnerability to hernia, our study showed an increased proportion (37.0%) of hernia subjects in the prime ages of 27–52 years, which corroborates the findings of a study conducted in Ashanti Region, Ghana, which reported an increased prevalence (35.4%) of hernia in adults [16]. The variation in disease burden in the two studies could be due to differences in study design; unlike the study by Ohene-Yeboah et al. [16], ours was hospital-based and had a case-control design. Again, this finding was consistent with a similar study conducted by Ashindoitiang et al. [17] in which the highest burden of hernia was among older subjects and attributes this phenomenon to ageing-associated wasting of muscles which tends to facilitate the development of a hernia. It is worth noting that both the studies by Ohene-Yeboah et al. [16] and Ashindoitiang et al. [17] involved only male subjects presenting with inguinal hernia, unlike the present study, which involved both gender and different types of herniae.

The burden of hernia in males was enormous compared to that in females in the present study. This observation suggests an increased male susceptibility to hernia, by a male: female ratio of 5.8:1 which is similar to a study conducted in Nigeria [18]. Also, this finding was consistent with the findings of a study conducted in Russia which reported among other factors, age and male gender as risk factors for developing hernia [6]. This gender-associated difference in the overall hernia prevalence may be ascribed to the increased involvement of males in more strenuous activities like farming, whereas females in most rural districts like the current study setting are responsible for household chores [19].

Our study also revealed a significantly increased burden of inguinal hernia among the cases, which is consistent with existing literature that suggests inguinal hernia is the predominant type of abdominal wall hernia [20]. The increased occurrence of inguinal hernia is ascribed to the altered architecture of the abdominal wall in humans, which may have resulted from evolutionary changes [21]. Also, the inguinal hernia was more common in males, which is consistent with a previous study conducted by Tigabie et al. [22] in Ethiopia. A strenuous task like weightlifting raises the pressure within the intra-abdominal region, which then weakens and causes damage to the transversalis fascia and subsequently predisposes to inguinal hernia [17]. Males are more likely than females to engage in such strenuous tasks, and this may explain the increased frequency of inguinal hernia among male subjects in this study. The damage to the transversalis fascia in inguinal hernia patients is ascribed to an elevated amount of matrix metalloproteinases that promote the breakdown of collagen [17]. Also, gender-specific conditions like hyperplasia of the prostate gland in males increase intra-abdominal pressure and predispose them to an increased risk of inguinal hernia [23]. This finding corroborates earlier literature [16] that suggests inguinal hernia is prevalent in males resident in rural settings in Ghana and some regions of sub-Saharan Africa.

Furthermore, inguinal hernia showed a consistently increasing pattern with ageing and is consistent with a previous study conducted in Ghana [16] and another from elsewhere [24]. However, our result is in contrast with a previous study from a developed country where children younger than 15 years bear the brunt of inguinal hernia [25], although this age-related susceptibility is not well understood.

The cases of strangulated hernia were predominantly of the inguinal type (68.0%), with peak incidence observed among males (73.9%) and subjects in the 0-26-year range (75.0%). In many rural communities in Ghana, men serve as the sole providers for their families, and the knowledge of them not being able to work for some time causes them to delay seeking surgical interventions for a hernia. Consequently, such delays may result in complications like strangulation and bowel obstructions. To further buttress the preponderance of strangulated hernia, a study conducted by Ohene-Yeboah and Dally [26] revealed 50.5% of inguinal hernia repairs at the Komfo Anokye Teaching Hospital in the same region of Ghana to be of the strangulated type.

The current study revealed significant variations in some erythrocyte- and leucocyte indices across the groups of participants studied. In particular, among the erythrocyte indices, we observed significantly increased HgB, MCHC, and RDW-CV in the hernia subjects, and these markers were higher in those with strangulation than in non-strangulated hernia and control groups. The increased HgB levels in the hernia groups in this study are similar to those reported in a prospective study by Panzuto et al. [27] in Italy. The high RDW-CV in the strangulated group is consistent with the findings of Akturk et al. [14], which reported high RDW among patients with strangulated hernia indicating its usefulness in identifying strangulation among patients who may require urgent surgical remedy. The RDW provides information on erythrocyte anisocytosis, and its elevation suggests an impaired synthesis of erythrocytes, which may be observed in haemoglobinopathies and some nutritional deficiencies (like iron-, cobalamin-, or folate deficiency), increased haemolysis, or following haemotransfusion [28]. Also, the variation in the size of erythrocytes could be due to pro-inflammatory cytokines that impede the maturation of erythrocytes by erythropoietin [8, 20]. The suggested anisocytosis, therefore, may have resulted from the inflammation-mediated discharge of the immature erythrocytes into circulation [14]. This could also account for the increased RBC, although not significant, and HgB among the cases. Furthermore, although HCT and RBC levels did not significantly vary across the groups, both were increased among strangulated hernia patients, which together with the significantly increased levels of HgB, and MCHC may suggest haemoconcentration that may have resulted from strangulation. In addition, a hernia forms a bulge on the muscles of the abdominal wall, and this puts pressure on the related blood vessels, which can disrupt normal blood circulation and culminate in ischaemia in the affected tissue [29]. This ischemic stress could be the cause of the increased erythrocyte indices, as a result of compensating for reduced oxygenation in the strangulated tissue.

Microcytosis was increased (22.2%) on blood analysis among subjects with a hernia, which agrees with a study by Kimer et al. [30] that attributed the suggested microcytosis in other forms of hernia to chronic blood loss. However, the study by Kimer et al. [30] was a case report involving only two subjects with Cameron lesions, which are common complications of large hiatal hernia and a known cause of chronic blood loss with resultant microcytosis. Also, thrombocytopenia was frequent (14.8%) in the hernia population, although no significant association was found. This could be attributed to the increased strangulation and subsequent compression of blood vessels, which reduces the rheology of blood through the lumen of the vessels and may cause platelets to activate by interacting with the endothelial wall.

Among the biomarkers studied, only the erythrocyte indices showed significant predictive accuracy for the occurrence of hernia and strangulation. The MCHC, age, HgB, and RDW were sensitive biomarkers for predicting the occurrence of hernia, while strangulation in hernia was predicted with the MCHC, HgB, and RBC. Our findings are consistent with an earlier study that reported elevated RDW as a strong predictive marker of mortality for patients seeking angiography [28].

The present study, however, had some limitations. Firstly, it could not afford to estimate serum electrolytes to determine hydration status, and secondly, the collagen disturbance/degradation was not assessed.

5. Conclusion

Our findings suggest that gender and age were significant determinants of hernia, with males and elderly patients more susceptible to hernia. Inguinal hernia and strangulation were common in the study setting, with increased susceptibility of males and patients in the ≤20-year group to both inguinal- and strangulated hernias. In addition, strangulation was frequent among patients with inguinal hernia, but not epigastric hernia and uterine prolapse. Furthermore, whereas this study showed the existence of significant variations in some erythrocyte- and leucocyte indices, platelet indices did not significantly differ across the three groups. Haemoglobin, MCHC, RDW-CV, and Abs GRAN were significantly increased in strangulated than non-strangulated hernia patients, but not platelet indices. Again, although significant derangements in HgB and MCHC were observed, they were not remarkable in the patient group. Overall, the erythrocyte indices were better predictive biomarkers for both hernia and strangulation, with MCHC showing the highest sensitivity for both herniation and strangulation. The sensitivity of the predictive indices for hernia increased in the following order: RDW<HgB<Age<MCHC, while that of strangulation increased in the order: RBC<HgB<MCHC. Therefore, a complete blood count is a useful predictive assay for the early detection of herniation and strangulation. We recommend that CBC should be incorporated into the routine workup for pre-surgery hernia patients in limited-resource settings.

6. Declarations

6.1. Author Contributions

Conceptualization, F.O-B., Y.A.W., C.N., D.S., and O.A-M.; methodology, F.O-B., Y.A.W., and D.S.; software, F.O-B.; validation, F.O-B., and Y.A.W.; formal analysis, F.O-B.; investigation, F.O-B., A-R.S., and A.G.; resources, F.O-B.; data curation, F.O-B., S.K.A, and K.M.; writing—original draft preparation, F.O-B., Y.A.W., D.S., C.N., O.A-M., and P.A.; writing—review and editing, F.O-B., D.S., C.N., C.A.D., R.D-T., R.V.D., and L.N.A.; visualization, F.O-B.; supervision, O.A-M., and F.O-B.; project administration, F.O-B.; funding acquisition, F.O-B. All authors have read and agreed to the published version of the manuscript.

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6.4. Ethical Approval

All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted following the Declaration of Helsinki, and the protocol was approved by the Committee on Human Research, Publication and Ethics of the Kwame Nkrumah University of Science and Technology (Reference: CHRPE/AP/320/22). Also, permission was sought from the management of Mankranso District Hospital. Subjects ≥18 years agreed by appending a thumbprint or signature on a consent form while parents/guardians consented on behalf of underaged (<18 years) subjects after the aim of the study was explained to them.

6.5. Data Availability Statement

The data presented in this study are openly available in the Havard Dataverse repository at https://doi.org/10.7910/DVN/QVKALE.

6.6. Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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