Patterns of hernia, haematological profile, and predictive ability of blood cell indices in pre-surgery patients; A case-control study in a district hospital 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. This study explored the patterns of hernia, haematological profile, and predictive ability of blood cell indices.

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 3.7% each of 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 ($p = 0.042$) were significantly elevated in strangulated than non-strangulated hernia and controls, while Abs GRAN ($p = 0.024$) was decreased in non-strangulated than strangulated hernia and controls. MCHC (AUC = 0.947 [0.895–0.999], $p \leq 0.001$) was the most sensitive predictor of 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 hernia. Inguinal hernia and strangulation were common in the study setting, especially, among males. Also, there were significant variations in erythrocyte- and leucocyte indices among hernia patients. Erythrocyte indices were significant predictive biomarkers for hernia and strangulation. CBC is a useful test for early detection of herniation and strangulation.

Introduction

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 if left untreated. The aetiology of hernia may be inherited due to the incapacity of some structures to close following delivery, or acquired due to 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 abdominal herniae among the frequently performed in standard operations [4]. However, available literature suggests that there exist no known global prevalence for hernia [5], and data on hernia is sparse across various types. Although, the exact burden of abdominal wall herniae remain elusive [4] that of groin hernia is estimated at 3.9%-18.3% [5]. In Africa, the rate of occurrence of inguinal hernia ranges from 60 to 175 cases for every 100,000 people [3]. Also, in sub-Saharan Africa, the burden of hernia cases and their resulting death

is huge [6] with prevalence ranging from 16% and exceeding 30% in some parts of Tanzania and 7.7% in Ghana [3].

The brunt of hernia disease is disproportionately higher in low-to-middle income economies, largely because they are bereft of fundamental resources including the capacity to diagnose, human resources, and other materials [7] needed to effectively manage cases. Such situations may cause difficulty and delays in treatment, and could further culminate in complications like strangulation, incarceration, and bowel obstruction in affected persons. The impact of several disease states on haematological indices have been studied worldwide, however, to the best of our knowledge there exists a dearth of literature on the effect of hernia on these diagnostic indices, although they are routinely and readily available. Although Akturk *et al.*,[8] evaluated blood cell markers in hernia patients with emphasis on only RDW, the study was limited by their inability to consider the complete blood count (CBC) in its entirety.

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

Methodology

Study design and setting

This single-centre unmatched case-control study was conducted between August and December 2019 among pre-surgery hernia patients seeking healthcare at the Mankranso Government Hospital. Mankranso Hospital has 88 inpatient bed capacity and serves inhabitants of the Ahafo-Ano South district in the Ashanti Region, Ghana. It provides outpatient and inpatient services. The hospital offers surgeries, laboratory, and medical imaging services, and special outpatient clinics for patients seeking antenatal care, antiretroviral therapy (ART), diabetes and hypertensive care, ophthalmic, and ear-nose-and-throat services. Also, it has separate wards for paediatrics, males, females, psychiatric, and pregnant mothers.

Study population

Fifty-four participants aged between 13 and 67 years were recruited into the study using non-randomized purposive sampling: 27 hernia cases and 27 healthy controls. The cases were recruited from patients diagnosed with hernia while controls were selected from healthy non-hernia participants. Hernia cases were diagnosed by a qualified physician following physical examinations and subsequent review of abdominal ultrasound reports. Criteria for recruiting cases were based on confirmation of hernia, while there was no evidence of hernia in the controls. All participants were screened for malaria, human immunodeficiency virus (HIV), viral hepatitis B and C, and haemoglobinopathies to rule-out diseases which can cause confounding effects. Participants with negative tests for these diseases were included, while, those with positive tests or presenting with other forms of swellings like hydroceles were excluded. Information on hernia type, presence of strangulation, age, and gender were extracted from participants' folders.

Physical examination and Ultrasound

The patients were palpated to see if there were visible and palpable hernia, a palpable impulse, or 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 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 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.

Blood specimen collection, processing and analysis

Five millilitres of venous blood was drawn by venesection from all participants with tri-potassium ethylenediaminetetraacetic acid (K_3EDTA) anticoagulated 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 clotting of the blood. The 2 mL blood specimen was then span at 3000 revolutions per minute for 5 minutes (HERMLE Z300K, Hermle LaborTechnik GmhH, Germany) and the plasma was used to test for HIV, and hepatitis B and C using rapid test kits. The 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).

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 (25th -75th 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 markers. P-values ≤ 0.05 were considered significant for all statistical analyses.

Results

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 years (21.75-54.00), with median age significantly higher in the hernia cases than controls (52.00 [37.00–56.00] vs 27.00 [20.00–42.00]; $p = 0.002$). Of the 54 subjects, the majority 66.7% (36) were males and 38.9% (21) were within the 27-52-year group. Of the 27 hernia cases, 85.2% (23) were males, 48.1% (13) were $\geq$ 53 years of age, whereas, majority (51.9% [14/27]) of the controls were females and 48.1% (13/27) were $\leq$ 26 years. Hernia was significantly associated with gender and age ($p = 0.008$ and $p = 0.004$, respectively) (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 distribution of Age (in years) between hernia and control groups; $p \leq 0.05$ was considered significant.

INSERT Table 1

Frequency of hernia and associated-strangulation among the participants

Figure 1 presents the frequency of hernia types detected and hernias-associated strangulation. Of the 27 hernia cases, 92.59% (25) were inguinal, and 3.7% (1) each of epigastric hernia and uterine prolapse were diagnosed. Hundred per cent (23/23) of the male patients presented with inguinal hernia. However, of the 4 female hernia cases, inguinal hernia was present in 50.0% (2), epigastric hernia in 25.0% (1) and uterine prolapse in 25.0% (1). All patients ≤ 26 years had inguinal hernia. Ninety per cent (9/10) of patients in the 27-52-year range had inguinal hernia, and 10.0% (1/10) epigastric hernia. In the ≥ 53-year group inguinal hernia was present in 92.3% (12/13), and uterine prolapse in 7.7% (1/13) ($p = 0.590$) (Fig. 1).

INSERT FIGURE 1

Figure 2 shows the frequency of hernia-associated strangulation among the participants stratified by hernia type, gender, and age. Of the 25 inguinal hernia cases, 68.0% (17) were strangulated, while the remaining 32.0% (8) were non-strangulated. However, 100.0% (1/1) each of epigastric hernia, and uterine prolapse were non-strangulated. The frequency of strangulation had no significant association with

hernia type ($p = 0.159$). The majority (73.9% [17]) of hernia in males were strangulated, while 100.0% (4/4) of the hernia in females were non-strangulated. Strangulation was significantly associated with gender ($p = 0.012$), and age ($p = 0.630$) (Fig. 2).

INSERT FIGURE 2

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 were significantly increased in the strangulated than in the non-strangulated hernia and controls ($p = 0.006$ and $p \leq 0.001$, respectively). Post hoc anlysis showed differences in mean HgB between strangulated hernia and controls (13.65 ± 1.68 vs 11.89 ± 1.60), while the mean MCHC differed between strangulated hernia and controls (31.62 ± 1.41 vs 29.03 ± 0.96), and between non-strangulated hernia and controls (31.41 ± 1.03 vs 29.03 ± 0.96). The median RDW-CV was significantly increased in strangulated than in the non-strangulated hernia and controls ($p = 0.042$). The difference in RDW-CV was between strangulated hernia and controls (13.70 [13.40–14.20] vs 13.10 (12.20–13.80), and between non-strangulated and controls (13.65 [13.25–14.68] vs 13.10 (12.20–13.80). However, for Abs GRAN, the non-strangulated group had significantly reduced medians than the strangulated hernia and controls ($p = 0.024$). The difference in Abs GRAN was between strangulated hernia and controls (3.10 [2.40–3.65] vs 4.30 [2.70–7.70]), and between non-strangulated hernia and controls (2.95 [1.95–4.50] vs 4.30 [2.70–7.70]) (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/μL)	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/μL)	2.43 ± 0.93	2.20 ± 0.99	1.94 ± 0.87	0.233
PLT (10^3/μL)	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/μL)	5.50 (4.60–7.60)	5.80 (4.50–6.70)	7.00 (5.80–10.70)	0.053
Abs GRAN (10^3/μL)	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/μL)	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 comparison 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.

INSERT Table 2

Predictive ability of blood cell indices and age among the study subjects

Figure 3 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], $p \leq 0.001$) 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 in the hernia subjects (Fig. 3).

INSERT FIGURE 3

Discussion

This hospital-based case-control study determined the patterns of hernia, haematological profile, and predictive ability of blood cell indices. This aimed to determine the usefulness of CBC, a routine haematological assay in predicting herniation and strangulation in pre-surgery patients in a district hospital in Ghana. Our findings showed that hernia was prevalent (48.1%) among older subjects ≥ 53 years of age and its occurrence significantly increased with increasing age. These findings corroborate the findings of a similar study conducted by Ashindoitiang *et al.*, [9] in which the highest burden of hernia was among older subjects, and they attributed this phenomenon to ageing-associated wasting of muscles which tend to facilitate the development of the hernia. This was consistent with other literature that suggest similar patterns in other forms of hernia [10].

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 6:1 which is similar to a study conducted in Nigeria [11]. Also, this finding is 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 [5]. This gender-associated difference in the overall hernia prevalence may be ascribed to increased involvement of males in more strenuous activities [2][12] like farming, whereas, females in most rural districts like the current study setting are responsible for less difficult routine household chores [12].

Furthermore, this study revealed a significantly increased burden of inguinal hernia among the cases and is consistent with existing literature that suggests inguinal hernia as the predominant type of abdominal wall hernia [13]. 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 [14]. Inguinal hernia was more common in males, which is consistent with findings of another study [15] that suggests a high

lifetime risk of inguinal hernia repair among males than females. Also, Ohene-Yeboah *et al*., [16] suggest that inguinal hernia is prevalent among males residing in some regions of sub-Saharan Africa and in Ghanaian rural settings where males are more likely to engage in activities that increase the pressure within the intra-abdominal region [9]. This increased abdominal pressure and its associated outcome may also result from gender-specific conditions like hyperplasia of the prostate gland in males [15]. Consequently, this weakens and cause damage to the transversalis fascia, and predisposes more males to inguinal hernia [9]. Furthrmore, damage to the transversalis fascia in inguinal hernia patients could also be ascribed to elevated amount of matrix metalloproteinases that promote the breakdown of collagen [9].

Also, inguinal hernia consistently increased with increasing age, which is consistent with a study conducted in Ghana [16]. However, our result is in contrast with another study from a developed country where children younger than 15 years were the most affected with inguinal hernia [17], and this young age-related susceptibility is not well elucidated.

The cases of strangulated hernia were predominantly (68.0%) of the inguinal type with peak incidence observed among males (73.9%) and subjects ≤ 26 years of age (75.0%). Similarly, a study conducted by Ohene-Yeboah and Dally [18] 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. In many rural communities in Ghana, men serve as sole providers for their families, and the knowledge of them not being able to work for some time cause them to delay in seeking surgical interventions to hernia. Consequently, such delays may result in complications like strangulation and bowel obstructions. To further buttress this assertion, Beltran *et al*., [19] suggest a relationship between the occurrence of stranlgulation and the time of manifestation of hernia to admission and surgery.

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 non-strangulated hernia and control groups. The increased HgB levels in the hernia groups in this study are similar to that reported in a prospective study by Panzuto *et al*., [20] in Italy. The increased RDW-CV in the strangulated group is consistent with findings of Akturk *et al*., [8] 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 ineffective synthesis of erythrocytes which may be observed in haemoglobinopathies and some nutritional deficiencies (like iron-, cobalamin- or folate deficiency), increased haemolysis or following haemotransfusion [21]. Also, the variation in the size of erythrocytes could be due to pro-inflammatory cytokines which impede the maturation of erythrocytes by erythropoietin [8,20]. The suggested anisocytosis, therefore, may have resulted from inflammation-mediated discharge of the immature erythrocytes into circulation [8]. 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, the formation of hernia on the muscles of the abdominal wall puts pressure on the associateted blood vessels, which can disrupt normal blood circulation and culminate in ischaemia in the affected tissue [19]. This ischemic stress could be the cause of the increased erythrocyte indices, as a result of compensation for reduced oxygenation in the strangulated tissue.

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 MCHC, HgB, and RBC. However, the reason for this is not well understood.

The present study, however, had some limitations. Firstly, it could not afford to estimate neutrophil-to-lymphocyte ratio (NLR) which is considered a biomarker for predicting the severity of adult strangulated inguinal hernia. Secondly, serum electrolytes to determine hydration status, and thirdly, collagen levels to assess connective tissue disturbance was not determined.

Conclusion

Our findings suggest that gender and age are significant determinants of hernia. Inguinal hernia and strangulation were common in the study setting, with increased susceptibility of the male gender. Furthermore, there exist significant variations in some erythrocyte- and leucocyte indices among hernia patients. The erythrocyte indices are better predictive biomarkers for both hernia and strangulation. Complete blood count, therefore, is a useful predictive tool for the early detection of herniation and strangulation. We recommend further studies on this baseline data to help elucidate the predictability of hernia using blood cell indices.

Declarations

Ethics

The study was approved by the Committee on Human Research, Publication and Ethics (CHRPE) of the Kwame Nkrumah University of Science and Technology (Reference: CHRPE/AP/320/22). Also, permission was sought from the Mankranso Hospital. Consent was obtained from all subjects and parents/guardians in the case of under aged subjects (<18 years) after the aim of the study was explained to them.

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Conflict of interest

The authors declare that no conflict of interest exist regarding the publication of this manuscript.

Author Contributions Statement

Author FO-B, YAW, and CN conceived and designed the study. Authors FO-B, YAW, DS, RD-T, RVD, SKA, and LNA wrote the protocol. Authors FO-B, A-RS, and AG collected the data. FO-B analysed, interpreted and visualized the data. FO-B, YAW, DS, OA-M, PA, CAD, and KM wrote the first draft of the manuscript. All authors critically reviewed, revised and approved the final manuscript.

Data availability

The dataset supporting the current study has been deposited in the Havard dataverse repository and available at https://doi.org/10.7910/DVN/QVKALE.

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Figures

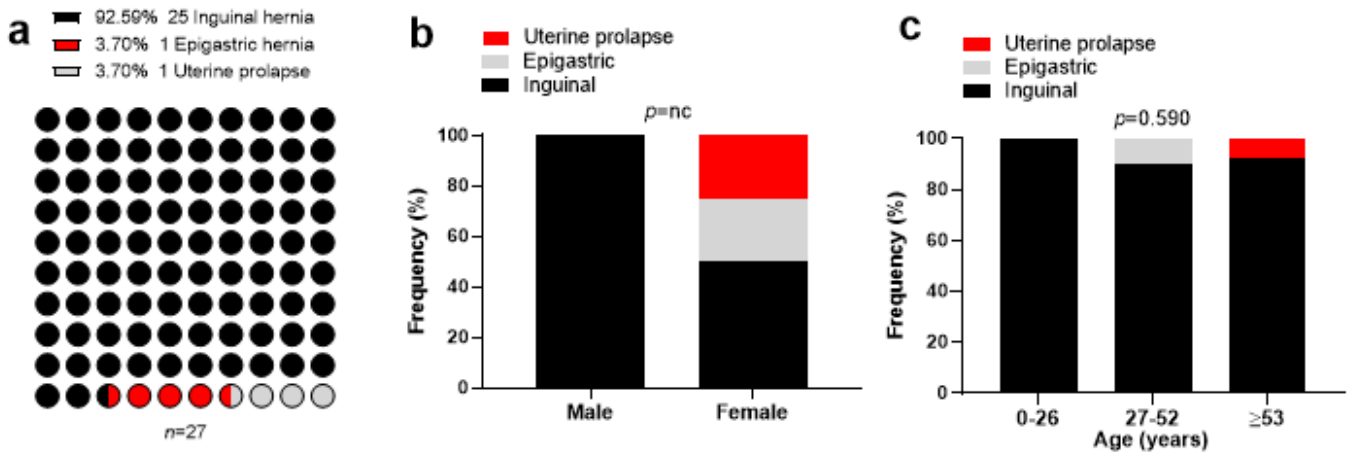

Figure 1

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; $p \leq 0.05$ was considered significant.

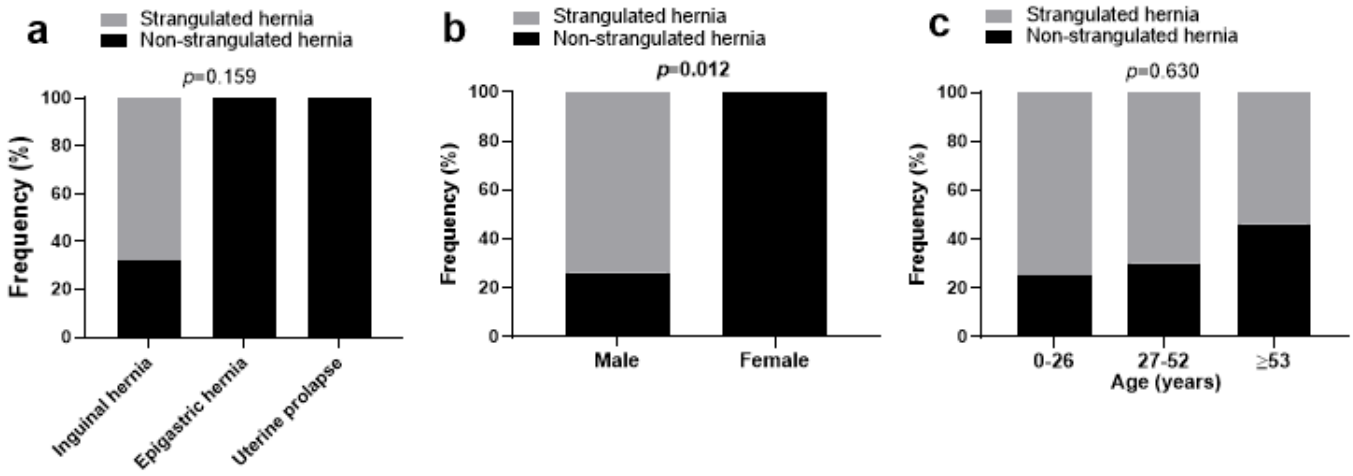

Figure 2

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; $p \leq 0.05$ was considered significant.

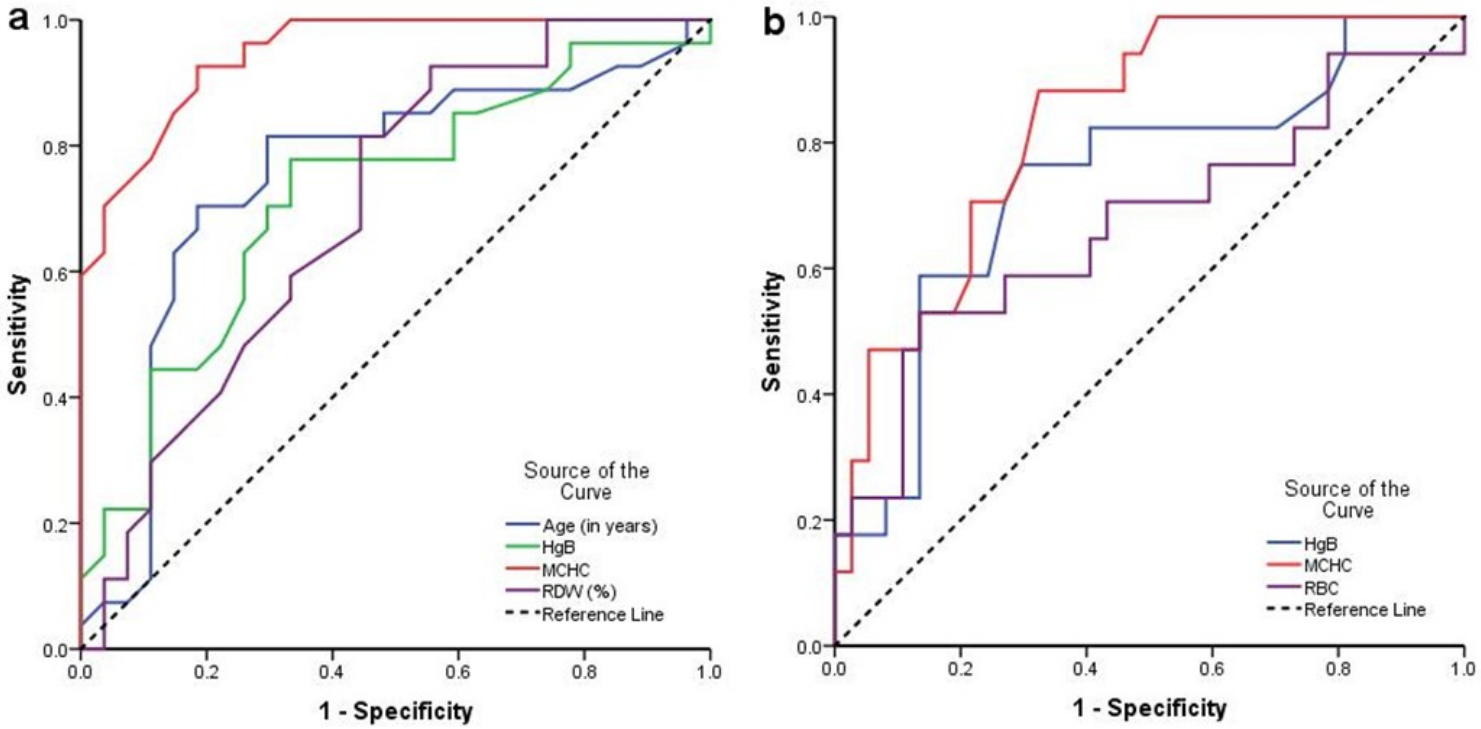

Figure 3

Predictive accuracy of blood cell indices and age for the occurrence of [a] hernia and [b] strangulation in hernia.

A receiver operating curve (ROC) with 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-CV: Red cell distribution width coefficient of variation. $p \leq 0.05$ was considered significant.