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Research Article:

Studies On Iron Profile in Prostate Cancer Patients on Therapy at Imo State University Teaching Hospital, Orlu

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ABSTRACT:
Prostate cancer (PCa) is a significant health problem in the ageing male, and changes in iron metabolism have been associated with cancer formation, progression, inflammation and oxidative stress. However, evidence on changes in iron profile in Nigerian men with prostate cancer is scarce. In this study, several iron profile characteristics in therapy-naïve prostate cancer patients were assessed and compared with that of men with benign prostatic hyperplasia (BPH) and seemingly healthy controls. It was a prospective comparative study of men attending the Imo State University Teaching Hospital, Orlu. Seventy five therapy naïve patients with prostate cancer, 75 therapy naïve patients with BPH and 75 apparently healthy controls were studied. Serum prostate specific antigen (PSA), iron, ferritin and total iron binding capacity (TIBC) were evaluated using normal laboratory procedures. Data were analysed by SPSS version 23.0 and results were presented as mean ± standard deviation. Statistical significance was defined at $p < 0.05$ and groups were compared using the Independent Student's t-test. Therapy naïve PCa patients had significantly higher concentration of PSA than controls (72.90 ± 10.09 vs. 2.04 ± 0.94 ng/mL; t = 54.27, p = 0.001) with significantly lower serum iron (79.31 ± 13.24 vs. 140.29 ± 18.34 µg/dL; t = -30.56, p = 0.001), higher ferritin (404.50 ± 92.02 vs. 108.07 ± 43.93; t = 22.27, p = 0.001) and lower TIBC (234.76 ± 40.00 vs. 335.67 ± 56.40 µg/dL; t = -10.15, p = 0.001). Similarly, BPH patients had significantly higher PSA, lower serum iron, greater ferritin and lower TIBC than controls ($p < 0.001$ for all comparisons). Direct comparison PCa and BPH showed significantly higher amounts of PSA and ferritin and significantly lower serum iron and TIBC concentrations in PCa patients ($p < 0.001$). In prostate cancer patients without therapy, we observed significant changes in parameters of iron profile: decreased levels of circulating iron and TIBC and increased levels of ferritin concentrations. The sequential pattern from controls, through BPH to PCa, indicates an increasing disturbance of systemic iron homeostasis in prostatic illness, with more dramatic abnormalities in prostate cancer. These data suggest that the evaluation of iron profile can give important auxiliary information regarding the metabolic and inflammatory milieu in prostate cancer, but these parameters cannot be regarded as independent diagnostic indicators.
Keyword: prostate cancer; benign prostatic hyperplasia; iron; ferritin; total iron-binding capacity; PSA; iron metabolism.

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INTRODUCTION

Prostate cancer (PCa) is a major health problem in ageing men globally and is one of the leading causes of cancer related morbidity and mortality. The prostate is a male reproductive gland located below the urinary bladder and surrounds the proximal urethra. It develops and works under the influence of androgens and plays a major role in male reproductive function by generating and secreting prostatic fluid, a component of semen, which promotes sperm viability and motility [1]. Prostate diseases are benign prostatic hyperplasia (BPH), prostatitis and prostate cancer. BPH and prostate cancer may develop in the same age range and generate similar lower urinary tract symptoms, but they are separate clinical disorders. BPH is a benign proliferation of prostatic stromal and epithelial elements. Prostate cancer (PCa) is a malignant neoplastic condition characterised by uncontrolled cell proliferation with the potential for local invasion and distant metastasis [2].

Prostate cancer is a common adenocarcinoma that originates from glandular epithelial cells of the prostate. The development of BPH is driven by the interplay of age, genetic predisposition, androgen signalling, environmental variables, inflammation and metabolic changes in the cells. Androgens are involved in prostate development, differentiation and normal function, and also play essential roles in prostate carcinogenesis. Thus, androgen deprivation and androgen-receptor-directed

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therapies have become important components in the treatment of advanced prostate cancer [3]. Localised prostate cancer is frequently curable but advanced disease can develop resistant to androgen deprivation therapy. This shift is sometimes called castration resistant prostate cancer and is characterised by persistent tumour growth despite decreased circulating androgen concentrations. This remains a major treatment problem.

Prostate cancer is mostly a disease of older men with the majority of instances occurring in the elderly. Changes in cellular metabolism, immunological responses, hormonal regulation and antioxidant defence that occur with age may promote carcinogenesis and disease development. Obesity, physical inactivity, dietary habits, environmental exposures and chronic inflammation have all been involved in the development and progression of prostate cancer [4]. Variability has been found in incidence and mortality rates among populations, with men of African descent suffering a disproportionately high burden of prostate cancer. Such disparities may be due to variation in screening and treatment, access to healthcare, environmental exposures, socioeconomic variables and genetic predisposition.

Changes in cellular metabolism are tightly related to the biological behaviour of prostate cancer. Among the critical micronutrients involved in cellular metabolism, iron has a particularly important place. Iron is required for many essential biological functions including oxygen delivery, mitochondrial energy production, DNA synthesis, ribonucleotide reduction and cell proliferation. Iron is carried principally in the circulation by transferrin and stored intracellularly predominantly as ferritin. Iron concentrations in the body are strictly controlled by processes of absorption, transport, storage and utilisation to maintain concentrations within physiological range. However, disruption of this homeostatic balance may have important pathogenic repercussions [5].

Iron metabolism is being recognised as a crucial facet of cancer biology. The rapidly dividing malignant cells have an elevated requirement for iron because iron-containing enzymes participate in DNA synthesis, mitochondrial metabolism, and other biosynthetic processes. Therefore, cancer cells may modify their iron intake, storage and use to meet their increased metabolic demands. Increased expression of proteins associated with iron acquisition and metabolism has been described in a number of malignancies, suggesting that iron availability may act as a regulator of cancer cell proliferation and survival [6]. Similarly, altered iron homeostasis in prostate cancer may contribute to malignant cell proliferation and metabolic adaptability.

Iron is a necessary nutrient for cellular function, yet excess or poorly regulated intracellular iron may contribute to oxidative stress. Iron can participate in redox processes that promote the formation of reactive oxygen species (ROS), especially in reactions involving hydrogen peroxide. Excessive ROS generation can cause oxidative damage to lipids, proteins and nucleic acids and may lead to genomic instability and cellular malfunction. However, cancer cells may respond to increased oxidative stress by up-regulation of antioxidant and cytoprotective pathways. These changes may let malignant cells to withstand increased metabolic activity and higher iron availability with little oxidative damage [7]. Thus, the relationship between iron and cancer is complex: while iron may enhance tumour proliferation, iron-induced oxidative stress may also lead to conditions that are conducive to the development of genomic abnormalities and tumour progression. Serum iron concentration reflects the circulating iron, of which a large proportion is bound to transferrin. Iron status is usually assessed by measuring serum iron and other indicators such as total iron binding capacity (TIBC), transferrin saturation and serum ferritin. These indexes provide complementary information on iron availability, transit and storage[8]. Changes in iron metabolism have been reported in a number of malignancies, however the interpretation of blood iron levels in cancer patients might be complicated by inflammation, nutritional condition, liver function and other disease-related variables. Inflammation can change the distribution of iron between circulation and storage pools through routes involving hepcidin and ferroportin. Thus, an iron panel rather than serum iron alone may present a more complete assessment of iron homeostasis in individuals with prostate cancer[9].

Prostate cancer and dietary iron intake is very complicated. The evidence for a direct link for total dietary iron intake with overall prostate cancer risk is inconsistent. However, several studies have revealed an association between higher iron intake and aggressive prostate cancer, particularly in advanced cases with extraprostatic extension, metastasis or higher Gleason scores [10]. These data show that iron might be more important for tumour progression and aggressiveness than for the initial genesis of prostate cancer. The molecular mechanisms behind this association are incompletely known and may include oxidative stress, cellular proliferation, mitochondrial metabolism, DNA synthesis and interactions with androgen-dependent signalling pathways.

Other micronutrients and antioxidant systems in addition to iron may affect prostate health and cancer biology. Selenium, zinc, iron and calcium have been shown to be involved in processes that are important for prostate function and disease [11]. Antioxidant molecules such as vitamins C and E, glutathione and coenzyme Q10 have a role in the maintenance of cellular redox equilibrium. But the association between antioxidants and cancer isn’t always so obvious. Normal cells are likely to be protected from excessive oxidative damage by

appropriate antioxidant defence, however cancer cells may also use antioxidant mechanisms to withstand the oxidative stress of fast growth and altered metabolism. Thus, both iron metabolism and antioxidant capability may influence the biological environment in which prostate cancer starts and progresses [12].

The clinical care of prostate cancer is based on the stage and biological characteristics of the illness and may include active surveillance, surgery, radiation, androgen deprivation therapy, chemotherapy and other systemic treatments. Treatment may change tumour metabolism and nutritional and biochemical markers may also be altered. Therefore, the analysis of biochemical markers during therapy, may provide useful information on the physiological status of patients and may contribute to the understanding of the changes associated with treatment. Iron status in prostate cancer patients undergoing therapy may be of particular importance because therapy, tumour burden, inflammation and dietary variables may alter iron metabolism individually or in combination[13].

There is paucity of data on iron-profile parameters among Nigerian men with prostate cancer, despite the increased interest in the link between iron metabolism and cancer. Furthermore, there is dearth of relevant published data on the changes in iron status of prostate cancer patients receiving treatment in the South-Eastern region of Nigeria especially in the Orlu area of Imo State. The definition of the pattern of iron-profile parameters in afflicted patients may be important as baseline information and may lead to a better understanding of the metabolic changes related with prostate cancer and its therapy.
The aim of this study was therefore to assess selected parameters of iron profile in prostate cancer patients on therapy in Imo State University Teaching Hospital, Orlu, to determine if there are measurable changes in the iron status of the prostate cancer patients and if such changes may have clinical significance in the management of prostate cancer.

MATERIALS AND METHODS

Study Area

The study was carried out at **Imo State University Teaching Hospital (IMSUTH), Orlu, Imo State, Nigeria**. The hospital is a tertiary healthcare institution that provides specialized and referral services to patients from Orlu and surrounding communities in Imo State and other parts of South-Eastern Nigeria. The hospital has a functional Urology Clinic where patients with prostate-related disorders are evaluated, diagnosed and managed.

Advocacy, Mobilization and Pre-Survey Contact

A letter of introduction was obtained from the Department of Medical Laboratory Science, Imo State University, and submitted to the Chief Medical Director of IMSUTH. The study proposal was submitted to the Research and Ethics Committee of the hospital for review, and ethical approval was obtained before commencement of the study.
Pre-survey visits were conducted at the Urology Clinic, where the researcher met with the consultant urologist and other relevant healthcare personnel. The purpose, objectives and procedures of the study were explained, and appropriate days for recruitment and sample collection were agreed upon.

Potential participants were approached during clinic visits and screened according to the predetermined eligibility criteria. The purpose and procedures of the study were explained to eligible participants, including the nature of the blood collection and laboratory investigations. Written informed consent was obtained from each participant before enrolment. Participants were informed that participation was voluntary and that they could withdraw from the study at any time without affecting their access to medical care.

Sample Size Determination

The minimum sample size was estimated using the formula described by Naing et al. (2006):
[N = \frac{Z^2P(1-P)}{d^2}]
Where:

- **N** = minimum required sample size
- **Z** = standard normal deviate at 95% confidence level (1.96)
- **P** = estimated prevalence or proportion
- **d** = desired margin of error (0.05)

Based on the calculated minimum sample size and allowance for adequate group representation, the study recruited 300 participants, comprising 75 therapy-naïve prostate cancer patients, 75 therapy-naïve benign prostatic hyperplasia patients and 150 apparently healthy controls.

Study Population

The study population comprised men attending the Urology Clinic of IMSUTH, Orlu, who were newly diagnosed with prostate cancer or benign prostatic hyperplasia and had not commenced therapy at the time of baseline sampling.
A total of 300 participants were enrolled. The study population consisted of:

- 75 therapy-naïve prostate cancer patients;
- 75 therapy-naïve benign prostatic hyperplasia patients; and
- 150 apparently healthy men who served as controls.

The participants were between 40 and 65 years of age. The control participants were selected to provide an appropriate age comparison with the patient groups and

were apparently healthy based on clinical assessment and relevant history.

Inclusion Criteria

Participants were eligible for inclusion if they met the following criteria:

1. Men aged 40–65 years who had been newly diagnosed with prostate cancer and had not commenced treatment at the time of recruitment.
2. Men aged 40–65 years who had been newly diagnosed with benign prostatic hyperplasia and had not commenced treatment at the time of recruitment.
3. Diagnosis was established by the attending physician/urologist using appropriate clinical and laboratory investigations, with histopathological confirmation where clinically indicated and available.
4. Participants who voluntarily consented to participate in the study.
5. Apparently healthy men within the specified age range who served as controls and satisfied the control eligibility criteria.

Exclusion Criteria

Participants were excluded if they:

1. Were younger than 40 years or older than 65 years.
2. Had a known history of diabetes mellitus or other major systemic disorders that could substantially influence iron metabolism.
3. Were current smokers or regular alcohol consumers.
4. Were receiving iron supplementation or other medications known to substantially alter iron metabolism before recruitment.
5. Had a history of other active malignancies or major chronic systemic disease, where applicable.
6. Declined consent or withdrew from the study.

The selection and clinical classification of participants were carried out with the assistance of the consultant urologist, physicians and nursing staff in the Urology Department of IMSUTH, Orlu.

Study Design

The study employed a prospective longitudinal comparative design involving therapy-naïve prostate cancer patients, therapy-naïve benign prostatic hyperplasia patients and apparently healthy controls.

The patient groups were followed during the course of their prescribed treatment to assess changes in selected biochemical parameters. Baseline samples were collected from the therapy-naïve patients before commencement of treatment, after which the patients were followed up at predetermined intervals during therapy.

The period of participant recruitment, classification, specimen collection and laboratory analysis was July 2024 to January 2025.

Sample Collection and Processing

Approximately 5 mL of venous blood was collected aseptically from each participant using standard venepuncture procedures. The blood was dispensed into a clean, dry, plain sample container and allowed to clot at room temperature.

The clotted blood was centrifuged at 3,000 revolutions per minute (rpm) for 15 minutes to separate the serum. The serum was carefully aspirated into appropriately labelled sterile sample containers and stored at −20°C until analysis.

All samples were identified using unique study codes to maintain confidentiality and minimize the possibility of sample misidentification. Laboratory analyses were performed using standard procedures and appropriate quality-control measures.

Laboratory Procedures

Commercially available analytical kits and reagents were used for the determination of the investigated biochemical parameters. All reagents were procured from recognized manufacturers and were used according to the manufacturers' instructions and standard operating procedures.

Determination of Serum Ferritin by ELISA

Serum ferritin concentration was determined using a commercially available Ferritin ELISA kit (Calbiotech) according to the manufacturer's instructions.

Principle

The assay is based on a solid-phase sandwich enzyme-linked immunosorbent assay employing a streptavidin–biotin system. Standards, serum samples and biotinylated anti-ferritin antibody were added to appropriately designated wells. Ferritin present in the samples bound specifically to the anti-ferritin antibody, while the biotinylated antibody was immobilized through the high-affinity interaction between biotin and streptavidin.

Following incubation, unbound substances were removed by washing. Horseradish peroxidase (HRP)-conjugated anti-ferritin reagent was subsequently added, resulting in the formation of an antibody–ferritin–antibody sandwich complex. After further washing to remove unbound conjugate, substrate was added.

The intensity of the colour developed was directly proportional to the concentration of ferritin in the sample. The absorbance was measured using an appropriate ELISA reader, and ferritin concentrations were obtained from a standard calibration curve.

Determination of Serum Iron

Serum iron concentration was determined using a commercially available Techo diagnostic kit according to the manufacturer's instructions.

Principle
Iron in serum is dissociated from the ferric iron [Fe(III)]–transferrin complex following the addition of an acidic buffer containing hydroxylamine. Hydroxylamine reduces Fe(III) to ferrous iron [Fe(II)]. The Fe(II) subsequently reacts with the chromogenic reagent Ferene to form a coloured ferrous–Ferene complex.
The intensity of the colour produced is directly proportional to the concentration of iron in the serum and is measured photometrically at approximately 560 nm.

Determination of Unsaturated Iron-Binding Capacity (UIBC)
Unsaturated iron-binding capacity (UIBC) was determined using a commercially available diagnostic kit according to the manufacturer's instructions.

Principle
UIBC measures the unsaturated iron-binding sites available on transferrin. A known excess amount of Fe(II) is added to the serum, allowing the available iron-binding sites on transferrin to bind the added iron. The unbound Fe(II) reacts with a chromogenic reagent to produce a coloured complex that is measured photometrically.
The difference between the amount of iron initially added and the amount remaining unbound represents the unsaturated iron-binding capacity of the serum.

For the assay, tubes were appropriately labelled blank, standard and test. Two millilitres (2.0 mL) of UIBC buffer reagent were added to each tube. For the blank, 1.0 mL of iron-free water was added. For the standard, 0.5 mL of iron-free water and 0.5 mL (500 µL) of iron standard were added. For each test, 0.5 mL (500 µL) of the respective serum sample and 0.5 mL (500 µL) of iron standard were added.

The contents of the tubes were mixed and the spectrophotometer was zeroed at 540 nm using the reagent blank. The absorbance of each tube was measured and recorded as A1.

Subsequently, 50 µL of iron colour reagent was added to each tube and mixed thoroughly. The tubes were incubated in a water bath at 37°C for 10 minutes. The spectrophotometer was then zeroed at 560 nm using the reagent blank, and the absorbance of each tube was measured and recorded as A2.

The UIBC concentration was calculated according to the manufacturer's formula:

$$[\text{UIBC } (\mu g/dL) = \frac{(A2_{standard}-A1_{standard})-(A2_{test}-A1_{test})}{A2_{standard}-A1_{standard}} \times \text{concentration of standard}]$$

Calculation of Total Iron-Binding Capacity (TIBC)
Total iron-binding capacity was calculated from the serum iron concentration and UIBC:

$$[\text{TIBC } (\mu g/dL) = \text{Serum Iron} + \text{UIBC}]$$

Calculation of Transferrin Saturation
Transferrin saturation (TS) was calculated as the proportion of serum iron relative to total iron-binding capacity and expressed as a percentage:

$$[\text{TS}(\%) = \frac{\text{Serum Iron}}{\text{TIBC}} \times 100]$$

Statistical Analysis
Data generated from the study were entered, coded and analysed using the Statistical Package for the Social Sciences (SPSS), version 23.0.Continuous variables were summarized using mean and standard deviation (mean ± SD). Comparisons between independent patient and control groups were performed using the independent-samples Student's t-test, where appropriate. Pearson's correlation coefficient was used to assess relationships between selected biochemical parameters.

For parameters measured repeatedly in the same patients during follow-up, the longitudinal nature of the data should ideally be accounted for using an appropriate repeated-measures statistical method, such as repeated-measures analysis of variance (ANOVA) or a linear mixed-effects model, rather than treating repeated observations as independent measurements. Statistical significance was set at $p < 0.05$

RESULT

1. Mean±SD Serum values of PSA, Iron, Ferritin, and TIBC in therapy naive prostate cancer patients (PCa) verses Controls.
There were significantlyhigher serum levels of PSA(72.90±10.09n verses (2.04±0.94ng/ml) ferritin (404.50±92.02 verses 108.07±43.93, p=0.001) in naive prostate cancer patients compared to controls respectively. While there were significant lower Serum levels of Iron (79.31±13.24ug/dl verses 140.29±18.34ug/dl, p=0.001) and TIBC (234.76±40.00 ug/dl verses 335.67±56.40 ug/dl,p=0.001) in naive prostate cancer patients compared to controls respectively.

Table 1: Mean ± SD serum values of PSA, Iron, ferritin, TIBC in therapy naive prostate cancer patients verses controls.

Variable	PCa (n = 75) Mean ± SD	Control (n = 75) Mean ± SD	t-value	P-value
PSA (ng/mL)	72.90 ± 10.09	2.04 ± 0.94	54.27	0.001
95% CI – Lower	70.29	1.80	—	—
95% CI – Upper	75.50	2.28	—	—
Fe (µg/dL)	79.31 ± 13.24	140.29 ± 18.34	−30.56	0.001
95% CI – Lower	75.89	135.55	—	—
95% CI – Upper	82.73	145.03	—	—
Ferritin (µg/dL)	404.50 ± 92.02	108.07 ± 43.93	22.27	0.001
95% CI – Lower	380.73	96.72	—	—
95% CI – Upper	428.27	119.42	—	—
TIBC (µg/dL)	234.76 ± 40.00	335.67 ± 56.40	−10.15	0.001
95% CI – Lower	224.42	321.10	—	—
95% CI – Upper	245.09	350.23	—	—

2. Mean±SD Serum values of PSA, Iron, Ferritin, and TIBC in therapy naive benign prostate hyperplasia (BPH) verses Controls.

There were significantly higherserum levels of PSA (10.42±3.06ng/ml verses 2.04±0.94ng/ml ,p=0.001), and Ferritin(286.05±32.92ug/dl verse 108.07±43.93ug/dl, p=0.001)in therapy naive benign prostate hyperplasia patients compared to controls respectively. Iron (92.52±16.94ug/dl verses 140.29±18.34ug/dl p=0.001)and TIBC((301.11±48.03 ug/dl verses 335.67±56.40 ug/dl,p=0.001) in therapy naive benign prostate hyperplasia patients compared to controls respectively.

Table 2: Mean±SD serum values of PSA, Iron, ferritin, TIBC in therapy naive benign prostate hyperplasia patients verses controls.

Variable	BPH (n = 75) Mean ± SD	Control (n = 75) Mean ± SD	t-value	P-value
PSA (ng/mL)	10.42 ± 3.06	2.04 ± 0.94	22.54	0.000
95% CI – Lower	9.63	1.80	—	—
95% CI – Upper	11.21	2.28	—	—
Fe (µg/dL)	92.52 ± 16.94	140.29 ± 18.34	−14.76	0.000
95% CI – Lower	88.14	135.55	—	—
95% CI – Upper	96.90	145.03	—	—
Ferritin (µg/dL)	286.05 ± 32.92	108.07 ± 43.93	24.37	0.000
95% CI – Lower	277.54	96.72	—	—
95% CI – Upper	294.55	119.42	—	—
TIBC (µg/dL)	301.11 ± 48.03	335.67 ± 0.56	−5.34	0.000
95% CI – Lower	289.70	321.10	—	—
95% CI – Upper	314.52	350.23	—	—

KEY: PCa-prostate cancer
BPH - benign prostate hyperplasia
Fe- Iron
F-- ferritin
TIBC - Total iron binding capacity

3: Mean±SD Serum values of PSA, Iron, Ferritin, and TIBC in therapy naive prostate cancer patients (PCa) verses therapy naive Benign prostate hyperplasia (BPH)

There were significantly higherserum levels of PSA(72.90±10.09ng/ml verses 10.42±3.06ng/ml,p=0.001), and Ferritin (404.50±92.02ug/dl verses 286.05±32.92ug/dl,p=0.001) in therapy naive prostate cancer patients compared to therapy naive benign prostate hyperplasia (BPH) respectively. Iron (79.31±13.24ug/dlverses 92.52±16.94ug/dl,p=0.001)and TIBC(234.76±40.00 ug/dl verses 302.11±48.03 ug/dl,p=0.001) in therapy naive prostate cancer patients compared to therapy naive benign prostate hyperplasia (BPH) respectively.

Table 3: Mean±SD serum values of PSA, Iron, ferritin, TIBC in therapy naive prostate cancer patients verses therapy naive benign prostate hyperplasia patients.

Variable	PCa (n = 75) Mean ± SD	BPH (n = 75) Mean ± SD	t-value	P-value
PSA (ng/mL)	72.90 ± 10.09	10.42 ± 3.06	57.03	0.000
95% CI – Lower	70.29	9.63	—	—
95% CI – Upper	75.50	11.21	—	—
Fe (µg/dL)	79.31 ± 13.24	92.52 ± 16.94	−5.36	0.000
95% CI – Lower	75.89	88.14	—	—
95% CI – Upper	82.73	96.90	—	—
Ferritin (µg/dL)	404.50 ± 92.02	286.05 ± 32.92	10.58	0.000
95% CI – Lower	380.73	277.54	—	—
95% CI – Upper	428.27	294.55	—	—
TIBC (µg/dL)	234.76 ± 40.00	302.11 ± 48.03	7.08	0.000
95% CI – Lower	224.42	289.70	—	—
95% CI – Upper	245.09	314.52	—	—

KEY: PCa -prostate cancer
BPH - benign prostate hyperplasia
Fe- Iron
F ferritin
TIBC - Total iron binding capacity

DISCUSSION

The present study evaluated selected iron-profile parameters namely serum iron, ferritin and total iron-binding capacity (TIBC) together with prostate-specific antigen (PSA) among therapy-naïve prostate cancer (PCa) patients, therapy-naïve benign prostatic hyperplasia (BPH) patients and apparently healthy controls at Imo State University Teaching Hospital, Orlu. The results showed substantial differences in PSA, serum iron, ferritin and TIBC between the groups. In general, prostate cancer was associated with significantly higher PSA and ferritin concentrations and lower serum iron and TIBC than presumably healthy individuals. Similar, albeit less marked, trends were found in patients with BPH. The results imply a possible relation between prostate illness, especially prostate cancer, and abnormalities in systemic iron homeostasis [14].

The study indicated that the serum PSA concentration was substantially greater in the patients with therapy-naïve prostate cancer (72.90 ± 10.09 ng/mL) than in the seemingly healthy controls (2.04 ± 0.94 ng/mL; p=0.001). This significant increase is consistent with the known clinical significance of PSA as a prostate specific biomarker. PSA is secreted by prostatic epithelial cells and disturbance of normal prostatic architecture, increased glandular activity and malignant transformation can lead to increased release of PSA into the circulation. The markedly increased PSA level detected in this study confirms the clinical categorisation of the patient group and is in accordance with severe prostatic disease.

The degree of PSA rise was significantly larger in the present prostate cancer group than in the BPH group with a mean PSA value of 10.42 +/- 3.06 ng/mL. This is crucial since PSA rise is not specific for cancer and may be seen in BPH and other prostate diseases. However, the much higher concentration of PSA in the prostate cancer patients points to a greater degree of prostatic pathological disturbance in this group. This is in keeping with the common observation that PSA levels are typically elevated in men with prostate cancer, especially those with clinically severe disease[15].

One of the important findings of the present investigation was that the serum iron concentration was considerably lower in therapy-naïve prostate cancer patients (79.31 ± 13.24 µg/dL) compared to controls (140.29 ± 18.34 µg/dL; p=0.001). This data suggests that low circulating iron is related with prostate cancer in the population investigated. Serum iron may be reduced due to altered iron utilisation, sequestration, inflammation, dietary variables or alterations in systemic iron regulation associated with malignancy.

One of the likely explanations for the decline in circulating iron is cancer linked inflammation. Inflammatory activities may change the distribution of iron, favouring its storage in tissues and lowering its availability in the circulation. This mechanism is frequently associated with increased iron sequestration and reduced circulation iron levels. Thus, the low serum iron reported in the prostate cancer patients may not be necessary true iron deficiency but a change in the way iron is trafficked in association with the disease[16].

The finding is also biologically relevant because malignant cells have increased requirements for iron to enable DNA synthesis, mitochondrial metabolism, and cell proliferation. The availability of iron has been

observed to affect the growth and survival of cancer cells. Tumour cells may thus modify iron uptake and utilisation to meet their higher metabolic requirements. Thus, the lower circulating iron concentration noted in the present study may represent enhanced cellular utilisation or redistribution of iron rather than merely decreased dietary intake[17].

Compared to serum iron, ferritin was significantly increased in therapy-naïve prostate cancer patients (404.50 ± 92.02) compared to controls (108.07 ± 43.93; p=0.001). A particularly striking finding was the co-existence of low serum iron and high ferritin. Ferritin is the primary intracellular iron storage protein and is also an acute phase reactant; Increased serum ferritin may imply increased iron storage and systemic inflammation.

Low circulating iron and high ferritin can be consistent with an inflammatory or functional iron-restriction pattern. In malignant disease, inflammatory signalling can enhance sequestration of iron in storage compartments and reduce its availability in the circulation. Therefore, the elevated content of ferritin in the prostate cancer group may be due to changes in iron storage and the inflammatory milieu of the tumour.

Elevated ferritin was also found to be compatible with data that altered iron metabolism may contribute to cancer biology. Cancer cells require iron for several metabolic activities and changes in proteins that mediate iron uptake, storage and utilisation may contribute to tumour formation. It has been pointed out that cancer cells may evolve antioxidant and adaptive responses that enable them to endure increased metabolic and oxidative stress caused by changes in iron availability [18]. The high ferritin levels in the present study may thus be part of the systemic response to the altered iron metabolism in prostate cancer.

Ferritin should not, however, be used as the sole index of body iron reserves in the patient with cancer. Ferritin is an acute phase protein and its level may rise in response to inflammation, infection and tissue damage. Thus, the elevated ferritin in prostate cancer patients may represent a combination of iron storage and inflammatory activity. This is particularly noteworthy when considering the data in conjunction with the lower serum iron concentration [19].

The study also showed significantly reduced TIBC in therapy-naïve prostate cancer patients (234.76 ± 40.00 µg/dL) compared to controls (335.67 ± 56.40 µg/dL; p=0.001). TIBC is an indirect measure of the blood's capacity to bind iron and is closely related to circulating transferrin. Decreased TIBC may be seen in inflammatory states and chronic disease when hepatic synthesis of transferrin may be decreased. Therefore, the simultaneous drop in serum iron and TIBC and the rise in ferritin are consistent with an altered iron profile seen with chronic illness or inflammation. Therefore, the combination of low serum iron, low TIBC and high ferritin is a noteworthy characteristic in the present investigation. The findings may reflect abnormalities in iron distribution and control associated with prostate cancer rather than isolated iron shortage alone. This trend demands assessment of inflammation, nutritional condition and other clinical variables in interpreting iron-profile results in prostate cancer patients.

The present study also indicated substantial changes in iron-profile parameters in medication naïve BPH patients compared to seemingly healthy controls. Serum PSA was substantially (p=0.001) higher in BPH patients (10.42 ± 3.06 ng/mL) than in controls (2.04 ± 0.94 ng/mL). This is an expected discovery as the enlargement and structural changes in the prostate in BPH can enhance the release of PSA into circulation. It is important to point out that this result highlights the non-specificity of PSA increase for prostate cancer.

Serum iron was considerably lower in BPH patients (92.52 ± 16.94 µg/dL) in comparison to controls (140.29 ± 18.34 µg/dL; p=0.001). The drop was less marked than that in prostate cancer but suggests that changes in systemic iron status may also be present in benign prostatic illness. This discovery suggests the potential that alterations in iron metabolism could not be primarily linked to malignant transformation but might also be connected with persistent prostatic enlargement, inflammation or age-related metabolic abnormalities.

The reduced serum iron concentration in BPH patients may be potentially connected to persistent inflammatory activity associated with prostatic hypertrophy. There is increasing association of BPH with inflammation. Inflammation can impact systemic distribution of iron . The role of inflammation in BPH and lower urinary tract symptoms has been emphasised as potentially important. Thus, aberrant management of iron may be a consequence of chronic inflammatory signalling, even in the absence of malignancy [20].

BPH patients had considerably higher levels of Ferritin (286.05 ± 32.92) than controls (108.07 ± 43.93; p=0.001). The increase is noteworthy as it happened in the setting of decreased serum iron. Increased ferritin in BPH may be a marker for increased iron storage, inflammatory activity or both as reported in the prostate cancer group. Ferritin increase was, however, significantly higher in prostate cancer than in BPH, suggesting a more significant disruption of systemic iron homeostasis in malignant illness.

TIBC was considerably reduced in BPH patients (301.11 ± 48.03 µg/dL) compared to controls (335.67 ± 56.40 µg/dL, p<0.001). The decrease was not as great as for prostate cancer but the pattern of change was similar.

This may indicate that BPH is also connected with some altered iron transport or inflammatory control.

The results in BPH show a pattern of lower serum iron, higher ferritin and lower TIBC, although the changes were less pronounced than those shown in prostate cancer. This difference may have therapeutic implications as both BPH and prostate cancer can lead to high PSA, but the patterns of their respective iron profiles may differ in intensity [21].

Direct comparison of therapy-naïve prostate cancer and BPH patients showed substantial differences in all parameters evaluated. Prostate cancer patients had significantly elevated serum PSA levels (72.90 ± 10.09 ng/mL) compared to BPH patients (10.42 ± 3.06 ng/mL; $p<0.001$). This is in keeping with the more severe pathological derangement seen with malignant illness and demonstrates a significantly higher PSA rise in the cancer patients.

Also, the level of ferritin was considerably greater in prostate cancer patients (404.50 ± 92.02) as compared to BPH patients (286.05 ± 32.92; $p<0.001$). These differences suggest that the change in ferritin concentration was more pronounced in malignant than in benign prostatic illness. Because ferritin is affected by both iron storage and inflammation, the higher quantity in prostate cancer could be a marker of increased inflammatory activity, disturbed iron storage, or increased metabolic demands owing to malignancy.

Serum iron was substantially lower in patients with prostate cancer (79.31 ± 13.24 µg/dL) than in those with BPH (92.52 ± 16.94 µg/dL; $p<0.001$). This finding further demonstrated that the loss of iron in circulation was more marked in prostate cancer. The difference may represent increased sequestration, utilisation or disease-associated alterations in systemic iron control in malignancy.
Similarly, TIBC was significantly decreased in prostate cancer patients (234.76 ± 40.00 µg/dL) than in BPH patients (around 302 µg/dL; $p<0.001$). increasingly decreasing TIBC values in controls, BPH and prostate cancer, combined with increasingly increased ferritin, indicating that the degree of disturbance in systemic iron parameters may correlate with the severity or biological aspects of the underlying prostate disease.

The pattern is one of the most important observations of the study. Thus, iron homeostasis is more significantly altered in prostate cancer than in BPH. However, the observational nature of the study precludes the data from showing that changed iron status causes prostate cancer or that these characteristics are independent predictors of disease progression [22].

These data lend support to the emerging idea that iron metabolism may be relevant to prostate cancer biology. Iron is essential for DNA synthesis, mitochondrial respiration and several enzymatic processes needed for cell growth. Thus, rapidly multiplying cancer cells have a substantial requirement for iron. Increased cellular demand for iron may cause iron to be redistributed from the circulation to tissues, which could contribute to the decreased serum iron seen in the present prostate cancer group.
However, excess intracellular iron can also enhance oxidative processes and reactive oxygen species formation. Oxidative stress can also damage cellular macromolecules and DNA, and can lead to genomic instability. Cancer cells can adapt to this environment via up-regulation of antioxidant defences and alterations in iron-storage systems. The role of antioxidant systems in the maintenance of cellular redox homeostasis has been reaffirmed and the biological importance of oxidative stress and antioxidant systems has been emphasized [23].

Therefore, increased levels of ferritin in prostate cancer may play a role in iron storage and in the cellular response to oxidative and inflammatory stress. Sequestration of iron by ferritin may protect the cell from potentially detrimental effects of free iron, and influence iron availability for cellular metabolism. Therefore, the link between iron, oxidative stress and tumour growth is complex.
However, the present findings should not be construed as evidence that elevated ferritin is a direct cause of prostate cancer. Ferritin is a generic biomarker and can be elevated in a variety of inflammatory and neoplastic disorders. Further measurements, e.g. of transferrin, transferrin saturation, soluble transferrin receptor, hepcidin and inflammatory markers would allow a more complete assessment of the mechanisms responsible for the observed changes.
The findings of this investigation have possible clinical relevance. First, the high rise of PSA among prostate cancer patients validates its continuing importance as a biomarker of prostatic illness. However, PSA was also raised in BPH, thus its interpretation should always be linked with clinical findings and other diagnostic studies. Secondly, the changes found in serum iron, ferritin and TIBC suggest that iron profile parameters can be changed in benign and malignant prostate disease. The particularly strong changes in prostate cancer patients suggest that iron metabolism may have potential importance for the biochemical characterisation of prostate cancer.

However, the outcomes of this study indicate that blood iron and ferritin are not independent diagnostic indicators for prostate cancer at the current time. Their levels are affected by a number of factors including inflammation, dietary state, liver function, infection and other systemic diseases. Thus, the clinical relevance of their interpretation may depend on the concomitant interpretation of known diagnostic and clinical parameters [24].

However, the results might be a starting point for subsequent studies exploring whether a combined assessment of PSA and chosen iron profile criteria can better characterise prostate disease or give information on disease severity. In particular, prospective trials in bigger populations with clinical staging might be helpful.

The findings of the current study are generally in line with the increasing evidence supporting the link between cancer and changes in iron metabolism. There is biological plausibility for altered iron management in malignant disease since iron availability is critical for cancer-cell growth and survival. Likewise, pointed to the ability of cancer cells to respond to oxidative stress and altered iron metabolism [25].

The present discovery of higher ferritin in prostate cancer patients is also in agreement with reports showing ferritin levels are increased in malignant and inflammatory situations. However, the disparities in ferritin concentrations reported by different studies may be explained by changes in study populations, disease stage, nutritional status, treatment history and laboratory methodology.

Biologically, the finding of low serum iron and TIBC in the present study is also consistent with the pattern of iron restriction seen regularly in chronic inflammatory conditions. Chronic inflammation may be associated with prostate cancer and inflammation-mediated changes in iron distribution might partly explain the findings.

Particularly notable is the reduced amount of alteration in BPH patients compared to prostate cancer patients. It shows that some variations in iron status may be related to benign prostatic disease and more marked alterations may occur in malignant disease. However, longterm investigations are needed to identify whether these changes are connected with tumour load, disease stage or treatment response.

CONCLUSION

The investigation reveals substantial differences in serum PSA, iron, ferritin and TIBC among therapy-naive prostate cancer patients, BPH patients and seemingly healthy controls. The greatest PSA and ferritin levels were found in prostate cancer patients and lowest serum iron and TIBC levels were observed. Patients with BPH showed an intermediate pattern with PSA and ferritin greater than controls and serum iron and TIBC lower than controls.

The data imply that prostate cancer is associated with important changes in systemic iron homeostasis. High ferritin with low serum iron and TIBC may suggest complicated interplay between iron sequestration, inflammation, altered iron utilisation and tumour-related metabolic alterations. However, these characteristics should be considered as biochemical markers of altered physiology and not as definite diagnostic criteria for prostate cancer.

Further studies including inflammatory markers, transferrin, transferrin saturation, hepcidin, soluble transferrin receptor, nutritional indices and clinical staging are suggested to clarify the mechanisms underlying the observed alterations as well as to establish their potential clinical value in the management of prostate cancer.

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