RADIOLOGICAL ANATOMY OF THE ARTERIAL SUPPLY OF THE PROSTATE GLAND

A Dissertation submitted in Partial Fulfillment for Award of the Fellowship in Interventional Radiology of the Ghana College of Physicians in the Faculty of Radiology

By

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DECLARATION

It is hereby affirmed that this work titled **"IMAGING PATTERNS OF THE ARTERIAL SUPPLY OF THE PROSTATE GLAND**" was carried out by me at the Department of Radiology, Euracare Advanced Diagnostics and Heart Centre, Accra. In addition, the work is original and has not been presented to any other college for any reason or for publication in any journal/literature.

Dr JIMAH Bashiru Babatunde

ATTESTATION PAGE

This is to certify that Dr. Bashiru Babatunde Jimah has been a fellow in Interventional Radiology during the period January 2020 to December 2021 at Ghana College of Physicians and Surgeon, Faculty of Radiology, 37 Military Hospital.

This Dissertation titled " Imaging Patterns of The Arterial Supply of The Prostate Gland' is original work done by him.

This work has the College of Health Sciences, University of Ghana Ethics and Protocol Committee's approval and was carried out under my supervision.

Supervisor:

Name: Dr Benjamin Dabo Sarkodie

Signature: …….

Interventional Radiologist,
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CERTIFICATION

This is to certify that Dr. Bashiru Babatunde Jimah has been a fellow in Interventional Radiology during the period January 2020 to December 2021 at Ghana College of Physicians and Surgeon, Faculty of Radiology, 37 Military Hospital

This Dissertation titled “Imaging Patterns of The Arterial Supply of The Prostate Gland’ is a original work done by him.

Head of Department:

Name: Dr Micheal Amedi

Signature: ……..

37 Military Hospital

DEDICATION

This work is dedicated to the almighty Allah, my family and my mentor, Dr Dabo Sarkodie.

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I would like to thank Dr. Benjamin Dabo Sarkodie. Supervisor and Medical Director, Euracare Advance Imaging and Heart Centre for giving me the opportunity to complete this fellowship. I am extremely grateful for his support, coaching and wisdom, throughout the period.

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ABSTRACT

Background: In West Africa and Ghana, prostate arterial embolization (PAE) is a novel procedure. To ensure effective prostatic arterial embolization and selective intervention, a thorough understanding of prostate artery anatomy and its relationship to prostate size is required.

Aim: The purpose of this study is to describe the anatomy of adult male prostate arterial supply and correlate them with prostate gland size and artery diameter on Computed Tomography of patients presenting to Euracare Advanced Diagnostic and Heart Centre.

Methodology: A prospective cross-sectional study was conducted, at Euracare Advanced Diagnostics and Heart Centre. Patients who presented for Computed Tomography Angiography of the pelvis were included in the study. A total of 104 pelvic halves (52 males) were studied, and pertinent conclusions were reached. The diameter of the prostate artery and the volume of the prostate gland were measured. The Pearson Correlation coefficient was used to calculate the correlation between prostate artery diameter and prostate gland volume. The branching pattern of the prostate artery was classified using the de Assis et al (2015) classification, which serves as the foundation for most classifications.

Result: According to the data, 37 (71.15 %) of the patients had enlarged prostate gland with a volume greater than 30ml. All of the patients aged 60 and above had an enlarged prostate gland and were mostly married. A higher proportion of patients with enlarged prostate (18, 94.74 %) had a history of prostate disease. In each pelvic half, one prostate artery was discovered. There were three types of prostate arterial branching. The majority of the pelvic halves (61, 58.7 %) had type 1, followed by type III and type II. In 50% of the pelvic halves, the origin was symmetrical type I. The mean prostate artery diameter was 1.28mm $\pm$ 0.16 on the right and 1.26mm $\pm$ 0.18 on the left, which was higher among those over 60. The average prostate gland volume was 42.58$\pm$14.17ml. The mean volume was higher in those over 60 (54.22$\pm$2.52 ml) compared to those under 60 (32.60$\pm$5.11ml), p =0.0000. The prostate gland volume and the diameter of the right (r=0.4771, p=0.0003) and left (r=0.5131, p=0.0001) arteries showed a significant positive correlation. Similar findings were made with those who had enlarged prostate glands with the right (r-0.3559, p=0.0306) and left (r = 0.4176, p=0.0101) prostate arteries..

Conclusion: The prostate arteries in the study population had type I, III, and II origins. The mean prostate artery diameter increases with increasing age and increasing prostate volume.

Keywords; Internal iliac artery, prostate artery, computed tomography angiography, digital subtraction angiography

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LIST OF ABBREVIATIONS

- BPH - Benign Prostatic Hyperplasia
- CTA - Computed Tomography angiography
- DSA - Digital Subtraction Angiography
- PAE - Prostate artery embolization
- MRA - Magnetic Resonance Angiography
- MIP - Maximum Intensity Projection
- PA - Prostate artery
- TRUS - Transrectal ultrasound
- APA - Accessory pudendal arteries
- MRSI - MR spectroscopic imaging
- DCE-MRI - Dynamic contrast enhanced MRI
- IIA - Internal iliac artery

CHAPTER ONE

BACKGROUND

1.1: Background

Prostate diseases are slowly edging a high incidence in Africa, particularly Sub-Saharan region (1,2). Benign enlargement of the prostate gland is gradually increasing in prevalence, affecting 50-80% of 60-70years (3) men and the increasing prevalence is associated with age. The Baltimore longitudinal study on ageing (4) suggest that, there is a 2-2.5% prostate growth rate per year for older males. Benign prostatic enlargement leads to varying severity of lower urinary tract obstructive and irritating symptoms which worsens with age and severely reduce the patients quality of life and often mimic malignancy (5) which may require additional radiological and /or surgical interventions and attendant cost. The size of the prostate gland has been contentious in the current literature. In this study, a prostate gland is said to be enlarged when the volume exceeds $30cm^3$/30ml (6). About 69% of prostate enlargement occurs among males of ages 40 years and above (7). Also, prostate enlargement is associated with family history of the disease, obesity, poor diet, lack of physical exercise, diabetes and related complications and erectile dysfunction (3,5,8,9).

Until recently, prostate diseases are diagnosed mainly through palpation, digital rectal examination, urinalysis, prostate-specific antigen, urodynamic tests and cystoscopy (10). The development of medical imaging techniques such as Computed Tomography, urological ultrasound scanning, Magnetic Resonance Imaging (MRI), transrectal ultrasound scanning and guided biopsy, as well as, Digital Subtraction Angiography (DSA), has improved the diagnosis of prostate anomalies (8). Prostate artery embolization (PAE) has been employed in many parts of the world to manage patients with symptoms of benign prostate enlargement worldwide (10).

Ultrasonography is routinely used for sizing the prostate gland. This is because the procedure is fast, cost effective and does not involve ionizing radiation. There are two methods of ultrasound scan of the prostate gland. Transabdominal and transrectal approach. Transabdominal requires the use of the full patient urinary bladder such that the urine provides an acoustic window for imaging the pelvis. The disadvantage is that, it is inconvenient to the patient and time consuming as the patient may wait for a longer period to fill the bladder. The transrectal ultrasound scan requires the patient to empty the bladder prior to the procedure. It give better assessment of the prostate volume compared to the transabdominal scan and only interchangeable when assessing prostate volumes of less than $30cm^3$(11). It may be uncomfortable for the patient, but has the added advantage of guiding interventions of the prostate gland such as biopsy and drainage of prostatic abscess.

Prostate artery embolization (PAE) is a relatively new procedure for the management of benign prostate hyperplasia (BPH). Worldly PAE is becoming acceptable and it is fast becoming a preferred option for benign prostate hyperplasia. Until recently, BPH was managed in West Africa and Ghana by surgical intervention. This novel treatment is now available in Ghana and West Africa(10,12). Initial studies of prostate artery embolization shows promising resultants in both animal and human models(13,14).

DeMeritt et al (15). presented a case report of 76year old man severe gross hematuria due to 305ml benign prostatic hyperplasia, received multiple transfusion, severe cardiomyopathy and therefore not a candidate for surgery. He had a successful digital subtraction angiography and embolotherapy with 150–250 micrometer particles of polyvinyl alcohol until stasis was achieved. The prostate volume reduced from 305ml to 235 mL in 2months, then 160ml in 6 months and finally to 190ml over a period of 12months, achieving 40% reduction.

Carnevale et al (16) observed 39.7% and 48.7% prostate volume reduction post prostate artery embolization of two patients who had BPH and urethral catheter dependent. The 67year and 68year old men had prostate volume of 69g and 54g respectively. The 67-year-old had bilateral prostate artery embolization and 68-year-old had unilateral embolization. The 67-year-old patient had spontaneous urination when the catheter was removed, 15days after the procedure. This

spontaneous urination occurred at day 9 for the 68-year-old patient. The patients had improved quality of life and significantly reduced prostate size.

In 2011, Pisco et al.(17) assessed 15 patients with various degrees of benign prostate hyperplasia. The study sought to determine whether prostate artery embolization is a viable treatment option for symptomatic benign prostatic enlargement (BPE). The patients were refractory to medical management. The patient range from 62– 82 years. Embolization was done with 200-micrometer polyvinyl alcohol particles (PVA) particles and no sexual dysfunction was recorded after the procedure. They recorded a reduction in the mean prostate size 26.5mL ($P<0.001$) by ultrasound, improved quality of life, improve erectile function and improved flow rate.

For effective prostatic arterial embolization and to ensure selective intervention, a clear appreciation of the pelvic and prostate arterial anatomy is important(18). Pre-embolization computed tomographic angiography (CTA) and magnetic resonance angiography (MRA) to outline the different vascular pedicles and aberrant vascular supply to the prostate gland will ensure successful embolization and minimize complications.

1.2. Problem statement

Currently prostate artery embolization is recommended for moderate to severe symptomatic BPH patients(19). PAE offers improved quality of life, significant prostate size reduction in the short to long term for patients who have become catheter independent (19).

Despite these innovations, imaging studies on prostatic arteries (PAs) examinations in Portugal (20), Alexandria (14), France (21), Brazil (22), New Jersey (23), Argentina (24) have reported different patterns in arterial vascularization of the prostate gland during PAE. Also, noted during PAE is the difficulty in identifying and catharizing the prostate arteries, differentiating PA from the vesical arteries (20).

This suggest that the pattern of arterial supply to the prostate gland varies within a population (i.e. individuals belonging to one ethnic or culture group) and between populations. Therefore, each population must have a clear understanding of what pertains in their population and extent of variation in prostate artery supply that exist in the male population for better diagnosis and

management of prostate artery anomalies. While PAE is widely employed in worldwide, little is known about the pattern of prostate artery anatomy, correlation between the prostate artery diameter and prostate gland size in Sub-Saharan African population. The available literature in Africa and Ghana focuses on the epidemiology and imaging diagnosis of prostate anomalies, but much more research is needed to understand the anatomy of the prostate gland's arterial supply.

It is against this backdrop that this study is being undertaken to establish the origin pattern of the prostate arteries and correlation between the prostate artery diameter and prostate gland size in the Ghanaian setting using Computed Tomography Angiography of the male pelvis seen at Euracare Advanced Diagnostic and Heart Centre.

The study seeks to ascertain the correlation between the prostate artery diameter and prostate gland volume in men. The view is that findings would establish a baseline for further studies and influence prostate artery embolization in Ghana.

1.3 Justification

Prostate artery embolization has been introduced in Ghana since March 2019 (25). Most patients' quality of life is negatively impacted by benign prostatic hyperplasia, which causes obstructive and irritating symptoms. The majority of these patients become catheter dependent and thus vulnerable to catheter-related complications such as septiceamia and skin ulceration as a result of prolonged catheter use.

Medical treatment includes - adrenergic blockers, 5-reductase inhibitors, and low-dose oral phosphodiesterase inhibitors. Alfuzosin, finasteride, and tadalafil are examples of these medications (26).

Most patients are managed on medications, and surgical options such as transurethral prostatectomy introduced if patients are refractory to the medical therapy(27). Prolonged use of the medications, intermittent acute urinary retention requiring hospitalization, and high procedure-related costs are common complications (28).

Prior to surgical intervention, symptoms of most patients are relieved through urethral or suprapubic catherization. Unfortunately, some patients may refuse the surgical option or due to comorbidities are poor surgical candidates. Such patients become catheter dependent and this affects their quality of life.

The introduction of prostate artery embolization as a treatment option is therefore a welcoming idea and requires careful selection of patients, precise pre-embolization planning and honing of embolization skills. Pre-embolization planning necessitates a thorough understanding of the prostate gland's arterial anatomy. It helps in equipment selection, type of embolic agents to use, possible complications and how to manage them.

The pre-embolization CTA and DSA will delineate the arterial anatomy and especially helps to avoid non-target embolization. Documenting the prostate gland arterial anatomy therefore cannot be overstated. It will narrow the knowledge gap in the correlation between the prostate artery diameter and prostate gland size.

1.4 Aim

1.4.1 General Objectives

The aim of this study is to describe the radiological anatomy of prostate arterial supply of adult male and correlate with the prostate gland volume on Computed Tomography Angiography of patients presenting to Euracare Advanced Diagnostic and Heart Centre.

1.4.2 Specific objective

1 To identify the branching patterns of prostate artery in Ghanaian men
2 To measure the diameter of the prostate arteries among adult males.
3 To measure the volume of the prostate gland among adult males.
4 To determine the relationship between diameter of the prostate arteries and the volume of the prostate gland among adult males

1.5 Hypothesis

1. H0: There is no significant correlation between the diameter of the prostate artery and the volume of the prostate gland of adult males.
2. H1: There is a significant correlation between the diameter of the prostate artery and the prostate size of adult males.

CHAPTER TWO

LITERATURE REVIEW

2.1 Anatomy of the Prostate Gland

The prostate gland is the male reproductive system's largest accessory gland (29). It generates an alkaline fluid that accounts for 25% of the seminal fluid. It is made up of glandular and stromal elements that are fused together within a pseudo capsule. The inner layer is made up of smooth muscle, and the outer layer is made up of collagen (29).

The prostatic plexus innervates the prostate and receives arterial supply from the internal iliac artery. The internal iliac nodes are responsible for lymphatic drainage.

The prostate gland is situated posterior to the pubic symphysis. Anteriorly is bounded by the rectum and urinary bladder inferiorly. The zonal anatomy of the prostate are, the central zone (CZ), transition zone (TZ), peripheral zone (PZ), and periurethral zone (29).

The peripheral zone contains approximately 70% of the glandular tissue. It wraps around the distal urethra and extends from the base to the apex. The peripheral zone is made up of ductal and acinar elements that are intertwined with smooth muscle. It is the site of the majority of prostate gland diseases (29).

The central zone, which is located at the base of the prostate, represents nearly 25% of the glandular tissue. It encircles the ejaculatory ducts and narrows to a point at the verumontanum. The verumontanum is a mucosal fold that indents the prostatic urethra, which is where the ejaculatory ducts enter.

The transition zone accounts for only 5% of the glandular tissue. It has two small glandular tissue lobules. In benign prostatic hyperplasia, this enlarges (29).

The periurethral zone contains mucosal and sub-mucosal glands and may increase compression of the urethral in BPH.

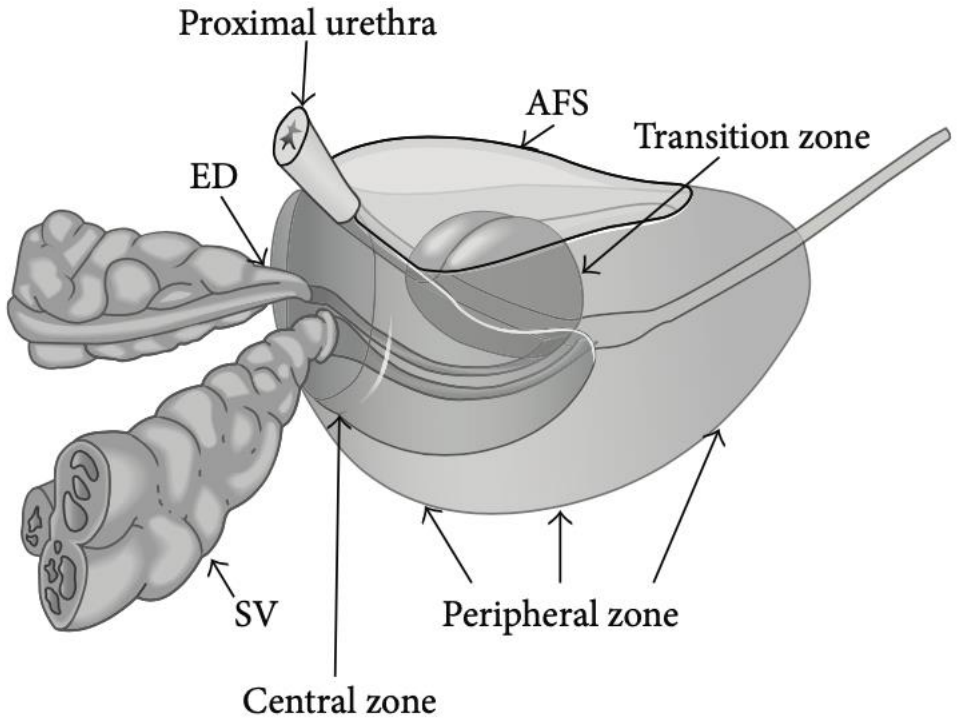


Figure 2.1. The zonal anatomy of the prostate gland is depicted graphically.
AFS - anterior fibromuscular stroma; ED - ejaculatory ducts; and SV - seminal vesicles (29).

2.2. Imaging features of the prostate gland anatomy

2.2.1 Magnetic Resonance Imaging features of the prostate gland anatomy

High-resolution T2 weighted sequence, diffusion weighted imaging, and MR spectroscopic imaging (MRSI) or dynamic contrast enhanced MRI are all part of the MRI protocol (DCE-MRI).

The T2W images depict the zonal anatomical structure and capsule of the prostate. It is critical in the assessment of prostate cancer detection and staging (29). Functional studies such as MR spectroscopic and dynamic contrast enhanced MRI improves the sensitivity and specificity of detecting assessing prostate anomalies.

The peripheral zone is hyperintense on T2 weighted MR images (Figure 2.2.a). On T2 weighted MR images, anterior fibromuscular stroma hypointense is due to fibrous and smooth muscular elements (Figure 2.2.b). The pseudocapsule is sharply demarcated rim of hypointensity on T2W

images. On T2 weighted images, the neurovascular bundle appear as peripherally located hypointense structures (Figure 2.2.c).

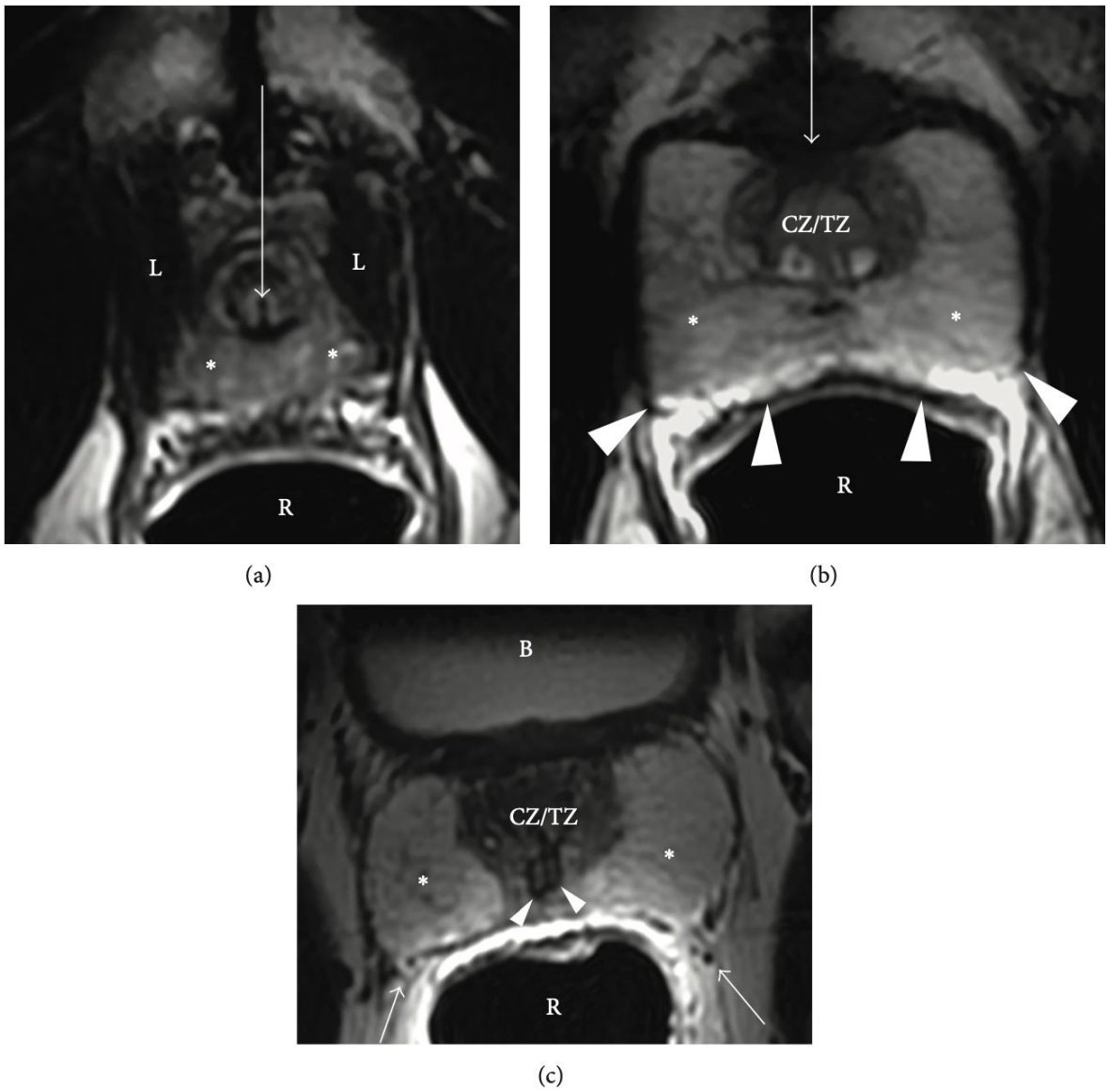


Figure 2.2. Three in a series of axial T2W images of the prostate gland male.
(a) The distal prostatic urethra (white arrow) is surrounded by hyperdense peripheral zone tissue (∗). Posteriorly located is the rectum (R). The levator ani muscles are found on the lateral side of the body (L). (b) At the midgland level, hyperintense peripheral zone tissue (*) surrounds central (CZ)/transition (TZ) zones. The anterior fibromuscular stroma is a dark T2 tissue band found anteriorly (arrow). Posterolateral neurovascular bundles (arrows). R: rectum; B: bladder (29).

2.2.1 Transrectal ultrasound scan features of the prostate gland anatomy

Transrectal ultrasound (TRUS), is important in the diagnosis of prostate malignancy and to guide prostate interventions. The myriad of indications are grouped into four main categories namely (1).

- prostate malignancy diagnosis and management,
- BPH workup,
- Evaluation of infertility,
- Guided interventions drainage or aspiration of prostatic collections

The zonal anatomy of the prostate gland, as illustrated in section 2.1 above, also applies to transrectal sonography. The inner gland of the prostate on TRUS consists of the anterior fibromuscular stroma (AFS), transition zone (TZ), periurethral tissue, and central zone (CZ). The peripheral zone PZ refers to the outer gland(30). The transition zone is homogeneously hypoechoic and centrally located.

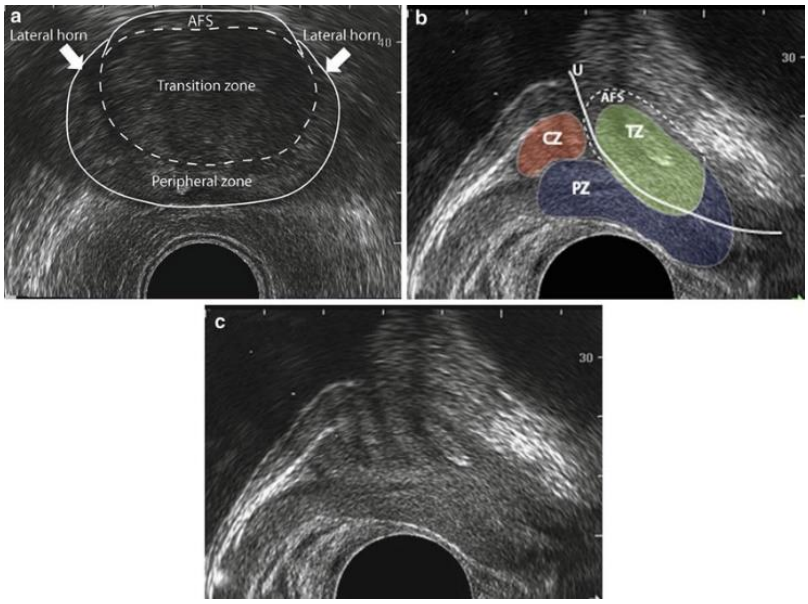


Figure 2.2.1: Transrectal sonograms of the prostate (a) shows axial representation of the zonal anatomy and shows anterior fibromuscular stroma (AFS) anteriorly. (b and c) shows the zonal anatomy of the prostate in the sagittal plane. U urethra; CZ central zone; TZ transition zone; PZ peripheral zone; AFS anterior fibromuscular stroma (1).

2.3 Disease pattern of prostate gland

Pathologies of the prostate gland include infection, inflammatory conditions, benign and malignant tumours and infarction. Previous studies on prostate gland have provided significant insight of prostate enlargement and benign prostatic (5,7,8). Benign prostatic hyperplasia (BPH) may lead to bladder outlet obstruction evident by obstructive and irritating symptoms (7,8,31,32).

The symptoms of prostate disease are classified as obstructive or irritating symptoms (Table 2.3). The cause of these symptoms are multifactorial and may not only be related to prostate but detrusor muscle dysfunction, overreactive bladder, neurovascular abnormalities (33).

Tetteh in Ghana reported that a greater proportion of ghanaians studied have experienced urinary incontinence (66.7%), swollen glands (66.7%), painful urination(100%) with dribbling urinal stream and had to strain during urination.

Table 2.3: Lower Urinary Tract Symptoms

Obstructive symptoms • Poor stream • Hesitancy • Straining • Intermittent stream and dribbling • Incontinence • Urinary retention usually chronic
Irritating symptoms • Frequency • Urgency • Nocturia • Urge incontinence

2.3.1 Epidemiology of prostate gland diseases

Documented evidence globally suggest benign enlargement of the prostate gland is extremely common prostate disease which increased among ageing population (34–37). The incidence of prostate diseases vary by geographical area, for instance, trend of BPH differs significantly between High-Income Countries (HICs) and Low and Middle-Income Countries(LMICs) (34). Major factors associated with prostate diseases include age, race, hormonal, genetic influence and lifestyle (9,38–40). Diseases of the prostate are generally regarded as the diseases of elderly men (34,39). Among the risk factors for BPH include hypertension, hypercholesterolemia, diabetes, family history of prostate disturbances, hormonal disturbances, alcohol and red meat consumption, and smoking (38). Empirical evidence of these may provide a rational for effective medical or preventive interventions especially among adult males in developing countries.

Xu et al. (34) analysed multicenter data obtained from the Global Burden of Disease 2019 study to assess the global, regional, and national incidence, year lived with disability (YLD), and their age- standardized rates (ASRs) for 21 regions for Benign Prostatic Hyperplasia from 1990 to 2019 among 204 countries and territories from 1990 to 2019. The study also estimated the annual percentage changes (EAPCs) of the ASRs. The results showed that global incidence, 11.26 million (95% uncertainty interval [UI]: 8.79, 14.46) new cases and 1.86 million (95%UI: 1.13, 2.78) YLD due to BPH in 2019. The global ASRs of incidence (EAPC: −0.031, 95% CI: −0.050, −0.012) and YLD (EAPC: −0.058, 95% CI: −0.084, −0.031) decreased slightly from 1990 to 2019, whereas the absolute numbers increased dramatically from 1990 (incidence- 105.7% and YLD- 110.6%), mainly driven by the population growth (53.5% for incidence and 54.4% for YLD) and population

aging (55.7% for incidence and 63.2% for YLD) (34). The EAPC in West Africa increased from 1990 (EAPC: 0.031, 95%UI: 0.02-0.0422) to in 2019 (EAPC: 0.0429, 5%UI:0.031-0.0053), which is relatively higher than estimates those from High-Income Asia Pasific but lower compared to High-Income North America(34).

In the quest to better understand the increasing prevalence of lower urinary tract symptoms suggestive of benign prostatic hyperplasia (LUTS/BPH) among older people in China, Zhang et al. (37) conducted a secondary analysis of a cohort sample. In this study, the weighted overall prevalence of LUTS/BPH from a longitunal study is 10.66% (95% CI 9.36 to 12.12)(37). This study reported the prevalence of 14.67% (95% CI 11.80 to 18.09) and it increased with ageing among individuals aged over 70 years. The prevalence of LUTS/BPH is likely to increase among people residing in urban areas (13.55%, 95% CI 10.95 to 16.64) compared to those living in rural areas (8.38%, 95% CI 6.90 to 10.15) (37).

In a population-based study in Nigeria, to assess the male adults above 40years, it was estimated that, the prevalence of enlarged prostate was 68.3% (7). It was established that the association between the prostate volume and increasing age was statistically significant ($p < 0.001$). Another study reported the prevalence of prostate enlargement at different time interval in Nigeria (10). This study revealed a high prevalence of prostate enlargement among aged population; from 2010 to 2014, a prevalence range of 54.52%-80.74% (10).

In Ghana, a number of studies have reported the incidence of prostate diseases and associated risk factors (36,38,39,41). Common prostate diseases reported among Ghanaians include prostatitis, benign prostate hyperplasia, and erectile dysfunction among others.

In a study by Egote et al. (39), the age as a risk factor for prostate diseases from a 6-year (2009 to 2014) selective prospective study among males (40 years and above) in the Brong Ahafo region was determined. These patients were routinely screened for prostate lesions using positive family history, serum prostate specific antigen (PSA) test, digital rectal examination and ultrasound scan. While documenting age, diagnosis and grading of carcinomas. This study reported age range of 42- 101 years and a higher incidence of prostate diseases in the year 2010. A higher number of prostatic lesions were recorded between the ages 60-89 years. The prevalence of benign prostate hyperplasia was 51.78%, and 40.07% with adenocarcinomas, 0.85% with chronic prostatitis as well as 7.3% for both prostatitis and benign prostate hyperplasia. The authors alluded that Ghanaian men between the ages of 50 and 89 are highly predisposed to prostate diseases compared to those <50 years and >89 years.

Another study in Ghana by Asare et al. (41) also reported on the high degree of prostate related LUTS in a prospective cross-sectional community study in Accra, Ghana. The authors determined the prevalence of asymptomatic LUTS in men in a Ghanaian Community as well as its underlying risk factors. One hundred and eleven (111) men (aged: 40–70 years) were recruited from a community in Ghana. The International Prostate Symptoms Score (IPSS) questionnaire (were administered) and ultrasonographic imaging of the prostate volume (PV) were utlized to collect data. IPSS score >7 plus PV > 30 cm3 was definitive of lower urinary tract symptoms (LUTS positive -LP or LUTS negative –LN). Risk factors studied were cholesterol (CHOL), triglyceride (TG), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), very low-density lipoprotein (VLDL), coronary risk (CR), BMI and Blood Pressure. They reported that the prevalence of LUTS (using only IPSS definition alone) was 42.3% and IPSS in combination with Prostate Volume was 27.0%. The results further showed that LN subjects had

enlarged prostate (41.98%) and LP, 100%. In a multivariant analysis HDL-C, BMI and triglyceride were significant contributors to LUTS. Authors of this study recommended enhancement in community education to sensitize the general Ghanaian population (41).

2.3.2 Clinical examination of prostate gland diseases

In assessing patients for bladder outlet obstruction, effort must be made to exclude differential diagnosis such as malignancy of the prostate or bladder, infections, bladder muscle pathologies and urethral stricture. Chronic retention due to bladder outlet obstruction could to recurrent urinary tract infections and renal failure(33).

Patients' assessment for benign prostate hyperplasia before PAE, must include(33)

- detailed clinical history,
- a thorough physical examination,
- previous treatment and medications
- review drugs that affect bladder function
- assessment for severity of nocturnal polyuria.
- Screening for prostate cancer is mandatory and urologist referral is indicated.

Prostate-specific antigen (PSA) is a protein made by cells in the prostate gland (both normal cells and and cancer cells) (38). PSA is usually found in semen, but samples can be found in blood. BPH is one possible cause of a high PSA level. Inflammation of the prostate, is another common cause of a high PSA level. The PSA level in blood is measured in units called nanograms per milliliter (ng/mL). According to American Cancer Society guideline for the early detection of prostate cancer (38,42), a person with (PSA> 4.0ng/ml) is said to have BPH.

In Ghana, male adults are routinely screened for prostate lesions using positive family history, serum prostate specific antigen (PSA) test, digital rectal examination and ultrasound scan (39,43).

2.4. Imaging features of prostate diseases

2.4.1. Magnetic Resonance imaging of prostate diseases

Benign prostate enlargement may include glandular hyperplasia or stromal hyperplasia. Glandular hyperplasia is hyperintense (Figure 2.4 a) and while stromal is hypointense in signal (Figure 2.4.1 a).

On T2W images, prostate cancer frequently appears as a low signal, ill-defined lesion in the peripheral zone. The majority of prostate cancers (>70%) occur in the peripheral zone, which has a high signal, making cancers easy to detect on MRI (Figure 2.4.2).

Clinical and laboratory correlation is important to exclude other differential diagnosis(29).

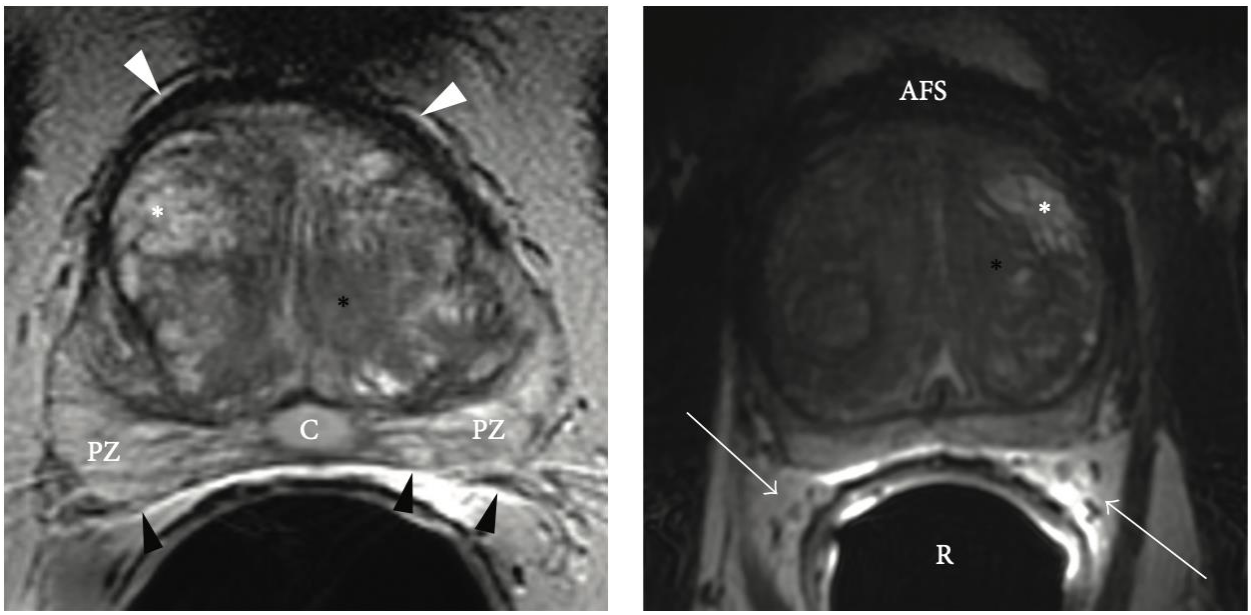
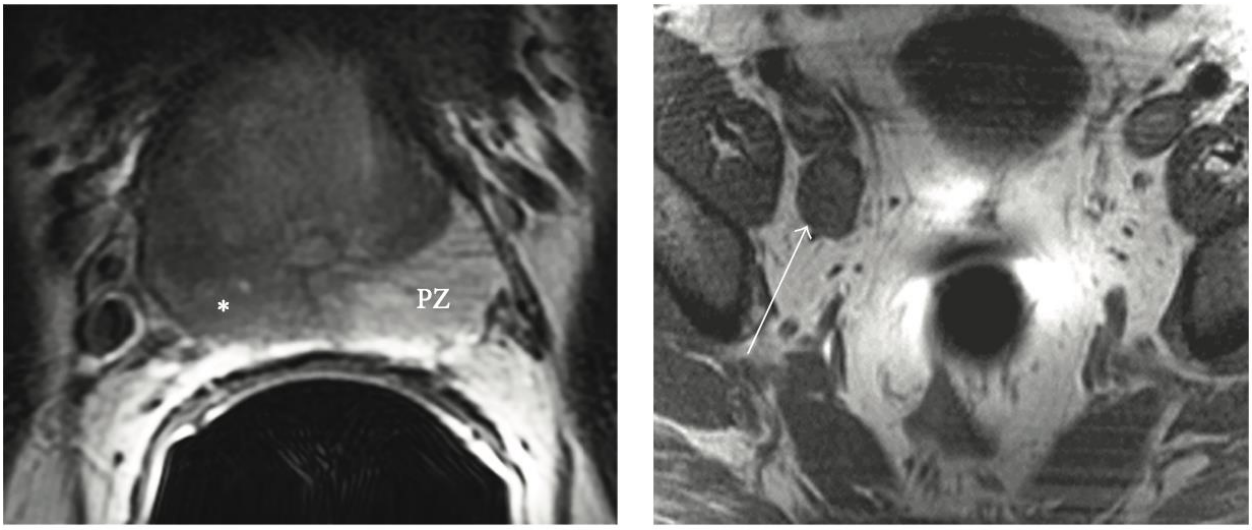


Figure 2.4.1: Two in a series of axial T2W MRI images of the prostate gland (a and b) midgland level.
Both glandular (white asterisk) and stromal (black asterisk) Hyperplasia has been identified. The white arrowheads represent the anterior fibromuscular stroma; the black arrowheads represent the rectoprostatic angle; and the PZ represents the peripheral zone. (29).



(a) (b)

Figure 2.4.2. Two in a series of axial TW MRI images of the prostate gland with cancer. (a) showing hypointense signal within the right peripheral zone (*). The PZ is normal high signal-peripheral zone. (b) shows one in a series of axial T1W image with an enlarged right external iliac lymph node(29).

2.4.2. Transrectal sonographic features of prostate diseases

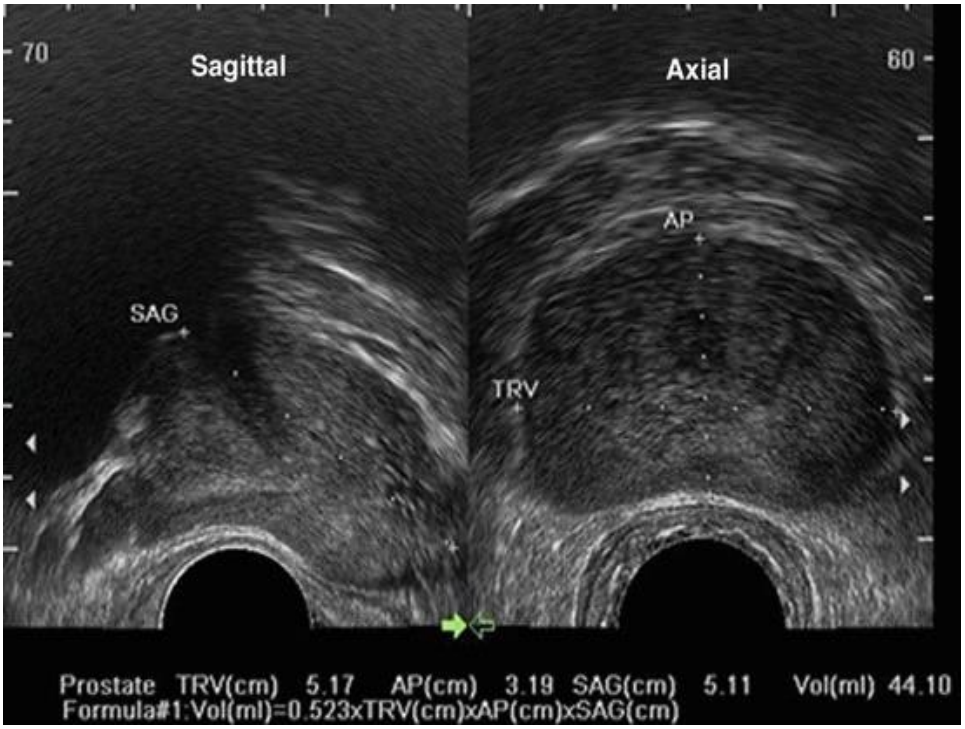


Figure 2.4.2a. Prostate volume is measured in three dimensions using transrectal sonograms. The width (TRV) and height (AP) are measured in transverse view. The length (SAG) is measured in sagittal view. The machine automatically calculates the volume or uses the ellipsoid formula (0.52 x transverse diameter x A–P diameter x longitudinal diameter) to estimate the volume (1,2), which is similar to the methodology used in the current study.

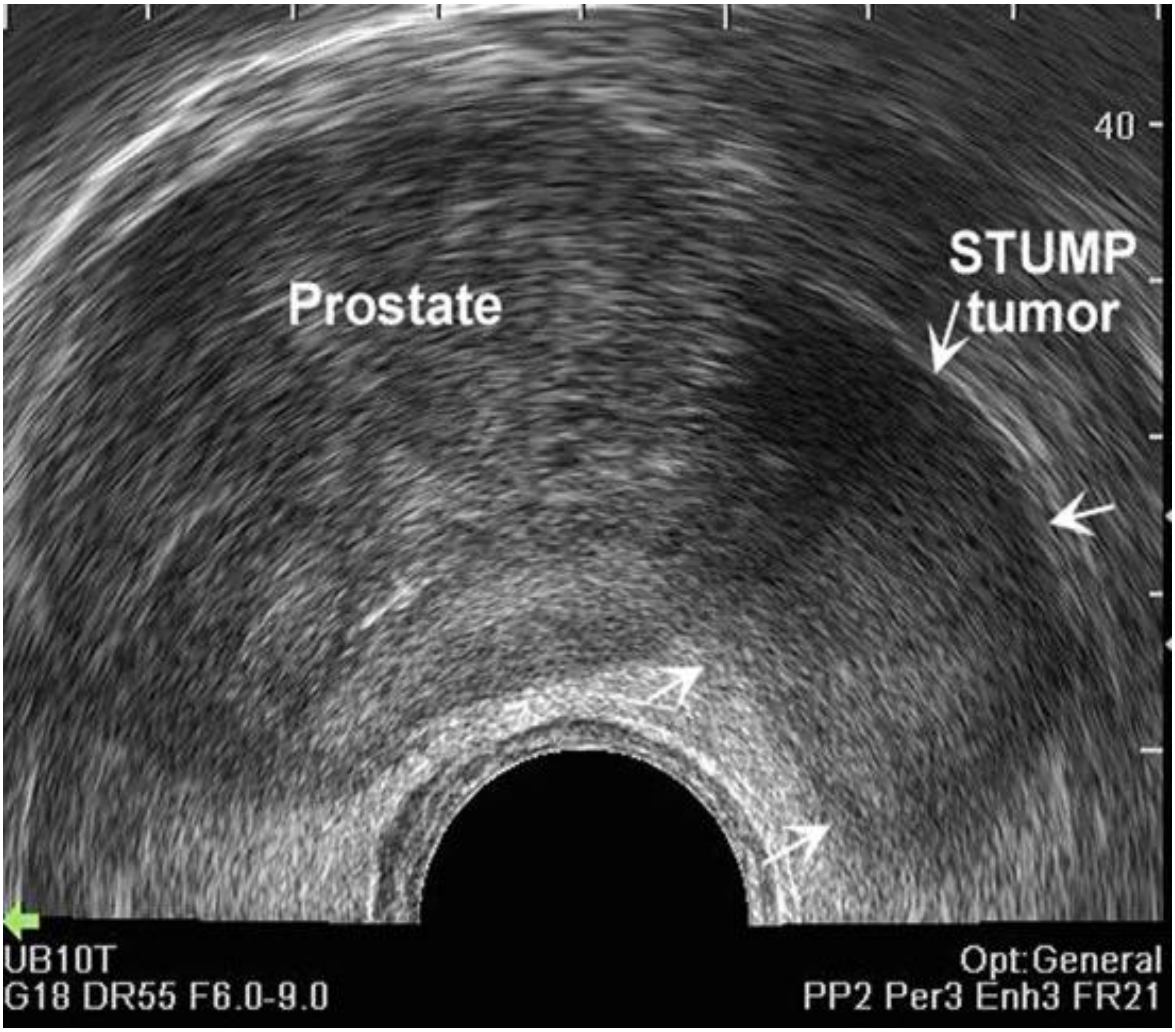


Figure 2.4.2 b. An axial sonogram of the prostate reveals a hypoechoic solid mass adjoining the gland's left lateral margin, confirmed as a stromal tumor (1).

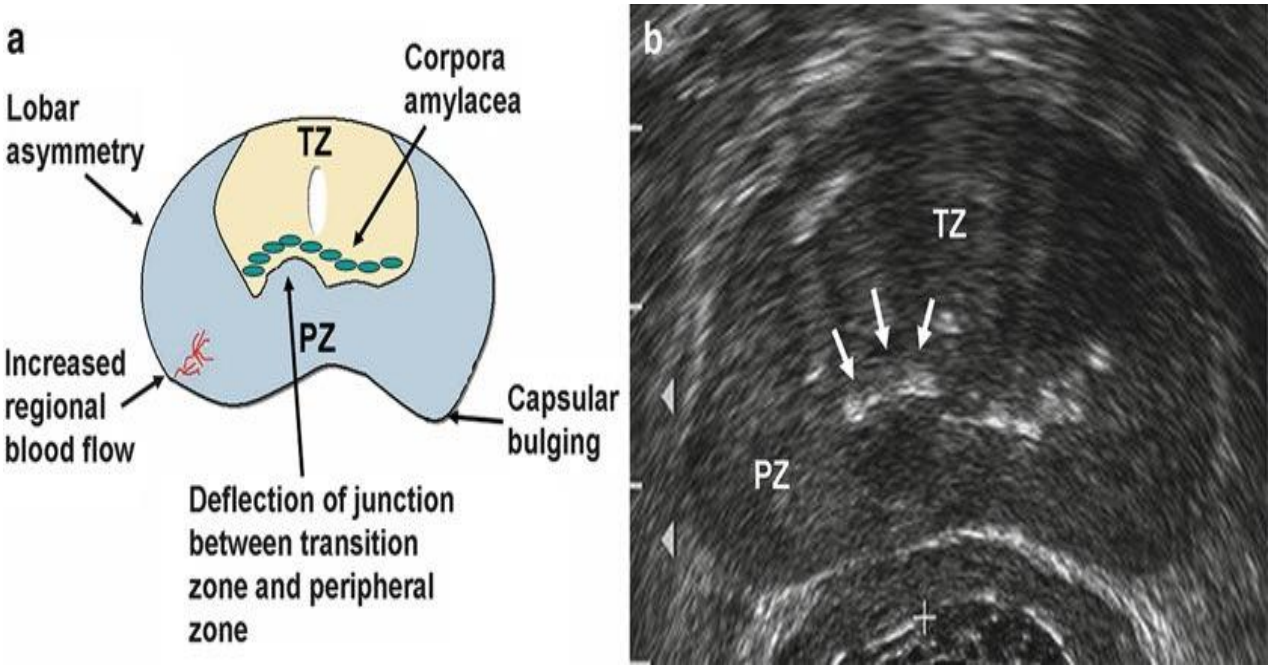


Figure 2.4.2c (a and b) suspicious findings for prostate cancer are depicted. (b) A transverse sonographic image of the prostate shows an upward deflection of the transition zone-peripheral zone junction, as indicated by the corpora amylacea (arrows) (1).

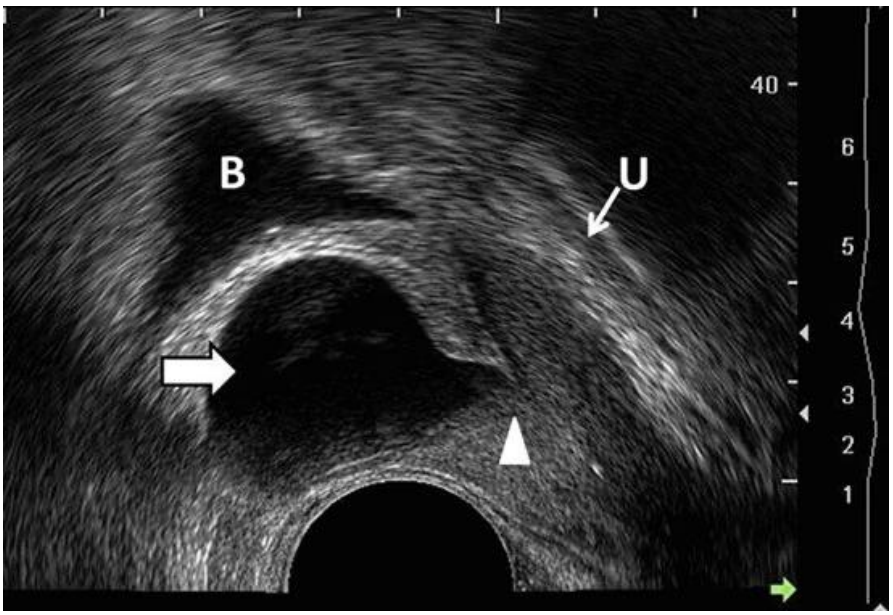


Figure 2.4.2d .Transrectal sagittal sonogram of the prostate demonstrating utricular cyst. The image shows a well-defined pear-shaped anechoic lesion in the midline consistent with utricular cyst (arrow). B bladder, ureter (U) (1)

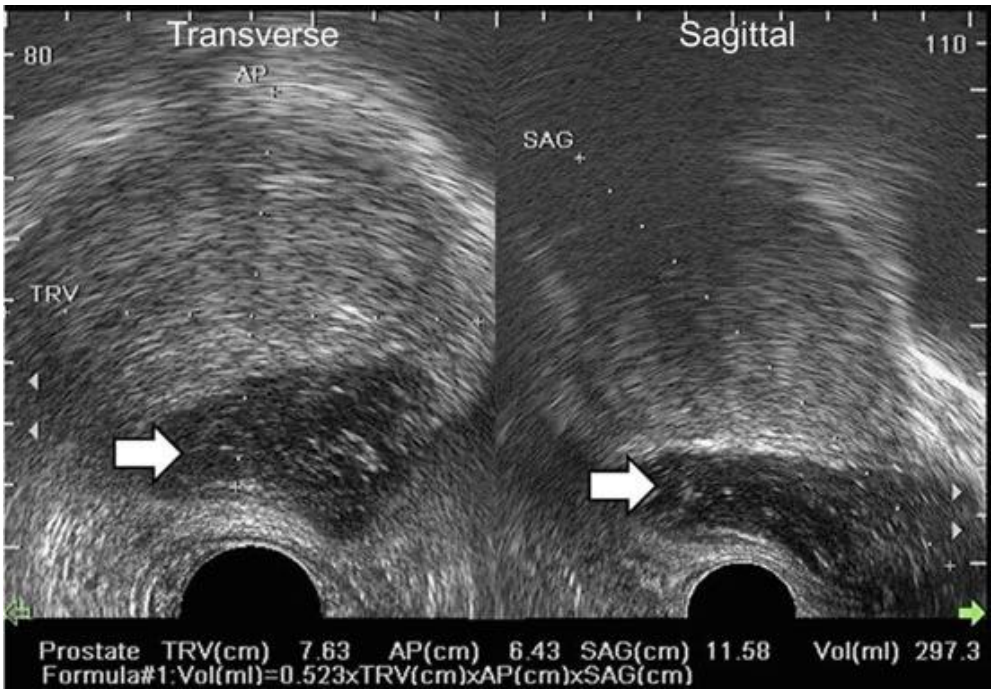


Figure 2.4.2e Transrectal sagittal sonogram of the prostate demonstrating abscess. Prostate abscesses (arrows) appear as hypoechoic lesions with hyperechoic fossa consistent with gas bubbles on axial and sagittal views (1).

2.5 Pathophysiology of Prostate Enlargement

Prostate enlargement starts in the periurethral region and glandular tissues in the transition zone. The presence of prostatic incursion by enlargement into the urethral lumen and/or bladder neck results in significant change in bladder outlet resistance due to mechanical obstruction. In spite of the fact that the size of the prostate does not appear to be a significant predictor of clinical deterioration, the larger the prostate, the greater the probability of future clinical deterioration (31).

With a prostate growth rate of 2-2.5 percent, aging is a significant risk factor for prostate cancer. With age comes significant inflammation and microvascular illness, with the resulting ischaemia and oxidative stress, and the formation of BPH (44) is a result of these factors coming together.

Besides heredity and hormones, other risk factors include inflammation and lifestyle variables such as a poor diet, insufficient exercise, smoking, and excessive drinking (9).

These elements contribute to the rise in the number and size of cells through epithelial and stromal proliferation, which is a proliferative process. As enlargement progresses, prostatic intrusion into the urethral lumen or bladder neck may occur, resulting in obstruction of the bladder outflow (BOO).

Clinical benign prostatic hyperplasia is characterized as the presence of at least two of the following characteristics (45):

- • moderate to severe lower urinary tract manifestations, as measured by an international prostate symptom score of 8 or higher;
- an enlarged prostate, as evidenced by imaging evidence of total prostatic volume [TPV] >30 mL;
- decreased maximal flow rate of less than 15 mL per second.

Genetic linkage has been associated with the development of BPH especially in men less than 60years. The literature suggest inheritance of the gene in autosomal dominant fashion leading to BPH.

The development of clinical BPH has been linked to testosterone. The enzyme type II 5-alpha reductase converts testosterone to dihydrotestosterone (DHT) in the prostate. Cell proliferation, differentiation, morphogenesis, and functional maintenance are all affected by DHT (46).

The epithelium and stromal tissues of the prostate include the receptors for epithelial growth factor, fibroblast growth factor, and transforming growth factor-beta. The stimulation of these growth hormones results in stromal cell proliferation and substantial tissue remodeling, which ultimately leads to BPH (47).

2.6. Management and Treatment of prostate gland anomalies

The initial management requires lifetime modification such as regular physical exercise, eating foods rich in fibre and vegetables, reducing fatty diet, fluid restriction for nocturia, frequency and polyuria (33).

Treatment options include -adrenergic blockers, 5-alpha-reductase inhibitors, and a low-dose oral phosphodiesterase (PDE)-5 inhibitor (tadalafil) (48–50). The type of medication prescribed is determined by a variety of parameters, including the severity of the symptoms, the volume of the gland, and the PSA value. The drugs affect the smooth muscle relaxation in the bladder neck and prostatic stroma, as well as preventing testosterone conversion to dihydrotestosterone, which reduces cellular proliferation in the bladder neck and prostate. It may take up to 6 months for the medications to have a meaningful effect on prostate size reduction. Hypotension, headache, dizziness, erectile dysfunction, and ejaculatory dysfunction are some of the most common adverse effects, although there are others as well (49).

Surgical procedures have long been regarded as the gold standard of medical care. The following are some examples of surgical indications (26):

- ineffective medical therapy;
- a wish to discontinue medication;
- a significantly high PVR volume; recurring urinary tract infections,
- recurrent hematuria,
- bladder calculus;
- postrenal acute kidney injury.

Open prostatectomy, transurethral microwave thermotherapy, transurethral resection of the prostate, high-intensity focused ultrasound, transurethral electro vaporization, prostatic stent insertion, and a variety of other surgical options are available (51). The transurethral prostatectomy is the surgical gold standard in this setting.

Commonest complications of surgical management are bleeding, dilutional hyponatremia resection syndrome. A review of 3885 patients showed ~2.5% of the patients required transfusion

following intraoperative bleeding (51). The dilutional hyponatremia is associated with bladder irrigation with isotonic fluid. Other complications include ejaculatory dysfunction, urethral strictures and incontinence of urine and erectile dysfunction (33).

Recently, prostate artery embolization shows promise in the management of BPH. This intervention provides a targeted model of investigating and embolizing the prostate arteries. However, efficient application of this treatment modality requires the radiologist to have better understanding of the pattern and variations that may exist in each gland examined (52,53).

PAE is being studied to understand where it fits into the BPH management scheme. Patients with intermediate to severe lower urinary tract obstruction caused by benign prostatic hyperplasia who have not responded to medications or find the treatments unpleasant due to side effects are candidates for prostate artery embolization. It's also for patients who aren't candidates for surgery owing to comorbidity or patient desire, in order to avoid the aforementioned risks (54).

2.6.1 Non-surgical management of prostate gland anomalies

The current management strategies involve lifestyle modifications, pharmacotherapy, physiotherapy, and surgical interventions as indicated (55). Pharmacists are in the unique position of being accessible sources of healthcare information for the BPH patient population. Understanding the symptoms of this disorder and therapy options will be beneficial for pharmacists who have increased chances to answer BPH-related questions from their patients (55).

These classes of agent for managing prostate diseases such as LUTS and BPH include Alpha 1-adrenoceptors (α1-blockers), 5- Alpha reductase inhibitors (5-ARIs), Antimuscarinic or Anticholinergics, Combination therapy of two or more agents (59–62).

Common class of medical treatment of BPH, mechanisms of action, advantages, side effects and recommendation have been documented in Table 2.6.

Table 2.6.1: Agent of medical treatment of BPH, mechanisms of action, advantages, side effects and recommendation

Class of agent (types of drugs)	subgroup	Mechanisms of action	Advantages	Side effects	Recommendation
Alpha 1-adrenoceptors (α1-blockers)	Terazosin, doxazosin, tamsulosin, alfuzosin, silodosin	α1-receptors are highly expressed in the smooth muscle cells of the prostate gland, bladder neck, and urethra (60). Based on this physiological mechanism, a1-adrenergic antagonists bind to α1-adrenoceptors on the smooth muscle cells of the urethra and cause relaxation in smooth muscle tone, thereby reducing urethral resistance and relieving LUTS (61).	α 1-blockers are commonest agent prescribed by urologists to treat BPH, and it improves patients with LUTS. They reduce IPSS and increased the urinary flow rate (57).	This include postural hypotension, dizziness, asthenia, abnormal ejaculation, and intraoperative floppy iris syndrome (61).	For men with moderate to severe LUTS, and high risk of BPH. The choice of agent should depend on the patient's comorbidities, side effect profiles and tolerance (62).
5- Alpha reductase inhibitors (5-ARIs)	Finasteride, dutasteride	The testosterone and dihydrotestosterone (DHT) are known to promote the development of BPH and increase androgen-related activities in the prostate (58). The 5-ARIs can inhibit the conversion of testosterone and reduce the levels of DHT, thereby shrinking an enlarged prostate and preventing the progression of disease into BPH (58).	5-ARIs can significantly reduce PV and serum levels of PSA (60).	5-ARI treatments are associated with a range of side effects in BPH patients, including decreased libido, gynecomastia, and erectile dysfunction (ED) (60).	For men with moderate to severe LUTS and enlarged prostates (40 mL) or elevated prostate specific antigen levels ([1.4–1.6 lg/L)
Antimuscarinic/ Anticholinergics	Oxybutynin, tolterodine, darifenacin and solifenacin	Antimuscarinic agent has the ability to inhibit the action of acetylcholine and hence reducing the contractility of the detrusor muscle (48).	Anticholinergic agents are appropriate and effective treatment alternatives for the management of LUTS secondary to BPH in	Common side effects include dry mouth, constipation, urinary difficulties, nasopharyngitis,	Muscarinic receptor antagonists should be considered in men with LUTS who have predominantly vesical storage symptoms (48).

			men without an elevated post void residual urine volume(PVR) and when LUTS are predominantly irritative (63).	dizziness, confusion and restlessness (48).	This class of drugs should be used with caution in men with BPH and infravesical obstruction due to the possibility of incomplete emptying and the development of acute urinary retention (48,63).
Phosphodiesterase 5 inhibitors iPDE5s	tadalafil	The likely mechanisms of action stem from effects on smooth muscle relaxation, endothelial cell proliferation, improved blood flow, and activity on the prostatic efferent nerves.	iPDE5s significant reduction of IPSS after twelve weeks. iPDE5s is noted for the treatment of erectile dysfunction.		
Combination therapy	α1-blockers + 5-ARIs	α1 antagonist and 5ARi have different mechanisms of action, they have been used in combination to complement each other for faster, better and more sustained improvements in LUTS, urinary flow and prevention of BPH progression	McConnell et al. (56) conducted a longitudinal study(MTOPS Study) to assess the long-effect of α1-blockers or 5 a -reductase inhibitors, combined therapy on the clinical progression of BPH. The study found that long-term combination therapy with doxazosin and finasteride was safe and reduced the risk of overall clinical progression of BPH	Despite the obvious evidence of long-term benefits of combination therapy with doxazosin and finasteride, the potential side effects of these agents cannot be overemphasized. Effects such as postural hypotension, dizziness, asthenia, abnormal ejaculation, decreased libido, gynecomastia, etc. (56,60,61).	In treating patients with lower urinary tract symptoms and benign prostatic hyperplasia, combination therapy (of α1-blockers and 5-ARIs) is recommended since it is safe and the most effective therapy for men with an increased risk of progression (56,57). Patients successfully treated with combination therapy may be given the option of discontinuing the α1-

			significantly more than did treatment with either drug alone (56). It seems clear that combination therapy has both the advantages of α1-antagonist in providing early symptomatic relief and of 5ARi in prevention of BPH progression (57).		blocker after 6 to 9 months of therapy.
	α1-blockers + anticholinergics	Combination of anticholinergic drugs and α1-blocker may reduce storage symptoms and urinary frequency	A combine action of anticholinergic drugs and α1-blocker may increase the potency of individual drugs	It can increase the risk of acute urinary retention in patients with BPH with baseline postvoid volume > 150 mL, the rate of acute urinary retention is reduced in patients with postvoid volume < 150 mL	
	iPDE5s and α1-blockers	Combination of iPDE5s and α1-blocker	When compared to the group that only used iPDE5s to treat erectile dysfunction, combination therapy resulted in a statistically significant rise in the International Index of Erectile Function-	May cause symptomatic hypotension	Tadalafil, uroselective alpha-blockers (tamsulosin, alfuzosin), modest dosages of alpha-blockers, spacing doses for many hours rather than using both simultaneously, or waiting until the patient is on a stable dose of one

			Erectile Function (IIEF-EF).		medicine before starting the second one can help lessen this risk.
	iPDE5s and i5ARs		When compared to finasteride alone, combination therapy (tadalafil + finasteride) reduced the mean IPSS after 26 weeks by 5.5 points vs. 4.5 points, respectively. Patients improved with combination therapy compared to finasteride alone, but there was no overall clinical improvement.		In males with BPH, adding tadalafil to finasteride treatment may relieve urine symptoms moderately.

Beta-3 agonists are another type. This is a new class of medications that stimulates the sympathetic nervous system during bladder filling, encouraging detrusor muscle relaxation, improving bladder functional capacity, decreasing urine frequency and urgency episodes, and decreasing urinary urge. There is no interference in detrusor contraction and, thus, in the voiding process since it does not impact the parasympathetic system, which reduces the danger of urine retention.

2.6.2. Surgical management of prostate gland anomalies

Treatment of lower urinary tract symptoms (LUTS) and BPH has shifted over the last decades, with medical therapy being the primary treatment modality while surgery for emergency management of BPH (12,64,65). Surgery is recommended when patients have BPH-related complications (e.g., urinary retention, renal insufficiency, or recurrent urinary tract infections), or when patients fail to improve with conservative therapy or refuse drug treatment (66).

Also, very few studies have compared the effectiveness, safety, patient satisfaction, and costs of drug to surgical treatment for symptomatic BPH (12,64–66). Surgical therapy is indicated for patients with moderate- to-severe LUTS secondary to BPH who have failed medical therapy for more than 6 months (62).

Surgical management of patients with BPH have been categorized in invasive surgery and minimally invasive procedures. The invasive surgery include transurethral resection of the prostate, Laser prostatectomy/treatment, and open prostatectomy. Examples of minimally invasive surgical therapies (MIST): Transurethral incision of the prostate, thermo ablative strategies, prostatic stent, and prostatic artery embolization (12,59,67). Identified type of surgeries, indications, contraindications and complications and why patients refuse (Table 2.6.2)

Table 2.6.2. Type of surgical procedure, indications, contraindications and complications and why patients refuse

Types of surgery	Indications	Procedure	Contraindications	Complications	why patients refuse
A). Invasive surgery: Transurethral resection of the prostate, Laser prostatectomy/treatment, and open prostatectomy					
Transurethral Resection of the Prostate	TURP remains the gold standard and benchmark for surgical therapy for treatment of LUTS secondary to BPH (62,65). This procedure is most suitable for patients with prostate volumes < 80 mL, due to the limitations of successfully performing surgery as prostate volume size increases (65).	This procedure involves the resection of prostatic tissue circumferentially from the bladder neck to just cephalad to the verumontanum. It has been reported that success rate of TURP is higher in patients with preoperative Qmax < 15 mL/s (consistent with obstructed voiding) and men substantially bothered by urinary symptoms (12).	Not effective treatment for men with BPH when the prostate size is less than 30 mL (12,64).	Pain Prolonged use of catheter post-surgery.	An invasive procedure
Laser prostatectomy/ treatment	Absolute indications to recommend TURP include: urinary retention (intractable) and renal insufficiency. Relative indications to recommend TURP include: failure of medical therapy, recurrent cystitis, bladder calculi and persistent prostatic bleeding (62). Men with larger prostates who wish	An emerging evidence suggests a possible role of trans-urethral enucleation and laser vaporization as options for men with very large prostates (100g). Photoselective vaporization of the prostate involves the use of potassium titanyl phosphate and/or lithium borate lasers, referred to as “green light lasers,” as the wavelength is in the green portion of the visible. This wavelength is absorbed	Not effective treatment for men with BPH when the prostate size is less than 30 mL(12,64)	There is little bleeding or fluid absorption	An invasive procedure

	to avoid more-invasive surgery (68).	by water irrigation as well as hemoglobin and results in a penetration depth of 0.8 mm.			
Open prostatectomy	Prostatectomy is typically reserved for men with large prostates (> 80 mL) or men who cannot tolerate a trans-urethral procedure (62). The choice of open, laparoscopic or robotic assisted prostatectomy depend on the level of expertise with these techniques (67).	This simply removes the entire prostate gland with laparoscopic or robotic-assisted surgery	OP is associated with increased risk of blood loss, transfusion, and longer hospital stay when compared with the robotic approach. OP shows an average 10-point reduction in symptom scores and 14 mL/s improvement in Qmax.	It increased patients' risk of blood loss, transfusion, and longer hospital stay	Fear of delay in sexual function returning normal. Longer hospital stay and being invasive procedure (69,70).
B). Minimally invasive surgical therapies (MIST): Transurethral incision of the prostate, thermo ablative strategies, prostatic stent, and prostatic artery embolization					
Transurethral Incision of the prostate(TUIP)	TUIP is an effective treatment in men with moderate-to-severe LUTS secondary to BPH when the prostate size is less than 30 mL (12,64,65) and men who do not want a complete prostatectomy but need surgery are good candidates (68).	TUIP is typically an outpatient procedure involving one or two incisions in the prostate from the bladder neck to just cephalad to the verumontanum, which thereby reduces constriction of the urethra (64,65).	This procedure is not suitable for patients with prostate volumes < 80 mL, due to the limitations of successfully procedure (65).	About three days hospital stay and use catheter for three days post-surgery	The use of catheter for three days post-surgery
Thermo ablative strategies such as Transurethral microwave thermotherapy	TUMT is a reasonable treatment consideration for the patient who has moderate symptoms, small prostate size (62).	This procedure uses water vapor (steam) to destroy prostate cells squeezing the urethra. It uses a special handheld device with a needle	Large prostate size and evidence of severe bleeding	Acute bloody urine, and may need a catheter for some days	Painful and/or frequent urination

(TUMT), water vapor thermal therapy, etc.	Men who prefer not to have surgery or want to avoid sexual side effects may also be good candidates	at the end, which combines radiofrequency energy and water to create steam. The needle and steam cause rapid cell death. The body's natural healing response then breaks down and removes the dead tissue, causing the prostate to shrink (68).			
Prostate artery embolization (PAE)	A therapeutic modality for the management of LUTS secondary to BPH (70). PAE for the treatment of BPH should, at present, be considered only in patients prostate volume[50 mL]) (69,70). Patients with BPH and moderate-to-severe LUTS who are deemed not to be surgical candidates for any reason, including patients presenting with advanced age, multiple comorbidities, coagulopathy, or inability to stop anticoagulation or antiplatelet therapy (69).	Bilateral embolization of the prostate arteries is ideally performed through a single femoral or radial artery puncture. There is prostate artery catheterization while 100–200 lg of nitroglycerin may be injected to prevent vasospasm and to increase the diameter of the artery to facilitate distal catheterization. Super-selective CBCT may be used when the catheter is located in the prostate artery to confirm the adequate position and avoid non-targeted embolization (69–71).	Patients suffering from neurologic disease, bladder dysfunction, urinary tract infection, stone disease, and urethral stricture, among others. Patients with severe atherosclerosis and/or tortuosity of the vessels depicted with CTA may be excluded.	Self-limiting hematuria, self-limiting hematospermia, self-limiting urge incontinence, UTI, non-target embolization-penile ulcer, and hematoma were among the consequences reported.	Current evidence remains limited. There is no clear indications and contraindications for PAE. Risk of catheterization for 2 weeks. Painful and require analgesic

2.7 Patterns of prostate artery

The biggest challenge of prostate artery embolisation is the identification of the prostate arteries (20). According to Bilhim et al. (72) digital subtraction angiography alone during the procedure makes it difficult to identify the prostate arteries especially differentiating them from vesical and middle rectal arteries. As a result, it is critical to properly identify the prostate arteries in the pre-procedure Computed Tomography angiography (CTA) and patients with severe arterial disease that would make cannulation of the arteries impossible and jeopardize the procedure's technical success are ruled out.

The internal iliac artery (IIA) supplies the pelvic organs, pelvic walls, the gluteal region and the perineum. Yamaki et al. (73) classified the branching pattern of IIA, into five types, after modifying Adachi's classification. The new classification was to make it simple and easy for clinical purposes. Yamaki et al. (73) dissected 645 adult, cadaveric pelvic halves, over a sixteen-year period. They considered 'superior gluteal artery, inferior gluteal artery, internal pudendal artery and umbilical artery' as the principal vessels for classification using Adachi's classification (73).

Summary of Adachi's classification (73)

Type I: The superior gluteal artery arises seperately from the main stem, and the inferior gluteal and internal pudendal arteries have a common trunk that is the second branch. If the division occurs within the pelvis (type Ia) or outside the pelvis (type lb).

Type II: The superior and inferior gluteal arteries have a shared trunk, while the internal pudendal artery has its own primary stem, which is the second branch. Type IIa occurs when the superior gluteal and inferior gluteal arteries bifurcate within the pelvis. Type IIb occurs when the division occurs outside of the pelvis.

Type III: The internal iliac artery splits into three primary branches (superior gluteal, lower gluteal, and internal pudendal), with the internal pudendal artery being the last branch.

Type IV: A shared trunk gives rise to the superior gluteal, inferior gluteal, and internal pudendal arteries. Type IVa occurs when the superior gluteal artery emerges first from the common trunk and then separates into the inferior gluteal and internal pudendal arteries. It is IVb if the internal pudendal artery branches from the common trunk first, then separates into the superior and inferior gluteal arteries.

Type V: The superior gluteal and internal pudendal arteries originate from a common trunk, and the inferior gluteal artery branches independently from the common trunk..

Yamaki et al found a higher prevalence of Adachi's type I in their studies (58%). Type II was significantly lower than Adachi's. The least prevalent type was type V, with most studies reporting <1%.

Based on the anterior and posterior division module, Yamaki et al. classified internal iliac artery branching patterns into 4 categories. They were divided into four groups based on how the superior gluteal artery (SGA), inferior gluteal artery (IGA), and internal pudendal artery (IPA) branch.

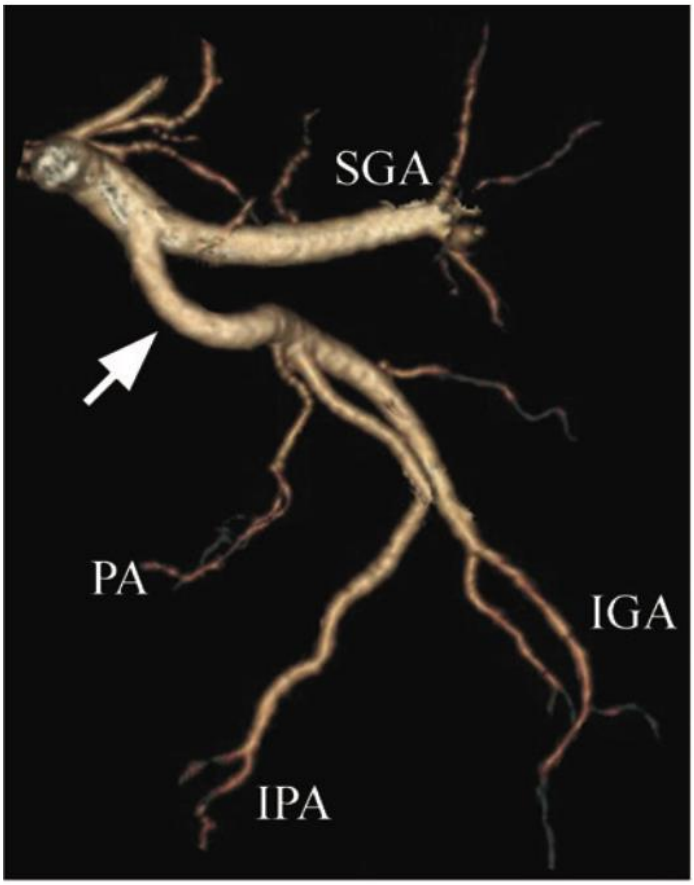


Figure 2.7.1Shows one in a series of 3D reformatted CT angiography of the pelvis showing group A branching pattern of the internal iliac artery (33).

Group A

- Posterior division – Superior gluteal artery (SGA)
- Anterior division – Inferior gluteal (IGA) and internal pudendal artery (IPA)

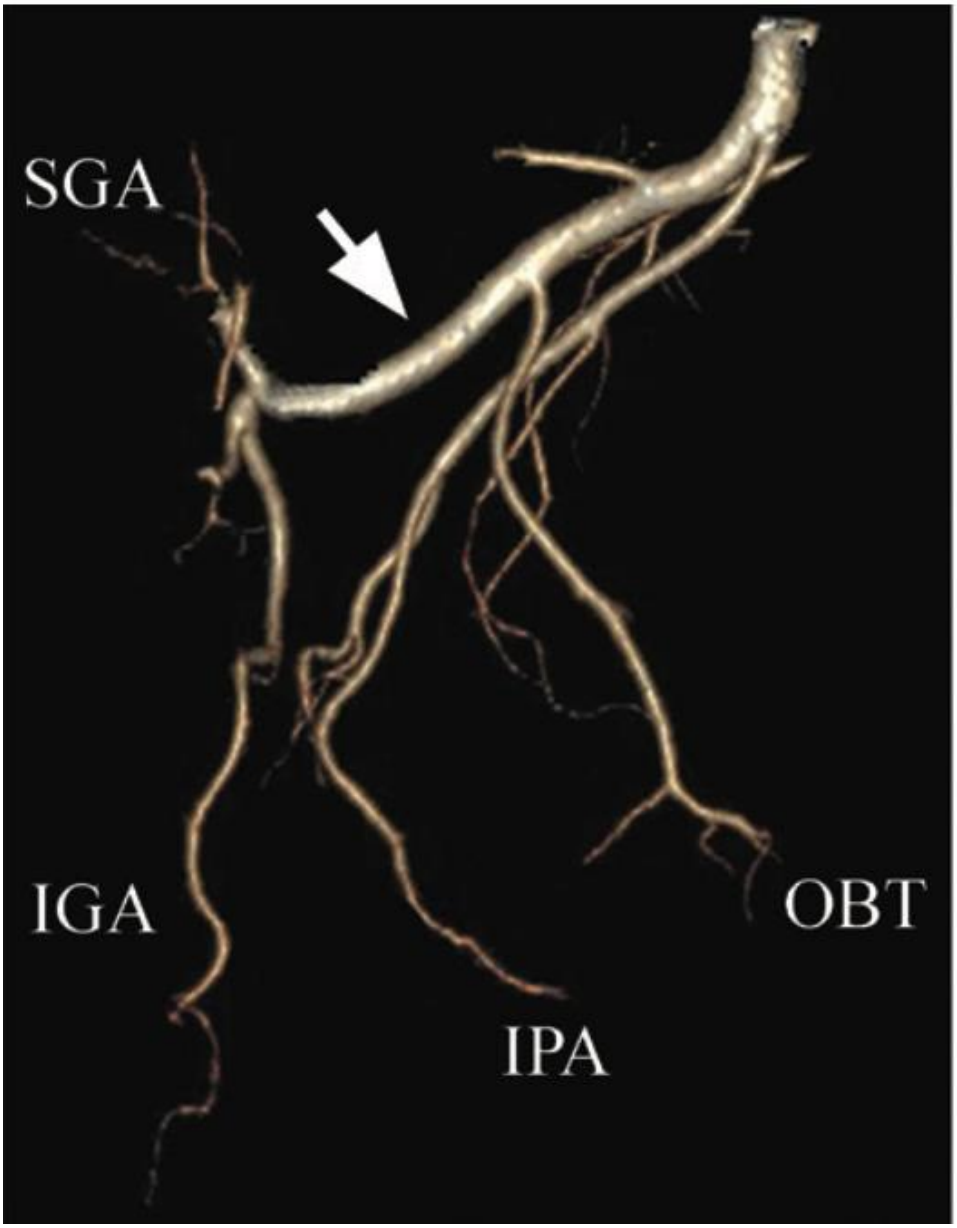


Figure 2.7.2 Shows one in a series of 3D reformatted CT angiography of the pelvis showing group B branching pattern of the internal iliac artery. The obturator artery OBT arises from the gluteal trunk(33).

Group B

- Posterior division – Superior (SGA) and inferior gluteal (IGA) arteries arise from the gluteal trunk.
- Anterior division – Internal pudendal artery IPA

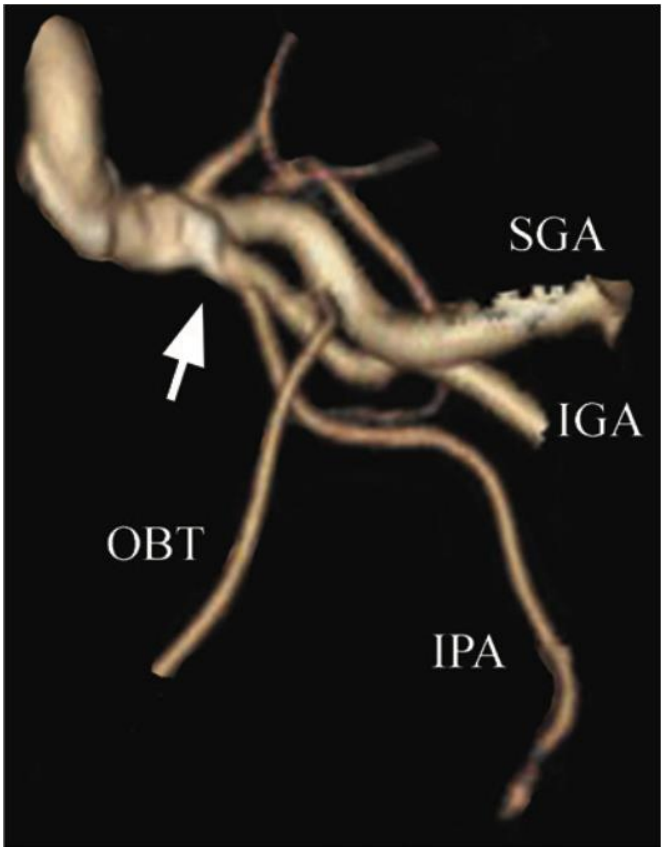


Figure 2.7.3 Shows one in a series of 3D reformatted CT angiography of the pelvis showing group C branching pattern of the internal iliac artery. The obturator artery OBT arises from the superior gluteal artery(33).

Group C

- The internal iliac artery is trifurcated into the superior gluteal (SGA), inferior gluteal (IGA), and internal pudendal arteries (IPA).

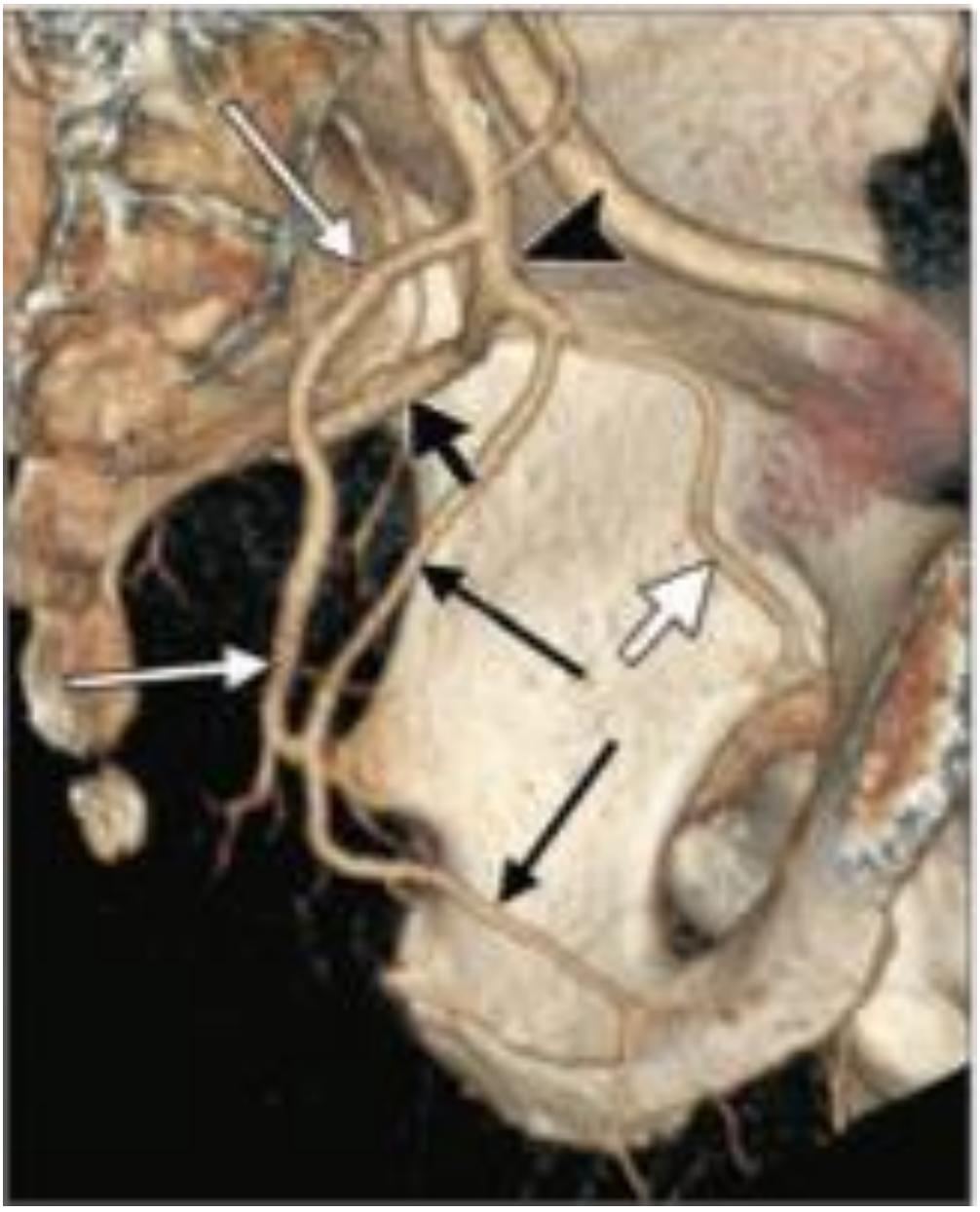


Figure 2.7.4 Shows one in a series of 3D reformatted CT angiography group D branching of internal iliac artery. Anterior division (arrowhead) with the superior gluteal artery (thick black arrow), and internal pudendal artery (thin black arrows). Posterior division gives rise to inferior gluteal artery (thin white arrows). Obturator artery emerging from superior gluteal artery is indicated by a thick white arrow (74).

Group D

- Posterior division: Superior gluteal and internal pudendal arteries have a single trunk.
- Anterior division: Inferior gluteal artery

2.8 Gluteal arteries

Of all the internal iliac branches, the superior gluteal artery is the largest. It has a superior concave trajectory and arises from the posterior division. The larger sciatic foramen, beneath the pyriformis muscle, is where it exits the pelvis. The superior and inferior lateral sacral arteries, as well as the parietal muscular and iliolumbar arteries, are major branches. In the gluteal region, the artery divides into superficial and deep muscular branches.

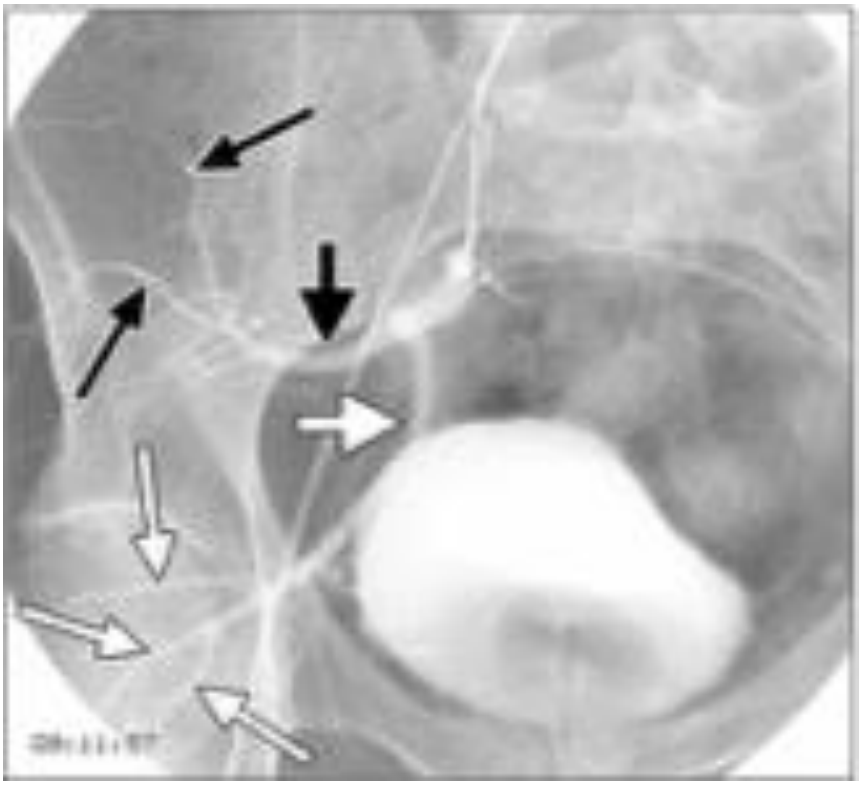


Figure 2.8.1: The gluteal arteries are visible on conventional angiography of the posterior division of the internal iliac artery in AP projection.

The superior gluteal artery (thick black arrow) exists the pelvis through the superior half of the greater sciatic foramen and travels to the gluteal region, where it terminates as superficial and deep muscle branches (thin black arrows) (74).

The inferior gluteal artery, which has a variable origin, is the second largest branch of the internal iliac artery. It could come from either the anterior (group A bifurcation) or posterior (group B bifurcation). It leaves the pelvis via the greater sciatic foramen behind the internal pudendal artery on a downward and outward trajectory.

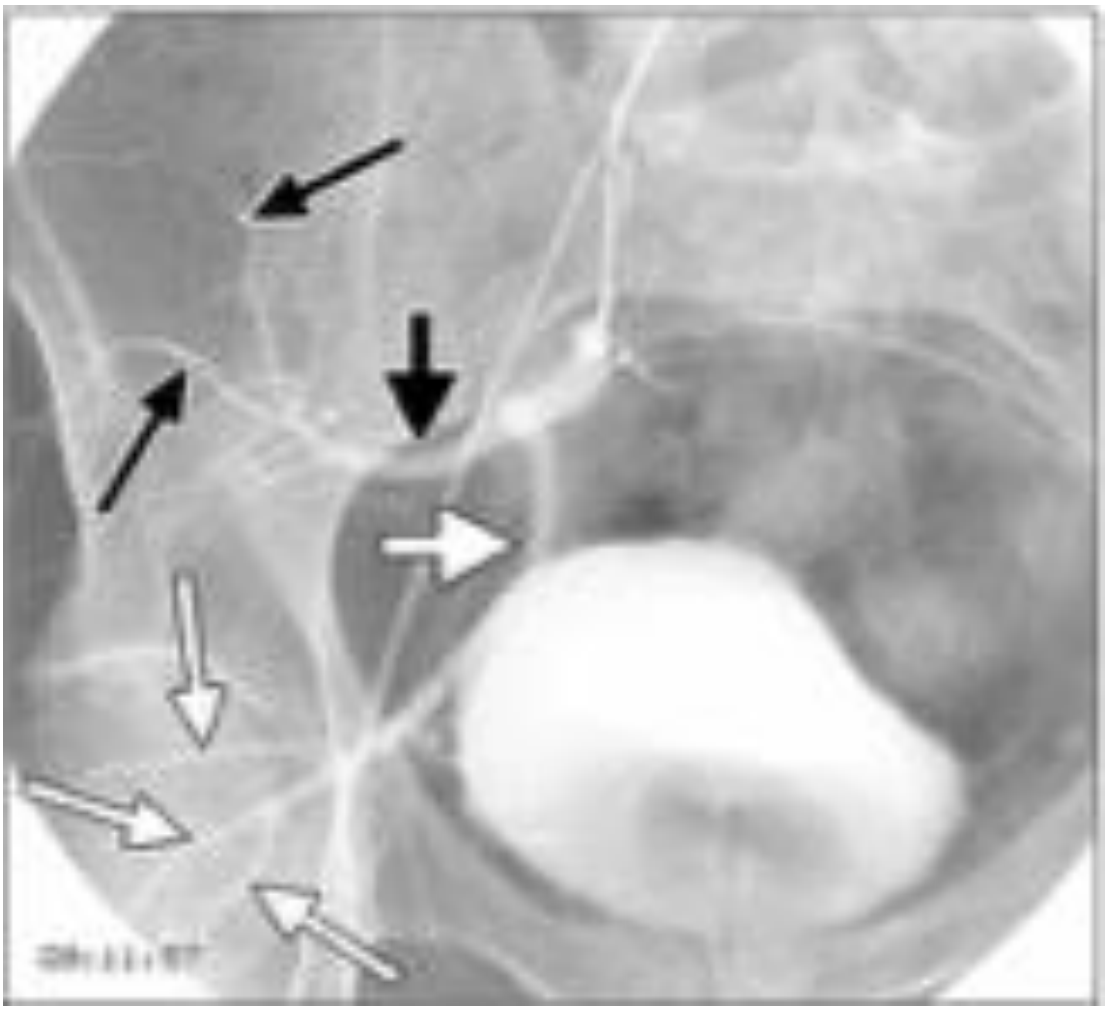


Figure 2.8.2: Angiography of the posterior segment of the internal iliac artery in AP projection reveals gluteal arteries.
The inferior gluteal artery (thick white arrow) arises from the posterior division of the IIA (group B bifurcation), exits the pelvis through the inferior part of the greater sciatic foramen, and ends with numerous muscular branches in the inferior gluteal region (thin white arrows) (74).

2.9. Internal pudendal artery

The internal pudendal artery supplies the perineum and male external genitalia (Figure 2.9.1)(74). It begins in the anterior division of the IIA and travels downward and outward, exiting the pelvis beneath the superior gluteal artery and entering the greater sciatic foramen on the inferior side. It then travels through the ischial spine and resurfaces in the pelvis via the lesser sciatic foramen. Superior and inferior vesical arteries, the middle rectal artery, the prostatic artery, and the vesiculodeferential artery are among the branches.

It gives branches to the following arteries in the perineum: tiny muscle branches, inferior rectal artery, and perineal scrotal artery. The internal pudendal artery has two terminal branches: the perineal scrotal artery and the penile artery. The penile artery gives rise to the dorsal artery of the penis and the deep artery of the penis (cavernosal artery).

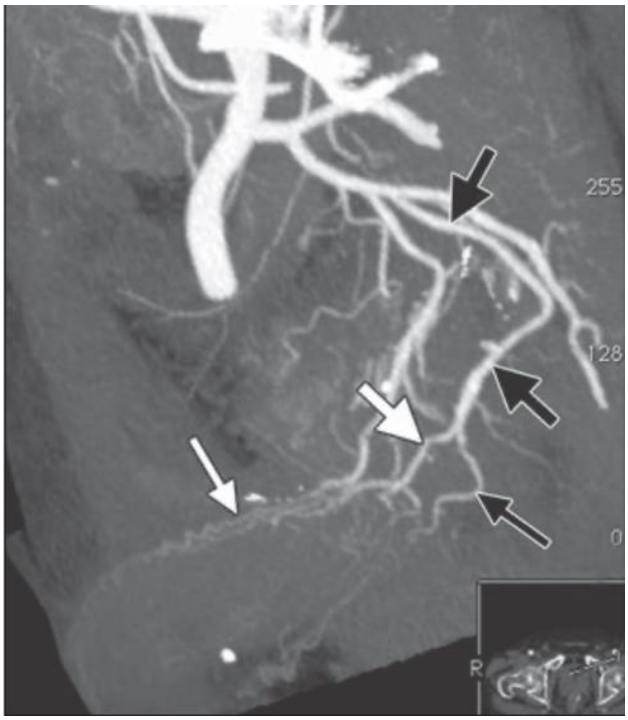


Figure 2.9.1: One in a series of 3D MIP reformatted CT angiography of the internal pudendal artery making a 90° curve to enter the perineum (thick black arrows).
It divides into two branches beyond the curve: the perineal scrotal artery (thin black arrow) and the penile artery (thick white arrow). The dorsal artery of the penis joins the penile artery (thin white arrow) (74).

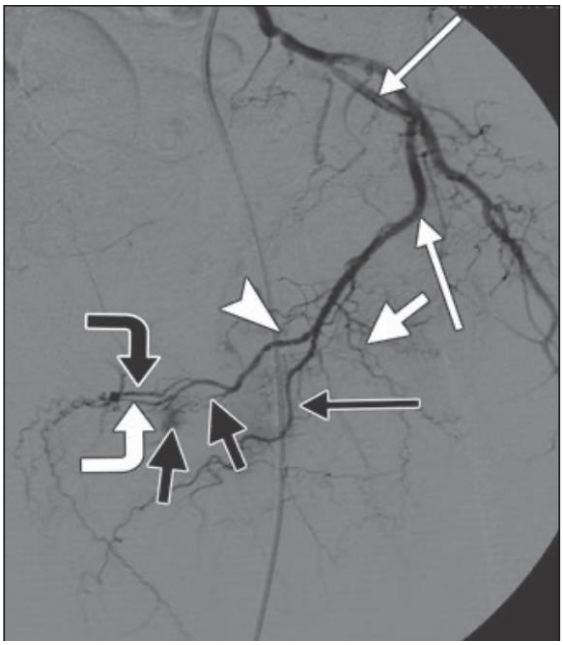


Figure 2.9.2: Internal pudendal artery DSA.
The internal pudendal artery (thin white arrows) enters the perineum and supplies muscle branches (thick white arrow). It divides into two branches: the perineal scrotal artery (thin black arrow) and the penile artery (arrowhead). The penile artery gives rise to the bulbar artery (thick black arrows) with typical capillary blush and terminates in the cavernosal artery (white curved arrow) and the dorsal artery of the penis (black curved arrow) (74).

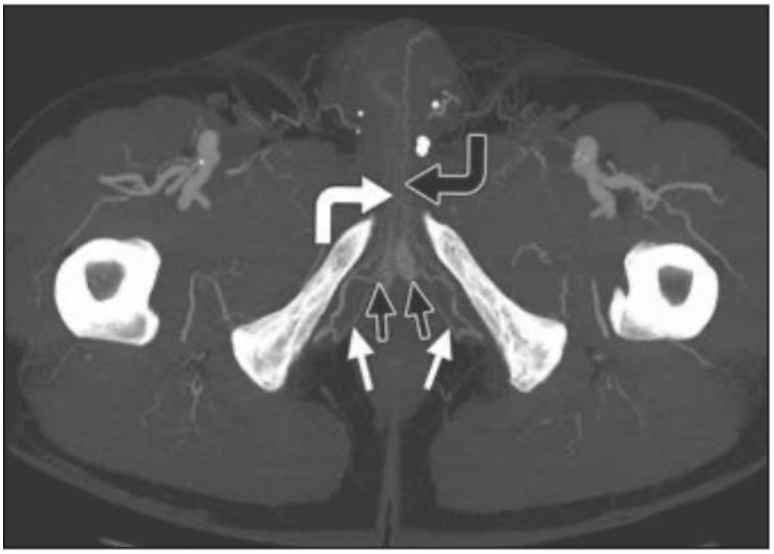


Figure 2.9.3: An axial MIP reformatted CT angiography of the penile artery.
The perineal scrotal artery (white straight arrows), bulbar artery with capillary blush (black straight arrows), cavernosal artery (white curved arrow), and dorsal artery of penis (black curved arrow) (74).

2.10. Obturator artery

The obturator artery is formed by the internal iliac artery. In 66% of cases, it originates from the anterior or posterior divisions. In 30% of cases, it arises from the inferior epigastric artery, a branch of the external iliac artery also known as the aberrant, auxiliary, or corona mortis artery(74). (Figure 2.10.1(74)).

The obturator artery emerges from the IIA in a straight line and travels forward and downward along the pelvic margin before exiting through the obturator foramen. Parietal muscular branches, as well as vesical and prostatic arteries, are among the branches. Internal and external muscular branches are the terminal branches. If the origin is from the epigastric artery, It travels inside before descending vertically to the top of the obturator foramen. The artery could have the same branches and endpoints mentioned previously(74).

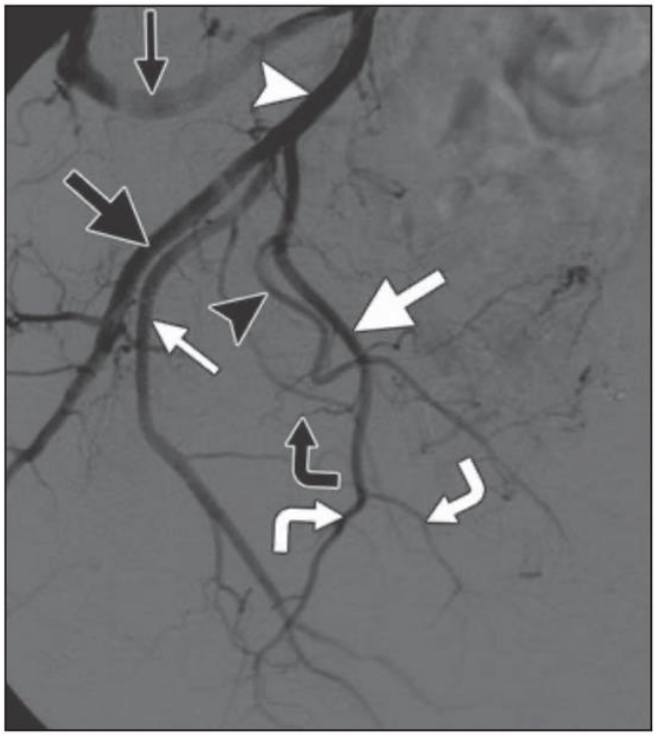


Figure 2.10.1: The internal iliac artery is visualized via a DSA.
Group A origin. The internal and external muscular branches (curved white arrows) of the obturator artery (thick white arrow) arise from the anterior division of the common anterior gluteal–pudendal trunk (white arrowhead), which bifurcates into the internal pudendal (thin white arrow) and inferior gluteal (thick black arrow) arteries. The posterior division of the superior gluteal artery is shown by a thin black arrow. Obturator artery gives rise to parietal muscle branches (curved black arrow) and the prostatic artery (black arrowhead) (74).

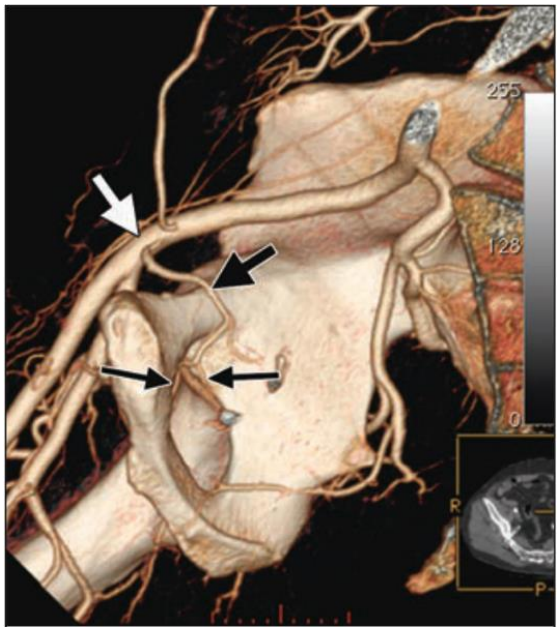


Figure 2.10.2: The obturator artery has an abnormal origin, as seen in this 3D volume-rendered reformatted CT angiography. The external iliac artery gives rise to the obturator artery (thick black arrows), which divides into internal and exterior muscle branches (thin black arrows) (74).

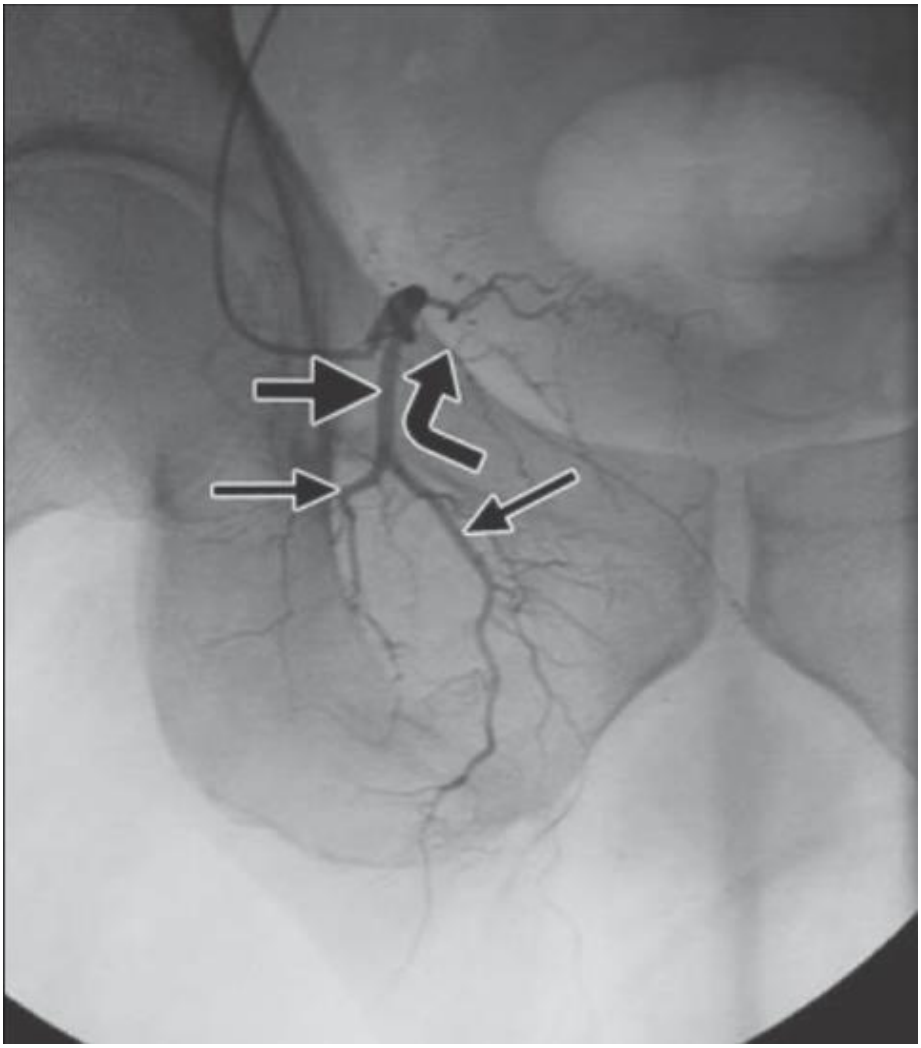


Figure 2.10.3: In AP view, selective DSA reveals the right auxiliary obturator artery.
The obturator artery (thick black arrows) starts from the external iliac artery and travels to the obturator foramen, where it gives rise to muscular branches (curved arrow) before terminating in internal and external muscular branches (thin black arrows) (74).

2.11. Important anatomic variants

2.11.1. Accessory Pudendal Arteries

The accessory pudendal arteries (APAs) run superior to the pelvic diaphragm, then dorsally to the pubic bone, before entering the penile hilum. They provide the corpora cavernosa with either a unilateral or bilateral arterial blood supply(75).

Apical APAs and lateral APAs are the two forms of APAs. The lateral APAs run close to the prostate's base and run along the anterolateral side of the prostate (Fig.2.11.1).

The apical APAs are located adjacent to the anterolateral prostatic apex, inferolateral to the pubovesical ligaments. The APAs show variable supply to the penis in a number of series, supplying only 3.2% of patients(74). Non target embolization of any of these vessels will result in penile ischaemia and interventional radiologist must be aware.

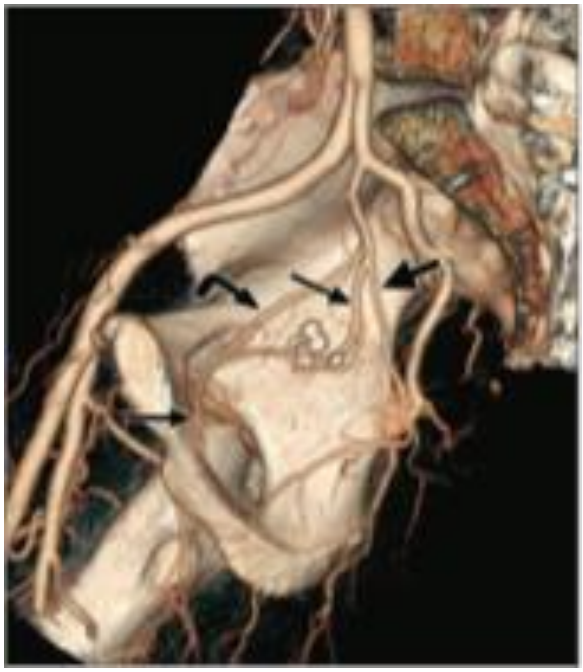


Figure 2.11.1: A 3D volume-rendered reformatted CT angiography
Lateral Accessory pudendal arteries (thin straight arrows) emerging from internal pudendal artery(thick straight arrow) (74).

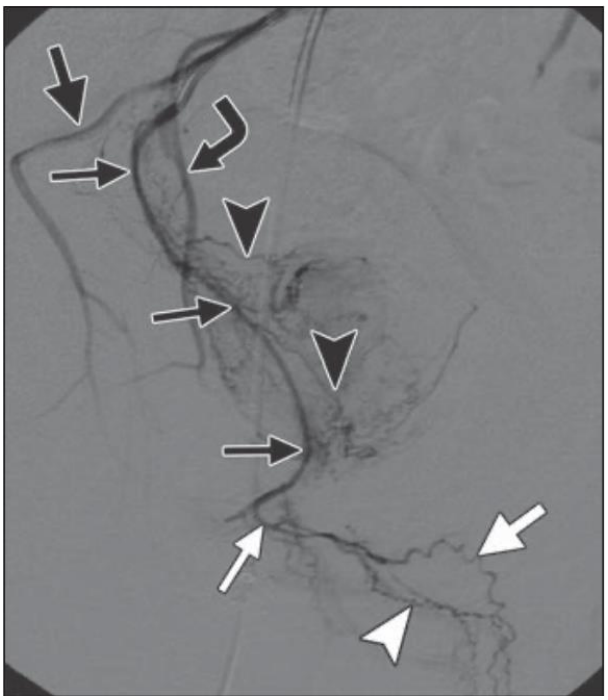


Figure 2.11.2: DSA of the right APA reveals the lateral APA (thin black arrows) terminating as the penile artery (thin white arrow) with the dorsal artery of the penis (thick white arrow) and cavernosal artery (white arrowhead).

The internal pudendal artery ends in the perineum with perineal scrotal artery. The lateral APA gives the prostatic arteries (black arrowhead). The obturator artery is visible (thick black arrow) (74).

2.11.2 Middle Rectal Arteries

The common prostate-rectal trunks, a branch of the internal pudendal or inferior gluteal arteries, or the common anterior gluteal–pudendal trunk are the most common sources of the middle rectal arteries (70 percent) Figure 2.11.2.a (74). It runs vertically downward, transversely medially, and terminates in the rectum, bifurcating into rectal branches and vertical branches, and anastomoses with the inferior rectal branches frequently.

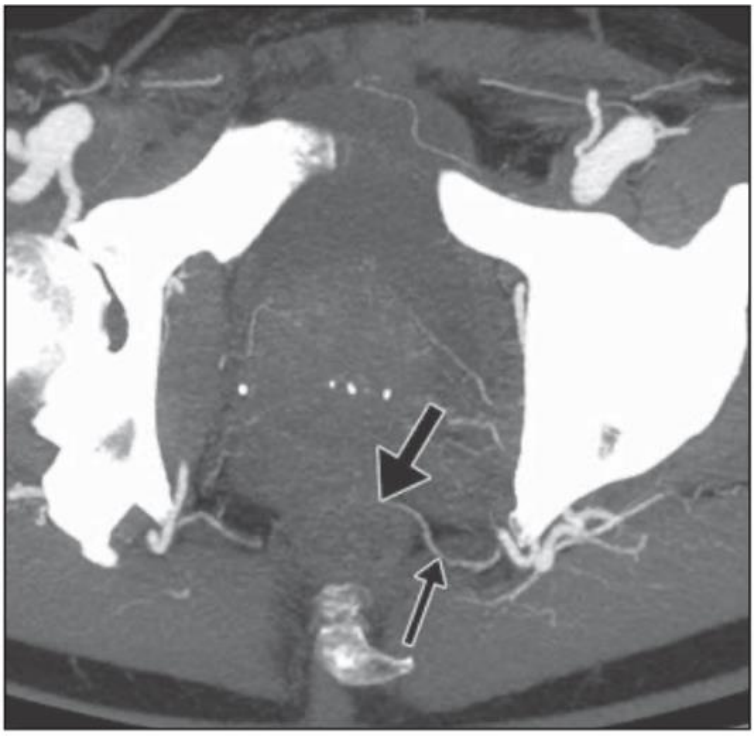


Figure 2.11.2.a: Axial MIP CT angiogram showing the middle rectal artery.
Middle rectal artery (thin black arrow) vascularizes rectal wall (thick black arrow) (74).

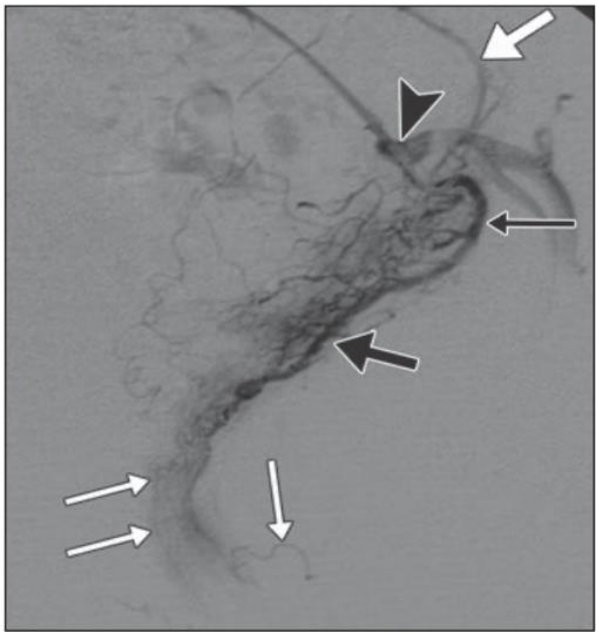


Figure 2.11.2.b: The middle rectal artery is seen on a digital subtraction angiography.
The anterior division of the internal iliac artery (arrowhead) gives rise to the middle rectal artery (thin black arrow), which vascularizes the rectal wall (thick black arrow) with anastomoses to the

superior and inferior mesenteric arteries (thick white arrow). Anal blush is also visible in the perineum, with anastomoses to the inferior rectal artery (thin white arrows) (74).

2.12 Prostate artery anatomy

On the basis of its vascular supply, the prostate gland is split into central and peripheral glands. The blood supply is made up of vessels that carry blood to both the central and peripheral glands.

The central and peripheral branches can have a similar trunk and bifurcate, or they can come from different parent arteries(76).

The prostate artery branches out from the vesicoprostatic artery, which gives the inferior vesical artery. The central and peripheral branches of the prostate artery referred to as the anterolateral or superior pedicle and the posterolateral or inferior pedicle divisions(33).

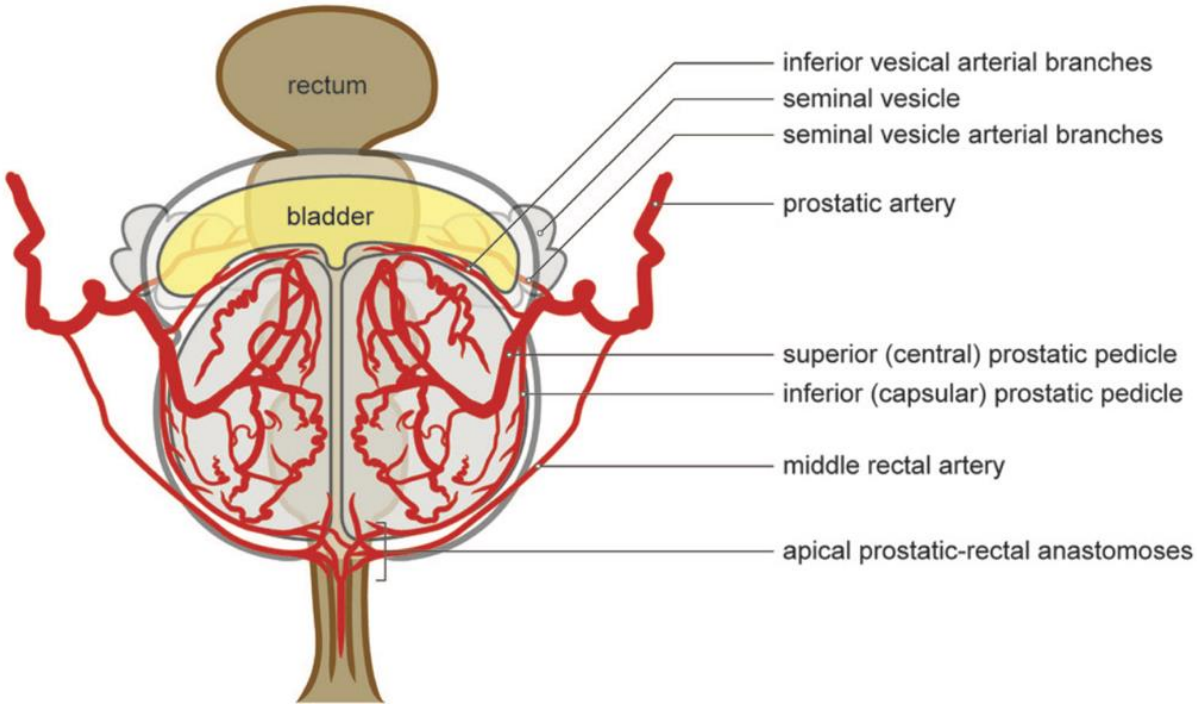


Figure 2.12.1. Schematic diagram showing the prostate artery and its divisions (superior and inferior prostatic pedicles (33).

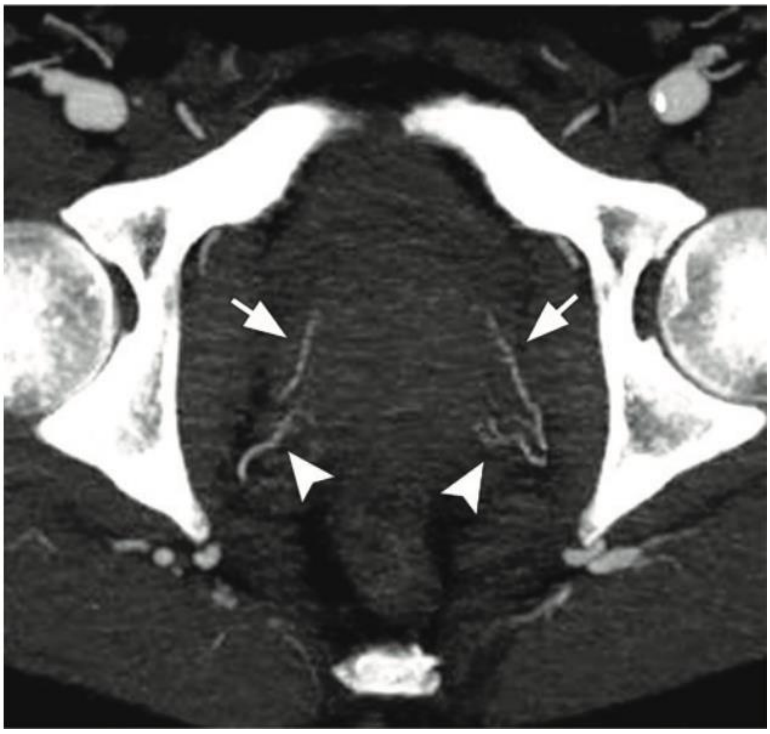


Figure 2.12.2. Axial CT angiogram maximum intensity projection reconstructed image showing the anterolateral/superior pedicle (arrows) and posterolateral or capsular/inferior pedicle (arrowheads) (33).

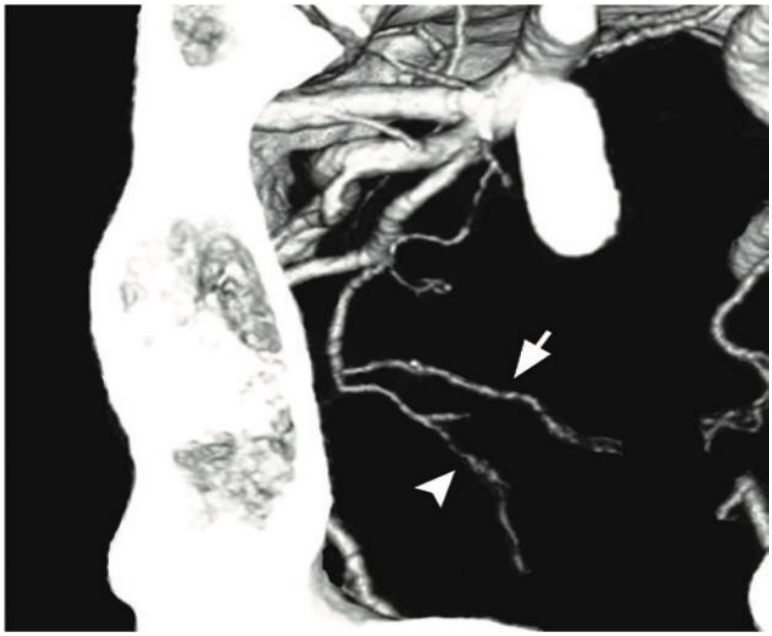


Figure 2.12.3. Axial CT angiogram 3D volume rendered reconstructed image of internal iliac artery showing the anterolateral/superior pedicle (arrow) and posterolateral or capsular/inferior pedicle (arrowhead) (33).

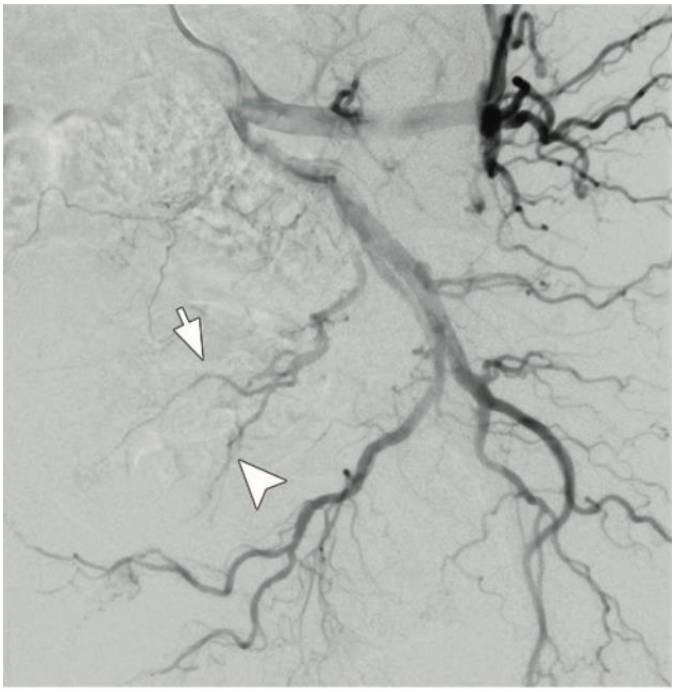


Figure 2.12.4. Digital subtraction angiographic image of the internal iliac artery showing the anterolateral/superior pedicle (arrow) and posterolateral or capsular/inferior pedicle (arrowhead) (33).

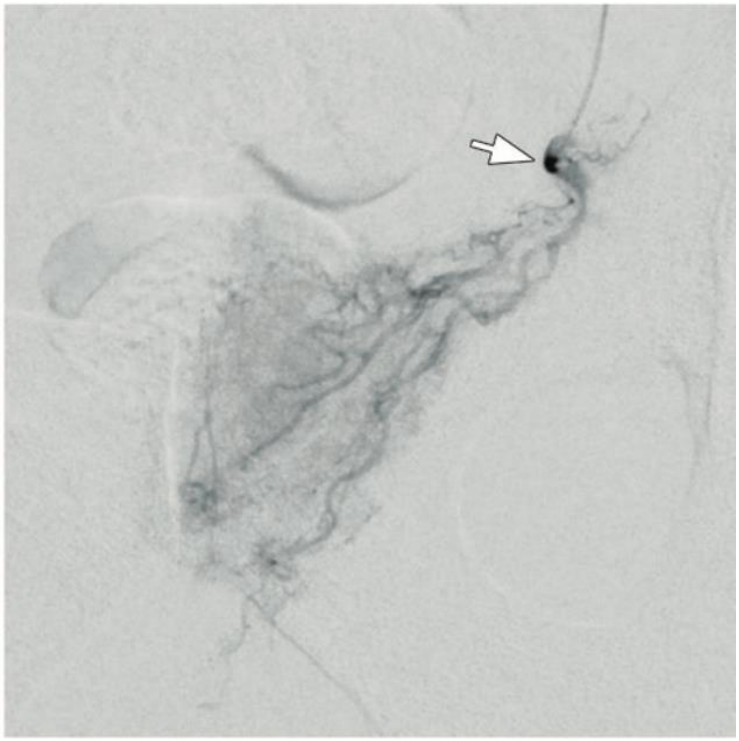


Figure 2.12.5. Both divisions of the prostate artery arise from a single trunk in this selective digital subtraction angiographic picture of the prostate artery (arrow) (33).

In 1955, Clegg (30) studied 21 pelvic halves and identified what he described as prostate-vesical trunk, from which a prostate artery branch was identified. They noted that this common trunk had a variable origin and division. In 50% of the cases, the artery bifurcates into prostate artery and small vesical arteries. The remaining 50% had separate prostate artery origin. The prostate artery follows a corkscrew pattern on the antero-inferior surface of the bladder, obliquely downward, forward, and medially toward the prostate gland, culminating in superior and inferior pedicles, according to Clegg(30).

Bouissou and Talazac(77) studied 100 pelvic halves, four years after Clegg and identified two independent prostate arteries, cranial and caudal. The cranial artery, which supplies the inner and cranial glands, was found to be enlarged in patients with benign prostatic hyperplasia (BPH). The peripheral and caudal glands are supplied via the caudal artery.

The origin and number of prostate arteries vary, and in certain patients, they may be asymmetrical.

The prostate gland is separated into four quadrants on an axial CT scan, two antero-lateral and two postero-lateral. When the prostate arteries reach the gland's surface, they divide into these quadrants. The cranial branch supplies the inner gland and passes into the antero-lateral quadrants (11 o'clock on the right side and 1-o'clock on the left side). The postero-lateral quadrants are supplied by the caudal branches, which are normally located at 7 o'clock on the right side and 5 o'clock on the left side(20). These vessels create numerous anastomosis for both ipsilateral and contralateral prostate arteries.

de Assis et al. (13) classification provides a framework for standardizing the origin of the prostate arteries and forms the basis for use in this project.

2.13 De Assis et al.(13) **Classification Description**

Type I - The prostate artery is derived from the anterior division of the internal iliac artery, which shares a trunk with the superior vesical artery (SVA)

Type II - The prostate artery is derived from the anterior division of the internal iliac artery (gluteal-pudendal trunk), which is inferior to the SVA.

Type III – The obturator artery is the source of the prostate artery.

Type IV- The internal pudendal artery is the source of the prostate artery.

Type V - Origins that are less prevalent

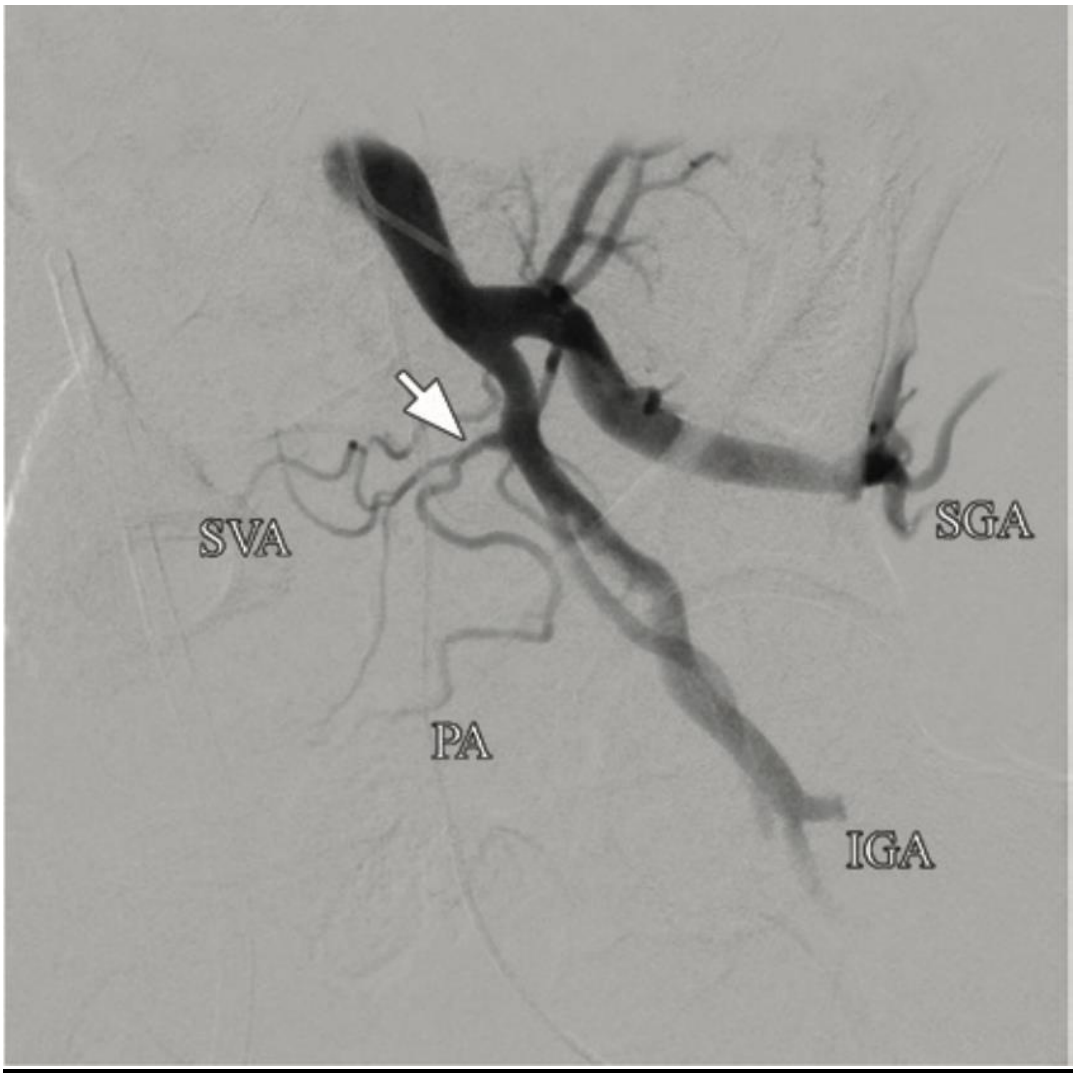


Figure 2.13.1. PA Origin Type 1 Classification.

Internal iliac artery DSA. IGA is for inferior gluteal artery, SGA stands for superior gluteal artery, PA stands for prostate artery, and SVA stands for superior vesical artery (type I) (33).

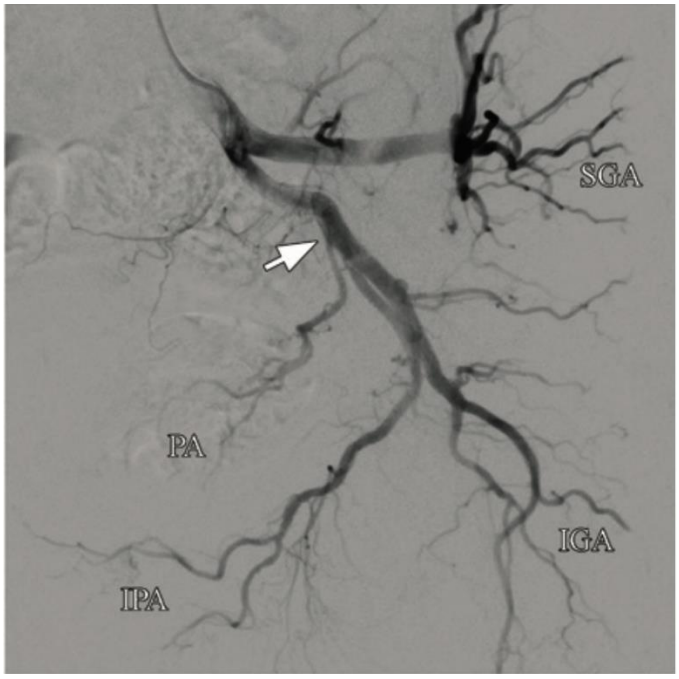


Figure 2.13.2 PA origin classified as Type II.

Internal iliac artery DSA. PA=prostate artery, IPA=internal pudendal artery – type II PA arising from the anterior division of the internal iliac artery, ie-gluteal-pudendal trunk (arrow) (33).

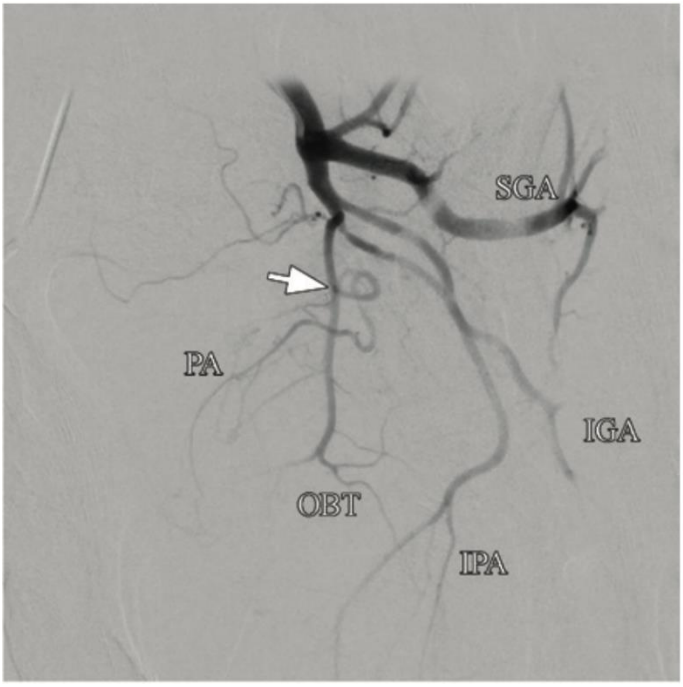


Figure 2.13.3. PA origins classified as Type III.
Internal iliac arter DSA. PA = prostate artery, IPA = internal pudendal artery, OBT = obturator artery – demonstrate a type III PA arising from the obturator artery (arrow) (33).

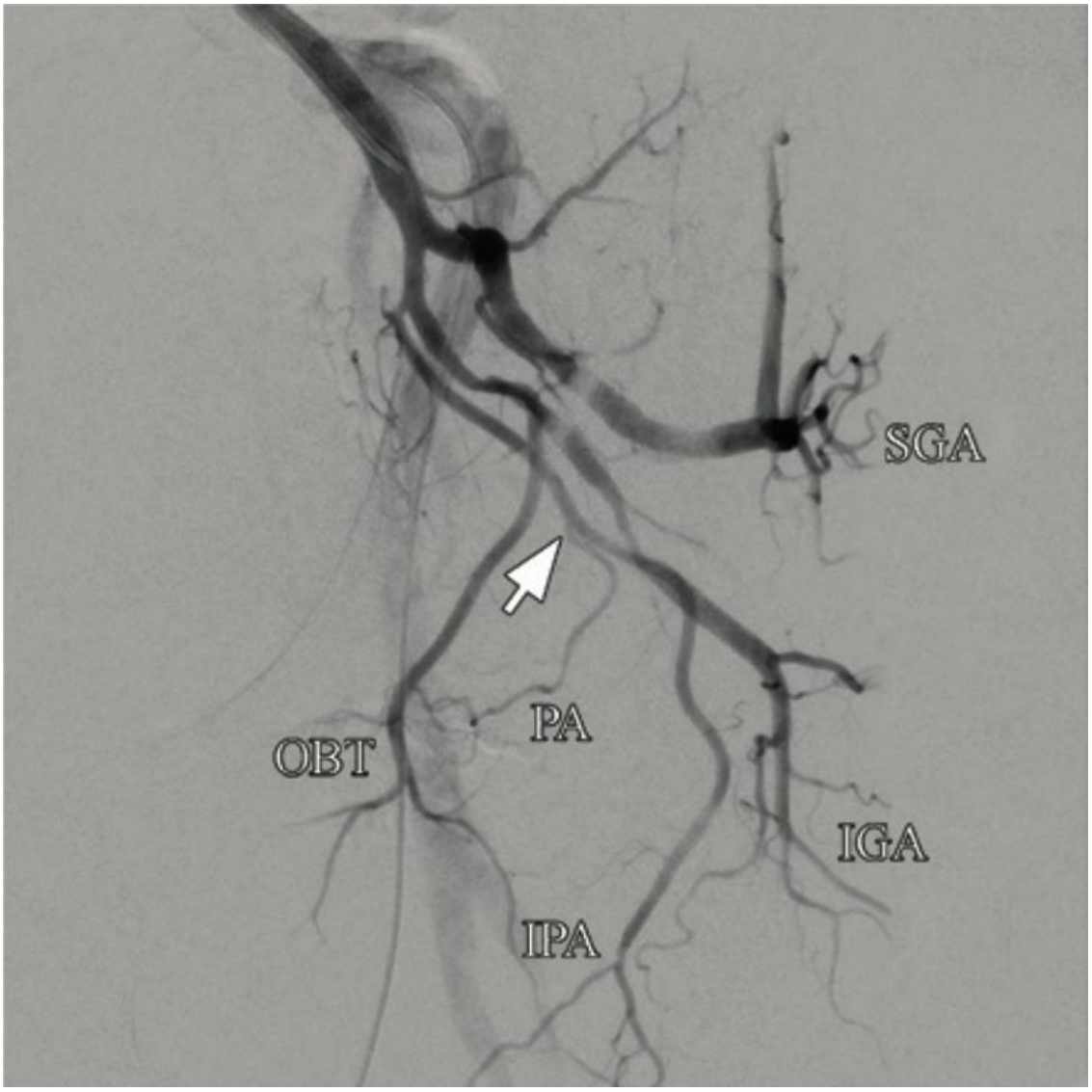


Figure 2.13.4 PA origin classified as Type IV.

Internal iliac artery DSA. IGA = inferior gluteal artery, SGA = superior gluteal artery, PA = prostate artery, IPA = internal pudendal artery, OBT = obturator artery (arrow) (33).

2.14 Variants Anatomy of the prostate artery

In 30-40% of cases, the middle rectal artery arises from the prostate artery(33).

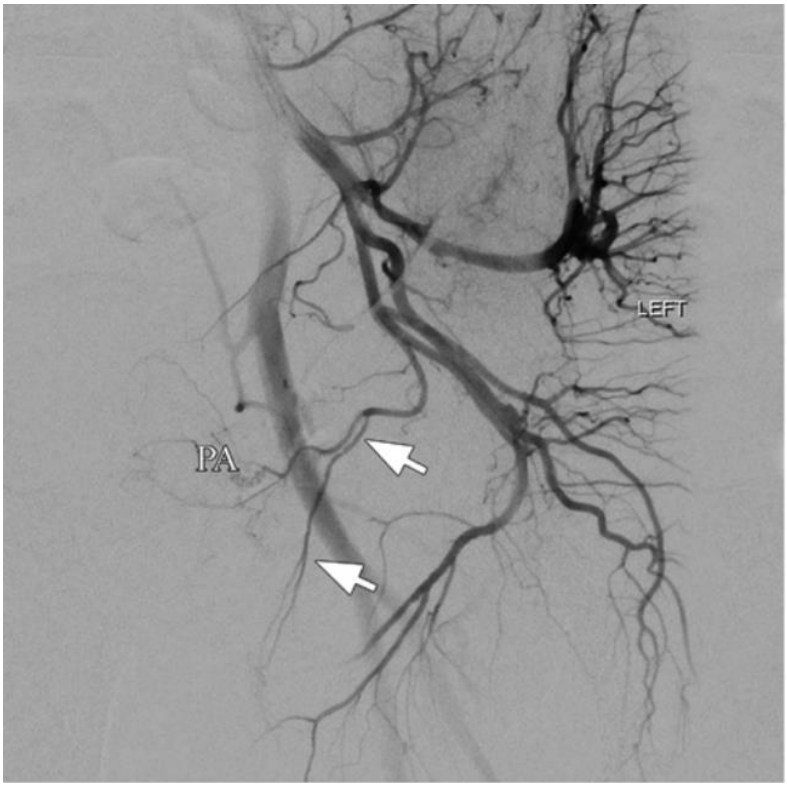


Figure 2.13.5 Internal iliac artery DSA.
The prostate artery is abbreviated as PA. The middle rectal artery (arrows) originates from the PA and follows a craniocaudal path. (33)

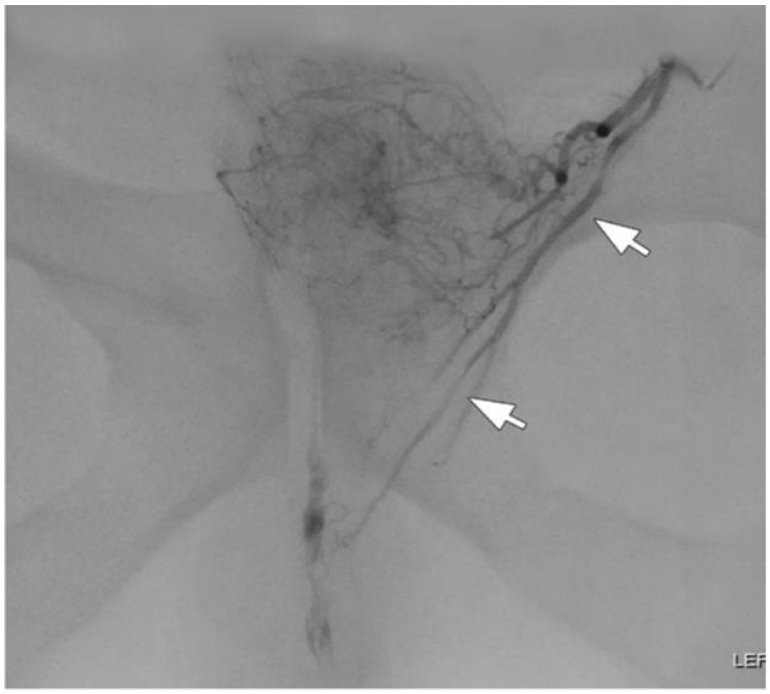


Figure 2.13.6. The middle rectal artery (arrows) and rectal blush are visible on a selective PA arteriogram. (33).

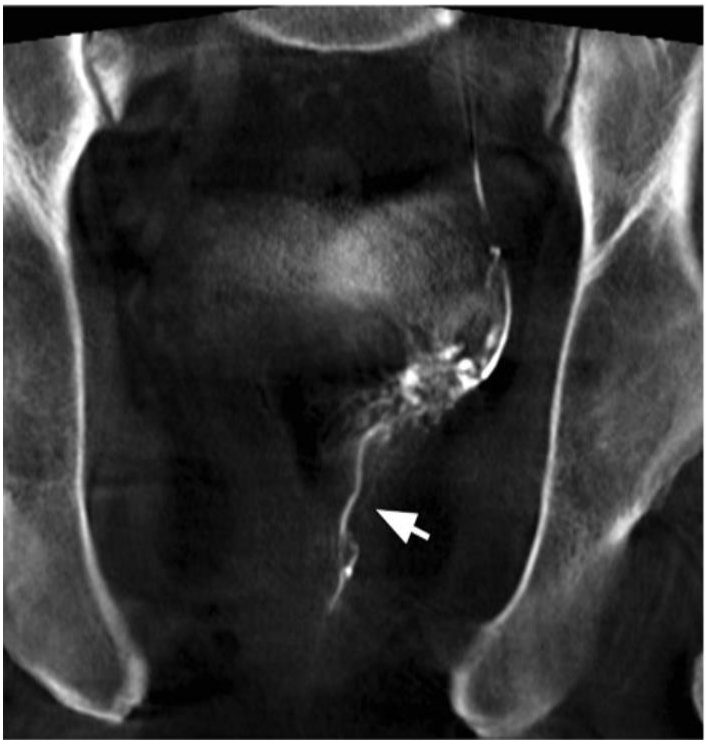


Figure 2.13.7. The craniocaudal path of the main rectal artery is seen in this coronary cone-beam CT image (arrow) (33).

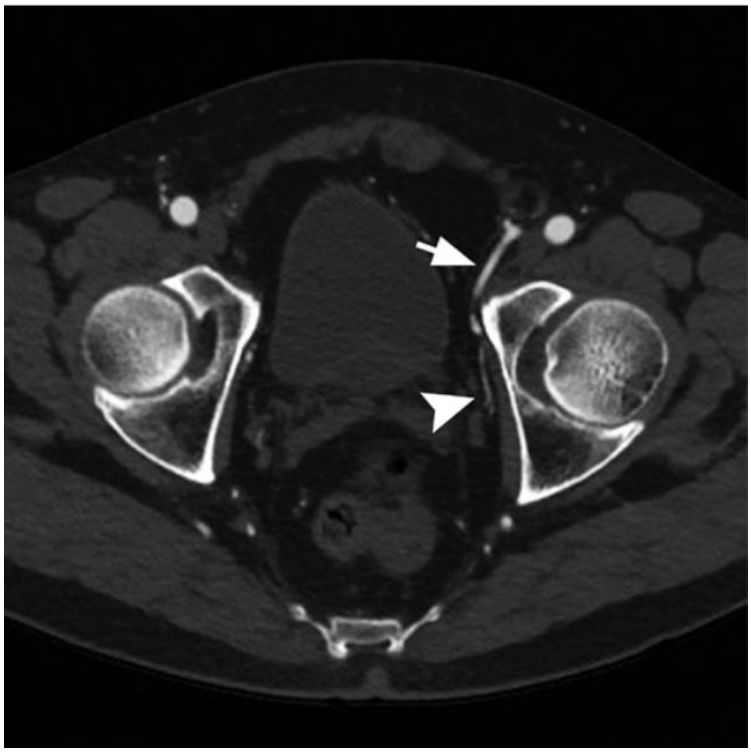


Figure 2.13.8. An auxiliary obturator artery gives rise to the prostate artery (PA).
The PA (arrowhead) arises from an auxiliary obturator artery on a pre-procedural CT angiography (arrow) (33).

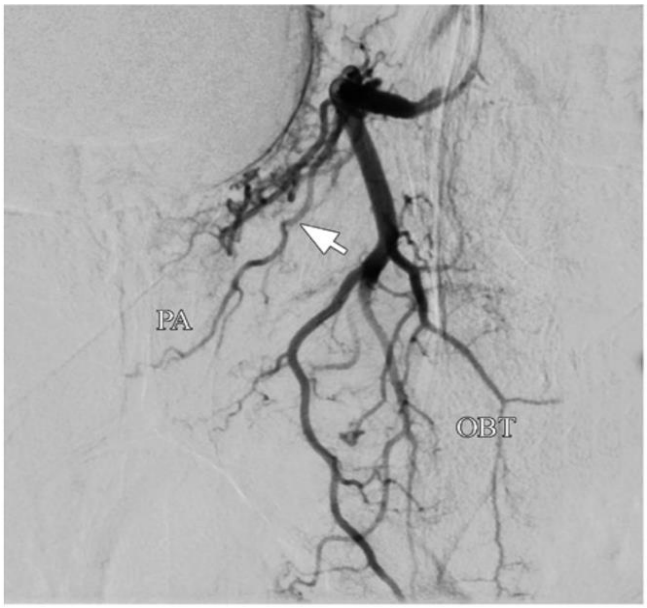


Figure 2.13.9 An auxiliary obturator artery is the source of the PA(arrow).
The PA is seen this selective inferior epigastric artery arteriogram. Obturator artery (OBT) (33).

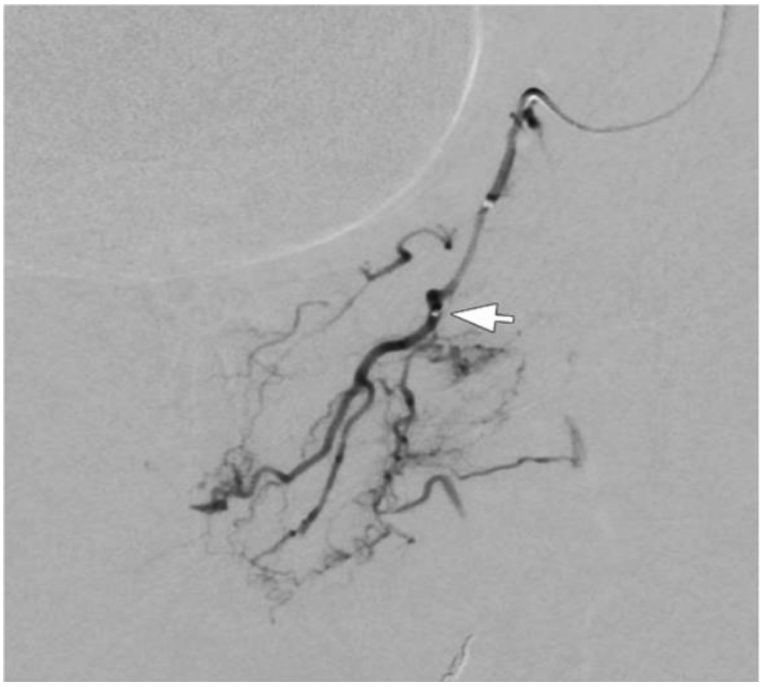


Figure 2.13.10. An accessory obturator artery giving the prostate artery PA.
After microcatheter selection of the PA (arrow), a digital subtraction angiography shows the distinctive appearance of prostatic branches(33).

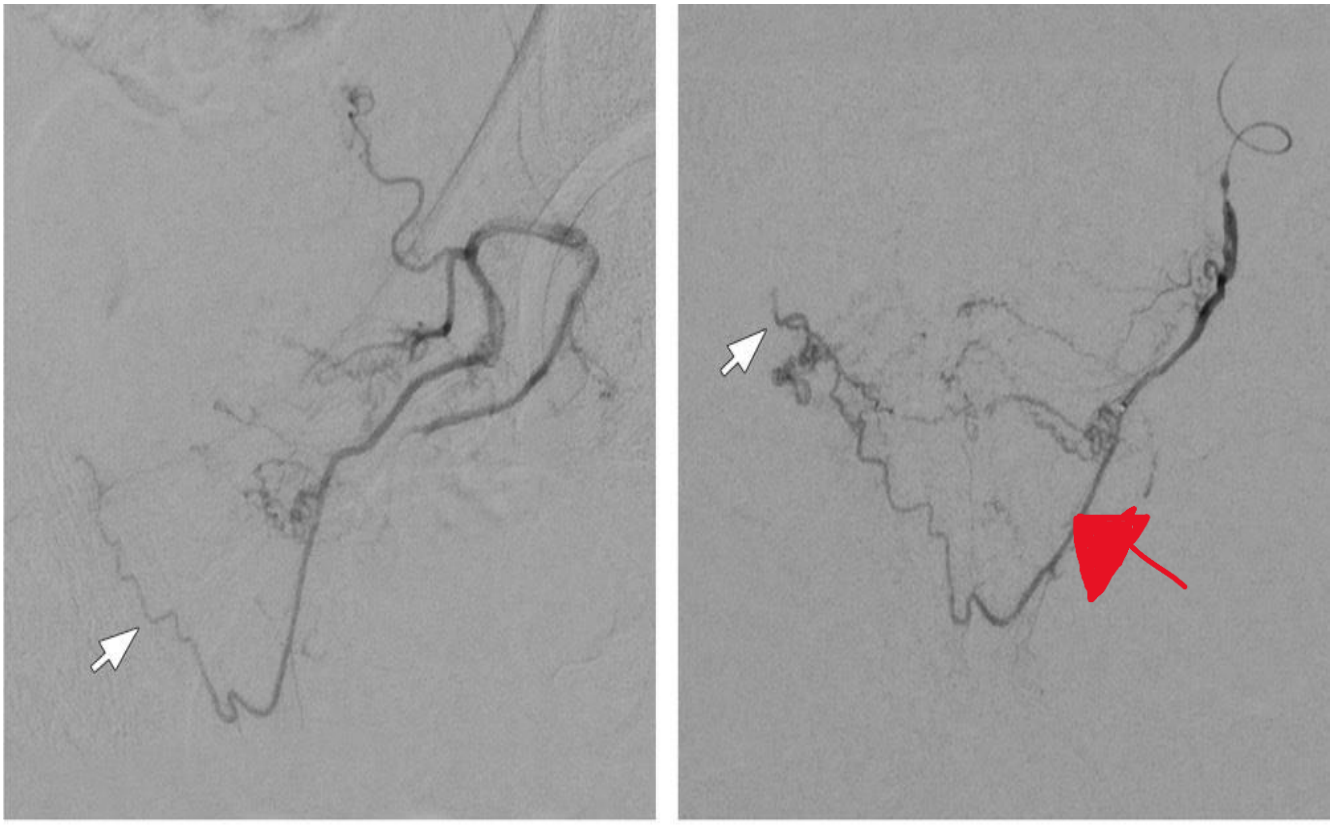


Figure 2.13.11. Arteriogram of the prostate artery with cross-pelvic vasculature.
(a) A vessel crosses the midline (arrow) to the right prostatic area on a left prostate artery arteriogram. (b) DSA of the prostate artery shows the microcatheter (red arrow) in the prostate artery, revealing filling of the right prostate artery across the pelvis (arrow) (33).

2.15. Imaging modalities to evaluate prostate arteries

Transrectal ultrasonography, computed tomography angiography, magnetic resonance angiography, digital subtraction angiography, and cone-beam CT scan can all be used to examine the prostate arteries(54,78–80).

2.15.1 Digital subtraction angiography (DSA)

The gold standard for evaluating pelvic vascular anatomy is digital subtraction angiography(81). It allows real-time guidance of procedures such as PAE. Currently angiography suites have digital fluoroscopy systems, mounted on C-arms with post-processing software.

Advantages of Digital subtraction angiography

- reduced dosage of contrast medium used,
- With the advent of rotational computed angiography, computed tomography-like slices are generated and reviewed intraoperatively.

Limitations of Digital subtraction angiography

- invasive procedure,
- catheter related complications such as inadvertent arterial puncture,
- the use of ionizing radiation
- images are distorted by patient movement
- small collateral vessels may be not visualised.

- Allergy to contrast medium, which may be severe and reported in 0.1%
- Increased risk of nephrotoxicity especially in children and patient with pre-existing renal impairment

2.15.2 Computed tomography angiography (CTA)

The anatomy of the internal iliac artery and the prostate arteries can be delineated using CT or MR angiography. Radiologists prefer the use of CTA due to the speed of acquisition, spatial resolution and the ability to visualize very small arteries and CT angiography may also help identify the origins of the prostatic artery, which can be one of the more challenging steps in the procedure (78).

The current multislice CT scanners have improved spatial resolution and enables examination from aorta to pelvic region in a single bolus contrast injection. Post processing softwares enables reformations and Volumetric rendering at a workstation for easily interpretation
The protocol is determined by the institution and may vary depending on the type of equipment.

The power settings are 80–120 kV and 200–300 mA; the matrix is 1024 x 1024 pixels; the field of view is 400 mm; the voxels are 0.625 x 0.625; and the pitch is one. At a rate of 4–6 mL/sec, the contrast media is bolus tracked in the abdominal aorta above the renal arteries or aortic bifurcation, with a goal threshold of 300 HU (82). The average acquisition time is three seconds. Before imaging, vasodilation with 800 mg of sublingual nitroglycerin given over 3–5 minutes is an option. This will increase the diameter of the prostate artery and the peak opacification. Screening patients for hypotension and halting drugs like phosphodiesterase inhibitors 48 hours before the procedure are among the precautions (78).

Images are analyzed in 1.25mm slices, with multiplanar reformatted images and maximum intensity projection.

Advantages of Computed Tomography Angiography

- CTA is cost effective compared to magnetic resonance imaging
- It is fast and provides
- It provides both luminal and extraluminal pathologies simultaneously.
- It gives detailed prostate arterial anatomy needed for pre-intervention planning(20).

Limitation of Computed Tomography Angiography

- CTA imaging requires the administration of at least 100 mL of iodinated contrast medium
- lack of sensitivity in identifying small PAs, which may exclude potential candidates
- In vessels with extensive calcifications, arterial luminal stenosis is near impossible. This is because over staging leading to false negative stenosis or occlusion due to the "blooming" effect of the calcium in calcified plaques (83).
- Increased risk of nephrotoxicity especially in children, elderly and patient with pre-existing renal impairment
- Increased post-processing time

2.15.3 Magnetic Resonance Angiography (MRA)

MRA uses gadolinium-contrast bolus chase protocols in combination with phased-array pelvic angiography coil.

For patient with preexisting renal or cardiac impairment, time of flight sequences can be used without the need for gadolinium-enhancement.

Advantages of Magnetic Resonance Angiography

- It does not involve ionizing radiation
- It can be done without the use of contrast medium
- Images are not affected by arterial calcifications

Limitations of Magnetic Resonance Angiography

- Images are affected by motion
- Patients who are claustrophobic may require sedation.
- Metallic implants may produce susceptibility
- In patients with renal impairment, gadolinium-based contrast agents may cause nephrogenic systemic fibrosis.

2.15.4 Cone-Beam CT scan

Cone-beam CT usage in pelvic angiography helps in identifying the origins of the prostate arteries, evaluating prostate gland perfusion after prostate artery catheterization and to evaluate non target vasculature(33).

The procedure involves the use of hand injection of 1-3ml of contrast medium over 3seconds with 4-6second delay before imaging. The use of a power injector at a rate of 0.3 mL/sec is the second alternative. The radiologist and assistants are exposed to less radiation because many digital

subtraction angiography acquisitions to identify the prostate arteries are avoided. The prostate arteries can be easily identified using the automatic vascular tracking software(79)..

In one series, the software was able to identify prostate arteries with 92% sensitivity(84). The software also helps to detect variants and collateral prostate arteries. Cone-beam CT was used in another study to identify 36 percent of subjects with possible nontarget embolization locations(14).

Advantatges of Cone-Beam CT scan

- It is a useful technique that can potentially mitigate the risk of nontarget embolization.
- It provides confirmation of the arterial vascular anatomy resulting in median lobe hyperplasia before embolization
- It identifies sites of potential nontarget embolization before embolization,
- It use to confirm prostatic parenchymal perfusion before embolization.
- this technique can potentially improve the safety of the procedure of nontarget embolization and enhance patient acceptance
- it likely to improve the quality of life of patients

Limitations of Cone-Beam CT scan

- This might indirectly contribute to procedure time
- It provides less temporal and in-plane spatial resolution than DSA

2.16. Correlation between diameter of prostate artery and prostate volume

The link between the diameter of the prostate artery and prostate volume has been studied less extensively, particularly in Sub-Saharan Africa. For example, a research in Nigeria assessed the mean prostate volume (PV) among 120 male patients(85) to be 72.7944.38mls, with a longitudinal diameter of 5.631.17cm, an anterior diameter of 4.480.95cm, and a transverse diameter of 4.971.06cm (7).

In the Democratic Republic of Congo, Mubenga et al.(86) investigated 979 adult men (>40 years) from three different ethnicities. Their goal was to examine prostate volume among key ethnic groups and see if there was any correlation with specific anthropometric parameters. The study found that the average prostate volume was 32 (interquartile range (IQR): 22-49) with statistically significant differences between ethnic groups. However, neither the diameter of the prostate artery nor the relationship between prostate volume and the diameter of the prostate arteries were measured in these research (86).

Bilhim et al. (20) retrospectively reviewed 75 Portuguese men who had pelvic CT angiography and selective pelvic DSA prior to PA embolization for BPH. The study discovered that those with the corkscrew pattern had greater prostate volumes (mean, 111.9 mL) than those without the pattern (mean prostate volume, 67.0 mL)(20). Patients with only two PAs (one on each pelvic side) had a higher mean PA diameter (1.9 mm) than those with three (1.5 mm) or four (1.3 mm). There was no link between the number of PAs and age, prostate volume, PSA, or the existence of the corkscrew pattern (20).

CHAPTER THREE

METHODOLOGY

3.1 Study Design

It was a prospective cross-sectional study, to describe the radiological anatomy of the prostate artery and to ascertain the correlation between the arterial diameter and prostate gland size in adult males. The study involved adult male patients presenting for pelvis computed tomograghy angiography at Euracare Advanced Diagnostic and Heart Centre. The study was conducted from August to November 2021.

The origin of the prostate artery was documented for each pelvic half. The de Assis et al. (13) classification was used to classify the prostate artery origin. The prostate artery's diameter and the prostate gland's volume were measured in millimeters and centimeters respectively. The volume was calculated using the ellipsoidal formula (length L x width W x height H x 0.52). The prostate was measured in L (apex to base), H (anterior to posterior), and W (width to height) (lateral to lateral). A formal informed consent was signed by the patient.

3.2 Study Site

The study was conducted at the Department of Radiology, Euracare Advanced Diagnostics and Heart Centre (EADHC), Accra, Ghana. The EADHC, is a private medical institution offering diagnostic imaging and minimally invasive procedures for a wide range of interventional radiology procedures including prostate artery embolization and pelvic CT angiography. It is the only centre in Ghana where prostate artery embolisation and lower limb angioplasty are done, hence has higher number of patients performing pelvic CTA.

3.3 Study population

All adult male patients of ages 18 years and above presenting at EADHC, for pelvic computed tomography angiography were enrolled consecutively until the sample size was achieved. In Ghana, individuals of age 18 years and above are generally considered as adults.

Inclusion criteria

- Adult male patients for pelvic computed tomography angiography, within four months period from August to November 2021 were enrolled.

Exclusion criteria

- Young male patients (of ages less than 18 years) presenting at EADHC for pelvic or lower limb computed tomography angiography,
- Male patients presenting at EADHC for other procedures.
- All females presenting at EADHC for pelvic or lower limb computed tomography angiography.

3.4 Sample size determination

Hulley et al. (87) formula's was used to calculate the sample size for the study. The anticipated two-tailed probability type I error of 0.05 and a power of 0.80 are plugged into the formula below to find the sample size required assuming a minimum correlation coefficient (r) of 0.4 existed between the prostatic volume and diameter of the prostatic artery.

$$N = [(Z_\alpha + Z_\beta) \div C]^2 + 3.$$

Where Z_α is the standard normal deviate for α (1.960), Z_β is the standard normal deviate for β (0.842) and C is a constant defined as $C = 0.5 \times \ln [(1 + r)/(1 – r)]$

Substituting we have

$$N = \left[\frac{1.960 + 0.842}{0.4236}\right]^2 + 3 = 47$$

Applying a 10% non-response rate the final sample size comes to

$$N = 47 + \frac{47}{10} \approx 52$$

3.5 Patient Selection

The study was explained to all patients who met the inclusion critiria. Patients who agreed to join the study signed a consent form. Patients were consecutively selected until the required sample size was achieved.

Despite the disadvantaged generalizability of convenient sampling relative to probability sampling, non-probability convenience sampling as pertained in this study is justified by the fact that, this study is first in Ghana and West Africa and can therefore be described as formative stage. In other to compare with the existing literature which were all retrospective and employed convenient sampling, it was important to ensure homogeneity in the sampling technique.
Again, within the limitation of time and cost, probability sampling method will reguire great costs in terms of money, time, and effort. Indeed, many of the most prominent probability samples are

handled by Federal agencies or big research facilities with substantial annual budgets due to the expenses and challenges involved with probability samples.

Therefore, the limited number of patients available within the time constraints and cost justifies the use of convenient sampling.

3.6 Procedure:

3.6.1 Pelvic CTA was be done using Siemens 64-Slice Somatom Perspective CT scanner

Specification of the Scanner include Power settings of 120 kVp; 300 mA; Time 0.5sec, collimation 64 x 0.6mm and pitch of 0.8.

Technique (88)

Patient preparation

- Nitroglycerin was not given since it would dilate the prostate artery, affecting the vessel's real width.

Patient position

- supine position, body centered within the gantry
- both arms elevated

Tube voltage and current

- ≤120 kVp, 300 mA

Scout

- above the diaphragms to the pubic symphysis

Scan extent

- includes lung bases and pubic symphysis

Scan direction

- craniocaudal

Scan geometry

- field of view (FOV): 350 mm
- slice thickness: ≤0.75 mm, interval: ≤0.5 mm
- reconstruction algorithm: soft tissue, 3D volume rendering

Oral contrast

- Not used

Contrast injection considerations

- Non-contrast was performed first

- low molecular weight contrast medium (at a concentration of 350-370 mg/mL iodine)
- contrast volume: 70-100ml (1 mL/kg) with 50-70 mL saline chaser at 3-5 mL/s
- bolus tracking: abdominal aorta (Infrarenal)
- arterial phase: minimal scan delay
- portal venous phase: 30-50 seconds after the arterial phase or 60-80 seconds after contrast injection

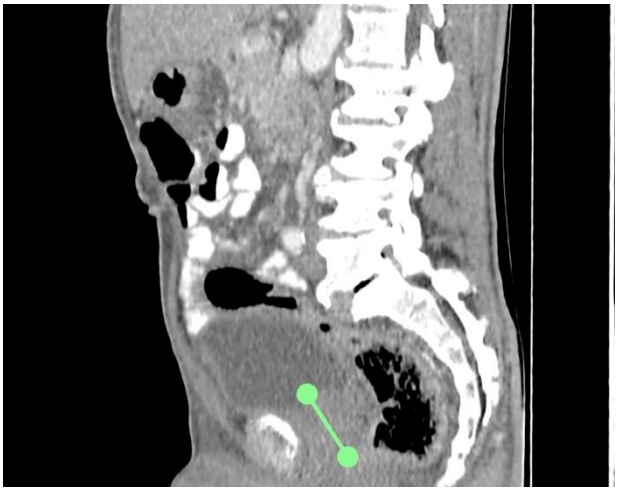
Respiration phase

- single breath-hold: inspiration

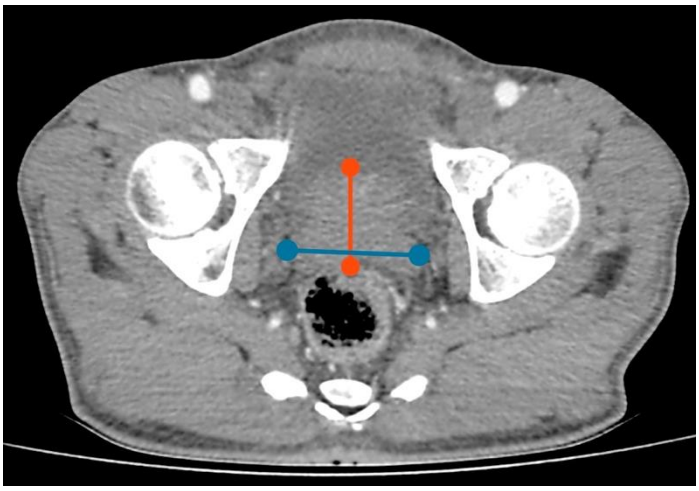
Multiplanar reconstructions

- axial images: axial to the body axis
- coronal images: coronal to the body axis
- sagittal images: sagittal to the body axis
- slice thickness: soft tissue ≤3 mm
- 3D volume rendering

3.6.2. **Measuring the prostate gland on CT scan using axial and sagittal images**



a.



b.

Figure 3.6.2a: Sagittal CT scan image of the pelvis showing how to measure the height of the prostate gland (green line).
Figure 3.6.2b: Axial CT scan image of the pelvis showing how to measure the length (AP diameter-red line) and width (Transverse diameter – blue line) of the prostate gland

3.6.3. Measuring the prostate artery diameter on CT scan using axial 3D volume

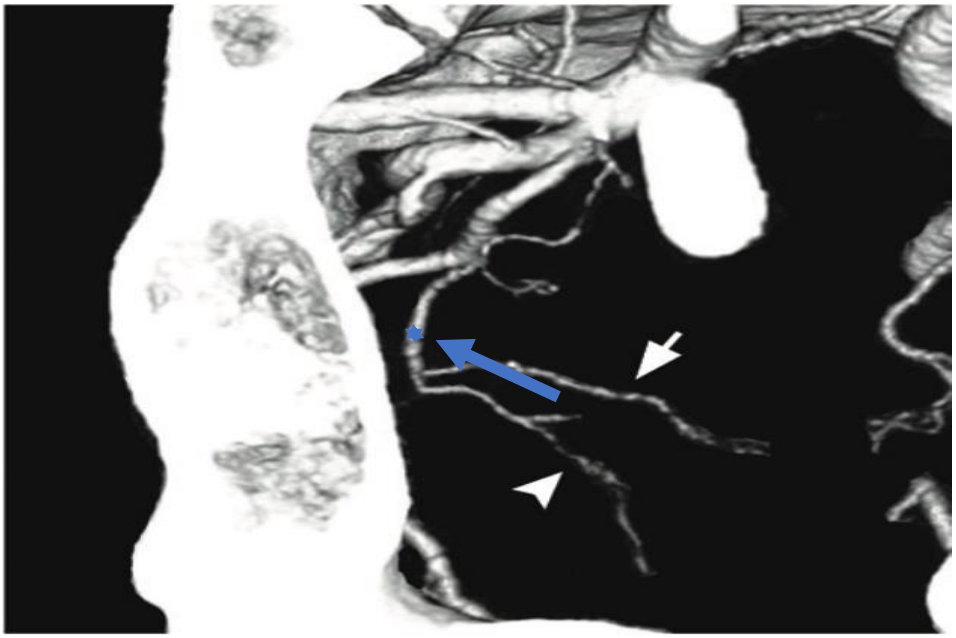


Figure 3.6.3 shows how to measure the diameter of the prostate artery.
The blue arrow shows measuring the widest diameter prior to bifurcation.

3.9. Data Management and Analysis

The data was entered and cleaned with Microsoft Excel version 2016. Further data management and analysis were performed using the STATA version 16. Patient characteristics (age group, marital status, history of prostate disease, level of education) were presented in frequencies and percentages while the diameter of arteries and volume of prostate gland were expressed as mean (standard deviation). T-test or ANOVA (for continuous variables) were done to assess the test of significant difference between men with enlarged prostate and without enlarged prostate at $P<0.05$. The Pearson correlation test was performed to assess the relationship between prostate volume and arterial diameter.

3.10. Dissemination of Results

Results of the study will be disseminated in reputable journals for publication and will be presented at Ghana Association of Radiologists annual conference.

3. 11. Ethical and Legal Considerations

The ethics and procedural review committee of the University of Ghana's College of Health Sciences gave their approval. CHS-Et/M.6-5.8/2020-2021 is the protocol identification number.

No invasive procedures were performed on the patients that could risk his life.
For everyone with a comparable request, the CTA and DSA were routine scans. There were no changes made to inconvenience the patients.

Except for a few minutes spent reading the consent form and filling out the socio-demographic section of the information retrieval form, the patient experienced no further costs.

CHAPTER FOUR

RESULTS

4.1 General characteristics of adult males

A total of 52 adult males were examined. Thirty-seven (71.15 %) of 52 adult males had an enlarged prostate gland (30cm^3), while 15 (28.85 %) had a normal prostate gland (30cm^3).

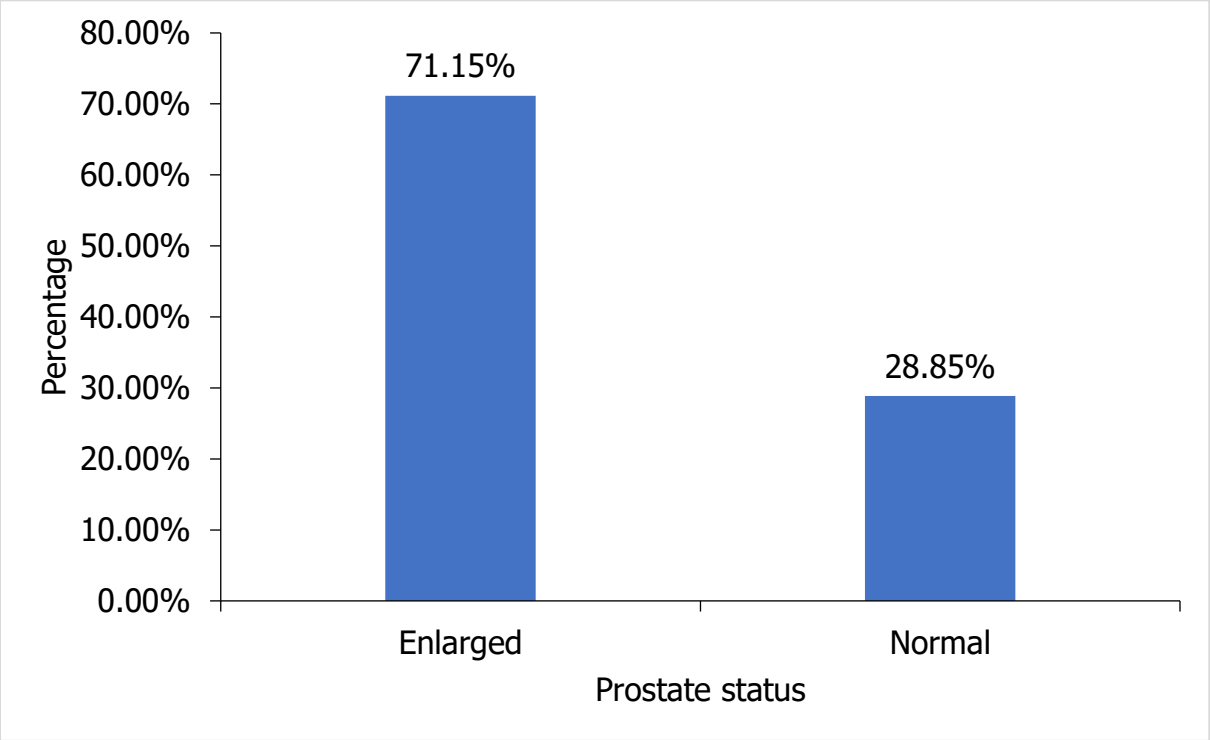


Figure 4.1. Prostate status of male participants.

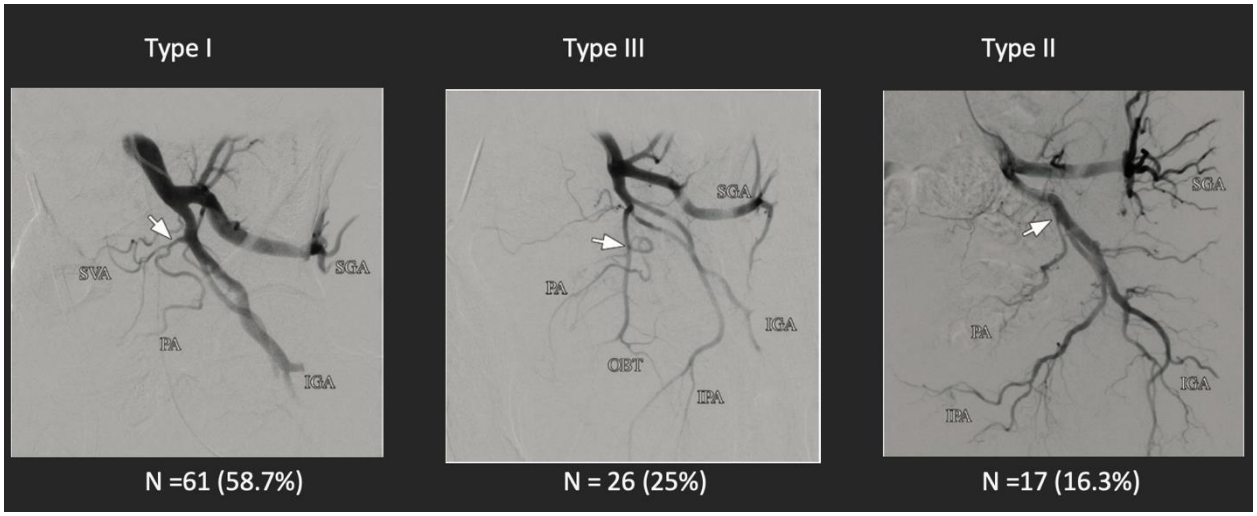
The prostate glands of all individuals aged 60 and above (24, 100%) were enlarged. Married men were more likely to have enlarged prostates (32, 71.11%). Patients with a history of prostate disease (HPD) had a higher percentage of enlarged prostate glands (18, 94.74%) than those without a history of prostate disease.

Table 4.1. Socio-demographic characteristics of adult males

Characteristics	Enlarged N=37 (%)	Normal N= 15 (%)	Total N=52(%)
Age			
<60 years	13 (46.43)	15 (53.57)	28 (53.85)
≥60 years	24 (100.00)	0 (0.00)	24(46.15)
Highest level of education			
Pre-tertiary	0 (0.00)	0 (0.00)	0 (0.00)
Tertiary	37(71.15)	15 (28.85)	52 (100.00)
Marital status			
Single	0 (0.00)	2 (100.00)	2 (3.85)
Married	32 (71.11)	13 (28.89)	45 (86.54)
Divorced	1 (100.00)	0 (0.00)	1 (1.92)
Widower	4 (100.00)	0 (0.00)	4 (7.69)
History of prostate Disease			
No	19 (57.58)	14 (42.42)	33 (63.46)
Yes	18 (94.74)	1 (5.26)	19 (36.54)

4.2. The origin of prostate artery in Ghanaian men using de Assis et al (2015) as reference.

The origin of the prostate artery was evaluated in 104 pelvic halves. In each pelvic half, one prostate artery was discovered. Although there are five different patterns of prostate artery origin by de Assis (Type I-V), only three were identified: type I, type II, and type III. The vast majority 61 pelvic halves, (58.7 %) were of type I arterial origin.



Reference for images(33)

Figure 4.2: The prostate artery branching pattern in the pelvis is represented by the digital subtraction angiography.

Prostate artery (PA), superior vesical artery (SVA), superior gluteal artery (SGA), inferior gluteal artery (IGA), obturator artery (OBT), and internal pudendal artery (IPA).

Type I - The prostate artery originate from anterior division of internal iliac artery in a common trunk with the superior vesical artery.

Type II – The prostate artery branches inferior to the superior vesical artery from the common gluteal-pudendal trunk

Type III - originating from the obturator artery

The type 1 artery was the most common source of the right and left prostatic arteries (Right - 50 %, Left - 67.3%). Bilateral type I origin pattern was found in half of the cases 52, (50%). A combination of type I origin pattern on the left and either a type II or III origin pattern on the right was noted in 9 (17.31%) cases. A third of the patients (33%) had a combination of types II and III origin.

Table 4.2. Prostate artery branching pattern among adult males (de Assis et al (2015) as reference.

Type of artery branching	Frequency (N=52)	Percentage (%)
Right Artery		
Type I	26	50.00
Type II	9	17.31
Type III	17	32.69
Left Artery		
Type I	35	67.31
Type II	8	15.38
Type III	9	17.31
Both pelvic		
Type I	61	58.7
Type II	17	16.3
Type III	26	25.0

4.3. The diameter of the prostate arteries

Table 4.3 shows the diameter of the prostate arteries in adult males. On the right and left sides, the prostate arteries had mean diameters of 1.28mm ±0.16 and 1.26mm ±0.18 respectively. For both left (1.32 ±0.14, p=0.0061) and right (1.33 ±0.16, p=0.0850), the mean diameter of the prostate arteries was greater in individuals over 60years. The mean diameter of the right prostate artery differed considerably between individuals who have a history of prostate disease (1.37 ±0.15) and without a history of prostate disease (1.19 ±0.16), p=0.002.

Table 4.3. The diameter of the prostate arteries among adult males

Characteristic	**Number**	**Prostate Artery Diameter (mean±SD)mm**			
		Left	**Test, P-value**	**Right**	**Test, P-value**
Overall diameter	52	1.28± 0.16		1.26 ± 0.18	
Age					
<60 years	28	1.24±0.18	t=-1.757[a]	1.20±0.17	t=-2.86 [a]
≥60 years	24	1.32±0.14	0.0850	1.33± 0.16	0.0061*
History of prostate Disease					
No	33	1.27± 0.17	t=-0.574 [a]	1.19±0.16	t=-4.103 [a]
Yes	19	1.30±0.16	0.5686	1.37±0.15	0.0002**

* Significant at P<0.05, **significant at P<0.001, [a] output of t-test, [b] ANOVA test

4.4 The volume of the prostate gland among adult males

The volume of the prostate gland is classified as normal when it is < 30cm^3 and enlarged when it is ≥30cm^3.

The average prostate gland volume for all subjects was 42.58±14.17cm3. This mean was significantly greater in those over 60years (54.22±2.52 cm3) than in those under 60years (32.60±5.11 cm3), with a p < 0.001. The mean prostate gland volume differs significantly between those who have had prostate disease (54.19±3.24 cm3) and those who have not had prostate disease (35.89±9.05cm3), p<0.001.

Table 4.4 The volume of the prostate gland among adult males.

Characteristic	**Number**	**Prostate gland Volume(mean ±SD)**cm^3	**P-value**
Overall	52	42.58±14.17	
Age			
<60 years	28	32.60±5.11	t=-8.480 [a]
≥60 years	24	54.22±2.52	< 0.001**
History of prostate Disease			
No	33	35.89±9.05	t=-5.701 [a]
Yes	19	54.19±3.24	< 0.001**

* Significant at P<0.05, **significant at P<0.001, [a] output of t-test, [b] ANOVA test

4.5 Graphical presentation of the relationship between diameter of the prostate arteries and the prostate volume among adult males

As shown in Fig 4.5a and 4.5b, there is a statistically significant positive correlation between the diameter of the prostate artery and volume of the prostate gland within the general group (C) and the enlarged group (B).

Fig 4.5a

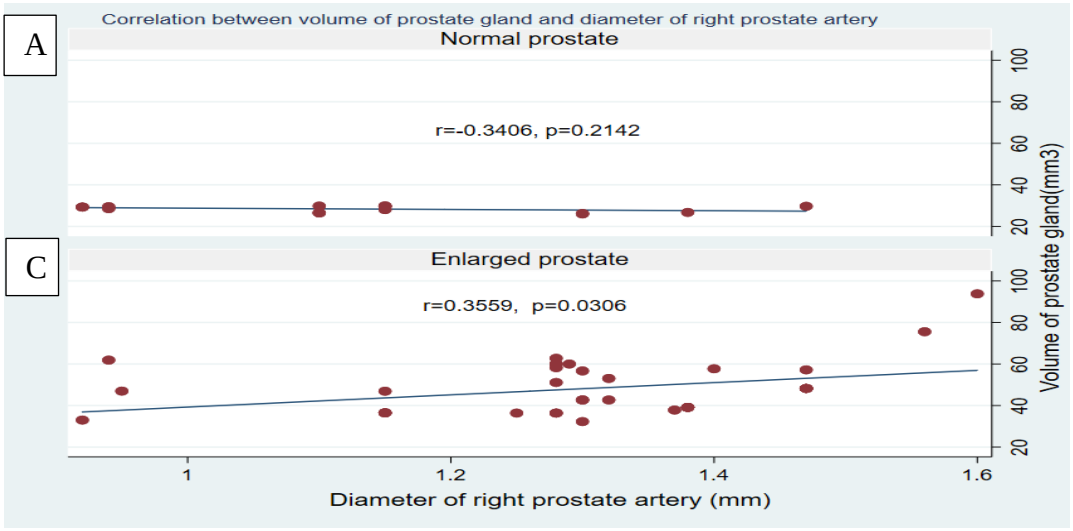


Fig 4.5b

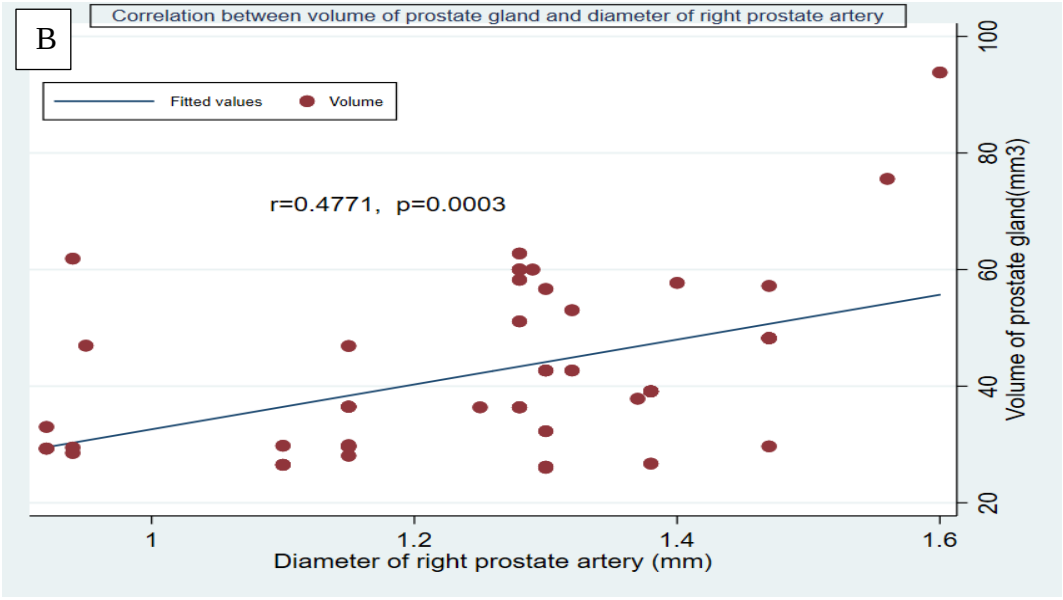


Fig. 4.5.a and b. Correlation between diameter of the right prostate arteries and the prostate volume among adult males (A)-normal group, (B) general group and (C) enlarged group

Fig 4.5c

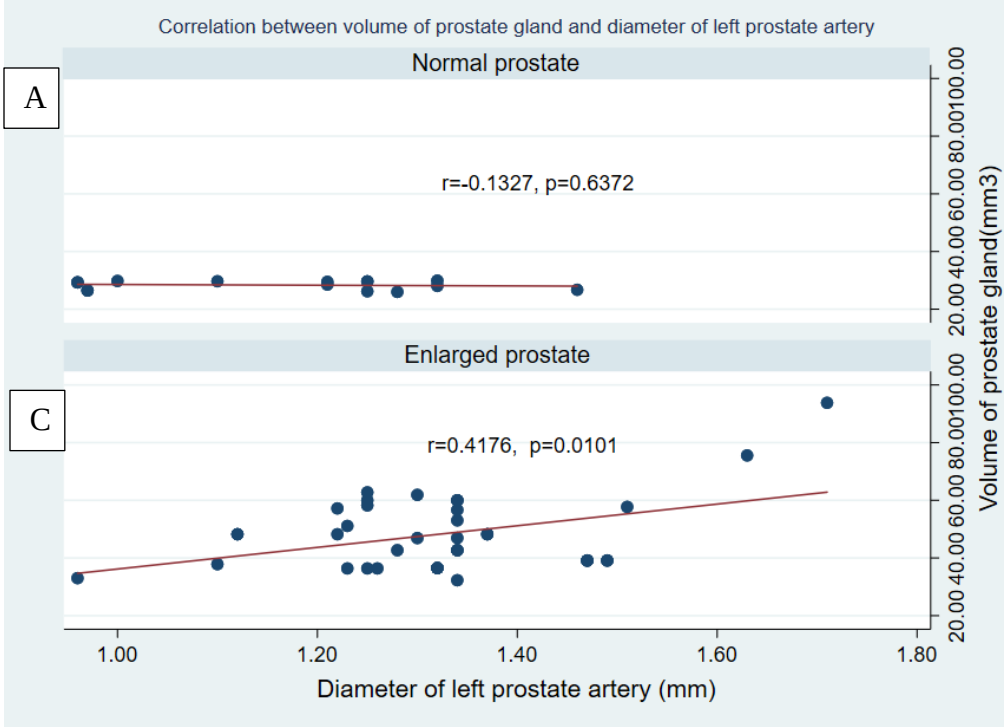


Fig 4.5d

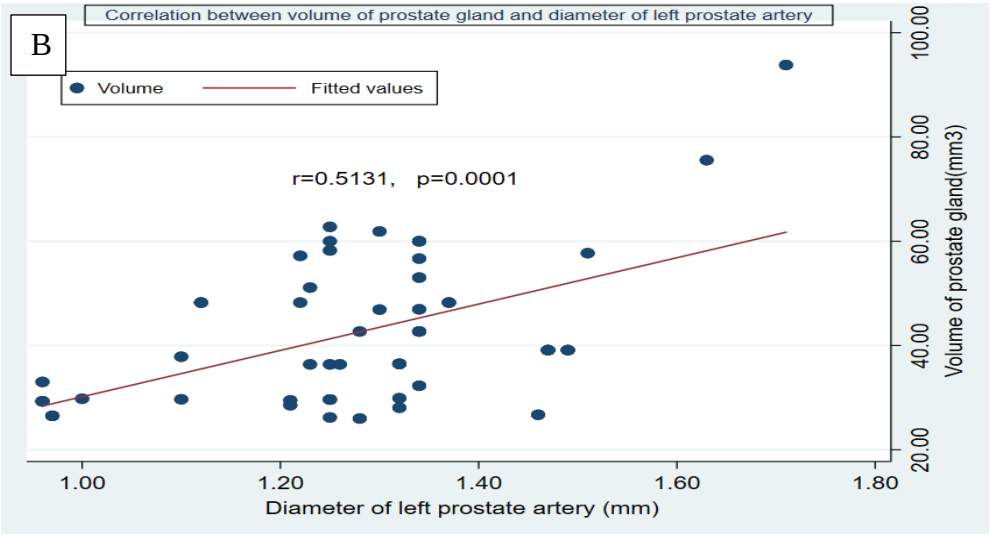


Figure 4.5.c and d. Correlation between diameter of the left prostate arteries and the prostate volume among adult males (A)-normal group, (B) general group and (C) enlarged group

4.7. Hypothesis

Testing hypothesis

There is no significant correlation between the prostate volume and the diameter of the prostate artery in adult males, according to the null hypothesis (H0). The prostate volume and the diameter of both the right ($p<0.001$) and left ($p<0.001$) prostate arteries were found to have a significant positive correlation using the Pearson correlation coefficient test. As a result, we reject H0 and confirm that there is a significant correlation between the prostate volume and the diameter of the prostate artery of adult males.

CHAPTER FIVE

DISCUSSION

The goal of this study was to characterize the imaging findings of prostate arterial supply in adult males, as well as to correlate prostate gland size with prostate artery diameter on computed tomography and/or digital subtraction angiography.

This chapter discusses the major findings concerning the branching patterns of the prostate arteries, the size of the prostate arteries, the effect of socio-demographic characteristics on prostate volume and prostate artery diameter, and the relationship between prostate artery diameter and prostate gland volume. This chapter also includes a discussion of future research potential to further define imaging patterns of the arterial supply within the prostate gland, as well as how the branching pattern can aid with prostate artery embolization.

Despite the fact that the de Assis et al. reference model includes five patterns, this investigation found three origin patterns of the prostate artery from the internal iliac artery. Most people over the age of 60 had an enlarged prostate gland, which was found to be associated to the diameter of the prostate artery.

5.1 Interpretation of Findings

5.1.1 Socio-demographic and prostate volume

The study included 52 men, 37 of whom had an enlarged prostate gland. Patients with enlarged prostate glands were above 60 years old and had a history of prostate illness. Similar prevalence was reportd by Yeboah et al. (36), who found a high prevalence of BPH and prostate cancer of 6% to 10% in men aged 50 years and above in Ghana, Trinidad and Tobago (36). The findings also corroborates another study in Ghana (39), which indicated that Ghanaian men between the ages of 50 and 89 are highly predisposed to prostate diseases compared to those <50 years and >89 years (39). A study conducted in Nigeria found that the prevalence of enlarged prostate gland ranged from 54.52 % to 80.74 % throughout a five-year period (10). This study further established that,

prostate enlargement showed progressive increase with increasing age. Prostate enlargement increases by 8% in males aged 30-40 years to over 80% in men over 60 years, according to the Baltimore longitudinal study on aging (4). Elswehere in Iran, the prevalence of prostate enlargement in men of age 40-year-old and older rises with age, with a prevalence of 36 % in 70-year-old men (89). These evidence underscore that age is an important risk factor of prostate lesions and the development of clinical benign prostatic hyperplasia(36,38,39). Although not documented, it is possible that men aged 60 and up have had many (history of) prostate disorders, which could explain the high prevalence of BPH in patients aged 60 and above. Furthermore, the small number of patients in this study may have impacted the age patterns of those evaluated.

5.1.2 Origin of the prostate artery

The development of prostatic artery embolization has led to better understand the complex male pelvic arterial anatomy. Adequate understanding of the prostatic arterial anatomy may provide a better understanding of some concerns associated with prostatic artery embolization, such as the risk of bladder wall ischemia or necrosis, or both (90). In this investigation, one prostate artery was found in all (100%) the 104 pelvic halves of adult males in Ghana. This discovery is consistent with findings of Nguyen et al. (91), Bilhim et al. (92), Wang et al. (80), de Assis et al. (13) and Amouyal et al.(93). For instance, Nguyen et al. (91) found single prostate artery in 630 pelvic halves out of 660 in a Vietnam population(91). Bilhim et al.(82) reported single PA in 57% of 150 male pelvic halves among adult in Portugal (82). Also, de Assis et al. (13) found 72% out of 199 hemipelves with one PA among men in Brazil. The higher prevalence of single prostate artery found in these studies could be attributed to the use of only CTA in the study but not in combination, as opposed to other authors' use of a combination of CTA, cone beam CT, and DSA. The observed variation in the proportion of single prostate artery could also be due to small number participants in the presentt study compared to previous studies(13,80,92,93).

The origin of the prostate artery was found to be symmetrical in 50% of the 52 patients. This finding contradicts the study by Wang et al. (80) conducted in the Chinese population where 87.8% (n-130) asymmetry between pelvic sides of the prostate artery origin was found. The differences in the symmetrical patterns of the prostate artery origin could be linked to imaging modalities used in the two studies. Unlike the current study, Wang et al. (80) combined cone beam CT with CTA

which has the potential to mitigate the risk of non-target embolization. It also provides confirmation of the arterial vascular anatomy before embolization, and it is essential in confirming prostatic parenchymal perfusion with retrograde tracing of the prostate artery to it origin (80). Obviously, the combination of cone beam CT and CTA provides better examination and visualization of PA in the both pelvic halves. This finding is significant during prostate artery embolization because each hemipelvis should be catheterized separately(79,80).

Efforts has been made to provide precise description of the distribution of the branches of the prostatic artery (PA) after its origin (13,91,92). The evaluation of PA anatomy in a systematic manner, adhering to a standard classification, will make PAE a faster, safer, and more effective procedure (13). From a clinical and radiologist point of view, the de Assis classification is the easiest and most reproducible classification of this complex vascular system (71) which has been the reference document for most studies in the field of prostate artery studies currently. The present study adapted the de Assis classification (13) for the origin of prostatic arteries.

This study revealed that only three PA origins (type I-III) were seen among the studied population. The most common origin of PA was the common trunk with the superior vesical artery (type I), followed by obturator artery (type III) and lastly as a branch of the anterior division of internal iliac artery, inferiorly to superior vesical artery (type II). This is consistent with the findings of previous studies by Nguyen et al.(91) in Vietnam, Eldem et al.(94) in Turkey and Wang et al. (92) in China. These studies reported that, the most common branching pattern or origin of PA was the common trunk with the superior vesical artery (type 1). For instance, Nguyen et al.(91) discovered that majority of the evaluated arteries had type I origin, followed by type IV, III, II, and V. Eldem et al.(94) used DSA, to evaluate 119 pelvic halves and discovered that type I was the most common origin, followed by type IV, III, I, and V. Moreover, Wang et al. (92) also reported similar high proportion of type I branching pattern observed in a Chinese population, followed by type II and type IV. On the contrary, de Assis et al. (13) study in Brazil reported five PA origins with PAs originating from the internal pudendal artery (type IV) as the most common type, followed by the common origin with superior vesical artery (type I), the obturator artery (type III), the anterior division of the internal iliac artery (type II), and less common origins of the the internal pudendal artery (type V). The difference in the number and patterns of PA origin seen in these studies could be linked to the level of utilization of tools and procedures in prostate artery embolization. Since

they are limitations to individual procedures (CTA and DSA) in PAE, combination of CTA, cone beam CT, and DSA could provide synergic effect to enhanced PA identification and description (79,80). The absence of vasodilator administration prior to the procedure in the present investigation could make it difficult to visualised the tiny branches of the internal pudendal artery, hence the inability to identify type IV. Although race and ethnicity have been linked with the incidence of BPH in epidemiological studies, the data from this study and other PAE studies on PA anatomy did not link the variation in the prevalence of PA origin classification to the race and ethnicity within and between the populations (10,13,71,80,93).

Although not documented, the variation in PA patterns among different population could be associated with the level of PAE equipment used and level of expertise as well as accuracy of the interventional radiologist performing the procedure. Also, the small number of participant studied may have contributed to the difference in the proportions of PA branching patterns or origin. The literature demonstrates the highly inconsistent and variable origins of the prostate artery, even within the same individual and among different populations. There was no case of prostate artery origin from the superior gluteal artery, inferior gluteal artery, middle rectal artery or the accessory pudendal artery.

The implications of these variable prostate artery origins is the difficulty it poses to prostate artery embolization (PAE). The variable pattern, along with small artery diameters, is a technical challenge during prostate artery embolization, resulting in lengthy procedure times and significant amounts of radiation exposure to both patients and medical personnel. In addition, non-target embolization has the potential to cause significant complications such as rectal and bladder ischeamia and penile ulcers.

The findings suggest that, radiologists would have to approach PAE in three ways, pre-procedure pelvic imaging including pelvic ultrasound to assess the prostate gland size and nodules, pelvic MRI to rule out prostate cancer and delineate the zonal anatomy. The pre-PAE CTA would include understanding of the pelvic and main prostatic vascular anatomy, selection of arterial access (femoral or radial) and selection of catheters to be used during the procedure. It also assesses the

level of calcification or stenosis in the origin of the prostate arteries, which will serve as contraindication to PAE.

Table 5.1.2 A summary of the studies conducted in the past based on reported prevalence and branching patterns in various populations.

Study	Year	Prevalence of the types of prostate artery origin, using de Assis as standard model. Decreasing order of occurrence				
		First	Second	Third	Fourth	Fifth
Jimah* (Ghana) (104 pelvic sides)	2021	Type I (n = 64, 58.7%)	Type III (n=26, 25%)	Type II (n=17, 16.3)	Type V Not seen	Type V Not seen
De Assis et al. (Brazil) (13) ** (267 pelvic sides)	2015	Type IV (n = 89, 31.1 %)	Type I (n = 82, 28.7 %)	Type III (n=54, 18.9%)	Type II (n=42, 14.7%)	Type V Not seen
Nguyen et al. (Vietnam) (91) (660 pelvic halves)	2019	Type I (n=223, 33.9%)	Type IV (n=157, 23.9%)	Type III (n=120, 18.3%)	Type II (n=91, 13.9%)	Type V (n=69, 10.4%)
Eldem et al. (Turkey) (94) (119pelvic sides)	2021	Type I (n = 43, 36.1%)	Type IV (n = 34, 28.6%),	Type III (n = 22, 18.5%)	Type II (n = 13, 10.9%)	Type V (n=7, 5.9%)
Wang et al. (China) (92) (296 pelvic sides)	2016	Type I (n= 118, 37.1%)	Type II (n =99, 31.1%)	Type IV (n = 77 (24.2%)	Type III Not seen	Type V Not seen
Bilhim et al. (Portuguese) (20) (150 pelvic sides)	2012	Type IV (n=73, 34.1%)	Type I (n=43, 20.1%)	Type II (n=38, 17.8%)	Type III (n= 27, 12.6%)	Type V

*Current study **Landmark study for comparison

5.1.3 Diameter of the prostate artery.

The diameter of the prostate artery varies from patient to patient and is never the same. The average diameter of the prostate artery in the general population was 1.27mm+0.17. This is less than the 1.6mm+0.3 mean diameter observed by Bilhim et al(20). They discovered that patients with one prostate artery on each side had larger prostate artery diameter (mean 1.9mm) than those with three prostate arteries (mean 1.6mm) or four prostate arteries (mean 1.3mm). Although broader evidence is required to ascertain the difference in mean diameter of PAs, the variation obserded suggests that adult males in European countries are more likely to have larger diameter than their counterpart in sub-Saharan Africa. Also, the observed differences in the mean diameter of the prostate artery could be attributed to the different sample sizes used as well as combined procedures (CT angiography and selective prostatic DSA) employed by Bilhim et al(20) in Portugal compared to CTA only in the present study. Larger diameter of the prostatic artery enhance catheterization compared to small diameters (69).

The current study found that older patients had larger prostate artery diameters than younger patients, with patients 60 years and older having mean diameters of (1.320.14, p=0.0061 for left) and (1.33 0.16, p=0.0850 for right). However, Bilhim et al. (20) and Wang et al. (92) did not observe any such association. The differences in findings could be attributed to aged ranges and number of participants studied. For instance, Bilhim et al. (20) study involved 75 male patients of aged 50 to 85 years, Wang et al.(92) 148 males within 56 to 86 years, while the present study involved 52 males of aged 36 to 81years. The age association with PA diameter in the present study is vital factor to assess prostate health as age has been identified as an important risk factor of prostate lesions and the development of clinical benign prostatic hyperplasia (36,38,39). Also, the contributions of ethnicity and race cannot be overemphasized, as the diamenter of PA varies within and between different populations. These variations are likely to be influence by lifestyles, environmental exposures that predispose the male adult to urinary tract infections and other prostate diseases.

Previous studies did not compare laterality and therefore comparison is impossible. It is also difficult to offer explanation why older patients had significantly larger left prostate artery diameters than the right.

The increase in diameter of the prostate artery for those with enlarged prostate gland, enhances cannulation and embolization of the prostate arteries during prostate artery embolization. Intra-arterial gylceryl trinitrate is often administered during prostate artery embolization when the anterior division of the internal iliac artery is catheterized to prevent spasm of the prostate artery. This enhances the cannulation of the artery and prevent non-target embolization.

5.1.4 The volume of prostate gland

In this study, prostate gland volume was classified as normal if it is less than $30cm^3$, and enlarged if it is greater than $30cm^3$. The average volume of the prostate gland for all adult males studied was $42.58\pm14.17cm^3$, which was comparable to the reported range of 30.3+9.8 to 49.0 +26.9 cm^3 in Europe and America(95). In Nigeria, Udeh et al.(85) reported a significantly higher prostate volume of $72.79 \pm 44.38ml$. This disparity could be attributed to numerical bias or sample size in the population studied. In this study, the mean prostate volume was significantly higher in males aged 60 and above compared to those aged under 60. Previous research(10,96) has found an association between older age and increased prostate volume or enlargement. Aging is likely to lengthen and increase male androgen predisposition, which is a potential physiological factor in prostate enlargement(31).

The mean volume of the prostate gland differs significantly between those who have a history of prostate disease and those who do not have a history of prostate disease. Existing prostate diseases may increase the risk of prostate gland enlargement, which may be complicated by age, genetics, hormones, growth factors, inflammation, and lifestyle factors(10,31). Pearson et al.(97) discovered that a high family history of prostate enlargement was more likely associated with risk inheritance rather than symptom severity.

5.1.5 Correlation between volume of prostate gland and diameter of the prostate artery

The diameter of the prostate artery was found to have a significant positive correlation with the volume of the prostate gland. This relationship remained constant for both the right and left prostate arteries. On the contrary, Bilhim et al. (20) and Wang et al. (92) found no significant correlation between the prostate volumes and prostate artery diameter among adult men in Portugal and China respectively. The differences could be attributed to the number of participants, ethnicity, lifestyle variations between countries, and level of accuracy in examining prostate arteries in these populations. According to the findings, increasing the volume of the prostate gland will likely increase the diameter of the prostate arteries, and vice versa. This is consistent with the findings of Wang et al. (92), who discovered that those with larger prostate volumes had a larger prostate artery diameter than those with medium-sized prostate volumes. Inflammation of prostate artery and gland has been linked to the development of benign prostate enlargement (31). The most common feature associated with benign prostate hyperplasia is the infiltration of inflammatory agents, and the degree of inflammation is related to prostate volume and weight (31).

There was a negative correlation between the prostate artery diameter and volume of the prostate gland, for those with normal prostate volume, even though it was not significant. This is explained by the fact that with normal prostate volume, there is reduction in the inflammatory markers within circulation, hence reduced amount within the prostate artery. This may result in the artery undergoing periodic spasms, hence reduced diameter at the time of imaging.

5.2 Limitations

1. The patients included in this study are those seen at Euracare Advanced Diagnostic and Heart Center, which is a premium facility, hence referral bias cannot be completely excluded.
2. This is prospective single-center evaluation and the results cannot be generalized. Further study from other centers and bigger sample size is necessary to confirm these findings.
3. A single person evaluated all the CTA which could introduce bias
4. The absence of cone beam CT
5. The constraints of financing the study myself.
6. The comparison of the results with other results with different methology could explain some of the differences in the current results and those in literature

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The study found that patients with enlarged prostate glands were above 60 years old and had a history of prostate illness.

Single prostate artery identified in all the one hundred and four pelvic halves of adult males in Ghana and this is consistent with current literature from other countries.

The commonest origin of the prostate artery is type I, where it shares a common trunk with the superior vesical artery, followed by obturator artery and then the anterior division of the internal iliac artery (common gluteal- pudendal trunk).

The diameter of the prostate artery and the volume of the prostate gland correlate positively. Though not observed in this study, the variant anatomy indicates that the prostate artery may supply the rectum, bladder, seminal vesicles, and contralateral prostate gland, and the importance of accurately establishing nontarget sites prior to embolization cannot be overstated.

6.2 Recommendation

6.2.1 Recommendation to improve practices

1. Cone-beam CT should be considered in the purchase of all catherterization equipments in Ghana in the future. This is a useful adjunctive technique to DSA in determining the anatomy of the prostate artery, which is limited by the use of only DSA.

2. Before embolization CTA should be performed on all patients to assess the extent of atherosclerosis in the internal iliac arteries, which may interfere with catheterization of the prostate arteries.

3. In order to reduce examiner bias, different interventional radiologists should performed the PAE procedures and imaging analysis.

6.2.2 Recommendation for future studies

1. This study was a single-center prospective evaluation of prostate arteries; a multicenter study is necessary to confirm the findings in a local context.

2. Fewer sociodemographic factors were studied, future studies should explore importance of the ethnic variations and the influence of other background characteristics of male adults on the health of prostate arteries and the gland.

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TIMELINES/WORK SCHEDULE –2021

GANTT CHART

TASK	ACTIVITIES	2021											
		J	F	M	A	M	J	J	A	S	O	N	D
1.Review of literature, Aim and Objectives, Rationale and Methodology (Proposal to GCPS)	Edit and Submission												
2. Proposal for Ethical Review Committee of UGMS	Edit and Submission												
3. Data collection and analysis, discussion. Discussion with supervisor	Tentative Start date following ethical approval												
4.Final Submission of Dissertation to GCPS													

BUDGET & LOGISTICS

Source of funding – Self

1. Review of literature, Aim and Objectives, Rationale and Methodology (Proposal to GCPS) – articles – 1015GhC. This may involve the purchase of at least five articles at 35$ and exchange rate of 6.GhC
2. Laptop – 2000 GhC. Literature search, data entry and final write up will all need a laptop
3. Photocopy – Total of 184 questionnaires and consent form with 5% wastage – 390copies – 195GhC. Each photocopy is estimated to cost 50p.
4. Miscellaneous - Fuel, phone calls and others – 1000GhC
5. Total – 4210GhC

APPENDICES

APPENDIX I: INFORMED CONSENT FORM

PATIENT INFORMATION LETTER AND INFORMED CONSENT FORM

Title of Research Project: Imaging patterns of the arterial supply of the prostate gland in Ghanaian men.

Principal Investigator: Dr Bashiru Jimah

Address: Radiology Department, 37 Military Hospital, jimah@uccsms.edu.gh, 0553299210

General Information about Research

Thank you for agreeing to participate in this research study. This form outlines the purpose of the study and provides a description of your involvement and rights as a participant.

Thank you for agreeing to participate in this study. This form outlines the purposes of the study and provides a description of your involvement and rights as a participant. I am Dr Jimah Bashiru of the Department of Radiology, 37 Military and carrying out the research in partial fulfillment of the award of Fellowship in Interventional Radiology from the Ghana College of Physicians and Surgeons.

The purpose of this project is:

To describe the radiological anatomy of the arterial supply of the prostate gland in Ghanaian men; a prospective cross-sectional study using Computed Tomography (CTA) at Euracare Advanced Diagnostic and Heart Centre.

The study will employ qualitative methods to collect data, such as age, analyzing your CT scan/DSA images and your prostate gland images. You are encouraged to ask any questions at any time about the nature of the study and the methods that I am using. Your suggestions and concerns are important to me. You may contact me at any time at the address/phone numbers listed above. If you have any questions about your rights as a research participant you can contact the EPRC Office between the hours of 8am-5pm on +233 [030] 294 0528, +233 [030] 266 5103 or email address: eprc@chs.edu.gh.

I guarantee that the following conditions will be met:

1. Your real name will not be used at any time during the information collection, or in the written report; instead, you and any other person involved in the study will be given an identification number.
2. Your participation in this research is voluntary; you have the right to withdraw at any point of the study, for any reason, and without prejudice, and the information collected and reports written will be turned over to you.
3. The confidentiality of the information that will be collected would be safeguarded and your privacy and anonymity will be ensured throughout the study and publication of the research material.
4. The study will not require any more than the routine used in the performance of CTA of the pelvis. No additional risk or discomforts is expected.
5. The findings of the research will add to the current literature on the anatomy of arterial supply of the prostate gland and improve the performance of treatment of enlarged prostate gland.
6. No additional cost will be incurred by you.

In pursuance of the above, I would be grateful if you could complete the attached informed consent form before any data is taken on you.

STATEMENT OF CONSENT/VOLUNTARY AGREEMENT

The above document describing the purpose, benefits, risks and procedures for the research [title: Imaging patterns of the arterial supply of the prostate gland in Ghanaian men] has been read and explained to me in detail. I have been allowed to ask any question(s) I have about the research and my question(s) has/have been answered to my satisfaction. I have been told that I may contact EPRC Administrator on +233 [030] 294 0528, +233 [030] 266 5103 or email address: eprc@chs.edu.gh and Dr Jimah Bashiru (0553299210 and jimah@uccsms.edu.gh) if I have questions about my rights as a study participant, to discuss problems, concerns or suggestions related to the research.

I understand that a copy of the information sheet and the informed consent forms will be given to me to take home after it has been signed.

I have read the consent form and agree to participate in this research study voluntarily.

_____ _____

Signature/Thumb print of Participant Date

_____ _____

Signature/Thumb print of Obtaining Consent Date

STATEMENT OF WITNESS

I was present while the benefits, risks and procedures were read to the volunteer. All questions were answered and the volunteer has agreed to take part in the research voluntarily.

_____ _____

Signature/Thumb print of Participant Date

_____ _____

Signature/Thumb print of Obtaining Consent Date

APPENDIX II

Data entry form

Age: ☐ ID: ☐

Highest level of Education: ☐

Marital status: ☐ Single. ☐ Married ☐ Divorce ☐ Widower

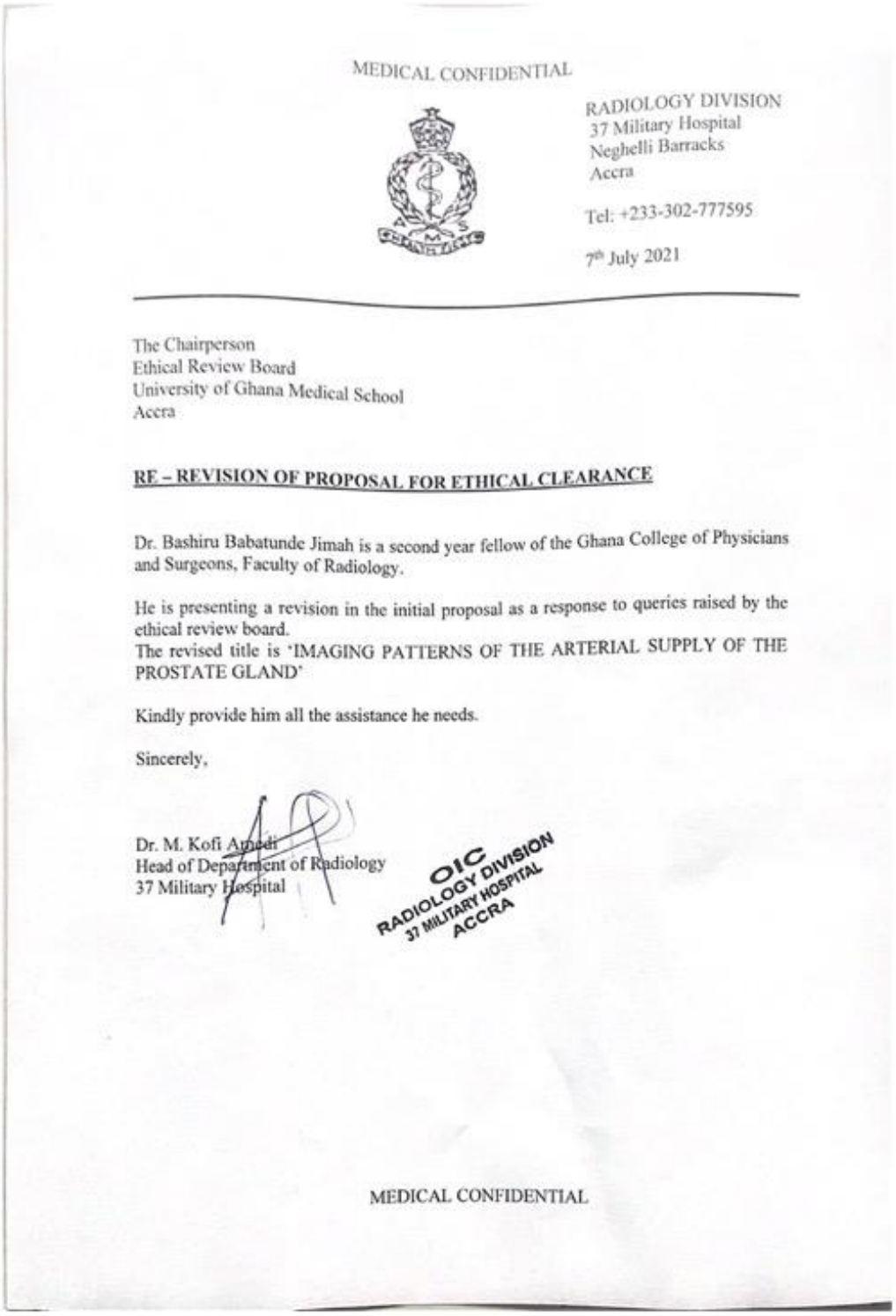
Have you been diagnosed of any prostate disease in the last 6months? ☐ Yes ☐ No

Prostate Volume: ☐

de Assis et al. Prostate artery branching pattern

	Right	Left
Type I	----------	----------
Type II	----------	----------
Type III	----------	----------
Type IV	----------	----------
Type V	----------	----------
Prostate artery diameter(mm)	----------	----------

APPENDIX III: ETHICAL CLEARANCE A



MEDICAL CONFIDENTIAL

RADIOLOGY DIVISION
37 Military Hospital
Neghelli Barracks
Accra

Tel: +233-302-777595

7th July 2021

The Chairperson
Ethical Review Board
University of Ghana Medical School
Accra

RE – REVISION OF PROPOSAL FOR ETHICAL CLEARANCE

Dr. Bashiru Babatunde Jimah is a second year fellow of the Ghana College of Physicians and Surgeons, Faculty of Radiology.

He is presenting a revision in the initial proposal as a response to queries raised by the ethical review board.
The revised title is 'IMAGING PATTERNS OF THE ARTERIAL SUPPLY OF THE PROSTATE GLAND'

Kindly provide him all the assistance he needs.

Sincerely,

Dr. M. Kofi Ameh
Head of Department of Radiology
37 Military Hospital

OIC
RADIOLOGY DIVISION
37 MILITARY HOSPITAL
ACCRA

MEDICAL CONFIDENTIAL

APPENDIX IV: ETHICAL CLEARANCE B

UNIVERSITY OF GHANA
COLLEGE OF HEALTH SCIENCES
ETHICAL AND PROTOCOL REVIEW COMMITTEE

EPRC/JULY/2021

f. No.:.....

Dr. Bashiru Babatunde Jimah
Dept. of Radiology
Military Hospital
37-Accra

ETHICAL CLEARANCE

Protocol Identification Number: ***CHS-Et/M.6 –5.8 /2020-2021***

FWA: 000185779 **IORG: 0005170**

The College of Health Sciences Ethical and Protocol Review Committee (E
reviewed and approved your research protocol.

Title of Protocol: **"Imaging patterns of the arterial supply of the prostat**

Principal Investigator: **Dr. Bashiru Babatunde Jimah**

This approval requires that you submit six-monthly review report(s) of the s
and a final full review report to the EPRC at the completion of the study
observe, or cause to be observed, procedures and records of the study be
implementation.

Please note that any significant modification(s) to this project/study must
Committee for review and approval before its implementation.

You are required to report all serious adverse events related to this study to
(7) days verbally and fourteen (14) days in writing.

As part of the review process, it is the Committee's duty to review the e
manuscript that may be produced from this study. You will therefore be re
Committee with any manuscript for publication.

This ethical clearance is valid until July 28, 2022.

Please always quote the protocol identification number in all future correspo
this protocol.

Signed: .....

Professor Andrew Anthony Adjei
Chair, Ethical and Protocol Review Committee

cc: **Provost, CHS**
The Rector (GCPS)
Head, Faculty of Radiology (GCPS)
The Head 37militry Hospital

O. Box KB 52, Korle Bu, Accra, Ghana. **Telephone:** +233 (0) 302 665103/4 • Fax
• **Email:** admin.chs@ug.edu.gh /provost.chs@ug.edu.gh • **Website:** www.ch