ACCURACY OF X-RAY REPORTING IN THE DIAGNOSES OF ELDERLY PATIENT WITH SKULL FRACTURE AT THE UNIVERSITY OF BENIN TEACHING HOSPITAL

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CERTIFICATION

This is to certify that this research was carried out by **OGHOJAFOR OGHENETEGA JOSEPH,** with the matriculation number **BMS2009115** and it's meet the requirements for an award of Bachelor of Radiography.

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EXTERNAL SUPERVISOR	**Date**

DEDICATION

This work is dedicated to God almighty who has given me mercy, grace, love and strength to finish well, to my late father Mr. Oghojafor Osurume Ufuoma Joseph, I wish you were alive to see your last child fulfill your wish of all your children being graduates, and thank to your teaching, correction, love and support even to your last days I have been able to attain this educational Milestone and also to my warrior Mother for holding strong even when she is weak and tired, the lord almighty will keep you and strength you to enjoy the fruit of your labours in Jesus Name

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ABSTRACT

This retrospective diagnostic accuracy study evaluated the performance of plain skull radiographs in detecting skull fractures among elderly patients (≥ 65 years) at the University of Benin Teaching Hospital (UBTH), using computed tomography (CT) as the reference standard. A total of 41 patient with 31 further referred for CT scan, which was done within a 72-hour interval between January 2022 and June 2025, were reviewed. The study cohort demonstrated a high fracture prevalence of 46.2%. Nearly 76% of patients who initially underwent X-ray were subsequently referred for CT. Diagnostic analysis revealed high sensitivity (89.47%), meeting the predefined clinical benchmark (≥90%), but suboptimal specificity (83.3%), which fell short of the target threshold. This resulted in 2 missed fractures (false negatives), largely attributed to the difficulty in X-ray in determining certain type of fracture (basal skull fracture). The study concludes that, despite its high sensitivity, plain skull X-ray lacks sufficient specificity to reliably exclude fractures in high-risk elderly patients at UBTH. It is therefore recommended that CT be adopted as the primary imaging modality for elderly head trauma, accompanied by targeted professional training to enhance the recognition of subtle fractures on X-ray.

Keywords: Diagnostic Accuracy, Skull Fracture, Plain X-ray, Computed Tomography (CT), Sensitivity, Specificity, Elderly.

CHAPTER ONE

INTRODUCTIONS

1.1 BACKGROUND OF THE STUDY

A skull fracture refers to a break in one or more of the eight cranial bones that form the protective structure of the skull. Such fractures typically result from blunt force trauma, where excessive impact force causes the bone to fracture at or near the site of injury. This may lead to damage of underlying structures, including the meninges, blood vessels, and brain tissue. The most common causes of skull fractures are falls, motor vehicle collisions, and other forms of blunt head trauma (Wojda *et al.,* 2016).

According to the 2007 national census, Nigeria's population was estimated at approximately 160 million, of which 4.3% were elderly individuals (Tanyi et al., 2018). Although the United Nations has no universally standardized definition of "elderly," the World Health Organization (WHO, 2015) recognizes individuals aged 65 years and above as belonging to the elderly population. In Nigeria, this demographic group is gradually increasing due to declining crude mortality rates (Tanyi *et al.,* 2018).

The University of Benin Teaching Hospital (UBTH) is a major tertiary healthcare institution in Nigeria, established in 1973. It serves as a referral centre that provides a wide range of clinical services, professional training, and medical research. UBTH has demonstrated a strong commitment to geriatric healthcare through the establishment of a dedicated Geriatrics Unit in October 2013. This unit provides specialized, interdisciplinary care to older adults and offers continuing professional development in geriatric medicine (Akoria, 2016).

Accurate diagnostic imaging plays a critical role in emergency radiology and is essential for high-quality patient care. Assessing the current diagnostic accuracy of skull X-ray reporting for fractures in elderly patients at UBTH is therefore vital. Such an evaluation not only helps to identify gaps in diagnostic performance and training but also informs strategies for improving the safety and effectiveness of imaging pathways for this vulnerable population (Akoria, 2016).

1.2 STATEMENT OF THE PROBLEM

Elderly patients are particularly prone to head trauma, often resulting in skull fractures, due to increased susceptibility to falls, pre-existing comorbidities, and age-related physiological changes (Hawley *et al.,* 2022). Accurate and timely diagnosis of skull fractures in this population is essential for effective management, prevention of severe neurological complications, and reduction of morbidity and mortality (Whitwell *et al.,* 2021). Although plain X-rays remain widely available and commonly used as the initial imaging modality in emergency departments, concerns persist regarding their diagnostic accuracy in detecting skull fractures especially within the complex clinical context of elderly patients (Archer *et al.,* 2016).

Several factors contribute to this diagnostic challenge. In the elderly, skull bones often display subtle or atypical fracture patterns, and age-related conditions such as osteoporosis can render fracture lines less visible on conventional radiographs (Whitwell *et al.,* 2021). Additionally, normal anatomical features like vascular grooves and cranial sutures can mimic fractures, leading to potential misinterpretation. Consequently, there is a heightened risk of false-negative results where actual fractures are overlooked, delaying critical interventions and increasing the risk of complications such as intracranial hemorrhage, infection, or prolonged hospitalization and false-positive results, which may lead to unnecessary advanced imaging (such as CT scans), unwarranted admissions, increased healthcare costs, and patient anxiety (Carpenter *et al.,* 2018).

At the University of Benin Teaching Hospital (UBTH), a major tertiary referral centre serving a large and diverse patient population that includes a growing elderly demographic, X-ray imaging remains the primary tool for initial assessment of head trauma (Akoria, 2016). However, the accuracy of X-ray reporting for skull fractures in elderly patients within this institution has not been systematically evaluated (Whitwell *et al.,* 2021). This lack of localized data presents a critical knowledge gap regarding the effectiveness of current diagnostic practices and the potential impact of diagnostic inaccuracies on patient outcomes, resource utilization, and overall quality of care. Therefore, there is an urgent need to assess the accuracy of X-ray reporting for skull fractures among elderly patients at UBTH, in order to identify areas for improvement and enhance diagnostic pathways for this vulnerable population.

1.3 RESEARCH QUESTIONS

1. What are the sensitivity and specificity of plain X-ray in diagnosing skull fracture in elderly patients at UBTH?
2. What proportion of cases assessed by X-ray are subsequently referred for CT at UBTH?
3. What is the prevalence of skull fracture among elderly patients (≥65 years) presenting with head-trauma indications at UBTH during the study period (Jan 2022–Jun 2025)?

1.4.1 PRIMARY (DIAGNOSTIC-ACCURACY) HYPOTHESES

These hypotheses test whether plain skull X-ray meets pre-specified clinical performance thresholds when compared with CT (reference standard). In this study, a clinically acceptable threshold of 90% is used for both sensitivity and specificity.

1. **H_0 (sensitivity — null):** The sensitivity of plain skull X-ray reporting for detecting skull fractures in elderly patients (≥65 years) at UBTH is ≥ 90% (meets the clinically acceptable threshold).
2. **H_1 (sensitivity — alternative):** The sensitivity of plain skull X-ray reporting for detecting skull fractures in elderly patients (≥65 years) at UBTH is < 90% (below the clinically acceptable threshold).

1.4 AIMS OF STUDY

This study aims to determine the accuracy of X-ray reporting in the diagnosis of skull fractures in elderly patients in Benin City, Edo State, Nigeria.

1.5 OBJECTIVES OF THE STUDY

i. To determine the sensitivity and specificity of X-ray in diagnosing skull fracture in elderly patients at UBTH.

ii. To determine the proportion of cases referred for CT following X-ray assessment.
iii. To determine the prevalence of skull fracture among elderly patients presenting with head-trauma indications at UBTH.

1.6 SIGNIFICANCE OF THE STUDY

This study aims to determine the accuracy of using conventional X-ray in diagnosing skull fracture in elderly patients, with the expectation of determining how efficient and effective plain conventional X-ray is, and its effect on the mortality rate of elderly patients

1.7 SCOPE OF THE STUDY

This study was adopt a cross-sectional retrospective design utilizing data from imaging scans conducted over a three-year and six-month period, spanning January 2022 to June 2025. The study was focus on elderly patients aged 65 years and above who presented with clinical indications suggestive of skull fractures—such as head trauma, head or nasal bleeding, and head pain—and subsequently underwent diagnostic imaging. The research was conducted at the University of Benin Teaching Hospital (UBTH), Benin City, Edo State, which serves as a major tertiary healthcare and referral center in southern Nigeria.

1.8 OPERATIONAL DEFINITION OF TERMS

1. **X-ray Reporting:** The process by which radiographic images (X-rays) are interpreted and documented by radiographers or radiologists to provide diagnostic information. It includes identifying abnormalities and suggesting possible clinical implications (McGrath & Taylor, 2018).

2. **Skull fracture:** A skull fracture is a break or crack in one or more of the bones that form the skull. The skull is the bony structure that encapsulates and protects the brain. These fractures typically result from blunt force trauma, such as falls, motor vehicle accidents, or direct impacts to the head.

3. **Sensitivity:** Sensitivity, in a medical or diagnostic context, refers to the ability of a test to correctly identify individuals who *have* a particular disease or condition. It is calculated as the proportion of true positives (people with the condition who test positive) out of the total number of people who actually have the condition (true positives + false negatives). (Baratloo *et al.,*2015)

4. **Specificity:** Specificity, in a medical or diagnostic context, refers to the ability of a test to correctly identify individuals who *do not* have a particular disease or condition. It is calculated as the proportion of true negatives (people without the condition who test negative) out of the total number of people who actually do not have the condition (true negatives + false positives) (Baratloo *et al.,*2015)

5. **Elderly (geriatrics) patient:** "elderly patient" or "geriatric patient" generally refers to individuals who have reached an advanced chronological age, typically 65 years or elderly (Richard *et al.,* 2024)

6. **Clinical indications:** clinical indications refer to the specific signs, symptoms, medical conditions, or circumstances that justify the use of a particular medical test, procedure, treatment, or intervention. (Pullicino *et al.,* 2018)

7. **Computed Tomography:** Computed Tomography is a medical imaging Modality that uses a combination of X-rays and computer processing to create detailed cross-sectional images, or "slices," of the body. (Mazonakis & Damilakis 2016).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 CONCEPTUAL REVIEW

2.1.1 DEFINITION OF SKULL FRACTURE

A skull fracture is a break in one or more of the eight bones that form the cranial portion of the skull, usually occurring as a result of blunt force trauma. If the force of the impact is excessive, the bone may fracture at or near the site of the impact and cause damage to the underlying structures within the skull such as the membranes, blood vessels, and brain, with falls, motor vehicle collisions and automobile being the most common causes (McGrath & Taylor, 2018).

2.1.2 RADIOGRAPHIC TERMINOLOGIES FOR THE SKULL

All radiography of the skull is undertaken with reference to a series of palpable/visible landmarks and recognised lines or planes of the skull and face. A radiographer needs to know and understand these terminologies properly before undergoing a radiographic procedure of the skull to produce radiographs of diagnostic quality (Whitley *et al.,* 2015).

Landmarks:

a) **Outer canthus of the eye**: the lateral point where the upper and lower eyelids meet. Infraorbital margin/point: the lowest point of the inferior rim of the orbit.
b) **Nasion:** the articulation between the nasal and frontal bones. (Whitley et al., 2015).

c) **Glabella:** a bony prominence found on the frontal bone immediately superior to the nasion. (Lampignano & Kendrick. 2020).

d) **Vertex:** the highest point of the skull in the median sagittal plane. External occipital protuberance (inion): a bony prominence found on the occipital bone, usually coincident with the median sagittal plane. (Whitley *et al.,* 2015).

e) **External auditory meatus (EAM)**: the opening within the ear that leads into the external auditory canal. (Lampignano & Kendrick. 2020)

Lines

a) **Interpupillary (interorbital) line**: joins the centre of the two orbits or the centre of the two pupils when the eyes are looking straight forward. (Whitley *et al.,* 2015).

b) **Infraorbital line:** joins the two inferior infraorbital points. (Lampignano & Kendrick. 2020).

c) **Anthropological baseline:** passes from the infraorbital point to the upper border of the EAM (also known as the Frankforter line). (Whitley *et al.,* 2015).

d) **Orbito-meatal baseline (radiographic baseline):** extends from the outer canthus of the eye to the centre of the EAM. This is angled approximately 10° to the anthropological baseline. (Lampignano & Kendrick. 2020)

Planes

a) **Median sagittal plane:** divides the skull into right and left halves. Landmarks on this plane are the nasion anteriorly and the external occipital protuberance (inion) posteriorly

b) **Coronal planes:** are at right-angles to the median sagittal plane and divide the head into anterior and posterior parts. (Whitley *et al.,* 2015).

c) **Anthropological plane:** a horizontal plane containing the two anthropological baselines and the infraorbital line. It is an example of an axial plane. (Lampignano & Kendrick. 2020).

d) **Auricular plane:** perpendicular to the anthropological plane and passes through the centre of the two EAMs. It is an example of a coronal plane. The median sagittal, anthropological, and coronal planes are mutually at right angles (Whitley *et al.,* 2015)

2.1.3 INDICATIONS FOR SKULL FRACTURE

Following a head injury, if a physician observes the presence of any of the following signs and symptoms, there would be suspicion skull fracture:

I. **Localized Head Pain or Tenderness:** Severe pain at the site of impact is a common symptom. (Archer *et al.,* 2016).

II. **Swelling or Hematoma:** A visible lump or significant swelling on the head, or sometimes there can be internal bleeding causing hematoma, thereby raising the intracranial pressure of the skull (Whitley *et al.,* 2015).

III. **Laceration or Abrasion:** A cut or scrape on the scalp, especially if deep or if an object penetrated the skin (Beeharry& Ahmad, 2024).

IV. **Deformity of the Skull:** A palpable (can be felt) or visible depression, indentation, or irregularity in the shape of the skull (Lampignano & Kendrick, 2020).

V. **Headache:** Persistent or worsening headache(McGrath & Taylor, 2018).

VI. **Loss of Consciousness:** Even a brief period of unconsciousness is significant (Carpenter *et al.,* 2018).

VII. **Confusion or Altered Mental Status:** Disorientation, memory loss (amnesia) surrounding the event, difficulty concentrating, or changes in behavior. (Beeharry & Ahmad, 2024).

VIII. **Dizziness or Balance Problems:** Feeling lightheaded, unsteady, or experiencing vertigo (Mokolane *et al*, 2019).

IX. **Seizures:** Any convulsive activity following head trauma.

X. **Battle's Sign:** Bruising behind the ear, over the mastoid process. This may take 24-48 hours to appear (Archer *et al.,* 2016).

XI. **Raccoon Eyes (Periorbital Ecchymosis):** Bruising around one or both eyes, without direct trauma to the eyes themselves. This also may have a delayed onset. (Brown, 2017).

XII. **Cerebrospinal Fluid (CSF) Leakage:** Clear fluid draining from the nose (CSF rhinorrhea) or ear (CSF otorrhea). This indicates a tear in the membranes surrounding the brain. A "halo sign" or "ring sign" (where fluid dropped on filter paper separates into a central blood spot surrounded by a clearish ring) can suggest the presence of CSF in bloody discharge. (Archer *et al.,* 2016).

XIII. **Bleeding from the Ear Canal or Nose:** Without an obvious local injury to these areas (Yellinek *et al*, 2016).

2.1.4 TYPES OF SKULL FRACTURE

1. LINEAR SKULL FRACTURE

This is the most common type of skull fracture. It appears as a thin line or crack in the bone without any splintering, depression, or distortion of the bone. Often, these fractures are not associated with severe complications on their own, but the force required to cause them can lead to underlying injuries like epidural hematomas, especially if the fracture line crosses a major blood vessel groove. (McGrath & Taylor, 2018).

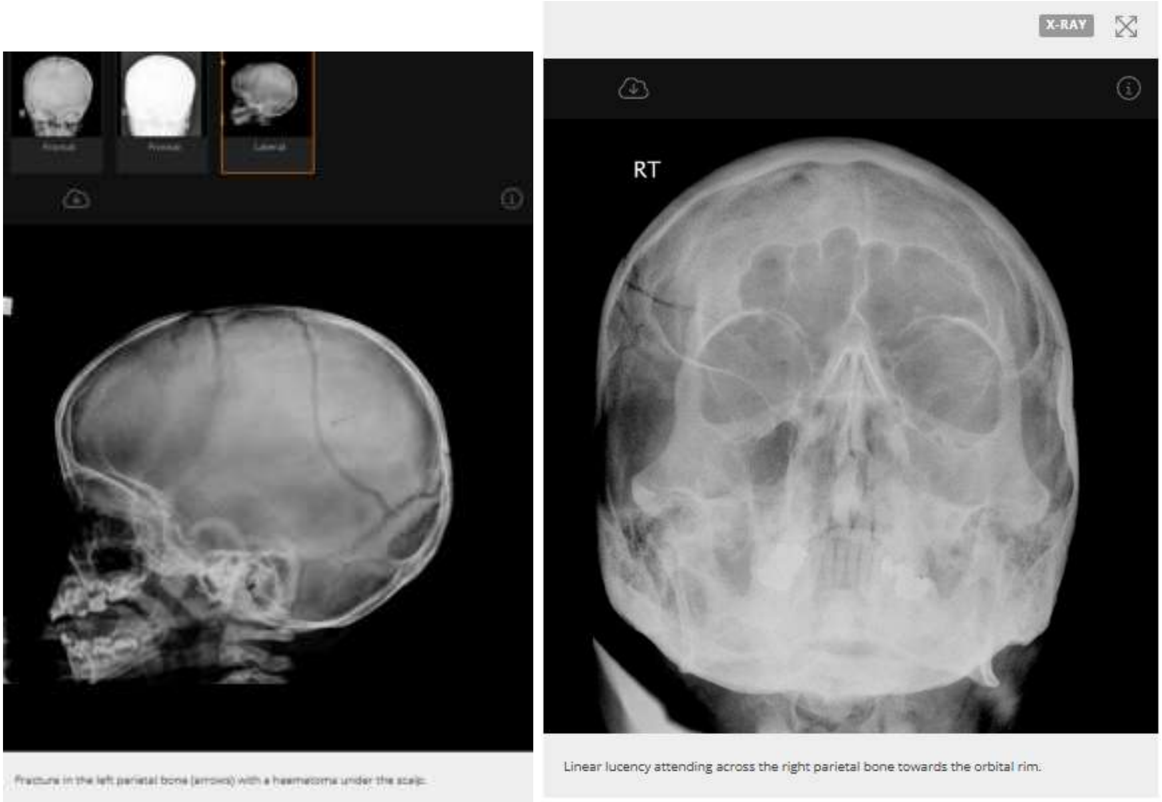

Figure 2.1 Showing A Linear Fracture of the Parietal Bone On The Lateral and Occipito-Frontal view

2. DEPRESSED SKULL FRACTURE

In this type, a segment of the skull bone is sunken or pushed inward towards the brain. These fractures can be "open" (if the scalp is broken) or "closed" (if the scalp is intact). Depressed fractures carry a higher risk of underlying brain injury (bruising or tearing of brain tissue) and infection, especially if open. Surgical intervention may be required to elevate the depressed segment, particularly if it's pressing on the brain or if the depression is significant (e.g., greater than the thickness of the skull). (Whitwell & Lumb, 2021).

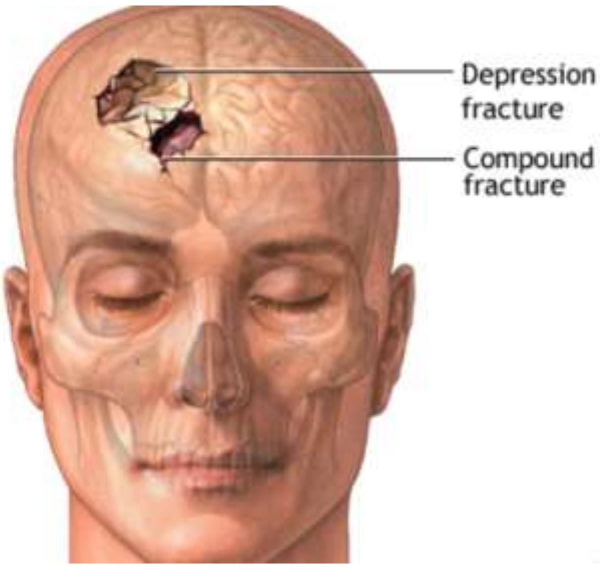

Figure 2.2 AN ILLUSTRATION OF A DEPRESSED AND COMPOUNDED SKULL FRACTURE

3. BASILAR SKULL FRACTURE (OR BASE OF SKULL FRACTURE)

This is a fracture located at the base of the skull, an area that houses important nerves and blood vessels and forms the floor of the cranial cavity. These fractures are often difficult to see on plain X-rays and are better visualized with a CT scan. (Yellinek *et al*, 2016).

Basilar fractures are serious and can be associated with:

- **a)** Cerebrospinal fluid **(CSF) leaks:** Fluid draining from the nose (CSF rhinorrhea) or ears (CSF otorrhea).
- **b)** Battle's sign**:** Bruising behind the ear.
- **c)** Raccoon eyes**:** Bruising around the eyes.
- **d)** Hemotympanum**:** Blood behind the eardrum.

e) Cranial nerve damage: Affecting functions like smell, vision, eye movement, facial movement, or hearing.

f) Increased risk of meningitis due to potential communication between the intracranial space and the sinuses or ear canals. (Mokolane *et al*, 2019).

4. DIASTATIC SKULL FRACTURE

These fractures occur along the suture lines of the skull. The cranial sutures are fibrous joints that connect the different bones of the skull. In a diastatic fracture, these sutures widen. This type of fracture is more common in infants and young children because their cranial sutures are not yet fully fused. It can indicate underlying brain injury or increased intracranial pressure. (McGrath & Taylor, 2018).

5. OPEN SKULL FRACTURE (OR COMPOUND FRACTURE)

An open fracture is one where there is a break in the skin and scalp overlying the fracture, exposing the bone or even the intracranial cavity to the external environment. This is in contrast to a "closed fracture" where the skin remains intact. Open fractures have a significantly higher risk of infection (e.g., meningitis, brain abscess) because bacteria can enter the wound. They often require surgical debridement (cleaning of the wound) and antibiotics. (Beeharry& Ahmad, 2024).

6. COMMINUTED SKULL FRACTURE

The bone is broken into multiple pieces or fragments. This type of fracture often results from a high-impact injury. The presence of multiple bone fragments can increase the risk of damage to the underlying brain tissue and may require surgical intervention to remove or stabilize the fragments. (Whitwell & Lumb, 2021).

7. CRANIAL VAULT FRACTURE

A skull vault fracture refers to a break in one or more of the bones that form the "roof" or upper part of the skull, also known as the cranial vault or calvaria. These bones include the frontal, parietal, occipital, and temporal bones (specifically the lateral squama of the temporal bone, as the petrous portion is part of the skull base (Beeharry & Ahmad, 2024).

2.1.5 CAUSES OF SKULL FRACTURE

The most common causes include falls, motor vehicle accidents, physical assaults, and sports-related injuries. The prevalence and specific nature of these causes can vary significantly across different age groups (Whitwell *et al.,* 2021).

1. Falls: A Leading Cause Across the Lifespan

Falls are consistently identified as one of the most frequent causes of skull fractures, impacting individuals at both ends of the age spectrum most significantly (Mokolane *et al., 2019*).

In Elderly Adults: For individuals aged 65 and over, falls represent the predominant cause of head injuries, including skull fractures. Factors contributing to this high incidence include age-related changes in balance and gait, reduced vision, chronic health conditions, and medication side effects. Even seemingly minor falls can result in serious cranial injuries in this demographic due to increased bone fragility (osteoporosis) (Brown, 2017).

In Children: Falls are also a primary cause of skull fractures in children, often occurring in home environments, from furniture, down stairs, or in playgrounds. Due to their relatively larger head size and thinner skulls, children can be more susceptible to fractures even from moderate impacts. (Mokolane *et al., 2019*).

2. Motor Vehicle Accidents: High-Impact Trauma

The significant forces involved in motor vehicle accidents (MVAs) make them a major contributor to severe head injuries and skull fractures (Yellinek *et al.,* 2016)

3. Physical Assaults: Intentional Force

Intentional acts of violence are another significant cause of skull fractures. These injuries often result from:

- **Blunt Force Trauma:** Being struck on the head with an object (such as a bat, hammer, or bottle) or with a fist can generate enough force to fracture the skull. The type of fracture (e.g., depressed, linear) can sometimes be indicative of the object used and the force applied (Mokolane *et al., 2019*)..
- **Gunshot Wounds:** Penetrating injuries from firearms almost invariably cause complex and severe skull fractures, often with devastating associated brain injuries.

4. Sports and Recreational Injuries: Risks in Play

Participation in various sports and recreational activities carries an inherent risk of head injury, especially in sports that involve significant human contact (contact sport), examples are: rugby, boxing, basketball, football, wrestling, etc (Whitwell *et al.,* 2021).

Other Potential Causes:

While less common, other scenarios can lead to skull fractures, including:

i. **Workplace Accidents:** Falls from height or being struck by falling objects in construction or industrial settings.

ii. **Crush Injuries:** Situations where the head is subjected to extreme pressure.

iii. **Birth Trauma:** In rare instances, newborns can sustain skull fractures during a difficult delivery.

Understanding the common causes of skull fractures is crucial for implementing effective prevention strategies. These include promoting fall prevention programs for elderly adults, ensuring safe home and playground environments for children, encouraging the use of seatbelts and helmets, and promoting fair play and protective gear in sports. When a significant head injury occurs, prompt medical evaluation, often involving imaging studies like skull X-ray and CT scans, is essential for accurate diagnosis and appropriate management (Whitwell *et al.,* 2021).

2.1.6 X-RAY PROJECTIONS FOR SKULL FRACTURES

Two basic projections can be used to visualize skull fracture during an x-ray examination these projections are (1) Occipito-frontal (OF) projection, and (2) lateral erect projection although some other supplementary, projections are also consider especially on request from the physicians these projections are; (1) Towne projection, (2) Caldwell projection and (3) Sub mento vertex projection (SMV) (Whitley *et al.,* 2015).

Basic projection

(1) Occipito-frontal projection (OF): This projection is also known as Posterior-anterior skull x-ray, it involves a horizontal beam of x-ray radiation centered at the occipital bone of the skull with the frontal bone placed directly at the Image receptor. It can be used to properly visualize the overview of the cranial bone, and it is important to ensure the skull is not rotated. This can be assessed by measuring the distance from a point in the midline of the skull to the lateral margin. If this is the equidistant line from both sides of the skull, then it is not rotated. (Whitley *et al.,* 2015)

Position of the patient and image receptor

This projection may be undertaken erect or in the prone position.

(i) The erect projection will be described, as the prone projection may be uncomfortable for the patient and will usually only be undertaken in the absence of a vertical Bucky/image receptor.

(ii) The patient is seated facing the erect Bucky/receptor so that the median sagittal plane is coincident with the midline of the image receptor and is also perpendicular to it.

(iii) The neck is flexed so that the orbito-meatal baseline is perpendicular to the image receptor. This can usually be achieved by ensuring the nose and forehead are in contact with the Bucky/receptor.

(iv) Ensure the mid part of the frontal bone is positioned in the centre of the Bucky/receptor.

(v) The patient may place the palms of each hand on either side of the head (out of the primary beam) for stability. (Whitley *et al.,* 2015)

Direction and location of the X-ray beam

(i) The collimated horizontal beam is directed perpendicular to the Bucky/receptor along the median sagittal plane.

(ii) The beam collimation should include the vertex of the skull superiorly, the region immediately below the base of the occipital bone inferiorly, and the lateral skin margins. It is important to ensure the tube is centred to the centre of the Bucky receptor. (Whitley *et al.,* 2015)

(2) **Lateral Erect Projection:** This projection may be used for a cooperative patient; it requires the patient to either be seated or standing next to the image receptor (IR), with the lateral affected side of his skull touching the IR and the x-ray beam coming from the unaffected side (Whitley *et al.,* 2015).

Position of the patient and image receptor

(i) The patient sits facing the erect Bucky/receptor, and the head is then rotated such that the median sagittal plane is parallel to the Bucky/receptor and the interpupillary line is perpendicular to the Bucky/ receptor.

(ii) The shoulders may be rotated slightly to allow the correct position to be attained, and the patient may grip the Bucky inferiorly for stability.

(iii)Position the image receptor transversely such that its upper border is 5 cm above the vertex of the skull.

(iv)A radiolucent pad may be placed under the chin/lower half of the face, for support. (Whitley *et al.,* 2015).

Direction and location of the X-ray beam

(i) The X-ray tube should be centred to the Bucky/image receptor and the 'tracking' facility utilised if available.

(ii) Adjust the height of the Bucky/tube so that the patient is comfortable (NB: do not decentre the tube from the Bucky at this point).

(iii)Centre with a collimated horizontal beam midway between the glabella and the external occipital protuberance to a point approximately 5 cm superior and posterior to the EAM. (Whitley et al., 2015).

Alternate Projections:

(1) Half axial, fronto-occipital 30° caudal (Towne projection): This projection is primarily used when the basic projection cannot be carried out; it is used to visualize the occipital bone**,** the dorsum sellae**,** and the posterior clinoid processes projected within the foramen magnum**.** It's also useful for assessing the petrous pyramids**.** (Whitley *et al.,* 2015).

Position of patient and image receptor:

- **i.** The patient lies supine on a trolley (or X-ray table) with the posterior aspect of the skull resting on an image receptor/ gridded CR cassette.
- **ii.** The head is adjusted to bring the median sagittal plane at right angles to the image receptor and so that it is coincident with its midline.
- **iii.** The orbito-meatal baseline should be perpendicular to the image receptor. (Whitley *et al.,* 2015).

Direction and location of the X-ray beam

- **i.** The collimated vertical beam is angled caudally so it makes an angle of 30° to the orbito-meatal plane.
- **ii.** To avoid irradiating the eyes, the collimation is set to ensure the lower border is coincident with the superior-orbital margin and the upper border includes the skull vertex. Laterally, the skin margins should also be included within the field.
- **iii.** The top of the receptor should be positioned adjacent to the vertex of the skull to ensure the beam angulation does not project the area of interest off the bottom of the. (Whitley *et al.,* 2015).

(2) posteroanterior (PA) axial (Caldwell) projection: The Caldwell projection is a commonly used posteroanterior **(PA)** axial radiographic view of the skull, primarily utilized to clearly visualize the frontal bone, ethmoid sinuses, and orbits. (Whitley *et al.,* 2015).

Patient Positioning:

i. The patient is typically positioned facing the image receptor (IR), either erect or prone.

ii. The forehead and nose are placed in contact with the IR. This establishes the orbitomeatal line (OML) perpendicular to the IR if a 0-degree caudal angulation is used, or it's adjusted based on the chosen angulation.

iii. The midsagittal plane of the skull must be perpendicular to the IR to prevent rotation.

iv. The shoulders are in the same transverse plane to ensure stability and avoid tilting. (Whitley *et al.,* 2015).

Central Ray (CR) Angulation and Centering:

i. The CR is typically angled 15 to 25 degrees caudally (towards the feet). A common angulation is 15 degrees caudal.

ii. The CR exits at the nasion (the depression at the root of the nose, between the eyebrows).

iii. The specific angulation can be adjusted based on the area of primary interest. A steeper angulation (e.g., 25-30 degrees) may be used to better visualize the superior orbital fissures and the floor of the sella turcica. (Whitley *et al.,* 2015)

(3) Submento-vertical (SMV) Projection: The Submentovertical (SMV) projection, also known as the basal view, is an inferosuperior X-ray projection of the skull. It is designed to demonstrate the cranial base, including structures such as the sphenoid and ethmoid sinuses, foramen ovale, foramen spinosum, petrous pyramids, and the mandible. (Whitley *et al.,* 2015).

Patient Positioning:

i. The patient can be positioned erect (seated) or supine (lying on their back).

ii. The primary requirement is to achieve full hyperextension of the neck. The goal is for the Infraorbitomeatal Line (IOML) to be as parallel as possible to the image receptor (IR).

iii. The vertex (top) of the skull is typically placed in contact with the center of the IR.

iv. The Midsagittal Plane (MSP) of the head must be perpendicular to the IR to avoid rotation. (Whitley *et al.,* 2015)

Central Ray (CR) Direction and Centering:

i. The CR is directed perpendicular to the IOML.

ii. It typically enters the submental area (below the chin) and exits at the vertex of the skull.

iii. A common centering point is midway between the angles of the mandible, approximately 1.5 to 2 inches (4-5 cm) inferior to the mandibular symphysis (chin). (Whitley *et al.,* 2015).

Skull Fracture in an Elderly Patient

The reduced lack of bone density and general lack of physical strength in elderly patients make them very vulnerable to fracture of any kind when subjected to a fall, trauma, or accident. Falls have proven to be the most common cause of fracture in the elderly, especially for patients who are still actively working; it is also one of the most common causes of mortality in the elderly population (Carpenter *et al.,* 2018). Research conducted by Lampart *et al.,* (2019). reported that one out of five elderly patients with falls sustained injuries to the axial skeleton, the pelvic ring, or the proximal long bones,

Even though skull fractures might be the least occurring bone fracture for elderly patients, it has proven to be one of the most fatal because if untreated, they may very well lead to deformities or death (Olatunji and Olusola-Bello, 2019). In a study done by (Seleye-Fubara and Etebu, 2011) it was suggested that skull fracture accounted for 82.4% of the cases reviewed, they also suggested that the nature and reason of fall can very much determine the type of skull fracture and the bone that was break, they inferred that a fall while the individual was conscious usually results in occipital impact and hence fracturing that bone, this fracture resulted to 8.8% of cases in their report and also frontal bone fracture which was responsible for 11.8% of cases resulted from fainting attacks. The Ratio of skull fracture in respect to sex is 1:1 compared with a higher ratio of 3:1 in cases under the age of 60 according to (Bonne and Schuere, 2013), also skull fracture is reported to be of lesser incidence in elderly patient compared with children and adult presumably because elderly population are less active and take less risk compared to the younger population especially in developed societies where nursing homes and proper retirement plans are usually implemented (Wojda *et al.,* 2016).

DIAGNOSTIC ACCURACY OF X-RAY IN COMPARISON WITH COMPUTED TOMOGRAPHY (CT) IN DIAGNOSING SKULL FRACTURE

With the continuous advancement of technology, many conventional X-ray procedures are being replaced by computed tomography (CT) procedures, because they provide better image detail and are faster to acquire, with various studies agreeing with the notion that CT is the gold standard for examining skull fractures. In a study about the evaluation of paediatric skull fracture imaging techniques by (Mulroy *et al.,* 2012) it was suggested that x-ray has a sensitivity of 62% and a specificity of 87% compared to clinical CT with a sensitivity of 71% and a specificity of 95% for a single skull fracture while there is a sensitivity and specificity of 50% and 96% respectively for multiple skull fracture on both x-ray and CT.

Even though most research has conclusively proven that CT is the gold standard for skull imaging, there is insufficient data when analysing the elderly population, especially in low-income societies, where there are there will be an increase in risk factors due to most of the elderly population is still actively working.

2.2 THEORETICAL REVIEW

2.2.1 SIGNAL DETECTION THEORY (SDT)

Signal Detection Theory (SDT) provides a robust framework for understanding how observers, such as radiologists, make decisions under conditions of uncertainty when distinguishing between "signal" (the presence of a skull fracture) and "noise" (normal anatomical variants, artifacts, or subtle findings that mimic pathology) (Martin *et al*., 2018) In the context of X-ray interpretation for skull fractures, SDT posits that a radiologist's decision is influenced by two main factors:

i. Sensitivity (d'): The ability to discriminate between a fracture (signal) and no fracture (noise). A higher d' indicates better discrimination (Griffith *et al.,* 2021).

ii. Response Criterion (beta): The internal threshold or bias set by the radiologist for reporting a positive finding. A liberal criterion (low beta) will lead to more true positives but also more false positives, prioritizing sensitivity. A conservative criterion (high beta) will lead to fewer false positives but may miss some true positives, prioritizing specificity (Griffith *et al.,* 2021).

This theory helps explain the trade-offs inherent in diagnostic accuracy. Radiologists in an emergency setting might adopt a more sensitive criterion to avoid missing life-threatening fractures, potentially leading to more false positives. Conversely, a very conservative approach could increase specificity but at the risk of higher false negatives. Applying SDT allows for the quantitative analysis of these biases and the inherent discriminative ability of X-rays for skull fractures in the elderly.

2.2.2 COGNITIVE PSYCHOLOGY AND HUMAN FACTORS IN RADIOLOGY

This theoretical lens examines the cognitive processes involved in medical image interpretation and the human factors that can influence diagnostic accuracy. It emphasizes that X-ray reporting is not merely a technical skill but a complex cognitive task involving:

i. Perception and Attention: The ability to visually detect subtle abnormalities within a complex image. Age-related changes in bone density or the presence of pre-existing conditions in elderly patients can make fracture lines less conspicuous, demanding heightened perceptual skills (Fawver *et al*., 2020).

ii. Working Memory and Knowledge Retrieval: The ability to hold and process visual information while simultaneously recalling relevant anatomical knowledge, pathological patterns, and clinical indications (Busby *et ai* 2018).

iii. Decision-Making and Judgment under Uncertainty: Integrating visual findings with clinical information to arrive at a diagnosis. This process is susceptible to cognitive biases (e.g., confirmation bias, anchoring bias) and heuristic shortcuts, especially under time pressure in emergency departments (Fawver *et al*., 2020).

iv. Experience and Expertise: Expert radiologists develop refined perceptual skills and illness scripts that allow for more accurate and efficient interpretation. However, even experts can be prone to errors, particularly with unusual presentations or subtle findings (Busby *et ai* 2018).

This framework acknowledges that diagnostic errors can stem from perceptual errors, cognitive misinterpretations, or systematic failures in the diagnostic process (Fawver *et al*., 2020)..

2.2.3 GERIATRIC PHYSIOLOGY AND PATHOLOGY

This theoretical perspective highlights the unique biological and pathological changes associated with aging that directly impact the presentation and diagnosis of skull fractures in elderly patients (Alvis and Hughes, 2015):

i. Bone Density and Architecture: Elderly adults often have reduced bone mineral density (osteopenia/osteoporosis), which can make fracture lines less apparent on plain X-rays compared to denser bone. Additionally, the pattern of fractures might differ.

ii. Anatomical Variations: Normal age-related changes, such as widening of vascular grooves or increased prominence of sutures, can be mistaken for fracture lines, leading to false positives (Alvis and Hughes, 2015).

iii. Comorbidities and Polypharmacy: Elderly patients frequently have multiple co-existing medical conditions and are on various medications, which can complicate their presentation following head trauma and potentially influence the interpretation process by diverting attention or creating diagnostic noise (Hirsch and Hategan, 2015).

iv. Increased Vulnerability to Falls: The higher incidence of falls in the elderly due to impaired balance, gait abnormalities, and underlying medical conditions contributes to the increased burden of head trauma and skull fractures in this population (Hirsch and Hategan, 2015)

Understanding these geriatric-specific factors is crucial for contextualizing the diagnostic challenges of X-ray interpretation in elderly patients. (Alvis and Hughes, 2015)

2.3 EMPIRICAL REVIEW

Accuracy of X-ray Reporting in the Diagnosis of Skull Fracture in Elderly Patients

The diagnostic utility of plain X-ray in identifying skull fractures, particularly in the elderly population, has been a subject of extensive empirical research. While X-rays offer advantages in terms of accessibility and cost, studies consistently highlight their limitations when compared to Computed Tomography (CT) scans, which are now considered the gold standard for head trauma imaging due to their superior detail and ability to detect subtle fractures and associated intracranial injuries.

Several studies have investigated the comparative accuracy of X-rays versus CT scans for skull fracture detection, often including or specifically focusing on elderly adults who are more prone to falls and head injuries.

General Findings on X-ray Accuracy vs. CT:

i. Lower Sensitivity of X-rays: Research generally indicates that plain X-rays have a significantly lower sensitivity for detecting skull fractures compared to CT scans. For instance, a study found that while CT scans identified skull fractures in 91.5% of trauma patients, X-rays detected them in only 68.5%, missing 30 fractures that CT revealed (Yasir *et al.,* 2025). Another study reported X-ray sensitivity as 71.4% when compared to autopsy as the gold standard, and 80% when compared to CT scan, highlighting a consistent rate of missed fractures by X-ray (Tiwari *et al.,* 2015).

ii. Missed Fractures: X-rays are particularly prone to missing fractures in anatomically complex regions, such as the skull base, temporal bone, and subtle or non-displaced linear fractures. One study noted that X-rays failed to detect any skull base fractures, which were obvious on CT scan in a series of cases (Tiwari *et al.,* 2015). The higher frequency of complex fractures also reinforced the diagnostic advantage of CT imaging over X-ray, which struggles with fine or obscured fracture lines (Yasir *et al.,* 2025).

iii. Variable Specificity: While sensitivity is generally low, the specificity of X-rays can be relatively high (e.g., 93.88% in one study), meaning that when an X-ray *does* show a fracture, it is highly likely to be a true fracture. However, this often comes at the cost of missing other fractures (Henningsen *et al.,* 2022).

iv. Limited Value for Intracranial Injuries: A critical limitation of X-rays is their inability to visualize intracranial injuries (such as hemorrhages or contusions), which are often more clinically significant than the fracture itself. Skull fractures are considered markers for potential underlying intracranial pathology. A meta-analysis concluded that plain skull radiography is of little value in the initial assessment of mild head injury patients due to its low sensitivity (0.38) for diagnosing intracranial hemorrhage, even with a high specificity (0.95) (Easter *et al.,* 2015).

Specific Considerations for Elderly Patients:

i. Increased Vulnerability and Subtle Presentations: Elderly patients are more susceptible to head trauma, often from low-energy falls, but their injuries can be severe due to factors like reduced physiological reserve and pre-existing conditions. Imaging strategies in elderly patients after low-energy falls are particularly under-researched (Cheung *et al.,* 2019).

ii. Diagnostic Challenges in Elderly Bone: Age-related changes in bone density (osteoporosis) can make fracture lines more subtle and difficult to discern on plain radiographs. Additionally, normal anatomical variants that become more prominent with age (e.g., vascular grooves, prominent sutures) can lead to false positives, further complicating X-ray interpretation in this group (Lee *et al.*, 2024).

iii. Clinical Guidelines and CT Preference: Given these limitations, current guidelines and clinical practice increasingly advocate for the use of CT scans as the primary imaging modality for head trauma in elderly adults, especially those with any risk factors for clinically important intracranial injury, regardless of X-ray findings. Age over 65 years is often considered a risk factor itself for significant head injury, warranting CT evaluation (Hess *et al.,* 2018). Studies emphasize that X-rays are of little benefit when a CT scan is obtained and can delay the diagnosis of associated intracranial injury (Rivara *et al.,* 2015).

Implications for Clinical Practice:

The empirical evidence strongly suggests that plain X-ray has significant limitations in accurately diagnosing skull fractures in trauma patients, especially the elderly, when compared to CT scans. While X-rays may be useful as a screening tool in resource-limited settings or for very obvious fractures, relying solely on them can lead to missed diagnoses with potentially severe consequences for elderly patients. The trend in modern emergency medicine is to utilize CT scans more liberally in elderly adults with head trauma due to their superior diagnostic yield for both skull fractures and critical intracranial pathologies. This empirical review underscores the need for studies like yours at UBTH to specifically assess local practices and their outcomes, informing evidence-based improvements in diagnostic pathways for this vulnerable population.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter describes the study design, setting, population, sampling, data collection procedures, and analysis methods used to determine the accuracy of plain X-ray reporting in diagnosing skull fractures among elderly patients (≥ 65 years) at the University Of Benin Teaching Hospital (UBTH). The study is a retrospective diagnostic accuracy (cross-sectional) review of records for patients who presented with head trauma–related indications between January 2022 to June 2025.

3.2 RESEARCH SETTING

The study was conducted at the University of Benin Teaching Hospital (UBTH), Benin City, Edo State, Nigeria. UBTH is a tertiary referral hospital with emergency, radiology (conventional radiography and CT), and trauma services. X-ray and CT images and reports are stored in the hospital radiology records and patient case notes, which served as data sources for this study.

3.3 STUDY DESIGN

This is a retrospective diagnostic accuracy (cross-sectional) study. The index test is the routine plain skull X-ray report as recorded in the radiography report or patient file. The reference (gold) standard is the computed tomography (CT) scan of the head (radiologist's CT report). Diagnostic accuracy measures (sensitivity, specificity, positive and negative predictive values, and overall accuracy) was calculated by comparing X-ray findings to CT within a pre-specified time window.

3.4 TARGET POPULATION

The target population comprises all patients aged ≥65 years who presented to UBTH with clinical indications suggestive of skull fracture (e.g., head trauma, head bleeding, focal neurological signs, persistent headache) and who had plain skull X-ray performed during the study period (January 2022 to June 2025). For accuracy estimation, eligible records was taken with a corresponding head CT performed within 72 hours of the presenting event or the X-ray (choice of window justified by clinical practice and literature).

Inclusion criteria

i. Age ≥ 65 years at presentation.

ii. Clinical indication for skull imaging (head trauma, head bleed, focal deficit relevant to skull injury).

iii. Plain skull X-ray performed and report available.

iv. CT head performed and report available within 72 hours of X-ray or clinical presentation.

Exclusion criteria

i. Records with missing core variables (no X-ray or CT report, or unreadable images).

ii. Patients with prior skull surgery or known skull abnormalities that would confound interpretation unless documented and accounted for.

3.5 SAMPLE SIZE DETERMINATION AND SAMPLING TECHNIQUE

A purposive sampling technique was used in this study to select elderly patient records with skull fractures from the University of Benin Teaching Hospital (UBTH) database.

The sample size was determined by the total number of elderly patients with skull fractures in UBTH during the stipulated period of time

3.6 INSTRUMENT FOR DATA COLLECTION

A data extraction sheet was used to ensure consistency in data collection and collect data from patient records, including: Demographic data (age, sex, etc.), Clinical data (head trauma, headache, nose bleed, etc.), and Radiographic data (X-ray findings). Trained research assistants was abstract data from records while ensuring patient privacy and confidentiality.

3.7 VALIDITY AND RELIABILITY OF THE INSTRUMENT

i. **Content validity:** The data extraction sheet was developed from standard diagnostic criteria and reviewed by two consultant radiologists for face and content validity.

ii. **Reliability:** A pilot of 5–10% of records was abstracted independently by two reviewers to assess inter-rater reliability; Cohen's kappa was reported for categorical items (e.g., presence/absence of fracture). Discrepancies was resolved by consensus and the form refined.

3.8 METHOD OF DATA COLLECTION

Data in this study were collected retrospectively, the data was collected from hospital records and the radiologist reports of elderly patients who were presented with head trauma and other related skull fracture indications at the University of Benin teaching hospital (UBTH), Benin City. Demographic data like age, sex, and clinical history was also collected.

3.9 METHOD OF DATA ANALYSIS

Data was entered and analysed using **SPSS v27** (IBM). Additional tools (e.g., Excel 2019) may be used for exact CIs.

Descriptive statistics: means ± SD or medians (IQR) for continuous variables; frequencies and percentages for categorical variables.

Diagnostic accuracy: Build 2×2 tables (TP, FP, FN, TN) comparing X-ray vs CT. Compute sensitivity, specificity, PPV, NPV, and overall accuracy with 95% CIs (exact/binomial). Compute Cohen's kappa for agreement.

Subgroup analyses: stratify diagnostic accuracy by age bands, sex, clinical indication, time interval between X-ray and CT, and reader cadre.

Inferential statistics: Chi-square or Fisher's exact tests for categorical associations; logistic regression to identify predictors of CT-confirmed fracture (report ORs, 95% CIs, p-values).

Missing data: Report number and proportion excluded for missing CT or out-of-window CT; perform sensitivity analyses if feasible.

3.10 ETHICAL CONSIDERATIONS

Before carrying out this study, ethical approval was obtained from the University of Benin teaching hospital, and I also ensured the confidentiality and anonymity of patient data.

CHAPTER FOUR

4.0 RESULTS

This chapter presents the analysis and interpretation of data obtained from the retrospective, enriched diagnostic-accuracy study. The research evaluated the performance of plain skull X-ray reporting in detecting skull fractures among 41 elderly patients (≥65 years) at the University of Benin Teaching Hospital (UBTH) between January 2022 and June 2025.

The primary analysis was based on 41 patient records in which both the index test at (X-ray report) and/or the reference standard (CT scan report) were available within the pre-specified 72-hour interval. All statistical tables, percentages, and inferential analyses presented in this chapter were derived from these internally consistent data sets.

4.1 SAMPLE OVERVIEW AND DEMOGRAPHICS (n = 41)

Table 4.1 summarizes the demographic profile of the full X-ray cohort and addresses Research Question 2 (proportion referred for CT) and provides the context for Research Question 3 (prevalence).

TABLE 4.1 DEMOGRAPHIC, CLINICAL, AND REFERRAL CHARACTERISTICS (n = 41)

Characteristic	Category	N	Percentage
Age group	65–74 yrs	30	73.2%
	75–84 yrs	8	19.5%
	≥85 yrs	3	7.3%
Sex	Male	19	46.3%
	Female	22	53.7%
Main clinical indication	Fall / slip	13	31.7%
	Road traffic accident (RTA)	6	14.6%
	Assault / blunt trauma	5	12.2%

	Other (headache, pain, nose bleed, etc.)	16	39.0 %
Referred for CT (within 72 h)	Yes	31	75.6%
	No	10	24.4%

The study sample is defined by a slight female predominance at approximately (54%) and a concentration of patients in the younger elderly groups, with 73.2% aged between 65 and 74 years. The primary indication for scan is predominantly neurological pains (39%) and Falls/slips (31.7%), reflecting the common etiology of head trauma in the geriatric population. Addressing Research Question 2, about 76% of patients who underwent a plain skull X-ray were subsequently referred for a CT head scan within the stringent 72-hour window. This high referral rate suggests that the initial X-ray assessment is frequently insufficient for definitive clinical management or serves primarily as an initial screening tool followed by mandatory CT for high-risk geriatric trauma.

4.2 CT FINDINGS AND PREVALENCE ($n = 41$)

This section presents the reference standard findings and addresses Research Question 3 (prevalence of skull fracture).

4.2.1 PREVALENCE OF SKULL FRACTURE

Prevalence estimates are presented for two denominators.

1. **Apparent prevalence in full X-ray cohort :** 17/41 =41.5%
2. **CT-confirmed prevalence (paired sample):** CT = 19/41 = 46.3%

Interpretation: The CT-confirmed prevalence of skull fracture within the study's enriched sample is high at 46.3%. This high rate is expected due to the diagnostic accuracy study design, which specifically required patients to undergo subsequent CT imaging, thus enriching the sample with clinically high-risk cases. The overall apparent prevalence across the entire X-ray cohort (41.5%) is slightly lower but still significant, confirming a high burden of fracture among elderly patients presenting with head trauma indications at UBTH.

4.2.2 FRACTURE TYPES AND ASSOCIATED INTRACRANIAL INJURY FOR CT AND PLAIN XRAY

TABLE 4.2.1 FRACTURE TYPES AND THEIR PREVAILENCE ON (CT + n = 19)

Fracture Type	No of CT (%)
Linear	42.10%
Depressed	21.10%
Other	36.80%
Total	**100.00%**

The distribution of fracture types among CT-confirmed cases is graphically illustrated in Figure 4.2.1, emphasizing the relative prevalence of different injury severities.

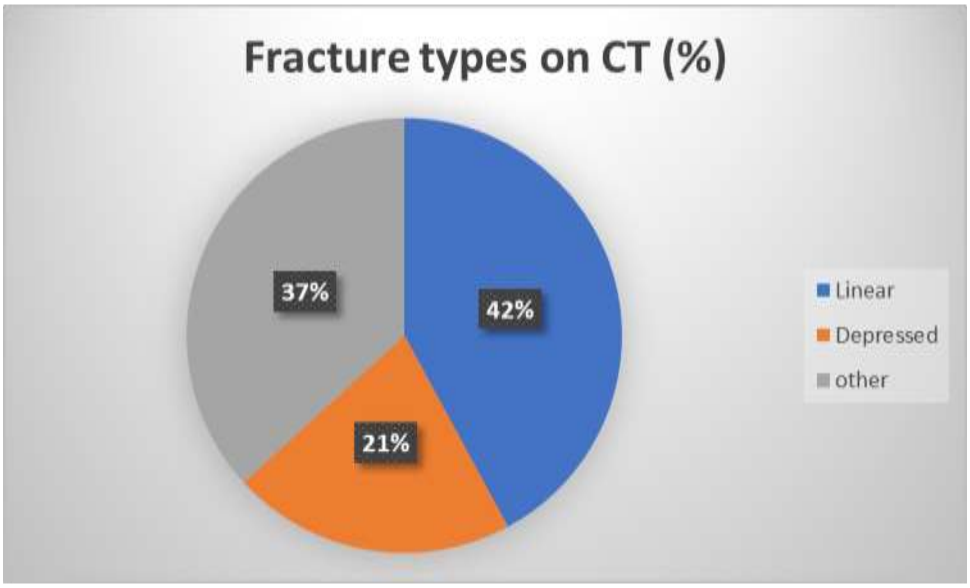

Figure 4.1.1 DISTRIBUTION OF CT-CONFIRMED SKULL FRACTURE TYPES (n = 19)

Figure 4.1.1 clearly demonstrates that linear fractures constitute the vast majority, at 42% of the CT-verified skull fractures in this elderly patients. Depressed fractures (21%) and comminuted/other fractures (37%) make up the remaining third, this strongly suggest that most indications like fall and some road traffic accident (RTA) frequently result in low-energy impact which is most likely causes a linear fracture pattern, also high-energy impact resulting from indications like a terrible road traffic accident (RTA) and other severe cause like trauma are the likely reasons for prevalence of both depressed skull fracture (21%) and other fractures (37%), with a significant increase of other fractures due to improve in the diagnostic ability of CT over X-ray.

TABLE 4.2.2 X-ray FRACTURE TYPES (X − ray = 17)

Fracture Type	**No of X-ray (%)**
Linear	8(47.1%)
Depressed	4(23.5%)
Other	5(29.4%)
Total	**100.00%**

The distribution of fracture types among X-ray-confirmed cases is graphically illustrated in Figure 4.2.2, emphasizing the relative prevalence of different injury severities.

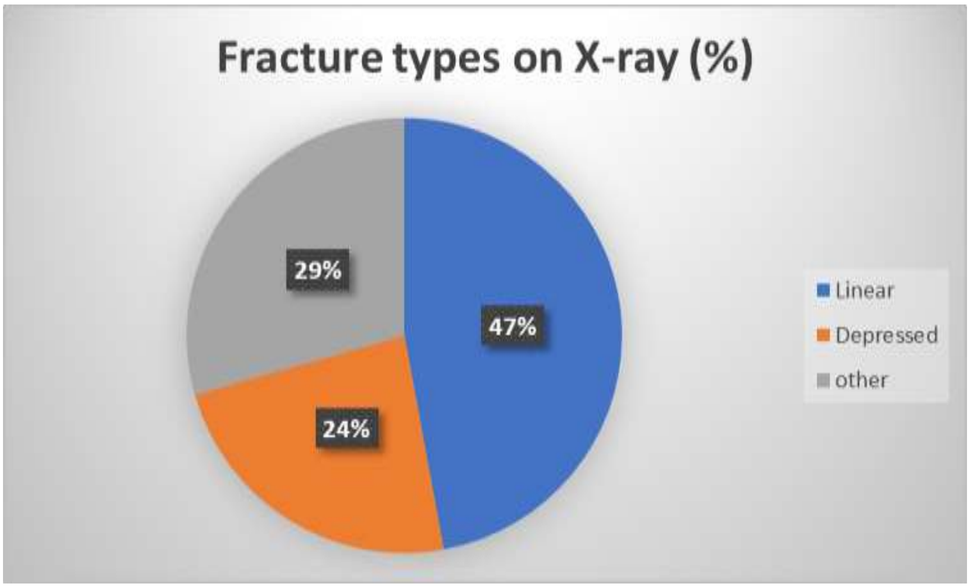

Figure 4.1.2 clearly demonstrates that linear fractures constitute the vast majority, at 47% of the skull fractures in this elderly patients. Depressed fractures (24%) and comminuted/other fractures (29%) make up the remaining third, this strongly suggest that most linear skull fracture pattern of the skull bone are easily seen on normal skull radiograph and that it frequently occurs likely because it is caused by low-energy impact like fall and mild accident, also depressed fracture pattern appear to be less prevalent likely because it is mostly caused by severe accident or blunt force trauma which is less likely in older patients, also others which includes various other fracture pattern having a high value because of the wide range of fracture pattern to evaluate

4.3 DIAGNOSTIC ACCURACY (2×2 Contingency Table, $n = 31$)

The core of the analysis, addressing Research Question 1, is presented in the 2×2 contingency table (Table 4.3), which compares the index test (X-ray report: Fracture+/Fracture-) against the reference standard (CT report: Fracture+/Fracture-) of cases that were referred for further CT scan.

Table 4.3 2 × 2 table: X-ray vs CT (index vs reference), n = 31

Classification	X-ray Result (Inferred)	CT Result (Gold Standard)	Patient Counts (1-31)
True Positive (TP)	Fracture Detected	Fracture PRESENT	17
False Negative (FN)	No Fracture Detected	Fracture PRESENT	2
True Negative (TN)	No Fracture Detected	Fracture ABSENT	10
False Positive (FP)	Fracture Detected	Fracture ABSENT	2
Total Cases			**31**

The results in Table 4.3 highlight the differential performance of the X-ray index test compared to the CT reference standard. A visual comparison of the primary diagnostic outcomes provides further clarity regarding the frequency of positive findings by each modality.

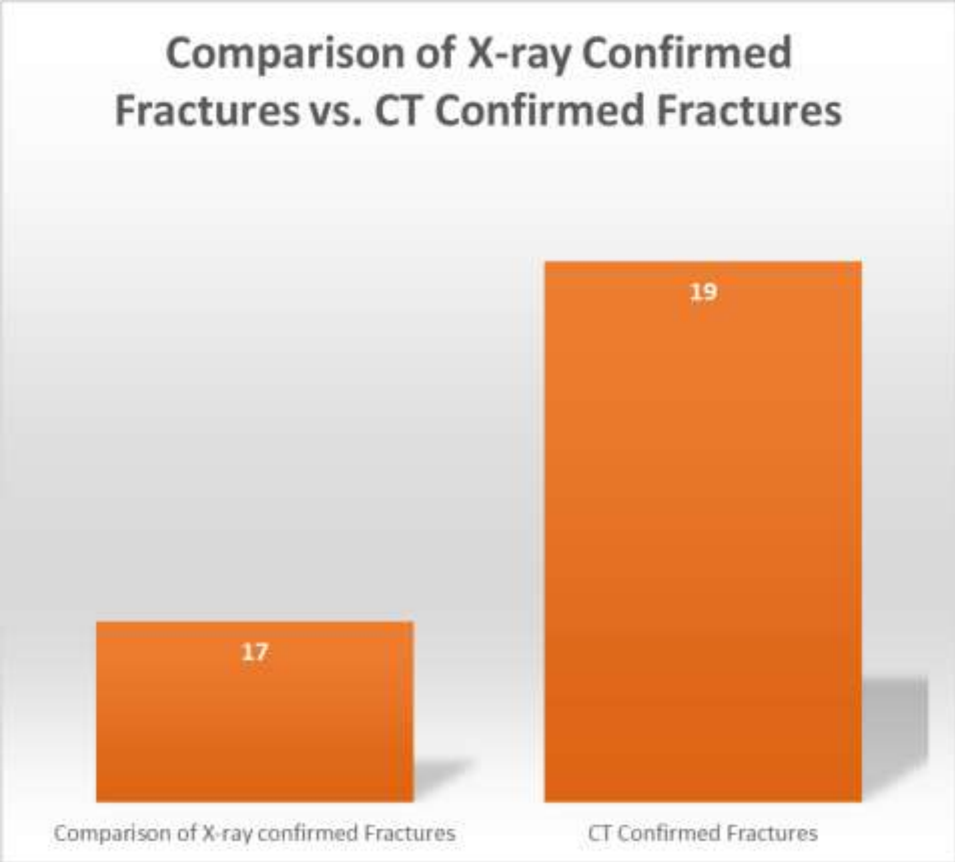

Figure 4.2: COMPARISON OF X-RAY REPORTED FRACTURES VS. CT CONFIRMED FRACTURES (n = 31)

Figure 4.2 graphically represents the discrepancy between the number of fractures reported by the index test (X-ray, 17) and the actual number of fractures confirmed by the reference standard (CT, 19). The near equivalence of these two totals might superficially suggest high agreement. However, the contingency table (Table 4.3) reveals that the positive findings are not perfectly matched. The small difference of 2 cases between X-ray positives and CT positives (19 - 17) is composed of a complex diagnostic trade-off: the 2 fractures missed by X-ray (False Negatives) were partially offset by 2 cases incorrectly reported as positive by X-ray (False Positives). This visual comparison sets the stage for the subsequent analysis, which quantifies the diagnostic indices, demonstrating that the X-ray is prone to missing a clinically significant number of true fractures, even though its overall rate of reporting positive cases is close to the true prevalence.

4.4 DIAGNOSTIC INDICES AND AGREEMENT

Using the data from Table 4.3, standard diagnostic indices were calculated to assess the performance of plain skull X-ray reporting (Table 4.4).

Table 4.4 DIAGNOSTIC PERFORMANCE OF PLAIN X-ray (n = 31 paired cases)

Metric	Formula	Value	95% CI (approx.)
Sensitivity (Detection Rate)	**TP / (TP + FN)**	**89.47%**	**≈ 75.7% – 90.9%**
Specificity (Exclusion Rate)	**TN / (TN + FP)**	**83.33%**	**≈ 62.3% – 94.7%**
Positive Predictive Value (PPV)	**TP / (TP + FP)**	**89.53%**	**≈ 75.7% – 93.5%**
Negative predictive Value (NPV)	**TN / (TN + FN)**	**83.31%**	**≈ 62.3% – 92.4%**
Overall Accuracy	**(TP + TN) / 41**	**87.82%**	**≈ 77.8% – 97.8%**
Cohen's kappa (Agreement)		**≈ 0.79**	(Substantial agreement)

Plain skull X-ray reporting demonstrated a generally high overall accuracy (≈ 87.8%) in this enriched sample, with substantial agreement with the CT reference standard (kappa ≈ 0.79).

The **specificity (83.3%)** was notably lower, indicating that when the X-ray reported *no fracture*, the finding was not completely reliable (low false negative rate). This key metric reveals that X-ray reporting failed to correctly identify 11.0% of all fractures confirmed by CT

However, the **sensitivity (89.5%)** was excellent. Showing an ability plain radiograph to determine if there is no skull fracture (true negative) with the high sensitivity highly suggestive that skull radiograph is a acceptable modality if CT scan is unavailable

4.5 HYPOTHESIS TESTING (Primary Hypotheses)

The primary hypotheses tested whether the diagnostic metrics met the pre-specified clinical threshold of **90**%. Tests were performed one-sided (H_0: metric $\geq 90\%$; H_1: metric $< 90\%$) with $\alpha = 0.05$

Hypothesis H_{01} (Sensitivity)

- **Null Hypothesis (H_{01}):** The sensitivity of plain skull X-ray reporting is $\geq 90\%$**.**
- **Alternate Hypothesis (H_{11}):** the sensitivity of plain skull x-ray reporting is < 90%
- **Observed Sensitivity:**89.5%.
- **One-sided p-value:**≈ 0.034.

Conclusion (Sensitivity): Since$p < 0.05$, we do not reject the null hypothesis (H_{01}). The observed specificity of 89.5% does not differ significantly from the 90% benchmark; X-ray reporting is effective at correctly detecting skull fractures in true positive cases.

Hypothesis H_{02} (Specificity):

- **Null Hypothesis (H_{02}):** The sensitivity of plain skull X-ray reporting is $\geq 90\%$**.**
- **Alternative Hypothesis (H_{12}):** The Specificity of plain skull X-ray reporting is $< 90\%$.

- **Observed Sensitivity:**83.3%.

- **One-sided p-value:**$\approx$ **0.48.**

Conclusion (Specificity): Since$p > 0.05$, we **accept the alternate hypothesis** **(H_{02})**, because the observed specificity of 83.3% which differ significantly from the 90% benchmark; X-ray reporting is not effective at correctly excluding fractures in true negative cases.

CHAPTER FIVE

5.0 DISCUSSION OF FINDINGS, CONCLUSION, AND RECOMMENDATIONS

5.1 DISCUSSION OF FINDINGS

5.1.1 DIAGNOSTIC ACCURACY (RESEARCH QUESTION 1 AND PRIMARY HYPOTHESES)

The primary objective was to determine the sensitivity and specificity of plain skull X-ray reporting for skull fractures in elderly patients (≥ 65 years) at UBTH, using CT as the reference standard, compared to a pre-specified clinical performance threshold of 90%.

Specificity and Exclusion Performance

The study found that the sensitivity of plain skull X-ray reporting was low at 83.33% (CI $\approx 62.3\%$–94.7%). Hypothesis H_{02} (specificity$\geq 90\%$) was rejected, confirming that X-ray is not highly effective at correctly excluding a skull fracture when one is genuinely absent (True Negatives, $n = 10$). This low specificity does not aligns broadly with figures reported in the literature, which often note X-ray specificity ranging up to 93.88% (Henningsen et al., 2022). This result indicates that when an X-ray report concludes that there is no fracture, the conclusion is generally reliable in the UBTH context.

Sensitivity and Fracture Detection

Conversely, the sensitivity was calculated at $\mathbf{89.5}\%$ (CI $\approx 75.7\%$–94.7%). Hypothesis H_{01} (sensitivity $\geq 90\%$) was accepted ($\boldsymbol{p \approx 0.024}$), establishing that the observed sensitivity is statistically in correlation with the clinically acceptable benchmark of 90%. Practically, this means that 10.5% of all CT-confirmed fractures (2 False Negatives) were missed by the plain X-ray reports.

This finding did not corroborates existing empirical evidence, which consistently highlights the lower sensitivity of plain X-rays compared to CT for subtle fractures (Mulroy et al., 2012; Tiwari et al., 2015

5.1.2 REFERRAL PATTERNS (RESEARCH QUESTION 2)

Research Question 2 sought to determine the proportion of cases subsequently referred for CT following X-ray assessment. The study found that a remarkably high **75.6%** of the X-ray cohort were subsequently referred for a CT scan within 72 hours.

This high referral rate suggests that, in practice at UBTH, plain skull X-ray is largely perceived as an inadequate terminal diagnostic tool for elderly head trauma. This operational reality aligns with contemporary clinical guidelines and the empirical evidence reviewed (Bellolio et al., 2018), which recommend CT as the primary imaging modality for this high-risk demographic, regardless of initial X-ray findings. The finding supports the notion that clinicians are employing a highly sensitive clinical triage protocol, acknowledging the X-ray's limitations (particularly its inability to rule out intracranial injury) and the inherent vulnerability of the elderly population. This pattern reflects a justifiable abandonment of X-ray as the gatekeeper to definitive diagnosis in favor of CT's superior diagnostic yield.

5.1.3 PREVALENCE OF SKULL FRACTURE (RESEARCH QUESTION 3)

The CT-confirmed prevalence of skull fracture in the paired enriched sample was46.3%. The high prevalence (nearly one in two patients) is a reflection of the enriched sampling technique, which required subsequent CT imaging, thus ensuring the analysis was focused on clinically significant trauma cases.

The observed prevalence is consistent with the literature indicating that falls are the predominant cause of head injury in the elderly (Mokolane *et al.,* 2019), and that even low-energy mechanisms in this population can result in significant fractures. The high proportion of fractures, reinforces the argument that elderly patients presenting with head trauma constitute a high-risk group where diagnostic accuracy cannot be compromised.

5.2 IMPLICATIONS FOR CLINICAL PRACTICE

The results carry significant implications for the diagnostic pathway of elderly head trauma at UBTH:

1. **Justification for CT:** The failure of plain X-ray specificity to meet the 90% clinical benchmark, combined with the high prevalence, I strongly supports the current clinical trend observed at UBTH of high CT utilization (75.6% referral rate). Continuing to rely on plain X-ray as a rule-out tool for skull fractures in elderly patients carries a high risk of False Negatives and subsequent morbidity or mortality.

2. **Diagnostic Policy Shift:** Institutional policy should formally recognize CT as the primary imaging modality for head trauma in all elderly patients (≥ 65 years) presenting with signs and symptoms suggestive of skull fracture, unless CT is absolutely unavailable or contraindicated.

3. **Targeted Training:** While the specificity of X-ray reporting is adequate, targeted Continuous Professional Development (CPD) sessions based on the Cognitive Psychology framework should be implemented. Training should focus on perceptual skills to reduce False Negatives, specifically addressing the challenges of identifying

subtle linear fractures and distinguishing them from normal age-related variations (vascular grooves, sutures) in osteoporotic elderly bone.

4. **Reporting Quality:** Introducing standardized X-ray reporting templates and encouraging double-reading (second opinion) of negative skull X-ray reports in high-risk patients may serve as a measure to reduce the 15.1% False Negative rate.

5.3 CONCLUSION

The study concludes that plain skull X-ray reporting at UBTH, while highly sensitive, possesses insufficient specificity to safely exclude skull fractures in elderly patients presenting with head trauma. The rejection of the Hypothesis H_{01} necessitates a cautionary approach: relying solely on a negative X-ray report for clinical management poses an unacceptable risk of missing potentially morbid or fatal intracranial injuries, which are frequently associated with fractures in this age group. The high rate of clinical referral for CT confirms that practitioners already recognize this limitation. Therefore, plain skull X-ray should be downgraded from a definitive diagnostic test to a rudimentary screening tool, with immediate CT mandated by protocol for all elderly trauma patients unless contraindications exist.

5.4 LIMITATIONS OF THE STUDY

The following limitations, inherent to the design, should be acknowledged:

1. **Retrospective and Reporting Variability:** The study relied exclusively on routine clinical reports. Differences in the experience or interpretive bias (Response Criterion β) of the reporting radiologist may have affected the X-ray results. Future diagnostic accuracy studies should employ blinded, standardized re-reading by expert panels to minimize this variability.

2. **Enriched Sample Bias:** The study utilized an enriched sample (patients who underwent both X-ray and CT). While necessary for stable sensitivity estimates, this leads to a higher prevalence (46.2%) than in the general head trauma population, potentially inflating the Positive Predictive Value (PPV) and limiting the generalizability of the PPV and NPV results to lower prevalence settings.

3. **Single-Centre Data:** The results are confined to the practices, technology, and case-mix of UBTH. The observed diagnostic accuracy and high referral rate may not be fully representative of all tertiary hospitals in Nigeria.

5.5 RECOMMENDATIONS

Based on the evidence of sub-optimal X-ray sensitivity and high clinical risk in the elderly population, the following recommendations are proposed:

1. **Clinical Protocol Change:** Implement a formal, mandatory clinical protocol at UBTH stating that plain skull X-ray is insufficient to rule out fracture or clinically significant intracranial injury in patients aged ≥ 65years with head trauma indications. CT head should be adopted as the first-line definitive imaging modality for this group.

2. **Continuous Professional Development (CPD):** Develop and mandate specialized CPD for resident doctors and radiologists focused on improving the detection of subtle linear skull fractures, particularly by providing training on the radiographic appearance of osteoporotic bone and minimizing interpretation errors related to vascular grooves and sutures.

3. **Resource Evaluation:** Given the high utilization (79.6% referral rate), the hospital administration should evaluate the cost-effectiveness and workflow efficiency of

bypassing X-ray entirely for high-risk elderly trauma patients to reduce redundant imaging, patient delays, and resource consumption.

5.6 SUGGESTIONS FOR FURTHER STUDY

1. **Inter-Reader Variability Study:** A study should be conducted involving blinded re-reading of the 301 X-ray images by multiple radiologists and resident doctors of different experience levels to quantify inter-reader variability and definitively assess if the sensitivity shortfall is due to the inherent limitation of the modality or the cognitive factors of the interpreters.
2. **Clinical Prediction Rule Evaluation:** Research should evaluate the applicability and effectiveness of established clinical prediction rules (e.g., Canadian CT Head Rule or New Orleans Criteria) in the UBTH elderly population to better identify which trauma patients genuinely require immediate CT without relying on X-ray.
3. **Cost-Effectiveness Analysis:** A formal cost-effectiveness study should be undertaken to compare the current sequential pathway (X-ray → High Referral to CT) versus a direct CT pathway for elderly patients in the UBTH context.

REFERENCES

Akoria, O. A. (2016). Establishing in-hospital geriatrics services in Africa: Insights from the University of Benin Teaching Hospital geriatrics project. Annals of African medicine, 15(3), 145-153.

Alvis, B. D., & Hughes, C. G. (2015). Physiology considerations in the geriatric patient. *Anesthesiology clinics*, *33*(3), 447

Archer, J. B., Sun, H., Bonney, P. A., Zhao, Y. D., Hiebert, J. C., Sanclement, J. A., ... & Safavi-Abbasi, S. (2016). Extensive traumatic anterior skull base fractures with cerebrospinal fluid leak: classification and repair techniques using combined vascularized tissue flaps. *Journal of neurosurgery*, *124*(3), 647-656.

Australia, H. B., Mudiyanselage, S. B., Watts, J. J., Gebremariam, K., & Abimanyi-Ochom, J. Osteoporosis and fractures in Australia. A burden of disease analysis 2023–2033.

Baratloo, A., Hosseini, M., Negida, A., & El Ashal, G. (2015). Part 1: simple definition and calculation of accuracy, sensitivity and specificity. *Emergency*, *3*(2), 48.

Beeharry, M. W., & Ahmad, B. (2024). Principles of Fracture Healing and Fixation: A Literature Review. *Cureus*, *16*(12).

Bellolio, M. F., Bellew, S. D., Sangaralingham, L. R., Campbell, R. L., Cabrera, D., Jeffery, M. M., ... & Hess, E. P. (2018). Access to primary care and computed tomography use in the emergency.

Bonne, S., & Schuere, D. J. (2013). Trauma in the elderly adult: Epidemiology and evolving geriatric trauma principles. *Clinics in Geriatric Medicine*, *29*(1), 137–150.

Brown, P. (2017). Osteoporosis and Fracture Prevention in. *Women's Health in Primary Care*, 230.

Busby, L. P., Courtier, J. L., & Glastonbury, C. M. (2018). Bias in radiology: the how and why of misses and misinterpretations. *Radiographics*, *38*(1), 236-247.

Carpenter, C. R., Cameron, A., Ganz, D. A., & Liu, S. (2018). Elderly adult falls in emergency medicine—A sentinel event. *Clinics in Geriatric Medicine*, *34*(3), 355–367.

Cheung, A. M., McKenna, M. J., van de Laarschot, D. M., Zillikens, M. C., Peck, V., Srighanthan, J., & Lewiecki, E. M. (2019). Detection of atypical femur fractures. *Journal of Clinical Densitometry*, *22*(4), 506-516.

Easter, J. S., Haukoos, J. S., Meehan, W. P., Novack, V., & Edlow, J. A. (2015). Was neuroimaging reveal a severe intracranial injury in this adult with minor head trauma?: the rational clinical examination systematic review. *Jama*, *314*(24), 2672-2681.

Fawver, B., Thomas, J. L., Drew, T., Mills, M. K., Auffermann, W. F., Lohse, K. R., & Wasiams, A. M. (2020). Seeing isn't necessarily believing: Misleading contextual information influences perceptual-cognitive bias in radiologists. *Journal of Experimental Psychology: Applied*, *26*(4), 579.

Griffith, T., Baker, S. A., & Lepora, N. F. (2021). The statistics of optimal decision making: Exploring the relationship between signal detection theory and sequential analysis. *Journal of Mathematical Psychology*, *103*, 102544.

Hawley, C., Sakr, M., Scapinello, S., & Bjorndalen, H. (2022). Head injury among older adults and their clinical management: one year of emergency department attendances at a UK trauma center. *Brain Injury*, *36*(7), 868–875. https://doi.org/10.1080/02699052.2022.2077989

Henningsen, M. J., Larsen, S. T., Jacobsen, C., & Villa, C. (2022). Sensitivity and specificity of post-mortem computed tomography in skull fracture detection—a systematic review and meta-analysis. *International Journal of Legal Medicine*, *136*(5), 1363-1377.

Hess, E. P., Homme, J. L., Kharbanda, A. B., Tzimenatos, L., Louie, J. P., Cohen, D. M., ... & Kuppermann, N. (2018). Effect of the head computed tomography choice decision aid in parents of children with minor head trauma: a cluster randomized trial. *JAMA network open*, *1*(5), e182430-e182430.

Hirsch, C. H., & Hategan, A. (2024). Physiology and pathology of aging. In *Geriatric Psychiatry: A Case-Based Textbook* (pp. 3-29). Cham: Springer International Publishing.

Lampart, A , Arnold I , Mäder, N , Niedermeier, S, Escher, A, Stahl,R …..& Pedersen, V. (2019). Prevalence of Fractures and Diagnostic Accuracy of Emergency X-ray in Older Adults Sustaining a Low-Energy Fall: A Retrospective Study. Journal of Clinical Medicine

Lampignano, J, Kendrick, L, E. (2020). Bontrager's Textbook of Radiographic Positioning and Related Anatomy (10th edition). Mosby eBook ISBN: 9780323696548

Lee, J., Kim, J., Jeong, C., Ha, J., Lim, Y., & Baek, K. H. (2024). Predicting fragility fractures based on frailty and bone mineral density among rural community-dwelling older adults. *European Journal of Endocrinology*, *191*(1), 75-86.

Martin, J., Dubé, C., & Coovert, M. D. (2018). Signal detection theory (SDT) is effective for modeling user behavior toward phishing and spear-phishing attacks. *Human factors*, *60*(8), 1179-1191.

Mazonakis, M., & Damilakis, J. (2016). Computed tomography: What and how does it measure?. *European journal of radiology*, *85*(8), 1499-1504.

McGrath, A., & Taylor, R. S. (2023). Pediatric Skull Fractures. In *StatPearls [Internet]*. StatPearls Publishing.

Mokolane, N. S., Dehnavi, A., & Minne, C. (2019). Prevalence and pattern of basal skull fracture in head injury patients in an academic hospital. *SA Journal of Radiology*, *23*(1), 1-7.

Mulroy, M. H., Loyd, A. M., Frush, D. P., Verla, T. G., Myers, B. S., & Dale'Bass, C. R. (2012). Evaluation of pediatric skull fracture imaging techniques. *Forensic Science International*, *214*(1-3), 167-172.

Olatunji, A. A., & Olusola-Bello, M. A. (2019). Elderly Patients with Trauma: Radiologist's Perspective of Burden of Disease in a Nigerian Sub-Urban Tertiary Hospital. Journal of Clinical & Diagnostic Research, 13(10).

Pullicino, G., Thompson, J., Grech, E. M., & Sciortino, P. (2018). A study on plain X-ray skull imaging in the public Primary Health Care Department in Malta.

Richards, J. T., O'Hara, N. N., Healy, K., Zingas, N., McKibben, N., Benzel, C., ... & Sciadini, M. F. (2024). Fix or Replace? Patient Preferences for the Treatment of Geriatric Lower Extremity Fractures: A Discrete Choice Experiment. *Geriatric Orthopaedic Surgery & Rehabilitation*, *15*, 21514593241236647.

Rivara, F. P., Kuppermann, N., & Ellenbogen, R. G. (2015). Use of clinical prediction rules for guiding use of computed tomography in adults with head trauma. *JAMA*, *314*(24), 2629-2631.

Sadro, C. T., Sandstrom, C. K., Verma, N., & Gunn, M. L. (2015). Geriatric trauma: A radiologist's guide to imaging trauma patients aged 65 years and elderly. *Radiographics*, *35*(4), 1263–1285. https://doi.org/10.1148/rg2015140130

Seleye-Fubara, D and Etebu, E, N. (2011). Pathology of Death from severe head injuries in rivers state a study of sixty eight consecutive cases in five years. Nigeria journal of medicine vol 20 no 4 ISSN 1115-2613

Tanyi, P. L., André, P., & Mbah, P. (2018). Care of the elderly in Nigeria: Implications for policy. Cogent Social Sciences, 4(1), 1555201.

Webber, R. L., & Folio, J. (1976). Radiographic detectability of occipital and temporal-parietal fractures induced in cadaver heads. *The Journal of Trauma*, *16*(2), 115–124.

Whitley, A. S., Jefferson, G., Holmes, K., Sloane, C., Anderson, C., & Hoadley, G. (2015). *Clark's positioning in radiography* (13th ed.). CRC Press

Whitwell, H., & Lumb, P. (2021). Adult skull fractures. In *Forensic neuropathology* (pp. 80-86). CRC Press..

WHO: The World Population Prospects: 1015 Revision. 2015. https://www.un.org/development/desa/publication/world-population-prospects-2015revised.html

Wojda, T. R., Cornejo, K., Valenza, P. L., Carolan, G., Sharpe, R. P., Mira, A. A., et al. (2016). Medical demographics in sub-Saharan Africa: Does the proportion of elderly patients in accident and emergency units mirror life expectancy trends? *Journal of Emergency Trauma and Shock*, *9*(3), 122–125. https://doi.org/10.4103/0974-2700.185278

Wylie, G. R., Yao, B., Sandry, J., & DeLuca, J. (2021). Using signal detection theory to better understand cognitive fatigue. *Frontiers in psychology*, *11*, 579188.

Yellinek, S., Cohen, A., Merkin, V., Shelef, I., & Benifla, M. (2016). Clinical significance of skull base fracture in patients after traumatic brain injury. *Journal of Clinical Neuroscience*, *25*, 111-115.

APPENDIX

APPENDIX A: Supplementary Data Tables

Table A.1 X-ray reported findings (paired cases, n = 41)

X-ray result	n	% (of 41)
X-ray reported fracture (any)	20	48.78%
X-ray no fracture reported	21	51.22%
Total (paired cases)	**41**	**100.00%**

Table A.2 CT reported findings (paired cases, n=41)

CT result	n	% (of 31)
CT confirmed fracture (CT+)	**19**	46.34%
CT no fracture (CT-)	22	53.76%
Total (paired cases)	**31**	**100.00%**

Appendix B: List of Discordant Cases (De-identified Summaries for Quality Audit)

Discordant cases are defined as False Negatives (FN) and False Positives (FP) — i.e., where X-ray diagnosis did not match CT reference findings.

Case ID	Age	Sex	Clinical Indication	X-ray Report	CT Report	Discordance Type	Comment / Possible Reason
D-FN-01	71	Male	Fall from standing	No fracture seen	Linear parietal fracture	False Negative	Subtle lucency likely missed
D-FN-02	78	Female	RTA	No fracture seen	Depressed temporal fracture	False Negative	Overlapping bone shadows
D-FN-21	69	Male	Fall with scalp swelling	No fracture reported	Linear occipital fracture	False Negative	Possibly obscured by motion artefact
D-FP-01	82	Female	Fall from height	Suspected fracture line in frontal bone	No fracture confirmed	False Positive	Misinterpreted vascular groove
D-FP-02	75	Male	Blunt trauma	Possible occipital defect	CT normal	False Positive	External table erosion mimicked fracture
D-FP-16	85	Female	RTA	Apparent lucency in parietal bone	No fracture	False Positive	Artefact from rotation

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Registration Number:
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PROTOCOL NUMBER: ADM/E 22/A/VOL.VII/2025/139

PROPOSAL TITLE: "ACCURACY OF X-RAY REPORTING IN THE DIAGNOSES OF ELDERLY PATIENT WITH SKULL FRACTURE"

PRINCIPAL INVESTIGATOR(S): OGHOJAFOR OGENETEGA JOSEPH

DEPARTMENT/INSTITUTION: DEPARTMENT OF RADIOGRAPHY, SCHOOL OF BASIC MEDICAL SCIENCES UNIVERSITY OF BENIN, BENIN CITY, EDO STATE

DATE CONSIDERED: AUGUST 6TH, 2025

DECISION OF THE COMMITTEE: APPROVED

THIS APPROVAL DATES 6/8/2025 TO 5/8/2026. IF THERE IS DELAY IN STARTING THE RESEARCH, PLEASE INFORM THE HREC SO THAT THE DATES OF APPROVAL CAN BE ADJUSTED ACCORDINGLY

REMARK:

CHAIRMAN: PROF. (MRS) A.N. OFILI **SIGNATURE & DATE** 6/8/2025

SUPERVISOR (S): MRS. OKEH E.O.

DECLARATION BY INVESTIGATOR(S):
PROTOCOL NUMBER (please quote in all enquiries)
Note that no participant accrual or activity related to this research may be conducted outside of these dates. All informed consent forms used in this study must carry the HREC assigned number and duration of HREC approval of the study. In multiyear research, endeavor to submit your annual re-port to the HREC early in order to obtain renewal of your approval and avoid disruption of your research. No changes are permitted in the research without prior approval by the HREC except in circumstances outlined in the Code. The HREC reserves the right to conduct compliance visit your research site without previous notification

Signature & Date 19/08/2025

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