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JCIMCR OPEN ACCESS Journal of Clinical Images and Medical Case Reports

ISSN 2766-7820

Research Article

Open Access, Volume 6

Modern radiological approaches to multiple myeloma: Innovations and practical solutions for diagnosis in resource-limited settings

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Received: Sep 26, 2025

Accepted: Oct 17, 2025

Published: Oct 24, 2025

Archived: www.jcimcr.org

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DOI: www.doi.org/10.52768/2766-7820/3819

Abstract

Multiple Myeloma (MM) is a growing health concern in Nigeria, particularly in the oil-rich Niger Delta, where it constitutes 8.2% of hematological malignancies, potentially linked to environmental pollution. Radiological imaging is critical for diagnosing MM by detecting bone lesions, but Nigeria's resource-limited healthcare system faces significant barriers. This review examines modern radiological approaches to MM diagnosis, highlighting innovations and practical solutions tailored to Nigeria's challenges. Skeletal surveys, the primary imaging modality, are widely used due to their affordability, but they lack the sensitivity of advanced techniques like low-dose whole-body CT, MRI, and PET-CT, which are rarely available due to equipment scarcity and high costs. A shortage of trained radiologists, estimated at less than one per million people, and low public awareness of MM symptoms further delay diagnoses, leading to advanced-stage presentations. Practical solutions include deploying mobile X-ray units for rural access, training radiographers in MM-specific imaging, and using telemedicine for remote specialist consultations. Low-cost digital X-ray systems and public-private partnerships can bridge resource gaps. Addressing environmental carcinogens through stricter regulations may reduce MM incidence. Adequate funding is paramount to implement these solutions, as it enables equipment procurement, workforce training, and public health campaigns. Sustained financial investment from government and international donors is critical to enhance diagnostic capacity, reduce MM-related morbidity, and improve survival outcomes in Nigeria's resource-constrained settings.

Keywords: Multiple myeloma; Hematology; Bone lesions; Imaging.

Citation: Salewa OE, Olanrewaju OP, Ogunlusi PS, Fatukasi JI, Adewole AS, et al. Modern radiological approaches to multiple myeloma: Innovations and practical solutions for diagnosis in resource-limited settings J Clin Images Med Case Rep. 2025; 6(10): 3819.

Introduction

Multiple Myeloma (MM), a formidable hematologic malignancy, emerges from the uncontrolled proliferation of plasma cells in the bone marrow, flooding the body with monoclonal immunoglobulins that wreak havoc, detectable in serum or urine, and causing end-organ damage [1]. Globally, MM accounts for 10% of hematologic cancers, striking 4-6 per 100,000 people annually, typically at age 70 [2]. In Nigeria, MM's burden is heavier, comprising 5-8.2% of hematologic malignancies, with a younger median diagnosis age of 59.9 years, possibly driven by environmental pollution from oil activities in the Niger Delta [3,4]. Patients endure bone pain, anemia, hypercalcemia, renal failure, and osteolytic lesions the CRAB criteria while 10-32% face extramedullary disease invading soft tissues or organs [5]. The International Myeloma Working Group (IMWG) defines MM by ≥10% clonal bone marrow plasma cells or biopsy-proven plasmacytoma, plus CRAB features or biomarkers like ≥60% plasma cells or >1 focal lesion on whole-body MRI [2]. Laboratory markers include paraprotein (IgG 60%, IgA 20%), elevated free light chains, immunoparesis, and normochromic anemia [6]. Radiological imaging is pivotal for detecting osteolytic lesions, staging, and monitoring treatment. Yet, in Nigeria's resource-scarce healthcare landscape, access to advanced imaging like low-dose CT, MRI, or PET-CT is severely limited, hampered by sparse equipment and a dire shortage of radiologists—fewer than one per million people [7,8]. Low public awareness delays health-seeking, pushing patients to late-stage diagnoses [9]. The funding gap, with Nigeria allocating only 3.7% of GDP to healthcare compared to global averages of 10%, has entrenched a diagnostic divide, denying Nigeria and Sub-Saharan Africa the tools and expertise needed to detect MM early, amplifying morbidity and mortality. Some diseases associated with monoclonal immunoglobulins are stated below:

Table 1: Plasma cell neoplasms (WHO, 2008).

Neoplastic
Monoclonal gammopathy of undetermined significance (MGUS)
Plasma cell myeloma
Variants:
Asymptomatic (smouldering) myeloma
Non-secretory myeloma
Plasma cell leukaemia
Plasmacytoma

Diagnosis of multiple myeloma

The diagnosis of Multiple Myeloma (MM) is based on the World Health Organization diagnostic criteria, which emphasize specific laboratory findings and clinical indicators, including malignant plasma cell presence and evidence of end-organ damage, commonly known as the CRAB criteria [2]. Clinical features typically include bone pain, the most prevalent symptom, alongside hypercalcemia, renal failure, and anemia, with lytic bone lesions detected on imaging studies and pathologic evidence of bone marrow infiltration [10]. Standard investigations for MM include a full blood count, Erythrocyte Sedimentation Rate (ESR) test, serum bilirubin test, serum and urine electrophoresis, and bone marrow aspirate and biopsy. The gold standard for MM diagnosis involves imaging techniques such as skeletal survey, PET scan, MRI, and CT scan [2].

Symptomatic myeloma is diagnosed if there is: Monoclonal protein in serum and/or urine, Increased clonal plasma cells in the bone marrow and Related organ or tissue impairment. A useful acronym for tissue damage is CRAB (hypercalaemia, renal impairment, anaemia, bone disease). Amyloid, hyperviscosity, recurrent infections, peripheral neuropathy and deep vein thrombosis are other clinical complications which are less frequently presenting features. The International Myeloma Working Group updated criteria for the diagnosis of multiple myeloma has following definition for multiple myeloma: Clonal bone marrow plasma cells ≥10% or biopsy-proven bony or extramedullary plasmacytoma and any one or more of the following myeloma defining events: evidence of end-organ damage that can be attributed to the underlying plasma cell proliferative disorder, specifically:

- Hypercalcemia: Serum calcium >0.25 mmol/L (>1 mg/dL) higher than the upper limit of normal or >2.75 mmol/L (>11 mg/dL)
- Renal insufficiency: Creatinine clearance <40 mL per min or serum creatinine >177 µmol/L (>2 mg/dL)
- Anemia: Hemoglobin value of >20 g/L below the lower limit of normal, or a hemoglobin value <100 g/L
- Bone lesions: One or more osteolytic lesions on skeletal radiography, CT, or PET-CT

any one or more of the following biomarkers of malignancy

- Clonal bone marrow plasma cell percentage ≥60%
- involved: uninvolved serum free light chain ratio ≥100
- >1 focal lesions on MRI studies

Clinical features of multiple myeloma include:

1. Bone pain (especially backache) resulting from vertebral collapse and pathological fractures.
2. Features of anaemia, such as lethargy or weakness.
3. Recurrent infections: related to deficient antibody production, abnormal cell-mediated immunity and neutropenia.
4. Features of renal failure and/or hypercalcaemia: polydipsia, polyuria, anorexia, vomiting, constipation and mental disturbance.
5. Abnormal bleeding tendency: myeloma protein may interfere with platelet function and coagulation factors; thrombocytopenia occurs in advanced disease.
6. Amyloidosis occurs in 5% with features such as macroglossia, carpal tunnel syndrome and diarrhoea.
7. In approximately 2% of cases there is a hyperviscosity syndrome with purpura, haemorrhages, visual failure, Central Nervous System (CNS) symptoms, neuropathies and heart failure

Table 2: Diseases associated with monoclonal immunoglobulins.

Neoplastic	Benign
Multiple myeloma	Chronic cold haemagglutinin disease Transient (e.g. with infections)
Solitary plasmacytoma	HIV infection
Monoclonal Gammopathy of Undetermined Significance (MGUS)	Gaucher's disease
Waldenström's macroglobulinaemia	
Non-Hodgkin lymphoma	
Primary amyloidosis	
Heavy-chain disease	

Laboratory findings include the following for diagnosis of MM include:

1. Presence of a paraprotein: Serum and urine should be screened by immunoglobulin electrophoresis. The paraprotein is immunoglobulin G (IgG) in 60% of cases, IgA in 20% and light chain only in almost all the rest.

2. Elevated serum immunoglobulin-free light chains: Immunoglobulin-Free Light Chains (FLC) are κ or λ light chain proteins, synthesized by plasma cells, that have not been paired with heavy chain. They are normally made in small quantities and filtered from the serum into the kidney but can be measured in serum. Typically, in myeloma there is an increase in either the κ or λ serum free light chain value.

3. Normal serum immunoglobulin levels (IgG, IgA and IgM) are reduced, a feature known as immunoparesis. The urine contains free light chains, Bence–Jones protein, in two- thirds of cases.

4. There is usually a normochromic normocytic or macrocytic anaemia. Rouleaux formation is marked in most cases. Neutropenia and thrombocytopenia occur in advanced disease. Abnormal plasma cells appear in the blood film in 15% of patients and can be detected by sensitive flow cytometry in over 50%.

5. High Erythrocyte Sedimentation Rate (ESR).

6. Increased plasma cells in the bone marrow (usually more than 20%) often with abnormal forms.

7. Radiological investigation of the skeleton reveals bone lesions such as osteolytic areas without evidence of surrounding osteoblastic reaction or sclerosis in 60% of patients or generalized osteoporosis in 20%.

8. Serum calcium elevation occurs in 45% of patients. Typically, the serum alkaline phosphatase is normal, except following pathological fractures.

9. The serum creatinine is raised in 20% of cases. Proteinaceous deposits from light chain proteinuria, hypercalcaemia, uric acid, amyloid and pyelonephritis may all contribute to renal failure.

10. A low serum albumin occurs with advanced disease.

11. Serum β2-microglobulin is often raised and is a useful indicator of prognosis.

12. The molecular and cytogenetic changes have been described earlier. Cytogenetic analysis shows that aneuploidy (more or less than 46 chromosomes) is almost universal.

Table 3: The clinical and laboratory features of monoclonal gammopathy of uncertain significance (MGUS), smouldering myeloma and symptomatic myeloma.

Feature	MGUS	Smoldering Myeloma	Symptomatic Myeloma
Marrow plasma cells	<10%	≥10%	≥10%
Paraprotein	<30 g/L	≥30 g/L	≥30 g/L
Normal immunoglobulins	Normal	Reduced	Reduced
Free light chain ratio	Normal/ abnormal	Abnormal	Abnormal
Clinical features	None	None	CRAB (hypercalcemia, renal failure, anemia, bone lesions)
Progression to symptomatic myeloma	1%/year	10%/year	-

Treatment and prognosis of multiple myeloma

Multiple Myeloma (MM) remains incurable with a median survival of 5.5 years (range <6 months to >10 years). The introduction of thalidomide, lenalidomide, and bortezomib (proteasome inhibitor) has provided significant survival gains. These are typically used in combination with older agents such as cyclophosphamide, melphalan, prednisolone, and doxorubicin. Treatment response is usually assessed by measuring serum markers and bone marrow sampling. Stem-cell harvest and autologous stem cell transplantation post-chemotherapeutic bone marrow ablation are also employed, although relapse is inevitable [11]. Treatment of MM consists of conventional chemotherapy or high-dose chemotherapy followed by allogeneic or autologous stem cell transplantation [12]. Over the last 5 years, biologic improvements have led to dramatic changes in therapeutic strategies for MM, raising the possibility of considering it a potentially curable disease [10]. Biologic drugs, such as proteasome inhibitors and immunomodulatory drugs, have shown efficacy in controlling MM, though high-dose melphalan chemotherapy with Autologous Stem Cell Transplantation (ASCT) remains the standard of care for eligible younger patients (<64 years old) [13]. Recently, novel agents, including immunomodulatory drugs like thalidomide, lenalidomide, and the proteasome inhibitor bortezomib, have been introduced as combined therapeutic measures, significantly improving treatment outcomes. This review will focus on the state-of-the-art radiological imaging techniques for MM diagnosis and their application in resource-limited settings like Nigeria.

Role of imaging as key player in diagnosis of multiple myeloma

Radiological Imaging in multiple myeloma

Radiological imaging is critical for detecting osteolytic lesions, diffuse osteopenia, or pathologic fractures, which define symptomatic Multiple Myeloma (MM) requiring treatment [2]. The International Myeloma Working Group (IMWG) recommends whole-body low-dose computed tomography (WBLDCT) as the first-line modality, with whole-body MRI (WB-MRI) and 18F-fluorodeoxyglucose positron emission tomography/computed tomography (FDG PET/CT) for enhanced sensitivity or

treatment monitoring [12]. In Nigeria, reliance on conventional radiography due to cost and availability constraints limits early detection [4].

Conventional radiography (X-Ray)

Conventional radiography, or skeletal survey, has been the reference standard for multiple myeloma (MM) diagnosis due to its wide availability and low costs [11]. It works by detecting bone lesions for initial staging and monitoring of MM. Lytic lesions in the flat bones of the skull and pelvis are typically characterized by stamped-out lesions without a sclerotic rim (Figure 1). Bone lesions in myeloma patients typically appear in flat bones (skull and pelvis) as punched-out ovoidal lytic areas without sclerosis of the surrounding bone (Figure 2), while bone lesions in long bones have different appearances such as endosteal scalloping, small lytic lesions, mottled areas of small multiple lesions, or large destructive lesions [13]. All these lesions represent replacement of the physiological bone marrow by clonally expanding plasma cells with consecutive destruction of the bone [14]. The following sites are most commonly affected: vertebrae in 65% of patients, ribs in 45%, skull in 40%, shoulders in 40%, pelvis in 30%, and long bones in 25% [15]. The detection of lytic bone lesions represents a criterion defining a symptomatic and treatment-requiring MM even in the absence of clinical symptoms [16]. The advantage of conventional radiography is its wide availability, low costs, and coverage of almost the entire skeletal system. The disadvantage is its low sensitivity, as lytic lesions are only detectable if more than 30% of the trabecular bone is destroyed [17]. Additionally, conventional radiography cannot detect or quantify diffuse bone marrow infiltration or extraosseous lesions. Another limitation is its inability to monitor therapy, since lytic lesions rarely show radiographically detectable changes despite a therapy response [18].

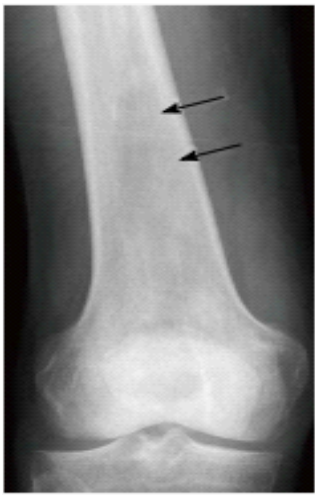

Figure 1: X-ray of an osseous myeloma lesion. Conventional X-ray of the right femoral bone showing an osteolytic lesion (arrows) represending an osseous myeloma manifestation

The limitations of X-rays include the following:

30% or more of the trabecular bone (the spongy part of the bone containing fat and bone marrow, where myeloma cells grow) must be missing before an X-ray can reveal the damage. A study showed that bone loss in lumbar vertebrae can be seen on an X-ray only when 50%-75% of the trabecular bone has already been destroyed. X-rays are not a sensitive study for focal lesions in the bone marrow. The appearance of a lytic lesion on an X-ray does not change following therapy, even if there is no longer any active myeloma there. X-ray provides low visualization of the spine and pelvis. X-ray cannot accurately depict the cause of lesions in myeloma. Because whole-body X-ray (WBXR) requires 20 separate films, the study is time-consuming.

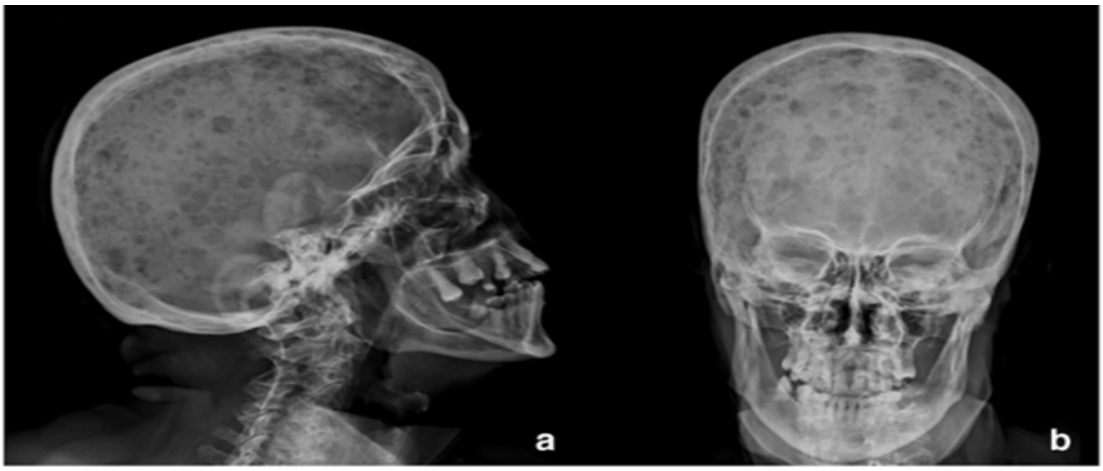

Figure 2: Skull radiographs on lateral **(a)** and frontal **(b)** projection showing the typical "punched out" appearance of bone lesions in multiple myeloma with uncountable small, well circumscribed lytic lesions without sclerosing of the surrounding bone.

Computed Tomography (CT) scan

Computed Tomography (CT) scan, sometimes called computed axial tomography (CAT) scan, is a radiological study that uses X-ray technology to create a cross-sectional, three-dimensional image of the inside of the body. It is a more precise study than X-ray and can provide clear, detailed images of bone. CT is increasingly replacing conventional radiography due to its higher sensitivity for osseous lesions and ability to diagnose extraosseous lesions [14]. It allows for detection of smaller osseous lesions that are not detectable by conventional radiography [19]. Early changes can be detected more reliably with CT. It is a very sensitive imaging modality used in detecting the osteolytic effects of multiple myeloma and has a higher sensitivity than plain radiography at detecting small lytic lesions [20]. CT findings in multiple myeloma consist of punched-out lytic lesions, expansile lesions with soft tissue masses, diffuse osteopenia, fractures, and, rarely, osteosclerosis [21]. It is of use in identifying bone destruction in cases where magnetic resonance imaging is negative, and hence may provide complementary imaging information [11]. It has the advantage of accurately demonstrating the presence and extent of extraosseous lesions. Additionally, CT scans offer

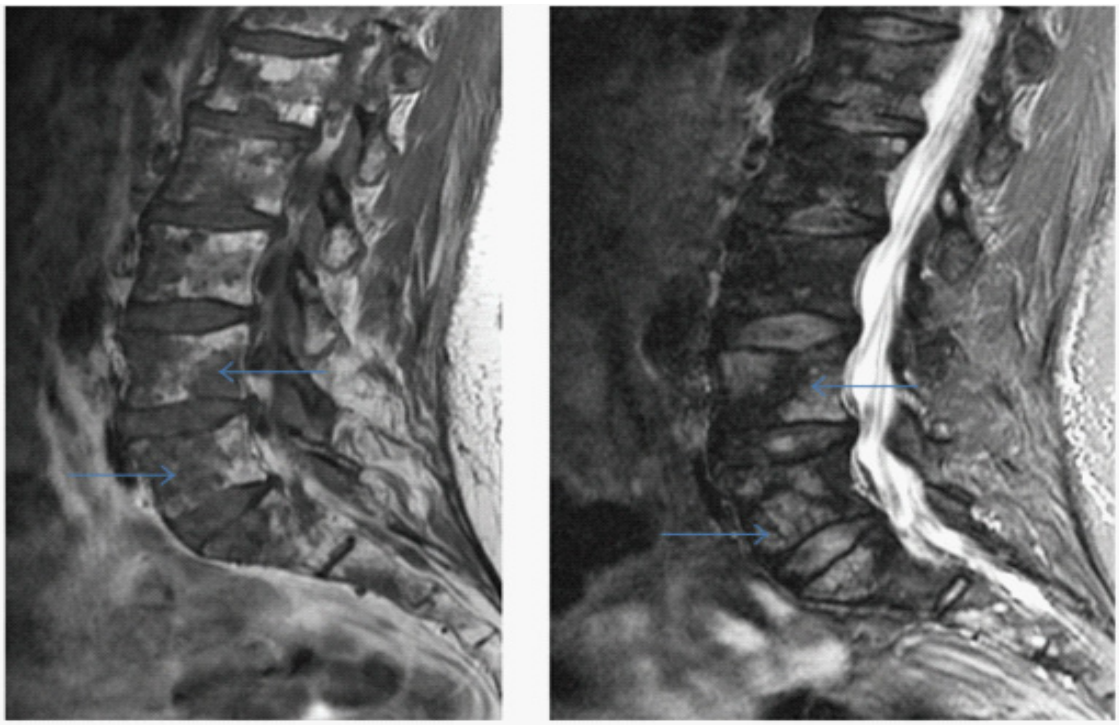

Figure 3: MRI sagittal T1-weighted sequence lumbar spine: diffuse permeative low signal myelomatous marrow lesions throughout the lumbar spine (arrow). **(b)** MRI sagittal T2-weighted STIR sequence (same patient): diffuse high signal myelomatous marrow lesions throughout the lumbar spine (arrow)

shorter imaging times and complication-free examinations of patients in the supine position without the need for repeated relocation, which is significant for patients with chronic pain. However, key limitations include radiation exposure, inability to detect diffuse bone marrow infiltration or bone marrow lesions without lytic reaction, and extraosseous lesions [1].

The limitations of CT scans include the following: CT cannot be used for treatment monitoring because bone lesions in myeloma regress slowly or not at all, even in patients in complete remission. CT is not as sensitive as MRI in detecting lesions outside the bone marrow (extramedullary disease) or in the vertebrae and pelvis. CT is an expensive study. Even in low-dose format, CT uses an increased level of radiation as compared to X-ray or to MRI, which doesn't use radiation at all

Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI) is a non-invasive study that uses magnetic energy and radio waves, not radiation, to produce detailed two- or three-dimensional images of structures inside the body. MRI scans map the location of water and fat in the body and produce detailed spatial images. MRI is the most sensitive and specific imaging technique for the early detection of Multiple Myeloma (MM) bone marrow infiltration, as it assesses bone marrow cellularity and composition [22]. Whole-body MRI (WBMRI) has emerged as the most sensitive imaging modality to date for detecting diffuse and focal MM in the spine and extra-axial skeleton [23]. Due to its ability to visualize large volumes of bone marrow without inducing radiation exposure and in an acceptable amount of time, MRI has become a favored imaging method for evaluating disease within the bone marrow (Figure 3). MRI also has prognostic significance; the number and pattern of lesions detected correlate well with treatment outcome and overall survival. It is the most sensitive method for initial staging, detecting both focal and diffuse bone marrow infiltration without ionizing radiation [13]. It should be considered in patients with inconspicuous radiography, solitary plasmacytoma, or suspected spinal cord/nerve root compression [24]. MRI predominantly reflects marrow infiltration, which may or may not be associated with bone destruction. Among all imaging techniques, MRI remains the most sensitive and specific for detecting bone marrow infiltration in a focal or diffuse way before the appearance of osteolytic lesions [2]. MRI provides unparalleled information about soft tissue definition and bone marrow extent of disease. It has higher sensitivity and specificity compared to whole-body X-ray, identifying up to 80% more focal lesions [17]. MRI is also superior in revealing additional areas of malignant lesions in patients with Solitary Plasmacytoma of the Bone (SPB). The main limitation of conventional MRI is its limited Field of View (FOV) for covering the entire skeleton. The recent introduction of WBMRI has strengthened the role of this technique in evaluating MM patients. WBMRI is a generally well-tolerated technique that offers additional benefits in assessing skeletal complications, such as spinal canal and/or nerve root compression, and is the most accurate method for differentiating benign from malignant vertebral compression fractures [25]. When WBMRI is not available, MRI of the spine and pelvis is an acceptable alternative to provide sufficient bone marrow imaging [25]. Limitations of WBMRI include its long acquisition time, cost, limited availability in clinical practice, and challenges for patients with claustrophobia, metallic devices, or prostheses.

The limitations of MRI include: MRI is an expensive, time-consuming procedure. Patients who have metal implants cannot undergo MRI. Claustrophobic patients can't undergo an MRI. There is approximately a 9-month or longer lag time before an MRI will look normal after an area of myeloma has been successfully treated and is no longer active, leading to a high false-positive rate. The IMWG guidelines therefore state that the use of MRI "for the follow-up of patients, before or after different therapies, in the absence of clinical indications is not recommended." Treatment for myeloma will interfere with MRI results. If possible, myeloma patients should not start treatment before a scheduled MRI. The MRI scanning technique that

is best for myeloma (with diffusion-weighted imaging) has not been standardized and is not widely available.

Positron Emission Tomography (PET) scan

Positron emission tomography in multiple myeloma: Positron Emission Tomography (PET) scanning is a "real-time" study that shows where, and to what extent, cancer cells are actively dividing in the body. It utilizes a radiolabeled glucose (FDG) analog in which the C-2 hydroxyl group is replaced by the positron-emitting [26]. Fluorodeoxyglucose (FDG) is not further metabolized in the glycolytic pathway, and the molecule becomes trapped intracellularly, allowing for an accurate assessment of glucose metabolic activity [27]. PET scans, similar to whole-body CT scans and whole-body MRI, are a good option for detecting bone lesions in Multiple Myeloma (MM). Studies have shown the usefulness of PET/CT, with high sensitivity and specificity reported in the detection of bone damage and extramedullary involvement. Before a PET scan, a patient is injected with a sugar-fluorine compound (FDG, or fluorodeoxyglucose). This compound is taken up by the body's actively multiplying cells as fuel for cell division. When the body is scanned, the areas with the highest concentration of sugar-fluorine uptake glow, caused by positrons emitted by the fluorine [28]. This process reveals "hot spots" where rapid metabolism can indicate areas of active cancer cell division. The scan covers the whole body and is highly sensitive in detecting potential tumor activity, measured in units of Standardized Uptake Value (SUV). Several factors influence SUV measurement variations, including blood glucose levels, time elapsed from injection to image acquisition, equipment calibration, patient's weight, injection technique, region of interest, reconstruction method, and matrix size. PET scans offer a one-stop-shop approach by providing a whole-body evaluation in one session, covering the entire skeletal system from vertex to feet, with a sensitivity of 55-90% for detecting bone marrow involvement in MM [29]. The greatest advantage of PET/CT is its contribution to post-treatment evaluation, enabling differentiation between metabolically active and inactive lesions. A baseline scan may also be helpful for comparing pre- and post-treatment imaging findings [30]. Disadvantages include high cost, limited availability, lack of standardized imaging criteria, and lack of interobserver reproducibility in result interpretation. Additionally, causes other than malignancy, such as inflammation, infection, postsurgical or biopsy areas, bone remodeling, fractures, and recent use of chemotherapy, radiation therapy, or growth factors, can increase cell metabolism and lead to false-positive results. Conversely, hyperglycemia and high-dose steroid therapy can cause false-negative results [27].

Some limitations to the use of PET scans include the following: They are time-consuming and expensive. Because areas of infection and inflammation can also take up FDG, PET scans can produce false-positive readings for cancer. There is some concern that skull lesions could be missed because of the normally high FDG uptake in the brain. As with MRI, therapy can interfere with PET results. Patients should not start therapy before a scheduled PET scan. Dexamethasone in particular is problematic. Dexamethasone interferes with PET results by slowing down the entry of glucose into tumor cells. PET studies used to determine the effect of treatment should not be performed until after the patient has been on dexamethasone for 2-3 weeks, and before the patient starts the next cycle of dexamethasone.

Diagnosis of multiple myeloma in a resource limited environment

Challenges in diagnosing and managing multiple myeloma in Nigeria

The rising prevalence of Multiple Myeloma (MM) in Africa, particularly in Nigeria's oil-rich Niger Delta, accounts for approximately 8.2% of hematological malignancies [31]. Effective MM management begins with a thorough history, highlighting epidemiology, pathogenesis, and clinical features, followed by investigations to confirm diagnosis and stage the disease prior to therapeutic interventions. Major challenges in MM management in developing countries lie in diagnosis and treatment, significantly contributing to complications, poor prognosis, and survival outcomes for patients in the region. This review outlines current diagnostic methods in Nigeria and challenges faced in diagnosing and treating MM in developing countries, using Nigeria as a case study. MM prevalence is increasing in Sub-Saharan African countries [32], with oil-rich areas most affected, likely due to environmental pollution, gas flaring, water contamination, oil spills, and weak environmental policies. This aligns with hypotheses suggesting occupational exposure in chemical, petroleum, and radiation industries may contribute to MM, though evidence remains inconsistent [33]. Another potential factor driving prevalence is the median age of diagnosis. In Nigeria, Africa's most populous nation, studies report a median diagnosis age of 59.9 years (45-78 years) [34], younger than the 65-year median in the USA [35]. This earlier diagnosis age suggests more individuals may develop MM by age 65, increasing disease burden. A male-to-female ratio of approximately 2:1 indicates gender disparity, though this likely has minimal impact on rising prevalence in developing countries. Limited data exist on premalignant plasma cell disorders in low- and middle-income countries. Monoclonal Gammopathy of Undetermined Significance and smoldering MM, known MM precursors, are often undiagnosed due to resource constraints, resulting in patients presenting at advanced disease stages.

Some challenges faced in the diagnosis of this disease in Nigeria include:

1. **Equipment:** The lack of modern equipment for diagnosis and staging of the disease is a key factor in the late diagnosis of MM in most developing countries, including Nigeria [36]. Most health institutions in developing countries, especially low-income ones, lack the infrastructural and medical capacities to handle comprehensive assessment investigations for MM patients. In a recent study in Nigeria, only 72% of patients with a preliminary diagnosis of MM could afford basic assessment tests required for confirmation and staging of the disease. Of these, 43% and 55.7% could perform immunoglobulin quantification and Bence Jones Protein tests, respectively. The commonest assessment tests done by patients are hematocrit, erythrocyte sedimentation rate, skeletal X-ray, bone marrow aspiration, and trephine biopsy in centers where hematologists are available [37]. About 56-60% of MM patients could afford serum electrolyte, urea, and creatinine assessment tests required for staging, while less than 50% could perform serum protein, globulin, and albumin level estimation. Serum albumin is essential for international prognostic staging of MM. Tests like β2-microglobulin, serum immunofixation, marrow aspirate and trephine biopsy with metaphase cytogenetic, FISH, immunophenotyping, Gene Expression Profiling (GEP), and plasma cell labeling index (PCLI) are not readily available in developing countries due to cost and prevailing poverty. Consequently, most MM diagnoses in these

regions are cytogenetically unknown and not internationally staged.

2. Limited access to trained specialists: The scarcity of trained radiologists and hematologists in Nigeria is a critical barrier to accurate and timely MM diagnosis. MM is a complex hematological malignancy requiring specialized expertise to interpret clinical symptoms (e.g., bone pain, anemia, renal impairment), laboratory results (e.g., serum protein electrophoresis, beta-2 microglobulin levels), and imaging findings (e.g., skeletal surveys or bone marrow biopsies) [38]. In Nigeria, the ratio of hematologists to the population is alarmingly low, estimated at less than one per million people, compared to high-income countries with significantly higher ratios [39]. This shortage is compounded by the uneven distribution of specialists, who are predominantly located in urban centers like Lagos and Abuja, leaving rural areas and regions such as the Niger Delta with minimal access to expert care [39]. General practitioners, often the first point of contact in Nigeria's healthcare system, may lack the training to recognize MM's early or atypical presentations, leading to misdiagnosis or delayed referrals [40]. For instance, premalignant conditions like Monoclonal Gammopathy of Undetermined Significance (MGUS) or smoldering MM, which require vigilant monitoring to prevent progression to MM, are frequently missed due to the absence of specialists capable of interpreting subtle diagnostic markers [41]. Moreover, the brain drain of medical professionals to high-income countries exacerbates this issue, as many trained specialists emigrate for better opportunities, further depleting Nigeria's healthcare workforce [8]. The lack of specialized training programs and continuing medical education in hematology also limits the capacity to build local expertise. This results in delayed or inaccurate diagnoses, contributing to advanced-stage presentations and poorer prognosis, as patients often reach tertiary centers only after significant disease progression [42].

3. Low public awareness and health-seeking behavior: Low public awareness of multiple myeloma and suboptimal health-seeking behavior significantly contribute to delayed or missed diagnoses in Nigeria. Unlike more prevalent diseases such as malaria or tuberculosis, MM is relatively rare and poorly understood among the general population, leading to a lack of recognition of its symptoms [9]. Common early symptoms of MM, such as chronic bone pain, fatigue, or recurrent infections, are often attributed to aging, manual labor, or other benign conditions, causing patients to delay seeking medical care [34]. Cultural beliefs and reliance on traditional healers, particularly in rural areas like the Niger Delta, further deter timely presentation to healthcare facilities [43]. For example, patients may seek herbal remedies or spiritual interventions for persistent symptoms, only approaching biomedical care when the disease has advanced to stages with severe complications, such as pathological fractures or renal failure [32]. Additionally, health literacy in Nigeria is low, with many individuals unaware of the importance of routine medical check-ups or screening for conditions like MGUS, which could facilitate early MM detection [39]. The absence of public health campaigns targeting hematological malignancies exacerbates this issue, as resources are often directed toward infectious diseases or maternal health priorities [40]. Stigma associated with cancer diagnoses can also discourage patients from pursuing diagnostic tests, fearing social ostracism or financial ruin. This delay in health-seeking behavior, combined with systemic barriers like long travel distances to diagnostic centers, results in patients presenting at late stages, reducing the likelihood of effective intervention [44].

4. Purchasing power of patients: Most MM patients in Nigeria do not benefit from accurate risk stratification and prognostic assessments as offered to their counterparts in developed countries due to the stark difference in the cost of these medical procedures [45]. In a 10-year retrospective study of 26 MM patients in the Niger Delta region of Nigeria, only one (3.8%) could afford a marrow metaphase cytogenetic (FISH) test, which identified a high-risk category (t(4,14) immunoglobulin A) multiple myeloma [37]. These challenges in diagnosis and disease staging contribute to the poor survival outcomes of people living with MM in these regions. Some other general challenges used that mitigate against early diagnosis and treatment of MM in Nigeria include:

Lack of standardized cancer statistics centre: There is no standard National cancer (MM) registry or Surveillance Epidemiology End-Result (SEER) cancer statistics review center in most developing countries including Nigeria. This has hindered getting accurate statistics of the disease in most developing countries.

Lack of standardized guideline for management of MM: There are no standard guidelines for the treatment of MM in many developing countries including Nigeria. This is responsible for the disparities in some of the outcomes. A lot of confounding issues have arisen as a result of disharmony in the management of the disease in many developing countries. There is a need to control all confounding issues that may arise as a result of heterogeneous management of the MM in developing countries. Each country is expected to design its own consensus guidelines that will best serve the patients putting international best practices in mind.

Psychosocial input: One of the components of a good palliative care of people living with terminal diseases such as MM is the psychosocial care. In developed countries, the social workers and the spiritualists have their roles to play in order to improve the quality of life of the patients. For instance, some patients who have financial challenges in procuring their treatment may not access social workers either because they are not there or they might be there but they are not functioning. This may create more health burden or even cause death of the patients in some cases.

Lack of funding from appropriate governmental bodies: National budgets allocated the health sector has dwindled over the last decade. This has adversely affected the health system in the Country. As a result, government alone cannot drive the health sector. The private health sector has also not made any significant improvement due to the absurdly high interest rates from financial Institutions. Foundationally, poor funding of NHIS by the federal government has led to poor management and outcome of diseases particularly cancer cases. Also, unavailability of NHIS-funded awareness and counseling programs has increased the burdens of psychosocial barriers, leading to late diagnosis of MM and inevitably, much poorer prognosis.

Recommendations for improving radiological diagnosis

1. Investment in modern equipment

Upgrade and maintain equipment: Health institutions should prioritize the procurement of modern diagnostic equipment. Establishing a maintenance plan for existing equipment can reduce downtime and improve the reliability of diagnostic services. This includes training for technicians to ensure proper operation and upkeep of machinery [19].

Public-private partnerships: Encourage collaboration between government and private sectors to finance the acquisition of advanced diagnostic technologies. This could involve tax incentives for private companies that invest in healthcare infrastructure.

2. Enhancing patient access

Subsidized testing programs: Implement government-funded programs to subsidize the costs of essential diagnostic tests for multiple myeloma (MM), particularly immunoglobulin quantification and cytogenetic testing. This can help increase the percentage of patients who can afford necessary assessments [46].

Mobile diagnostic units: Develop mobile radiology units to reach underserved areas, ensuring that patients in remote locations have access to necessary diagnostic services. This approach can help mitigate geographical barriers to healthcare access.

3. Standardization of guidelines and protocols

Establish national guidelines: Create comprehensive national guidelines for the diagnosis and management of MM, tailored to the specific needs and resources of the Nigerian healthcare system. This should include standardized protocols for radiological assessments and treatment pathways to ensure consistency in care delivery [13].

Develop a national cancer registry: Establish a standardized national cancer registry to collect and analyze data on MM cases. This would facilitate better tracking of disease prevalence and outcomes, ultimately informing policy and resource allocation [46].

4. Psychosocial support systems

Integrate psychosocial care: Develop programs that incorporate psychosocial support into the treatment of MM. Training social workers and integrating their services into healthcare facilities can help address the emotional and financial challenges faced by patients [13].

Community awareness campaigns: Launch educational campaigns to raise awareness about MM and the importance of early diagnosis. This can help reduce stigma and encourage patients to seek timely medical attention.

5. Government funding and policy support

Increase health sector budget: Advocate for increased budget allocations to the health sector, specifically for cancer care and diagnostic services. This funding is crucial for improving infrastructure and ensuring the availability of necessary resources [13].

Policy framework for healthcare investment: Develop a clear policy framework that encourages investment in healthcare infrastructure, focusing on diagnostic services. This should include incentives for both local and international investors to improve the healthcare landscape in Nigeria.

6. Training and capacity building

Continuous professional development: Implement regular training programs for radiologists and healthcare professionals to keep them updated on the latest diagnostic techniques and technologies. This can enhance their ability to interpret radiological findings accurately and effectively [19, 46].

Collaborative training initiatives: Partner with international organizations to provide training and resources for local healthcare workers, ensuring they have access to the latest knowledge and practices in radiological diagnosis.

By addressing these key areas, Nigeria can significantly improve the radiological diagnosis of multiple myeloma and enhance overall patient care outcomes.

Conclusion

Radiological imaging is critical for diagnosis, staging, and treatment monitoring in MM. While conventional radiography is still widely used, newer techniques like WBLDCT, WBMRI, and PET/CT offer higher sensitivity and specificity. An imaging algorithm incorporating these modalities is recommended, with WBMRI for initial staging and PET/CT for treatment response assessment. In resource-limited settings, optimizing radiographic technique and advocating for improved access to advanced imaging are also important strategies. Robust funding is also an important lifeline needed to transform this reality, powering the acquisition of cutting-edge imaging tools, training skilled radiologists, and launching vibrant awareness campaigns. Sustained investment from government into NHIS for cancer related diseases and global partnership is crucial to accelerate early diagnosis, curb delays, and brighten MM outcomes in Nigeria's challenging settings.

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