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REVIEW ARTICLE

Pathological Fractures Around the Hip: Approach to Diagnosis and Management

Abstract

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Pathological fractures due to metastatic disease are common around the hip (proximal femur and acetabulum) and represent an escalating concern in musculoskeletal oncology. These fractures should not be fixed straight away and management should focus on comprehensive clinical, laboratory, imaging workup and biopsy, and treatment plan should be tailored and personalized after inputs from medical and radiation oncologists. The goal of surgery is relief of pain, achievement of skeletal stability, restoration of function and mobility, and improvement in quality of life. Proactive identification of impending fractures and their fixation is crucial for better outcomes. When only the head and neck of femur are involved by the lesion, cemented hemiarthroplasty or total hip arthroplasty are ideal. For intertrochanteric and subtrochanteric pathological fractures, cephalon-medullary nailing and proximal femur endoprosthesis reconstruction are the viable options. For small or contained acetabular lesions, minimally invasive cementoplasty can provide pain relief and stabilization. When the bone stock is adequate, a standard cemented total hip arthroplasty may be performed. In cases with significant bone loss, additional support structures such as antiprotrusio cages or Harrington/modified Harrington techniques are often used to reinforce stability. For extensive pelvic destruction, pelvic endoprosthetic replacements might be necessary. The present review article is aimed at providing a comprehensive overview for decision-making and treatment approach of patients with pathological fractures around hip due to metastatic bone disease.

KEYWORDS

Hip Fractures; Fractures, Spontaneous; Bone Neoplasms; Neoplasm Metastasis; Arthroplasty, Replacement, Hip; Fracture Fixation, Internal; Biopsy; Palliative Care

Introduction

The hip joint plays a pivotal role in locomotion and functional independence. Both traumatic and pathological fractures around the hip are common and understanding the fundamental differences between the two is paramount for formulating correct treatment plan. Unlike traumatic fractures in otherwise healthy bones, pathological fractures occur during normal physiological loading on a diseased bone (i.e. without significant trauma).[1,2]

Pathological fractures can occur due to various disease conditions such as osteomyelitis, metabolic and endocrinal disorders (Osteoporosis, Hyperparathyroidism), hematological malignancies (Multiple Myeloma), Paget's disease, benign bone tumors and tumor like conditions (Simple Bone Cyst, Aneurysmal Bone Cyst, Giant Cell Tumor, Fibrous Dysplasia), primary malignant bone tumors (Osteosarcoma, Ewing's sarcoma, chondrosarcoma) and metastatic

bone disease.[2] Metastatic bone disease is a much more common cause of pathological fracture around hip than primary bone malignancies.[3,4] The focus of this review paper is on pathological hip fracture due to metastatic bone disease.

Growing incidence and Significance

Half of all primary cancers spread to the skeleton, making it the third most common site for metastasis, after the liver and lungs. Cancers originating in the breast, lung, prostate, kidney, and thyroid are particularly prone to bone metastases.[5] The proximal femur is the most frequent site of metastatic carcinoma in the appendicular skeleton. Among pathologic fractures in this region, about 50% occur in the femoral neck, 30% in the subtrochanteric area, and 20% in the intertrochanteric region.[6] Metastatic disease to the pelvis is also common. Ilium is more commonly involved followed by ischium and pubis.[7,8] Advances in treatments like chemotherapy, targeted molecular therapies, and radiation have significantly extended the lives of patients with metastatic cancer. However, this increased survival also raises the likelihood of developing bone metastases and subsequent pathological fractures.[9]

Evaluation of a pathological lesion or a fracture should be evaluated in a systematic manner. Without proper workup and a definitive diagnosis, these lesions should not be fixed straight away.[6] Treatment planning of such fractures requires multidisciplinary discussion amongst medical oncologists, radiation oncologists, pathologist, radiologist and onco-surgeons for better functional and oncological outcomes.

Clinical Presentation and Initial Assessment

Clinical presentation of an impending or established pathological fracture may vary, but maintaining a high index of suspicion is essential for timely diagnosis and effective management.

Unlike traumatic fractures, pathological fractures are usually preceded by prodromal pain. Onset is gradual or insidious and usually gnawing, dull ache which is present at rest and intensifies at night. It is usually not relieved by over the counter analgesics.[10,11] Pain is usually localized to groin or upper thigh or sometimes can be referred to distal thigh or knee. Pain with weight bearing or sharp pain is concerning for impending pathological fracture. Provocative tests like resisted straight leg raise or resisted hip extension can elicit pain in a pre-fracture state, but they are best avoided. A diffuse swelling around the site of pain is common in lymphoma or rapidly growing metastatic disease like renal or thyroid carcinomas. They tend to fracture without significant injury or trauma. Normal everyday movements like walking, getting out of bed or using stairs, or even sleeping on the affected side can lead to a fracture. For displaced fractures, classic presentation involves external rotation and abduction of the affected limb, which may appear noticeably shortened. Pain is typically elicited upon gentle rotation of the limb (the "log roll" maneuver) or with axial loading. Due to pain and instability, patients are unable to perform an active straight leg raise.

When metastatic bone disease or a pathological fracture is suspected, a comprehensive history and physical examination is essential. This should include detailed past medical and surgical history, assessment of exposure to carcinogens, prior radiation, and a thorough review of systems. Systemic features such as fever or unintentional weight loss may point toward metastatic disease and are particularly common with lymphoma. Respiratory symptoms like shortness of breath, chest pain, or hemoptysis may suggest a lung primary, while urinary difficulties may indicate prostate involvement and hematuria may raise suspicion of renal or urinary bladder origin. Similarly, breast discharge or rectal bleeding may signal breast and colorectal

primaries, respectively.[11] Jaundice may indicate a hepatobiliary primary, while palpable neck nodules could point to thyroid malignancy. Generalized lymphadenopathy or splenomegaly may be suggestive of lymphoma. A palpable breast mass, axillary lymphadenopathy, or nipple discharge often indicates a breast primary. Dullness on lung auscultation would raise suspicion of a pulmonary origin. On rectal examination, an enlarged and irregular prostate is highly suggestive of prostate carcinoma.[12]

Laboratory Work-Up

The standard laboratory evaluation for a patient presenting with a pathological fracture or a bone lesion of unknown primary origin includes a complete blood count (CBC) with differential, ESR and CRP, urinalysis, serum and urine protein electrophoresis, as well as calcium, phosphorus, alkaline phosphatase and parathyroid hormone levels.[11] CBC helps identify anemia, infection, or marrow infiltration; ESR/CRP assist in differentiating neoplastic from infectious causes; electrophoresis rules out plasma cell dyscrasias such as multiple myeloma; and calcium, phosphorus, and alkaline phosphatase provide insights into bone turnover and metabolic activity, with abnormalities often reflecting metastatic disease. PTH levels are needed to rule out bone lesions due to parathyroid abnormalities and routine urinalysis may reveal hematuria, indicating a possible renal primary. Increased uric acid, increased total protein, decreased albumin, hypercalcemia, elevated ESR, anemia and deranged RFT can be initial findings in a myeloma patient which warrant electrophoresis studies/ bone marrow aspiration/biopsy for definitive diagnosis. Elevated LDH levels could indicate presence of lymphoma.

There are various tumor markers that sometime help with diagnostic association. Elevated PSA (prostate specific antigen) is very helpful and specific marker for identifying a prostate primary. CEA

(Carcinoembryonic Antigen) and CA19.9, CA125, and CA19.9, are elevated in colorectal, ovarian, and pancreatic malignancies respectively, but are not very specific, which limit their diagnostic utility. Similarly, elevated CA15.3, CA-27-29 markers might suggest breast primary whereas AFP (alpha ferroprotein) may be elevated in cases of liver primary or germ cell tumors.[12]

Imaging modalities

A plain radiograph is considered the most important imaging modality for providing initial information about a pathological lesion. Radiographic views typically include an anteroposterior (AP) view of the pelvis with the affected hip internally rotated by 15 degrees, and a cross-table lateral view of the affected hip. Ideally, whole femur should be scanned to rule out other distal lesions. The frog-leg view should generally be avoided as it can cause severe pain and moreover, it carries the risk of displacing a non-displaced fracture or worsening a displaced one. Aggressive features include lesion diameter greater than 5 cm, evidence of cortical disruption, periosteal reaction, and presence of pathological fracture through the lesion.[13,14] Chest radiograph can be done in the same sitting to rule out pulmonary primary or lung metastases. CT is best for assessing cortical lesions, whereas MRI provides superior visualization of trabecular lesions and early skeletal metastases. As the gold standard for occult hip fractures, MRI offers excellent sensitivity and specificity, while also enabling detailed evaluation of soft tissues and bone marrow changes.[15]

If pathological lesion/ fracture around hip is identified in a patient with an unknown primary malignancy, after initial x rays, contrast CT Chest+Abdomen+Pelvis and Whole Body 99mTc bone scintigraphy should be obtained. They help in identifying the primary as well as help in evaluation of disease dissemination (staging)[13]. Bone scintigraphy can be false negative in aggressive and rapidly

growing lytic lesions such as myeloma. If multiple myeloma is suspected on basis of laboratory parameters, skeletal survey is preferred over bone scan. Breast mammography and USG thyroid should be done if primary clinical suspicion is breast or thyroid respectively.[11]

Recently, whole-body 18F-FDG PET/CT has gained popularity as it provides a single, comprehensive modality capable of detecting both the primary tumor and its metastatic spread including: skeletal, nodal, and visceral sites, with greater sensitivity and specificity. Unlike bone scans, which mainly demonstrate osteoblastic activity and may overlook purely lytic lesions, PET/CT visualizes tumor metabolism, allowing earlier detection of metastases It also guides biopsy by identifying the most metabolically active site within the lesion.[16,17]

Biopsy & Histopathological Diagnosis

A biopsy is crucial to establishing a diagnosis in metastatic pathological fractures. If a primary is known and staging work-up shows multiple bone lesions with or without other visceral or lymph nodal metastases, biopsy is performed at the most accessible site.[12] For example, a suspected lung carcinoma with a pathological hip fracture and multiple lesions in tibia/ulna, biopsy from tibial or ulnar lesion is easier. If multiple enlarged axillary/supraclavicular lymph nodal masses are present, lymph nodal biopsy can be less invasive than doing a biopsy from a hip lesion with an impending or established fracture. Image guided or CT guided biopsy increase the diagnostic yield.[13] Although open incisional biopsy yields more tissue for diagnostic accuracy, it leads to a bigger area of contamination at local site. Percutaneous needle biopsies are preferred whenever feasible. In case of unknown primary with a solitary lesion around hip with/without fracture, it should be treated as a primary malignant lesion and should be referred to orthopedic oncosurgeon ideally even before

biopsy. Immunohistochemistry (IHC) profiling of biopsy specimen is crucial, especially when primary the site is not identified. By analyzing expression of tissue specific markers, IHC provides valuable insights into the primary origin of metastatic disease.[18]

Prophylactic Fixation

Single bone metastases, whether pre-fracture or fractured, are optimally treated with wide resection and reconstruction to improve survival. For patients with multiple metastases, prophylactic fixation of at-risk bones is cost-effective and preserves function better than treating fractures after they occur. In cases of severe bone destruction, stability can be enhanced with acrylic cement, but when fixation is likely to fail, resection and reconstruction may be necessary.[19] Mirels introduced a scoring system to estimate the risk of pathological fractures, taking into account lesion site, pain, radiographic appearance, and size. [20] Scores ≥9 require prophylactic fixation prior to radiation therapy as there is high risk of fracture. Scores ≤ 7 means low risk for fracture and can be managed with radiation alone. (Table 1)

CT-based structural rigidity analysis (CTRA) quantitatively evaluates bone strength using CT-derived geometry and density, often comparing the weakness affected bone with the contralateral side. Early studies show that CTRA predicts pathological fractures more accurately than traditional methods like Mirels scoring system.[21] Treating impending fractures before they break is associated with less blood loss, shorter hospital stays, better function, and longer survival.[22]

Surgical considerations for Pathological Hip Fracture

Pathological fractures around hip should be evaluated by a multidisciplinary team for formulating a tailored treatment plan. They should not be fixed emergently. Instead, management plan should ensure early detection, quick assessment, and definitive surgical procedure.

Table 1. Mirel's score to assess pathological fracture risk

Variable	Risk Score		
	Score 1	Score 2	Score 3
Site	Upper Limb	Lower Limb	Pertrochanteric
Pain	Mild	Moderate	Functional
Lesion	Blastic	Mixed	Lytic
Size (relative to bone diameter)	<1/3	1/3-2/3	>2/3

Table 2. Revised Katagiri prognostic scoring system

Prognostic Factor	Score
Slow growth Hormone dependant breast and prostate, thyroid, multiple myeloma, lymphoma	0
Moderate growth Lung cancer treated with molecular targeted therapy Hormone independent breast and prostate, renal, endometrial and ovarian cancers	2
Rapid growth Lung cancer without molecularly targeted drugs, colorectal, gastric, pancreatic, head and neck, esophageal, nonrenal urological, melanoma, hepatocellular, gallbladder, cervical, and cancers of unknown origin	3
Visceral metastases Nodular visceral or cerebral metastases Disseminated metastases (pleural,peritoneal,leptomeningeal)	1 2
Laboratory data *Abnormal* (CRP≥ 4mg/dL; LDH> 250IU/L; albumin <3.7 g/dL) *Critical* (platelet < 1lakh/dL, serum calcium ≥ 10.3 mf/dL, total bilirubin ≥1.4)	1 2
ECOG PS 3 or 4	1
Previous chemotherapy	1
Multiple skeletal metastases	1
Total	10

CRP C-reactive Protein; *LDH* Lactate Dehydrogenase; *ECOG PS* Eastern Cooperative Oncology Group Performance Status

The primary objectives of surgery are to alleviate pain, provide skeletal stability, restore mobility and function, and enhance overall quality of life.[23] Various factors need to be considered before deciding the type of surgery like life expectancy, expected survival of patient, histological subtype of the primary lesion, performance status of the patient, response to adjuvants (chemotherapy and radiotherapy), fracture healing rates with fixation and whether the intent of surgery is curative or palliative.

Katagiri et al. proposed a prognostic scoring system for skeletal metastases based on tumor characteristics, patient status, extent of disease, treatment history, and laboratory results.[24] (Table 2) Survival outcomes correlate strongly with score: patients scoring ≤3 have favorable prognosis (91% one-year survival), those with 4–6 have intermediate prognosis (49% one-year survival), while scores ≥7 indicate poor survival (27% at six months, 6% at one year).[24]

If the expected life expectancy is already very poor or if functional recovery from surgery is likely to
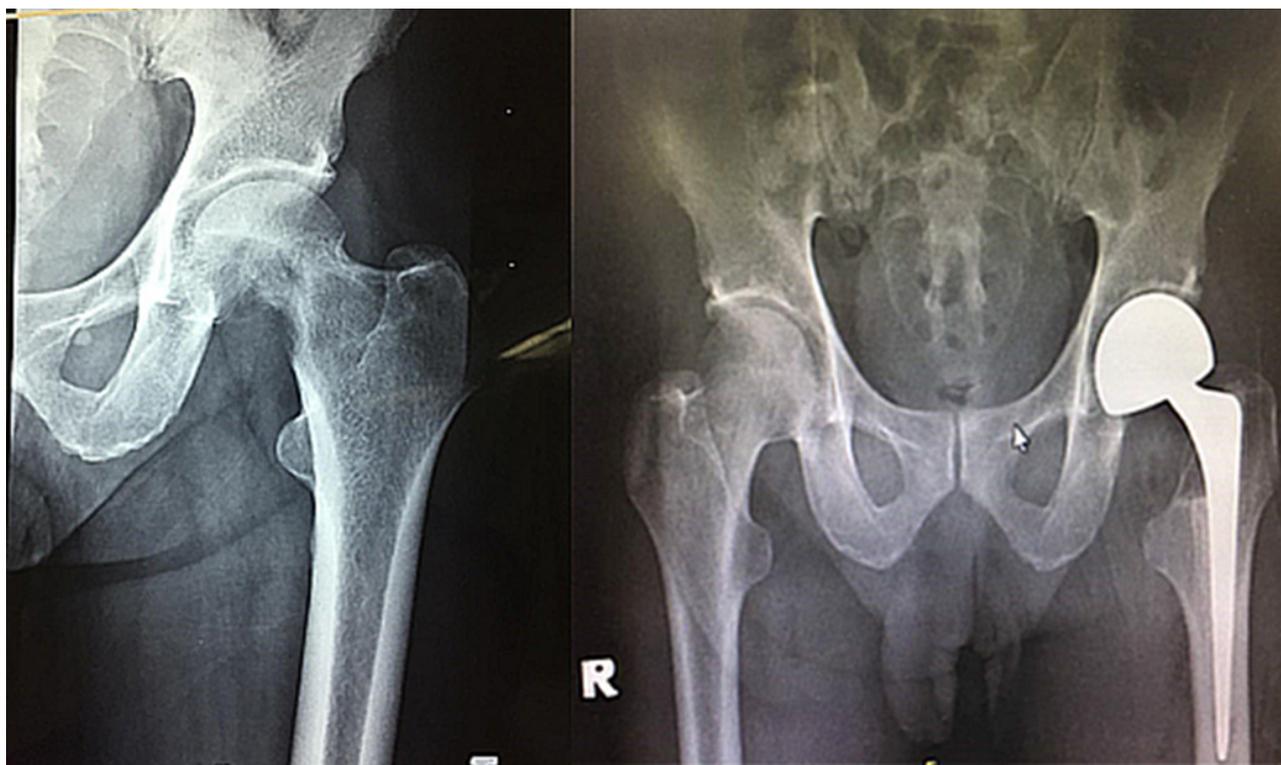
Figure 1 A 56-year-male with metastatic lung cancer confined to femoral head and neck, managed with cemented bipolar hemiarthroplasty
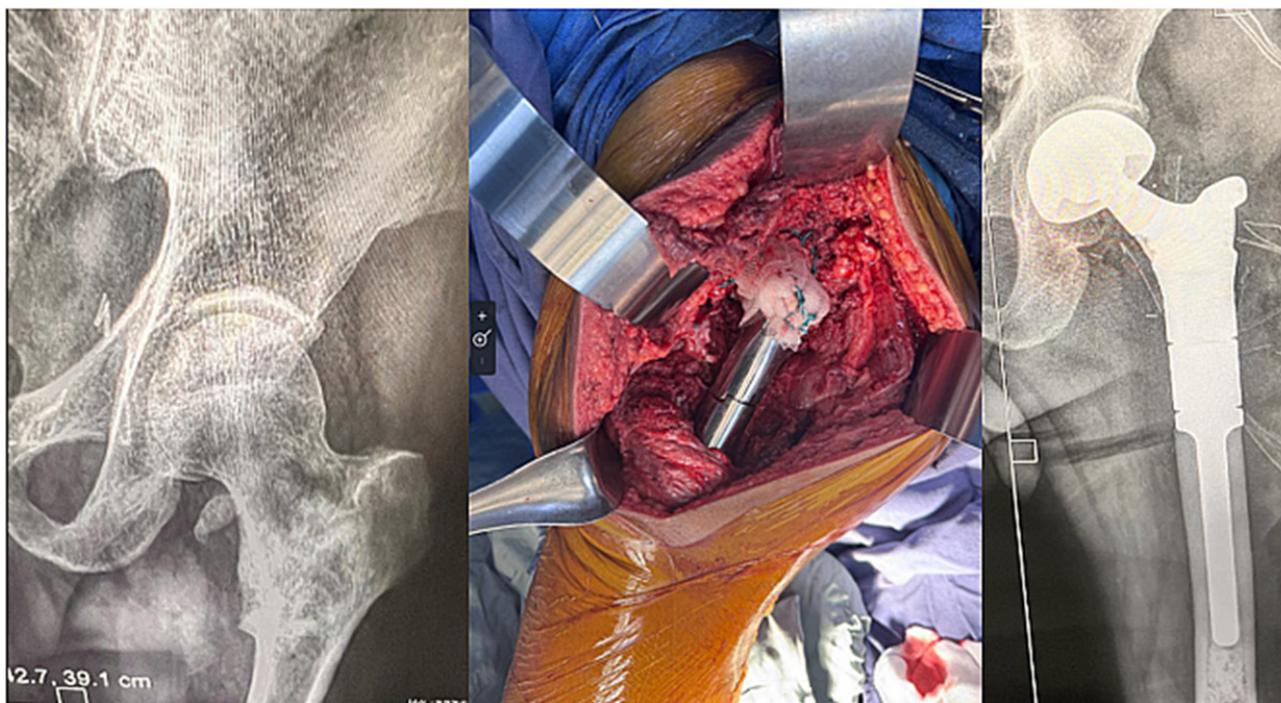
Figure 2 A 77-year-male with solitary metastatic renal cell carcinoma to proximal femur managed with proximal femur endoprosthesis. After tumor resection, deficient hip capsule was reconstructed using prolene mesh

take longer than the remaining life expectancy of the patient or if patient's medical comorbidities and preoperative health doesn't allow any major surgical procedure, non-operative palliative options must be considered.[11]

Pathological fracture with solitary metastases in proximal femur from a primary with good prognosis (well differentiated thyroid, prostate, breast, sensitive to adjuvants) are surgically treated like a primary sarcoma aiming at long term oncological cure.[9] When only head and neck of femur

Table 3. Harrington's metastatic acetabular insufficiency

Group	Description
I	Lateral cortices of the acetabulum as well as the superior and medial acetabular walls remain intact
II	Deficient medial acetabular wall
III	Acetabular dome defect
IV	Solitary metastases to be resected with curative intent

is involved (acetabulum spared), prosthetic replacement is preferred either with bipolar hemiarthroplasty or total hip replacement.[25] (Figure 1) Another principle in metastatic pathological fracture surgery is that "Intervention should address all areas of weakened bone, along with any likely to weaken subsequently".[26] Thus, long-stem implants are preferred to reinforce the shaft and to prevent failure in case of progression of the disease. However, long-stem prosthesis and intramedullary devices have been associated with cardiorespiratory events including pulmonary emboli, cardiac arrest and death.[27,28] in high-risk patients, such as those with severe cardiopulmonary disease, short stem prostheses and expedient surgery, with less blood loss, is advisable.[23]

When the lesion with or without accompanying fracture is peri-trochanteric or subtrochanteric and curative intent is aimed for, wide resection and proximal femoral endoprosthesis replacement is considered. (Figure 2) Distal cement restrictor is avoided so that cement reinforces the medullary canal and distal metaphysis. Uncemented stems are avoided as weight bearing is often
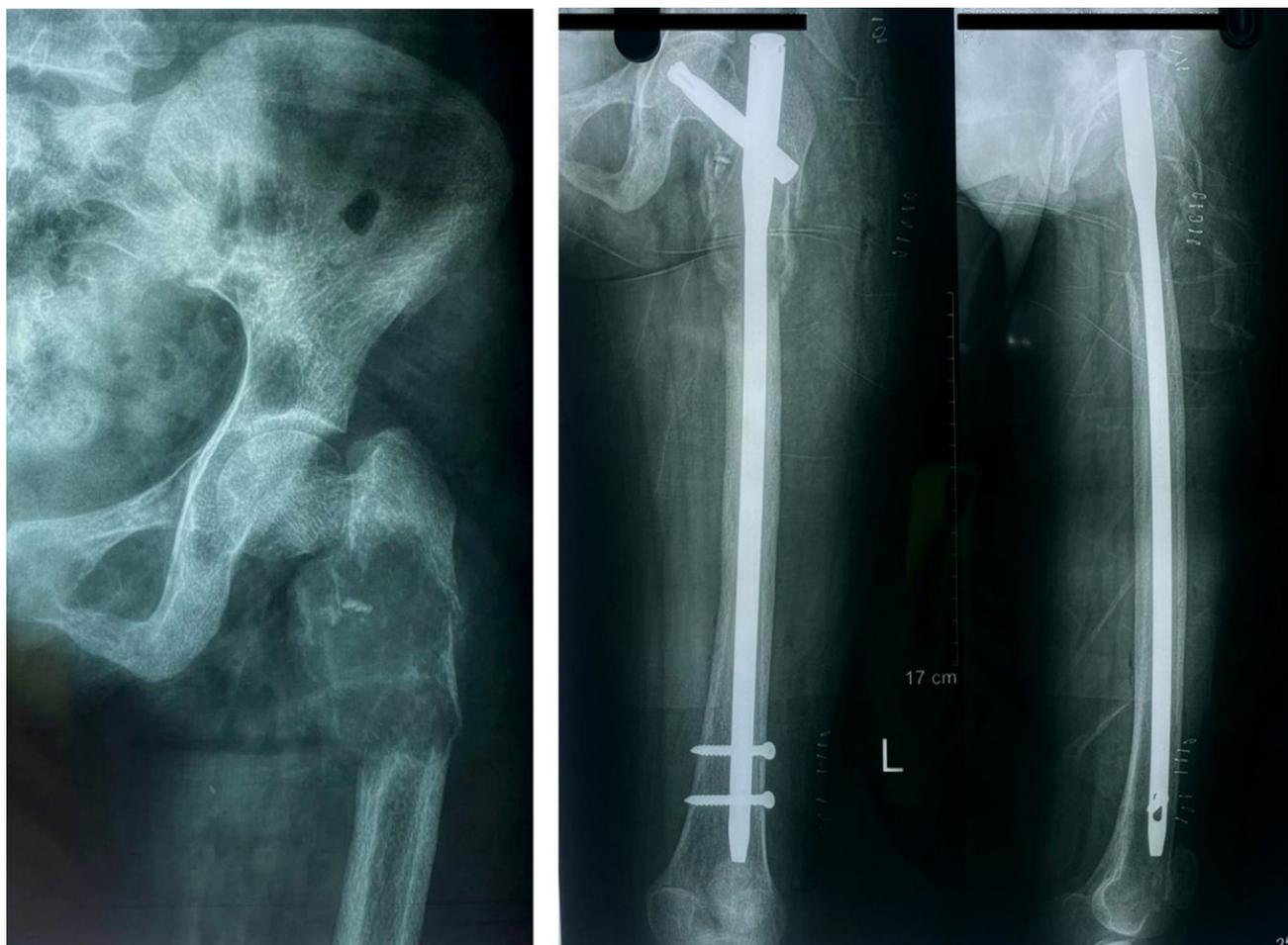
Figure 3 A 48-year-old female with Ca Breast with pathological proximal femur fracture with multiple skeletal metastasis managed with long cephalomedullary nail. Patient received postoperative radiation along with adjuvant chemotherapy and targeted therapy

delayed and if irradiation is needed, the ingrowth of bone in prosthesis is hampered.

Decision making regarding type of fixation in trochanteric or subtrochanteric fracture is not straight forward. Fixation with Dynamic Hip Screw (DHS) is not advised as failure rates are high.[29] Options are cephalomedullary nailing versus proximal femur endoprosthesis.[9,25] Reconstruction nails offer several benefits over endoprostheses, as they can be implanted using a minimally invasive, closed procedure and can provide stability to the entire femur. (Figure 3) Despite these advantages, they act as load-sharing devices and are susceptible to failure if the fracture fails to heal. They can be ideal for diseases such as myeloma/lymphoma, or even for breast carcinoma, with the potential for fracture healing with adjuvant treatment. Pathological fracture from lung primary rarely heal, and intermedullary nails can eventually fail.[30] Moreover, risk of femoral head avascular necrosis (AVN) following postoperative irradiation is another concern. Wide exposure, curettage of the lesion, cementation and fixation with nail/plate have no added benefit in terms of recovery, blood loss when compared to wide resection and endoprosthesis reconstruction.[9] Curettage of the highly vascular lesions with thyroid or renal primaries might lead to excessive bleeding, and preoperative embolization is usually needed.[11] In primaries with poor response to radiation therapy, the risks of local relapse is high in spite of curettage of the lesion. Endoprosthesis reconstruction is ideal in cases where life expectancy is more than one year, there is poor healing with adjuvant therapy, and when disease extends into the femoral neck.[25]

Metastatic disease in acetabulum is a dire event severely limiting patient's function and activities of daily living. Acetabular lesions with impending or established fractures need surgery aimed at a stable hip joint and immediate weight bearing.[31] Surgical procedures are more complex and extensive when compared to those for proximal femur metastatic disease.[32] The Harrington classification is commonly used for classifying peri-acetabular metastatic lesions.[33] (Table 3)

For small contained acetabular metastatic lesions without compromise in structural integrity but painful, minimally invasive image guided percutaneous cementoplasty has shown immediate pain relief and excellent short term outcomes.[34,35] Combining cementoplasty with percutaneous acetabular column screw augmentation offers a more stable construct, and with percutaneous radiofrequency ablation, will aid in tumor destruction and cement filling rates.[36,37]

Group I lesion disrupt the articular surface; however, walls and columns are intact. Conventional cemented total hip replacement is usually the reconstruction of choice.

Group II lesions have deficient medial wall and quadrilateral plate. Reconstruction will require flanged cups/antiprotrusio cages to transfer medial support to the dome and lateral rim. Due to high dislocation rates constrained liners, or dual-mobility constructs, should be utilized.[32]

Group III lesions have extensive periacetabular bone loss and weight bearing dome is deficient. Harrington popularized cemented Steinman pin construct where THA can be affixed. This technique facilitates the load transmission from deficient dome to the intact ilium and sacroiliac joint. After curettage of the lesion, three to four threaded Steinman pins are passed retrograde from the acetabular margin proximally and medially towards ilium and sacroiliac joint. Another group of three to four Steinman pins are passed anterograde from iliac crest inferiorly and medially towards the ischium. Cementation is done to create a scaffold for cemented THA.[38] Various modifications of the technique are published, more popular being three pin modified Harrington technique by Tillman RM et al, where three 6.5 mm Steinman pins were inserted from iliac crest, directed in front, medial and behind the acetabulum. This scaffold with cementation aids for cemented acetabular component placement.[39] Wei et al subclassified Group III lesions into IIIa where bone destruction is distal to inferior border of sacroiliac joint and IIIB where bone destruction extends proximal to sacro-iliac joint. Harrington/modified Harrington procedures are recommended in Group IIIA lesions whereas endoprosthetic reconstruction is advised for more aggressive Group IIIB lesions.[40]

Group IV lesions, resection is performed with anticipation of cure and reconstruction options are usually similar to those for resections for primary sarcomas. Traditional saddle prosthesis or ice-cream cone prosthesis are iliac stem endoprostheses.[41,42] Modified and evolved saddle design in Periacetabular Resection (PAR) endoprosthesis provides greater stability and improved longevity when compared to older saddle prosthesis.[43] In the recent years 3D printed modular pelvic endoprosthesis with porous titanium layer between bone & contact surface of endoprosthesis for better osteointegration as well as iliosacral screw fixation in addition to fixation in residual iliac bone have shown promising and encouraging functional outcomes with no added complications.[44] Without any prosthetic reconstruction, isolated hip transposition also gives acceptable functional results.[45,46] Femoral head is transposed to residual ilium or sacrum and polyethene mesh is used when capsuloplasty is needed. Resection arthroplasty (Girdlestone arthroplasty) is an option for an extensive metastatic disease, bedridden patients who have severe pain even at rest and are medically unlikely to tolerate major reconstructive pelvic surgery.[31]

Conclusion

Pathological fractures around hip pose a significant challenge for orthopedic and oncology care. Prior history of cancer, prodromal pain and/or absence of a significant trauma should

raise suspicion. Comprehensive clinical assessment, laboratory work-up, multi-modal imaging and biopsy are usually required for diagnosis and staging of the disease. They shouldn't be operated upon urgently, rather, multidisciplinary review is needed before formulating a treatment plan. Standard methods of fracture fixation as in traumatic fracture might be inappropriate. More complex fixation and reconstruction options are usually needed. Surgical options should carefully be decided after considering various factors related to the primary disease and its staging, location of disease, general condition and expected life expectancy of the patient. Treatment should be aimed at providing pain relief, immediate weight bearing, improved quality of life and adequate strength of fixation/reconstruction throughout the life expectancy of the patient.

Conflict of Interest

None

References

1. Coleman RE. Clinical features of metastatic bone disease and risk of skeletal morbidity. Clin Cancer Res An Off J Am Assoc Cancer Res. 2006 Oct;12(20 Pt 2):6243s-6249s. https://doi.org/10.1158/1078-0432.CCR-06-0931

2. Bryson DJ, Wicks L, Ashford RU. The investigation and management of suspected malignant pathological fractures: a review for the general orthopaedic surgeon. Injury. 2015 Oct;46(10):1891-9. https://doi.org/10.1016/j.injury.2015.07.028

3. Auran RL, Duran MD, De Comas AM, Jacofsky DJ. Management of Pathologic Fractures Around the Hip: Part 1-Femur. J Hip Surg. 2019 Jun;03(02):093-103. https://doi.org/10.1055/s-0039-1681080

4. Riemen AH, Aherne B, Bruce E, Boddie DE, McCullough LA. Pathological hip fractures. Orthop Trauma. 2020 Apr;34(2):64-72. https://doi.org/10.1016/j.mporth.2020.01.002

5. Coleman RE. Metastatic bone disease: clinical features, pathophysiology and treatment strategies. Cancer Treat Rev. 2001 Jun;27(3):165-76. https://doi.org/10.1053/ctrv.2000.0210

6. Jacofsky DJ, Haidukewych GJ. Management of pathologic fractures of the proximal femur: state of the art. J Orthop Trauma. 2004 Aug;18(7):459-69. https://doi.org/10.1097/00005131-200408000-00013

7. Müller DA, Capanna R. The surgical treatment of pelvic bone metastases. Adv Orthop. 2015;2015:525363. https://doi.org/10.1155/2015/525363

8. Picci P, Manfrini M, Fabbri N, Gambarotti M, Vanel D, editors. Atlas of Musculoskeletal Tumors and Tumorlike Lesions: The Rizzoli Case Archive. Cham: Springer International Publishing; 2014. https://doi.org/10.1007/978-3-319-01748-8

9. Capanna R, Campanacci DA. THE TREATMENT OF METASTASES IN THE APPENDICULAR SKELETON. J Bone Joint Surg Br. 2001 May;83-B(4):471-81. https://doi.org/10.1302/0301-620X.83B4.0830471

10. Wilkinson AN, Viola R, Brundage MD. Managing skeletal related events resulting from bone metastases. BMJ. 2008 Nov;337:a2041. https://doi.org/10.1136/bmj.a2041

11. Cheung FH. The practicing orthopedic surgeon's guide to managing long bone metastases. Orthop Clin North Am. 2014 Jan;45(1):109-19. https://doi.org/10.1016/j.ocl.2013.09.003

12. Hage WD, Aboulafia AJ, Aboulafia DM. Incidence, location, and diagnostic evaluation of metastatic bone disease. Orthop Clin North Am. 2000 Oct;31(4):515-528, vii. https://doi.org/10.1016/S0030-5898(05)70171-1

13. Rajan, Sreeraj; Sugath, Subin. Management of pathological fractures: Current consensus. Kerala Journal of Orthopaedics 3(1):p 42-53, Jan-Jun 2024. https://doi.org/10.4103/KJOO.KJOO_7_24

14. Rizzo SE, Kenan S. Pathologic Fractures. [Updated 2023 May 22]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK559077/. In.

15. Reginelli A, Patanè V, Urraro F, Russo A, De Chiara M, Clemente A, et al. Magnetic Resonance Imaging Evaluation of Bone Metastases Treated with Radiotherapy in Palliative Intent: A Multicenter Prospective Study on Clinical and Instrumental Evaluation Assessment Concordance (MARTE Study). Diagnostics (Basel, Switzerland). 2023 Jul;13(14):2334. https://doi.org/10.3390/diagnostics13142334

16. Niikura N, Costelloe CM, Madewell JE, Hayashi N, Yu TK, Liu J, et al. FDG-PET/CT compared with conventional imaging in the detection of distant metastases of primary breast cancer. Oncologist. 2011;16(8):1111-9. https://doi.org/10.1634/theoncologist.2011-0089

17. Chang Y, Gu Y, Ruan S, Xu S, Sun J, Jiang Z, et al. [18F]FDG PET/CT performs better than CT in determining the bone biopsy site : randomized controlled clinical trial. Cancer Imaging Off Publ Int Cancer Imaging Soc.

2024 Nov;24(1):160. https://doi.org/10.1186/s40644-024-00804-6

18. Oien KA, Dennis JL. Diagnostic work-up of carcinoma of unknown primary: from immunohistochemistry to molecular profiling. Ann Oncol Off J Eur Soc Med Oncol. 2012 Sep;23 Suppl 10:x271-277. https://doi.org/10.1093/annonc/mds357

19. Cirstoiu C, Cretu B, Iordache S, Popa M, Serban B, Cursaru A. Surgical management options for long-bone metastasis. EFORT open Rev. 2022 Mar;7(3):206-13. https://doi.org/10.1530/EOR-21-0119

20. Mirels H. Metastatic disease in long bones. A proposed scoring system for diagnosing impending pathologic fractures. Clin Orthop Relat Res. 1989 Dec;(249):256-64. https://doi.org/10.1097/00003086-198912000-00027

21. Damron TA, Nazarian A, Entezari V, Brown C, Grant W, Calderon N, et al. CT-based Structural Rigidity Analysis Is More Accurate Than Mirels Scoring for Fracture Prediction in Metastatic Femoral Lesions. Clin Orthop Relat Res. 2016 Mar;474(3):643-51. https://doi.org/10.1007/s11999-015-4453-0

22. Ward WG, Holsenbeck S, Dorey FJ, Spang J, Howe D. Metastatic disease of the femur: surgical treatment. Clin Orthop Relat Res. 2003 Oct;(415 Suppl):S230-244. https://doi.org/10.1097/01.blo.0000093849.72468.82

23. Weber KL, Randall RL, Grossman S, Parvizi J. Management of lower-extremity bone metastasis. J Bone Joint Surg Am. 2006 Dec;88 Suppl 4:11-9. https://doi.org/10.2106/JBJS.F.00635

24. Katagiri H, Okada R, Takagi T, Takahashi M, Murata H, Harada H, et al. New prognostic factors and scoring system for patients with skeletal metastasis. Cancer Med. 2014 Oct;3(5):1359-67. https://doi.org/10.1002/cam4.292

25. Bauer HCF. Controversies in the Surgical Management of Skeletal Metastases. J Bone Joint Surg Br. 2005 May;87(5):608-17. https://doi.org/10.1302/0301-620X.87B5.16021

26. Damron TA, Sim FH. Surgical treatment for metastatic disease of the pelvis and the proximal end of the femur. Instr Course Lect. 2000;49:461-70.

27. Herrenbruck T, Erickson EW, Damron TA, Heiner J. Adverse clinical events during cemented long-stem femoral arthroplasty. Clin Orthop Relat Res. 2002 Feb;(395):154-63. https://doi.org/10.1097/00003086-200202000-00017

28. Patterson BM, Healey JH, Cornell CN, Sharrock NE. Cardiac arrest during hip arthroplasty with a cemented long-stem component. A report of seven cases. J Bone Joint Surg Am. 1991 Feb;73(2):271-7. https://doi.org/10.2106/00004623-199173020-00015

29. Wedin R, Bauer HC, Wersäll P. Failures after operation for skeletal metastatic lesions of long bones. Clin Orthop Relat Res. 1999 Jan;(358):128-39. https://doi.org/10.1097/00003086-199901000-00016

30. Gainor BJ, Buchert P. Fracture healing in metastatic bone disease. Clin Orthop Relat Res. 1983 Sep;(178):297-302. https://doi.org/10.1097/00003086-198309000-00041

31. Issack PS, Kotwal SY, Lane JM. Management of metastatic bone disease of the acetabulum. J Am Acad Orthop Surg. 2013 Nov;21(11):685-95. https://doi.org/10.5435/JAAOS-21-11-685

32. Auran RL, Duran MD, De Comas AM, Jacofsky DJ. Management of Pathologic Fractures Around the Hip: Part 2-Acetabulum. J Hip Surg. 2019 Jun;03(02):104-12. https://doi.org/10.1055/s-0039-1681091

33. Harrington KD. The management of acetabular insufficiency secondary to metastatic malignant disease. J Bone Joint Surg Am. 1981 Apr;63(4):653-64. https://doi.org/10.2106/00004623-198163040-00017

34. Scaramuzzo L, Maccauro G, Rossi B, Messuti L, Maffulli N, Logroscino CA. Quality of life in patients following percutaneous PMMA acetabuloplasty for acetabular metastasis due to carcinoma. Acta Orthop Belg. 2009 Aug;75(4):484-9.

35. Harty JA, Brennan D, Eustace S, O'Byrne J. Percutaneous cementoplasty of acetabular bony metastasis. Surg J R Coll Surg Edinburgh Irel. 2003 Feb;1(1):48-50. https://doi.org/10.1016/S1479-666X(03)80010-0

36. Roux C, Tselikas L, Yevich S, Sandes Solha R, Hakime A, Teriitehau C, et al. Fluoroscopy and Cone-Beam CT-guided Fixation by Internal Cemented Screw for Pathologic Pelvic Fractures. Radiology. 2019 Feb;290(2):418-25. https://doi.org/10.1148/radiol.2018181105

37. Moynagh MR, Kurup AN, Callstrom MR. Thermal Ablation of Bone Metastases. Semin Intervent Radiol. 2018 Oct;35(4):299-308. https://doi.org/10.1055/s-0038-1673422

38. Harrington KD. Orthopaedic management of extremity and

pelvic lesions. Clin Orthop Relat Res. 1995 Mar;(312):136-47.

39. Tillman RM, Myers GJC, Abudu AT, Carter SR, Grimer RJ. The three-pin modified 'Harrington' procedure for advanced metastatic destruction of the acetabulum. J Bone Joint Surg Br. 2008 Jan;90-B(1):84-7. https://doi.org/10.1302/0301-620X.90B1.19892

40. Wei R, Lim CY, Yang Y, Tang XD, Yan TQ, Yang RL, et al. Surgical Treatment and Proposed Modified Classification for Harrington Class III Periacetabular Metastases. Orthop Surg. 2021 Apr;13(2):553-62. https://doi.org/10.1111/os.12918

41. Kitagawa Y, Ek E, Choong P. Pelvic Reconstruction Using Saddle Prosthesis following Limb Salvage Operation for Periacetabular Tumour. J Orthop Surg. 2006 Aug;14(2):155-62. https://doi.org/10.1177/230949900601400210

42. Hipfl C, Stihsen C, Puchner SE, Kaider A, Dominkus M, Funovics PT, et al. Pelvic reconstruction following resection of malignant bone tumours using a stemmed acetabular pedestal cup. Bone Joint J. 2017 Jun;99-B(6):841-8. https://doi.org/10.1302/0301-620X.99B6.BJJ-2016-0944.R1

43. Menendez LR, Ahlmann ER, Falkinstein Y, Allison DC. Periacetabular reconstruction with a new endoprosthesis. Clin Orthop Relat Res. 2009 Nov;467(11):2831-7. https://doi.org/10.1007/s11999-009-1043-z

44. Liang H, Ji T, Zhang Y, Wang Y, Guo W. Reconstruction with 3D-printed pelvic endoprostheses after resection of a pelvic tumour. Bone Joint J. 2017 Feb;99-B(2):267-75. https://doi.org/10.1302/0301-620X.99B2.BJJ-2016-0654.R1

45. Hillmann A, Hoffmann C, Gosheger G, Rodl R, Winkelmann W, Ozaki T. Tumors of the pelvis: complications after reconstruction. Arch Orthop Trauma Surg. 2003 Sep;123(7):340-4. https://doi.org/10.1007/s00402-003-0543-7

46. Kapoor L, Sahoo B, Majeed A, Banjara R, Kumar VS, Bakhshi S, et al. Leaving half the acetabulum in pelvic resections improves hip function. Is there a need to revisit conventional pelvic resections? J Surg Oncol. 2022 May;125(6):1032-41. https://doi.org/10.1002/jso.26806