Review article:
Reconstructive surgery following resection of primary and secondary tumours of the hip

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INTRODUCTION
The survival of patients with primary and secondary malignancies of bone and soft tissue has improved substantially with modern multimodality treatment. Advances in chemotherapy have made a significant impact on the control of local and systemic spread, while sophisticated imaging facilities now allow accurate anatomic delineation, which is important for achieving oncological margins. The principles of musculoskeletal tumour surgery have been well enunciated over the last decade and techniques for limb-sparing surgery now carry predictable and safe outcomes. Surgery of the pelvis remains difficult and, in particular, tumours of the periacetabulum, which includes the hip joint, pose anatomical, surgical and functional challenges.

ANATOMICAL CONSIDERATIONS
The anatomy of the pelvis is complex and great consideration must be paid to its contents and adjacent soft tissue structures in planning surgery. For surgical purposes, the pelvis may be divided into the posterior and anterior pelvis, and the periacetabulum. The posterior pelvis, which is dominated by the sacrum and sacroiliac joint, has the lumbo-sacral trunk traversing across the anterior sacroiliac joint before exiting through the greater sciatic notch. The sacrum contains the sacral plexus important for bowel and bladder function, while superior and anterior to all lays the bifurcation of the aorta and inferior vena cava and their iliac components. The periacetabulum, which contains the hip joint, has the sciatic nerve immediately posterior to it in the sciatic notch and the internal iliac vessels medial to the acetabulum. The anterior pelvis has the femoral vessels and nerve draped over the superior pubic ramus.

SURGICAL AND FUNCTIONAL CONSIDERATIONS
Treatment of benign lesions usually involves intralesional surgery with joint or limb preservation the primary aim. The treatment of pelvic malignancies, however, depends on whether these are primary or secondary tumours. Primary tumours are resected with curative intent whereas secondary tumours are operated on for palliation, which includes pain control and the preservation of joint function, if possible. In either case, a durable reconstruction is desired, particularly in metastatic pelvic disease where patients without visceral involvement may survive for many years.
Functional disability depends on the combination and the level of neuromuscular and bone resection. Posterior pelvic tumours are perhaps the most difficult to resect because of the great confluence of neural structures at this level the manner in which the roots of the lumbosacral trunk are so closely applied to the sacroiliac joint and the bone of the pelvic brim and intimate relations with vascular branches to the sacrum and ilium (e.g. ilio-lumbar arteries and sacral arteries). Surgery to this area may result in sciatic nerve injury from traction alone, while tumours involving the inner table of bone at this level may require neural resection to achieve an adequate margin. Resections of the periacetabulum, which may include the acetabulum, femoral head or both are frequently met with loss of normal hip joint function and associated with a limp. Patients should always be advised of the consistent nature of this outcome following periacetabular resections. Anterior pelvic resections are not as complicated as the former two areas because the femoral neurovascular structures are frequently protected by the underlying ilio-psoas and pectineus muscles and may be easily displaced out of harm’s way during surgical dissection. Sacrifice of the femoral nerve is not as poorly tolerated as that of the sciatic nerve. A good example of satisfactory lower limb function in the absence of femoral nerve activity can be seen in poliomyelitis.

INVESTIGATIONS

Apart from plain radiography, a variety of investigations that provide anatomical and functional imaging may be useful in demonstrating the tumour, its intrasosseous involvement and the surrounding tissue for assessing surgical margins.

Magnetic resonance imaging

Magnetic resonance imaging (MRI) has been one of the most valuable modalities for anatomical imaging over the last 2 decades. The advantages of this modality are the multiplanar imaging capabilities, unrivalled soft tissue contrast, ability to image whole compartments, assessing the marrow extent of tumour, identifying skip lesions or quantifying oedema (Fig. 1a). MRI is also extremely valuable in demonstrating the neurovascular structures adjacent to tumours, which is important in determining the resectability of tumours and the anticipated quality of surgical margins.

One shortcoming is the lack of specificity which can make differentiation between infection, trauma and benign or malignant tumour difficult. This is true for both bone and soft tissue tumours. MRI may also be susceptible to post-surgical artefacts. Inflammation, oedema and scarring are characteristics of surgery that may confound the interpretation of MRI. As MRI has a fundamental role in local staging of tumours, no surgery including biopsy should be performed prior to this test being performed.

Computed tomography

Computed tomography (CT) is readily available in most communities and is particularly sensitive for determining bone destruction and identifying calcified tumour matrix (Fig. 1b). With contrast enhancement, soft tissue lesions can also be demonstrated with great

Figure 1 (a) MRI scan of pelvic liposarcoma of psoas muscle. Note the soft tissue contrast that defines the thinned capsule of muscle tissue and adjacent vascular structures. (b) CT scan of posterior iliac chondrosarcoma. CT scans provide excellent imaging of calcified matrix (arrows).
accuracy using CT. The availability of sophisticated computer software now permits excellent three-dimensional reconstruction of anatomy, which facilitates surgical planning, and image co-registration allows the combination of multiple modalities of imaging on the same picture frame. The contraindications to MRI include the presence of pacemakers, metal hardware or debris in the patient, and these underscore the ongoing role of CT scanning in the work-up of tumours.

A disadvantage of CT scanning is the restriction of image acquisition to the axial plane. As yet, image reconstruction to provide coronal or sagittal views are inferior to what can be attained using MRI. Soft tissue contrast may also be difficult if tumours are iso-intense with muscle or fat.

Nuclear Medicine

The most widely used and well-recognised nuclear medicine technique in evaluating bone and soft tissue tumours is the bone scan. Basic nuclear scans include dynamic, static and delayed studies and utilise tracer material such as technetium–99 methylene diphosphonate (MDP) to demonstrate the response of surrounding bone to the adjacent tumour. Bone scanning is an excellent modality for local and systemic staging of disease. Multiple lesions are more likely to signify metastatic lesions while primary tumours need exclusion when a solitary lesion has been identified.

Another technique known as metabolic imaging assesses the basal metabolic rate or proliferative activity of tumours using radioisotopes that are metabolised by or concentrated in the tumour. Compared with technetium-MDP scans that measure the response of bone to the tumour, metabolic imaging highlights the activity of the tumour itself (Fig. 2). Thallium–201 chloride (TI–201) scanning is a good example of metabolic imaging. Malignant tumours frequently concentrate this tracer more avidly than normal soft tissue or bone. High affinity for TI–201 has been demonstrated in bone and soft tissue sarcomas. Other radioisotopes used in metabolic imaging of bone and soft tissue malignancies include F–18 flouromisonidazole, TC–99m sestamibi, and gallium–67 citrate.

Positron emission tomography (PET) is another example of metabolic imaging which is developing an increasingly important role in orthopaedic oncology. The most widely used tracer is flourine–18 fluorodeoxyglucose (F–18 FDG). F–18 FDG is an analogue of glucose and is transported into cells by a

![Figure 2](image-url)
range of glucose transporter proteins (GLUT 1 and 3). PET scanning gives a 3-dimensional image of metabolic activity over time. By quantifying regional radiotracer kinetics using PET, the metabolic rate within tumours may be determined. This is useful not only for grading tumours, but also for comparing pre- and post-treatment images, which is a potential means of following therapeutic response. Since heterogeneity of proliferative activity often exists within tumours, metabolic imaging approaches can also be helpful to guide biopsy of the most active and viable parts of the tumour.

BIOPSY

All lesions should be fully imaged before biopsy because surgically-created imaging artefacts can confound the interpretation of imaging studies, which may lead to under- or over-treatment. The purpose of biopsy is to diagnose or exclude sarcoma and this is important because the management of sarcoma varies diametrically from metastatic carcinoma.12,14 In this regard, sarcomas are resected en bloc with wide margins and with curative intent while metastases are frequently treated with intralesional excision. If a sarcoma is treated with intralesional surgery widespread seeding may occur. Thus, biopsy is extremely important. In addition, the mode of biopsy is also important as a misplaced biopsy site may jeopardise the potential for limb-sparing surgery by contaminating valuable flaps or creating haematomas that are sources of tumour seeding.10

In principle, biopsies should be minimally invasive. The preferred technique at our institution is CT-guided needle biopsy (Fig. 3a). The site for biopsy is marked out by the surgeon, placed in the line of the planned surgical incision, and confirmed by tattooing by the radiologist. Neurovascular planes and transperitoneal approaches should be avoided. At times, the position of the tumour may preclude biopsy, such as a medial acetabular wall tumour (Fig. 3b). In such circumstances, diagnoses are made in the context of all the tests performed. A multidisciplinary team approach is extremely valuable at times when biopsy cannot be safely performed.
MARGINS

Guidelines for surgical margins have been well established and 4 classes of margins exist; namely, intralesional, marginal, wide and radical. The preferred resection margin for pelvic tumours is the wide margin. This may not always be possible when dealing with a very large tumour, or one that is posterior in the pelvis for reasons discussed above. The choices of surgery are either internal hemipelvectomy where the lower limb is preserved or external hemipelvectomy where the pelvis and attached lower limb are sacrificed. The margin is rarely improved with external hemipelvectomy, thus limb-sparing surgery is preferred if the major neurovascular bundles can be preserved, adequate soft tissue cover is anticipated, and a functional limb remains following reconstruction.

SURGICAL CLASSIFICATION

Tumours of the hip joint involve either the periacetabulum or the proximal femur or both. Tumours on the pelvic side affecting the hip joint may be periacetabular, periacetabular and iliac, periacetabular and ischial, or hemipelvic. Depending upon the site of the tumours, pelvic resections (Fig. 4) may be classified into 3 types; namely, iliac (Type I), acetabular (Type II) and obturator (Type III). It is common for combinations of these resections to be employed. Tumours on the femoral side affecting the

Figure 4 Classification of pelvic resections depending upon location of tumours. Commonly, combinations of these resections are undertaken.
hip joint may involve solely the proximal femur or include the hip joint proper. Any tumour of the pelvis or femur that has breached the hip joint capsule necessitates the inclusion of the hip joint in the resection without opening the joint to the externa. This ensures containment of any joint effusion, which may be potentially contaminated by malignant cells.

Periacetabulum

Resections of the periacetabulum may involve part of or the whole acetabulum. Segmental resections of the acetabulum, such as anterior or posterior column, may be reconstructed with segmental anatomical specific osteo-articular allografts. If the whole acetabulum is sacrificed, a total acetabular allograft will be required. With this option the hip joint may be reconstructed either with a total hip joint replacement (cemented cup) or alternately with a bipolar arthroplasty. Our preferred technique is the bipolar arthroplasty because of the inherent instability following capsular resection, which may be corrected, in part, by the bipolar head.

Saddle prostheses are an easy method of reconstructing an articulation between pelvis and proximal femur. The problem is one of maintaining stability of the articulation with the pelvis. Dacron ties are useful for lashing the saddle to the pelvis to help with stability while a pseudocapsule develops about the joint. The motion provided by the saddle is limited but with appropriate patient selection, this technique is simple and durable (Fig. 5).

Reimplantation of resected pelvic bone following extracorporeal irradiation or autoclaving has been reported. In this technique, the tumour is curetted from the resected bone before irradiation or autoclaving, which is then followed by reimplantation. This is a useful technique in centres where allograft bone or prosthetic devices may not be readily available. The major complications of this procedure are infection and/or graft disintegration.

Computer aided design of acetabular prostheses has expanded the reconstructive options. The use of pelvic prostheses, which incorporate the acetabulum, has evolved slowly over the last decade and their use remains experimental. The difficulty with prosthetic fixation and their cost are major barriers to routine use.

Periacetabulum and ilium

Resections of the periacetabulum and ilium leave little proximal bone for connecting the lower limb to the axial skeleton. Ischio-femoral reconstructions, either by arthrodesis or pseudoarthrosis are simple and reliable techniques. Mobility at the pubic symphysis permits a range of flexion and extension of the reconstruction, but this may also give rise to aching symptoms (Fig. 6a).

If a rim of iliac crest being preserved is in continuity with the sacroiliac joint, a hemi-pelvic allograft may be inserted between it and the residual pubic rami (Fig. 6b). The iliac crest is a strong bar of bone, which allows transfer of forces from the allograft to the sacroiliac joint and together with pelvic reconstruction plates that span the allograft, may support the allograft pelvis and reduce the incidence of graft disintegration, which has plagued hemi-pelvic allograft reconstructions that previously used minimal fixation.

Periacetabulum and ischium

Ilio-femoral arthrodesis is a good technique for reconstructing combined resections of the periacetabulum and ischium that spare the ilium. The use of a large cobra-type plate for the arthrodesis and a post-operative hip spica to protect the reconstruction for at least 12 weeks enhances the success rate of fusion. Our preferred position for arthrodesis is in slight flexion and neutral alignment in the coronal plane.
Following resection, if significant iliac bone remains, the saddle prosthesis may be used as described above.

Hemi-pelvis

Hemi-pelvic resections are difficult to reconstruct because of the lack of biomechanically sound sites for fixation. Preservation of the lower limb, however, may still be attempted with success by leaving the limb flail after tumour resection. A post-operative hip spica allows fibrosis around and stabilisation of the proximal femur as a pseudoarthrosis gradually develops between the femoral head and sacrum. Despite a marked limp, patients frequently walk with little discomfort and are able to conduct activities of daily living without walking aids.

Periacetabulum and proximal femur

Extra-articular resections of the periacetabulum, which include a significant proportion of the proximal femur may once again be reconstructed with a saddle prosthesis. Others have attempted with varying success to create an arthrodesis between the femur and ilium using an intercalary segment of allograft. The length of the allograft and the difficulty in achieving strong and stable fixation proximally is a potential cause for non-union.

Periacetabular metastases

Periacetabular metastases frequently complicate the outcome of patients with metastatic carcinoma because the pelvis is one of the more common sites for spread. Traditionally, radiotherapy has been the mainstay of treatment of bone involvement. The progressive nature of dilated
of metastatic disease has deterred many from undertaking treatment of complex acetabular disease because the morbidity has been presumed to outweigh the benefits of surgery. Consequently, patients with acetabular metastases have had to endure the symptoms of pain, loss of function and infirmity.

The decision to operate is based upon knowledge of the extent of the local and systemic disease, the patient’s general condition, the expected patient’s longevity and whether the reconstruction is likely to improve function, mobility, and pain relief. In our institution, patients who have an anticipated lifespan of at least 2 months are given the opportunity of surgical reconstruction.

**SURGICAL CONSIDERATIONS**

Unlike surgery for primary tumours, the goal in metastatic surgery is to retain as much bone as is possible and this implies intralesional surgery in many instances. The procedures aim to transfer stresses to the strong surrounding normal bone and to prevent migration of the components. Metastasis is a progressive disease and therefore, any reconstructive procedure must be durable in the presence of ongoing destruction.

**CLASSIFICATION OF ACETABULAR METASTASES**

We employ a simple classification, which reflects specific anatomic deficiencies. Type I – Punctate lesions of the acetabulum with no significant loss of medial wall or superior dome integrity. Type II – Medial acetabular wall deficiency. Type III – Medial and supero-lateral deficiency of acetabulum.

**RECONSTRUCTIVE OPTIONS**

**Type I defects**

A standard cemented hip replacement will usually suffice for patients with minimal punctate lesions of the acetabulum (Fig. 8a). Cementless prostheses are not recommended because many patients have received radiotherapy and/or chemotherapy and reliable bone in-growth into the porous acetabular component cannot be expected.
Figure 8  (a) Type I periacetabular metastases treated with cemented hip arthroplasty. (b) Type II lesions treated with curettage and reinforcement ring. Prophylactic insertion of long stem femoral prosthesis is advocated for all metastases. (c) Bilateral Type II lesions treated with medial wall mesh and reinforcement rings. (d) Large supero-medial Type III lesion treated with medial wall mesh, steinmann pins to the iliac crest and sacrum and reinforcement ring. (e) Type III lesion complicated by destruction of the proximal femur. Calcar mesh and calcar bearing femoral prosthesis are used to reconstruct the proximal femur.
Type II defects

These lesions are prone to develop protrusio acetabulae and therefore, reconstruction with an anti-protrusio reinforcement ring is recommended (Fig. 8b). A variety of anti-protrusio rings are available and the choice is surgeon dependent. Ideally, the device must be able to be fixed at 2 points around the acetabulum to provide satisfactory stability. On occasions, the medial wall has been destroyed, thus exposing the obturator internus muscle. Here, medial wall reconstruction mesh is used to contain the defect and to supplement the reconstruction (Fig. 8c). An all-polyethylene cup is then used.

Type III defects

Involvement of the supero-lateral dome of the acetabulum implies that the part of the pelvis that transmits forces between the acetabulum and sacrum is compromised. Unless this is reconstructed, pathologic fracture and upward migration of the femoral head will occur. In reconstructing this part of the acetabulum, it is important to note the position of its lateral margin because this is a valuable guide to the orientation of the cup. Occasionally, the lateral part of the acetabulum is so involved as to require resection. It is advisable to preserve the lateral rim as long as possible prior to cementation in order to maintain orientation.

Reconstruction of type III lesions requires heavy Steinmann pins to bridge the defect and to transfer stresses between the cup and axial skeleton (Fig. 8d, e). In general, 2 groups are employed, one being directed downward from the iliac crest into the dome of the acetabulum, and another group directed upwards and medially from the lateral part of the acetabular dome to the saroiliac joint. In very large defects, pins can also be employed between the dome of the acetabulum and the superior pubic ramus. Following pin insertion, a reinforcement ring and mesh are used.

In all reconstructions for metastatic tumour, our preferred technique includes the use of a long-stem femoral prosthesis. This is because of the possibility for further lesions to develop along the femoral shaft, which may become problematic if they arise distal to the tip of the femoral component (Fig. 9). With a long-stem prosthesis, the femur is afforded protection against pathologic fracture. It is important to note that the majority of long-stem prostheses available are intended for revision surgery and there is a commensurate increase in body size with increases in stem length. Thus, their use in small women with metastatic disease may be limited.

Figure 9  Femoral head renal metastasis treated with bipolar hemiarthroplasty. 4 months later, 2 femoral metastases have developed distal to the standard stem.
SPECIFIC COMPLICATIONS

Infection

The risk of infection is higher in patients who have received either chemotherapy or radiotherapy than those who have not. This may be devastating if infection also involves an allograft. Not only will the construct have to be removed, there may be an unacceptably long delay before chemotherapy may be recommenced which in turn may have survival implications. We prescribe preoperative antibiotics for all patients and maintain this as an oral dose until the skin staples are removed at 21 days. (Early removal of staples is not recommended because of the delay in wound healing from radiotherapy and chemotherapy.) For patients who have received allografts, our preferred treatment is to prescribe 48 hours of vancomycin during the perioperative period, and then to continue antibiotics with a broad spectrum oral cephalosporin for 4 months.

Haemorrhage

Significant haemorrhage may occur with prolonged procedures or from vascular metastatic lesions. In addition, one should be constantly vigilant for the ubiquitous veins of the iliac system. Where significant bleeding from a vascular tumour is anticipated, preoperative embolization is advised. We undertake embolization no longer than 36 hours prior to surgery. Beyond this time, collateral channels are known to open and the benefit of embolization would be lost. In addition to embolization, we have found intraoperative rapid transfusion systems to be useful for maintaining transfusion rates of up to 1000 ml per minute if required. Special attention should be given to the coagulopathy that may develop with high volume transfusions and chilled blood products.

Dislocation

Dislocation of prosthetic joint replacement is much higher after tumour resection than primary or revision arthroplasty. The stability of a prosthetic joint depends upon adequate tissue tension, soft tissue barriers such as the joint capsule and the orientation of the prosthetic components. Pelvic resections are frequently associated with significant soft tissue resections and the placement of prosthetic components may be confounded by the loss of bone landmarks. This is particularly relevant where acetabular allografts are employed and where there is a risk of fixing the orientation of the acetabulum in an incorrect version. When proximal femoral resections are performed, sacrifice of the abductors also predispose to joint instability. If joint replacement is indicated, we recommend bipolar arthroplasty where possible as the larger head and bipolar articulation have the potential to increase joint stability.

CONCLUSION

Surgery of the hip following tumour resection is challenging. The morbidity from the above procedures may be great and the requirements on technical and human resources are high. A team approach to the diagnosis and management of tumours of the pelvis is likely to improve the standard of care and patient outcomes. Observing the principles of primary tumour surgery with particular attention to biopsy techniques and surgical margins can improve the local and systemic control of disease. The relief of pain and improvement of function in a palliative setting can be extremely rewarding.

REFERENCES


