Pelvic Resections

ANDREAS F. MAVROGENIS, MD; KONSTANTINOS SOULTANIS, MD; PAVLOS PATAPIS, MD; GIOVANNI GUERRA, MD; NICOLA FABBRI, MD; PIETRO RUGGIERI, MD, PhD; PANAYIOTIS J. PAPAGELOPOULOS, MD, DSc

The complexity of pelvic anatomy and the extent of tumor growth makes treatment of patients with primary bone sarcomas in the pelvis difficult in terms of local control. Before the 1970s, most tumors in the bony pelvis were surgically treated with hindquarter amputation. Currently, improved techniques for clinical staging, adjuvant treatments, evolutions in metallurgy, and development of new surgical techniques make limb-salvage surgery and reconstruction possible alternatives to hemipelvectomy and resection–arthrodesis. The advantages of amputation over resections at the pelvis are a lower incidence of complications, a limited area at risk for recurrence, and a faster recovery time compared with all but the most limited pelvic resections. The disadvantages, especially after periacetabular resections, are leg-length discrepancy and impaired hip and gait function. The indication for limb salvage is the ability to obtain wide margins without compromising survival and function. Although having to resect the sciatic nerve to obtain adequate margins does not always mean that an amputation should be performed, the combination of a major pelvic resection and the functional consequences of sciatic nerve resection results in an extremity usually not worth saving; loss of femoral nerve function does not result in a significant gait disturbance, especially if the hemipelvis is stable. Reconstruction options after major pelvic resections have also evolved, but they remain difficult, especially when the acetabulum is involved.

Drs Mavrogenis, Soultanis, and Papagelopoulos are from the First Department of Orthopaedics, and Dr Patapis is from the Department of Surgery, ATTIKON University Hospital, Athens University Medical School, Athens, Greece; and Drs Guerra, Fabbri, and Ruggieri are from the Fourth Department of Orthopaedics, Istituto Ortopedico Rizzoli, Bologna, Italy.

Drs Mavrogenis, Soultanis, Patapis, Guerra, Fabbri, Ruggieri, and Papagelopoulos have no relevant financial information to disclose.

Correspondence should be addressed to: Panayiotis J. Papagelopoulos, MD, DSc, First Department of Orthopaedics, ATTIKON University Hospital, Athens University Medical School, 1 Rimini, Chaidari, Athens, Greece (pjportho@otenet.gr).

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Primary bone sarcomas of the pelvis account for 5% to 10% of all malignant bone tumors, the most common of which are chondrosarcomas, Ewing’s sarcomas, and osteosarcomas. The prognosis and survival of patients with bone sarcomas in this location are much less favorable than for patients with tumors of the extremities. The advantage in this location is also difficult in terms of local control because of the complexity of pelvic anatomy, which increases the difficulty of resection and reconstruction.

Before the 1970s, most tumors in the bony pelvis were surgically treated with hindquarter amputation. Over the next decades, planning tools and imaging techniques greatly improved and made it possible to define the exact extent of a tumor and its relation to functionally important structures, such as the nerves, blood vessels, and intestinal organs. Currently, improved techniques for clinical staging, adjuvant treatments, evolutions in metallurgy, and development of new techniques in oncologic reconstruction make limb-salvage surgery and reconstruction at the pelvis possible as alternatives to hemipelvectomy and resection-arthrodesis.

Currently, much experience has been gained from primary tumor surgery that limb-salvage surgery is also performed for pelvic metastases in patients with favorable cancer types, solitary metastases, and long expected survival rates. The advantages of amputation over resections at the pelvis are a lower incidence of complications, a limited area at risk for recurrence, and a faster recovery time compared with all but the most limited pelvic resections. The disadvantages, especially after periacetabular resections, are the inevitable discrepancy in leg length and impaired hip and gait function.

**Indications and Contraindications**

The indication for limb salvage is the ability to obtain wide margins without compromising function. Contraindications for limb salvage, which means indications for a hindquarter amputation, include: (1) patients who had a resection in the past but now have local recurrence, unless the recurrence can definitely be widely resected or the amputation offers no oncological benefit; (2) a tumor that has extended across the sacroiliac joint to the sacral nerve root foramen; and (3) patients with lesions extending into the sciatic notch who have symptoms of sciatic nerve involvement.

Although having to resect the sciatic nerve to obtain adequate margins does not always mean that an amputation should be performed, the combination of a major pelvic resection with the functional consequences of sciatic nerve resection results in an extremity usually not worth saving. The femoral vessels can be bypassed (although it is more difficult to bypass the femoral vein), and the loss of femoral nerve function does not result in a significant gait disturbance, especially if the hemipelvis is stable.

**Staging and Surgical Planning**

Imaging studies, including plain radiographs, computed tomography (CT) scans, and magnetic resonance imaging of the pelvis and radiographs or CT scans of the chest, should be carefully examined. Conventional or magnetic resonance angiography of the pelvic vessels is important to evaluate tumor involvement and possibly to plan for wound closure with a flap. A venogram may also be useful if evidence exists of tumor thromboembolism in the iliac veins.

Biopsy is the last step of staging. It is usually performed using CT guidance and a 3- to 6-mm gauge needle. The treatment success relies on an appropriate and accurate biopsy placed in the appropriate location; this is especially true for tumors such as chondrosarcomas, whose treatment and outcome depend mostly on an adequate initial surgery. The biopsy track should be positioned in line with the eventual resection incision. Most pelvic sarcomas are resected through an incision over the iliac crest; therefore, the safest biopsy incision is directly over the iliac crest. If needle biopsy is not diagnostic, open incisional biopsy is recommended. Every attempt should be made to not contaminate the retroperitoneum. Transrectal, ultrasound-guided needle biopsy should be avoided for anterior sacrum tumors due to the risk of contamination.

Restaging should be performed after preoperative chemotherapy and radiation therapy to predict the adequacy of the planned tumor resection and assess the surgical margins in 3 dimensions (sagittal, coronal, and frontal) and 6 planes (proximal, distal, anterior, posterior, lateral, and medial). Current technology based on CT data from the bony pelvis may produce an individual 3-dimensional pelvic model for preoperative planning of the line of resection and an accurate reconstruction for a good fit to the remaining part of the pelvic bone.

The resection is usually planned for 2 to 5 weeks after the last chemotherapy session and 4 to 5 weeks after radiation therapy. An absolute neutrophil count of 500 to 1000 cells per µL is required. Intraoperative radiation therapy may be arranged after reviewing preoperative imaging of an area in which microscopic contamination may occur.

A multidisciplinary approach including colleagues from urology, vascular surgery, general surgery, colon and rectal surgery, orthopedic oncology, neurosurgery, plastic surgery, and spine surgery may be necessary. Prior to the procedure, the patient is evaluated by an urologist for bladder and ureter involvement of the tumor. Pancreascopy and pyloureterogram can be performed to evaluate tumor involvement; placement of ureteral stents or a pigtail catheter may be considered if one ureter appears to be involved by a tumor.
EXPOSURE

The standard exposure for pelvic bone resections involves the utilitarian pelvic incision, which is the extended ilioinguinal approach that extends from the pubic tubercle along the inguinal ligament to the anterior superior iliac spine and along the iliac crest to the posterior superior iliac spine (Figure 1A). Periacetabular resections require lateral extension of the incision to the thigh (Figure 1B). Posterior resections may require extension of the posterior incision to the midline of the spine with or without a perpendicular midline extension (Figure 1C). Anterior pelvic resections, such as ischiopubic resections, may require extension of the ilioinguinal incision to the contralateral pubic ramus and an additional perpendicular T-incision for femoral vessels exposure.

Different parts of the extended ilioinguinal approach may be used depending on the location and extent of the tumor. Anterior incisions to the area of the femoral vessels that extend distally and laterally, developing a lateral flap based on the glutteal arteries, are relatively risky because part of their blood supply comes from lateral branches of the femoral artery, which are interrupted anteriorly.

In the anterior pelvis, the incision for the ilioinguinal approach begins at the pubic tubercle and continues laterally to the anterior iliac crest. The medial two-thirds of the inguinal canal represent a reflection and coalescence of the internal and external oblique abdominal muscles and transversalis fascia. The abdominal musculature should be carefully dissected off of the iliac crest. The inguinal ligament should be detached at its lateral attachment to the anterior iliac crest and dissected off the deeper iliac fascia laterally and reflected proximally. Once the inguinal ligament is released, the iliopsoas, the femoral nerve and sheath, and the pelvic retroperitoneal space are exposed.

The femoral bundle should be identified midway between the pubic tubercle and iliac crest, just anterior to the superior pubic ramus. The femoral sheath should be fully dissected, and ligation of the inferior epigastric vessels should be performed for all periacetabular and ischiopubic resections. The femoral nerve lies deep into the iliopsoas muscle and tendon, lateral to the femoral sheath, and should be identified and protected. In men, the spermatic cord and its contents (ductus deferens, testicular artery, and genitofemoral nerve) should be dissected medially to laterally and retracted. In women, the round ligament may be sacrificed.

The pubic symphysis is exposed by detaching the anterior rectus abdominis and pyramidalis muscles from their insertion onto the ipsilateral pubic crest. Posterior to the symphysis is the retropubic, retroperitoneal space of Retzius. The bladder is separated from the anterior pubic bones by thick, fibrous tissue and retropubic fat. The urethra is just inferior to the pubic symphysis and is separated from it by the arcuate ligament. Division of the symphysis is performed with an osteotome or the Gigli saw from superior to inferior, with care to not damage the urethra. Once the anterior cut has been completed, the pelvis will open, but the sacropinal and sacropubic ligaments must be cut before the pelvis becomes loose.

In the posterior pelvis, the common iliac vessels should be traced deep into the pelvis; the inferior vena cava should be protected when performing surgery on the patient’s right side. The psoas may be separated from the iliacus muscle to enhance the exposure of the sciatic notch. The ureter is located because it crosses the common iliac artery just distal to the pelvic brim into its junction with the bladder and is retracted medially. The sciatic nerve comes closest to the pelvis at the greater sciatic notch. Usually, the nerve is not infiltrated and comes away from the tumor’s pseudocapsule without difficulty. Next, the obturator vessels and nerve are identified because they run along the inferior lateral pelvic brim, just anterior to the sciatic notch and gluteal vessels, and continue along the inferior surface of the superior ramus into the adductor compartment.

After the vascular structures have been visualized, the posterior sacroiliac joint should be identified. The L5 nerve root courses just below the transverse process of the L5 vertebra, where the iliolumbar ligament attaches to the posterior ilium. The L5 joins the L4 and sacral roots to form the sciatic nerve at the sciatic notch. The posterior flap should be as thick as possible.
However, the incidence of complications is lower and the patient recovers more quickly after an external hemipelvectomy. In addition, although the surgical margins may be the same, a limited area is at risk for recurrence after an amputation compared with a limb-salvage procedure.\textsuperscript{2,5,19,37} External hemipelvectomy is recommended in recurrent sarcomas after previous resection when there is sacral involvement and extension of the tumor across the sacroiliac joint and into the sciatic notch.\textsuperscript{5,12,31}

When the tumor involves the posterior pelvis and sacrum and extends to the lower lumbar spine, resection should include the ilium, the entire or part of the sacrum, and part of the lower spine to obtain wide or safe surgical margins; this procedure is defined as extended hemipelvectomy (Figure 4). Extended hemipelvectomy results in a large defect with subsequent destabilization of the spinopelvic segment; therefore, reconstruction is necessary for spinopelvic stability and function.\textsuperscript{3,12} It is suggested that extended hemipelvectomy may be best reserved for patients with localized disease. Considering the high failure rates and the increased morbidity, this type of surgery is not indicated for patients with metastatic disease at onset or with other severely compromising medical factors at presentation.

In addition, performing an extended hemipelvectomy for a patient who had prior surgeries at the same site may result in an increased risk for complications and local recurrence.\textsuperscript{12,31} When comparing the oncologic outcomes of patients who had either an internal or an external extended hemipelvectomy, no major differences were detected except for the longer follow-up of the patients who had an internal procedure.\textsuperscript{12} In general, when patients require major spinopelvic resection, which disrupts spinopelvic continuity and either resects the lumbosacral plexus or both the lumbosacral plexus and hip joint, the ultimate function of the limb is so poor that amputation of the limb (external extended hemipelvectomy) is often indicated.\textsuperscript{38,39}

**Type I Resections**

Type I resections can be achieved through the posterior aspect of the standard ilioinguinal approach. The anterior iliac osteotomy is made through the sciatic notch or just superior to the acetabulum. The posterior osteotomy is usually made through or adjacent to the sacroiliac joint. The iliolumbar ligament is encountered at the most superomedial aspect of the posterior iliac crest and should be released to enhance exposure. This ligament also serves as a good landmark for the L5 nerve root that should be identified just inferior and medial to the ligament.\textsuperscript{20,23,24,27,31}

**Type II Resections**

Type II (periaacetabular) resections are indicated for tumors involving the acetabulum and tumors of the hip joint or the proximal femur invading the acetabulum; in cases in which it appears possible to achieve surgical margins similar to those obtainable with hemipelvectomy; when the resection can preserve a reasonably functional limb (sparking at least in part the major nerves and permitting some recon-
Periacetabular resections require 3 osteotomies. The superior osteotomy should always be superior to the posterior iliac spine (through the greater sciatic notch). The anterior osteotomy is usually made through the anterior column of the acetabulum at the base of the superior pubic ramus. The posterior osteotomy may be located in the posterior acetabular column or the ischium. If the tumor is in the posterior column, it is recommended to remove en bloc the acetabulum with the ischium (type II, III resection) (Figure 5).20,23,24,31

Following most type III resections, a careful soft tissue reconstruction should be performed to prevent bladder or intestinal herniation into the inguinal defect, using a synthetic mesh, polytetrafluoroethylene (Gore-Tex; W. L. Gore & Associates, Inc, Newark, Delaware), or fascial allograft. A synthetic mesh, polytetrafluoroethylene does not require lumbar plexus division.18,47-52

The general approaches to sacral tumors include anterior, posterior, and combined approaches for large, aggressive sacral tumors extending to S1, the lumbar spine, or the pelvis. Anterior approaches include either transabdominal or retroperitoneal exposures, whereas posterior approaches involve sacral laminectomy and partial posterior sacrectomy.53 Sacral laminectomy is indicated for tumors largely confined to the sacral canal, such as neurogenic tumors, because of the ease of exposure to the neural elements. Sacral laminectomy as the primary exposure is not indicated for tumors originating outside the sacral canal or extending significantly into the pelvis.54 Posterior sacrectomy is indicated for tumors of the sacrum below the level of the sacroiliac joints, tumors without large presacral mass, tumors whose superior limit can be reached on digital rectal examination, and smaller lesions of the middle and distal sacrum not yet requiring resection above the level of the sacroiliac joint.54

**Type IV Resections and Sacrectomies**

Various sacrectomies have been described depending on the tumor’s location and its extension. In general, sacrectomies have been classified as partial or total and can be combined with some posterior iliac resections (type IV resection) and resection of part of the lower lumbar spine (extended hemipelvectomy).31,38,39,41

Partial sacrectomy is indicated for tumors of the sacrum below the S2 segment because it can usually be performed with wide margins, it does not require lumbopectivic reconstruction, and it preserves bowel and bladder function.8,42 Partial sacrectomy may be transverse, sagittal, or a combination. Lateral sacral tumors without sacroiliac joint involvement are treated by sagittal partial sacrectomy. Above or below the S2, lateral lesions with sacroiliac joint involvement are treated by sagittal sacrectomy and limited posterior iliac resection (type LIV resection). Above or below the S2 midline, tumors without sacroiliac joint involvement are treated by transverse sacrectomy.5,41,43

Total sacrectomy is indicated when a malignant or aggressive benign lesion involves the proximal sacrum with anterior extension.13,44,45 A radical surgical approach with sacral roots sacrifice is often warranted to achieve total resection with clear margins.46 However, a total sacrectomy can enhance local tumor control and overall patient survival despite potential complications and neurologic dysfunction.8,42 Techniques for total sacrectomy were pioneered in the 1960s and 1970s.47,48 Combined dorsal and ventral exposures have been described, and the use of the transpelvic vertical rectus abdominis myocutaneous flap for the reconstruction of large sacral defects has significantly reduced problems with wound healing.18,47-52

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A combined anteroposterior approach is indicated for tumors with extensive vascularity, primary proximal sacral tumors engaging the lumbosacral junction (in particular the upper S1 endplate), and tumors with significant presacral mass that penetrate the anterior pelvic fascia or involve the rectum.23,24,31,55

A synchronous abdominosacral approach to expose the sacrum anteriorly and posteriorly simultaneously in the lateral position for resection of sacral tumors has also been reported.48 However, with this approach it is more difficult to expose both the anterior and posterior sacrum, and the lateral position complicates efforts at soft tissue reconstruction or mechanical stabilization, if necessary.48

Hemicorporectomy

Hemicorporectomy or translumbar amputation involves amputation of the pelvis and lower extremities by disarticulation through the lumbar spine with concomitant transection of the aorta, inferior vena cava, and spinal cord and the creation of conduits for diversion of the urinary and fecal streams.56-58 Originally described in 1950, >50 cases of hemicorporectomy have been reported.56-58 Indications include the following:

- Locally advanced cancer confined to the pelvis and lower body that failed to respond to traditional therapies.
- Slow-growing malignancies confined to the lower body and certain benign conditions, most of which are complications of paraplegia.59,60
- Inoperable pelvic tumors by abdomino-perineal resection, pelvic exenteration, or hemipelvectomy with absolute absence of evidence of tumor metastasis outside of the pelvis.61
- Biologic nature of the tumor compatible with prolonged survival.61,62
- Severe crushing trauma to the pelvis and lower extremities.56
- Acute aortic occlusion.63
- As a last resort in the treatment of pelvic arteriovenous malformations and life-threatening diagnoses that resulted in complications of massive bleeding, soft tissue necrosis, sepsis, congestive heart failure, and bowel and bladder incontinence.56,57,64

Hemicorporectomy has been performed for carcinomas of the bladder, cervix, vagina, and prostate and bone tumors of the pelvis, including giant cell tumors and chordomas of the sacrum and chondrosarcomas.62 Patients with chordomas whose local resection or irradiation failed were excellent candidates for hemicorporectomy because these tumors grow slowly and rarely spread to distant sites; most of these patients eventually die from complications associated with local invasion, such as intestinal or urinary obstruction, bleeding, or sepsis.64 Paraplegics represent the majority of translumbar amputations for benign processes.57

Hemicorporectomy is performed in 2 stages. During the first stage, conduits for diversion of both the urinary and fecal streams are constructed. The second stage includes disarticulation through the lumbar spine with concomitant transection of the aorta, inferior vena cava, and spinal cord in an anterior-to-posterior approach.57 Disarticulation through the lumbar spine and division of the spinal cord is associated with untoward blood loss and neurogenic hypotension, which likely contributes to morbidity and length of hospital stay. After ligation of the inferior vena cava, Batson’s plexus becomes engorged, leading to a more challenging dissection and marked blood loss during division of the vertebral structures and spinal cord.57,58 However, hemicorporectomy results in such serious mutilation that it is questionable, from an ethical standpoint, whether it should be offered to patients.62 Use as a palliative procedure is precluded.62

Pelvic Reconstructions

The indications for pelvic reconstruction include young patients, resection of weight-bearing or moving elements (such as the hip joint), primary sarcomas or benign aggressive tumors with intention to cure, solitary pelvic bone metastasis in patients with “favorable” cancers such as thyroid, renal, and breast cancer with...
long life expectancies, and the availability of materials relative to the timing of surgery. The following alternatives are available for reconstruction of the pelvis or reattachment of the extremity following pelvic resections: flail hip, pseudarthrosis, arthrodesis, megaprosthetic, or allograft reconstruction.

Reconstructions for Type I and III Resections

The bony defect in type I resections can be reconstructed with autograft fibula, cortical or pelvic allograft, or bone cement (Figure 7). The advantages of replacing the resected bone are pelvic stability and maintenance of limb length. The disadvantages are the increased risks of infection and failure of the reconstruction. No formal reconstruction is required for type III resections.

Reconstructions for Type II Resections

Defects can be reconstructed with a pseudarthrosis (Figure 8) or arthrodesis, allografts (Figure 9), iliac allograft composites with a hip arthroplasty, custom-made metallic pelvic prostheses, saddle prostheses, or stemmed prostheses (Figure 10). Each reconstruction option has its own advantages and disadvantages, and most studies report a high failure rate; it is generally best to do the easiest reconstruction possible.

Flail hip does not involve a skeletal reconstructive procedure, only a soft tissue closure. Pseudarthrosis and arthrodesis involve establishment of a fibrous or solid union, respectively, between the proximal femur and the remaining pelvis (iliofemoral, ischiofemoral, or sacrofemoral) using a plate or similar implant, cables, cerclage wires, or screws. Disadvantages of arthrodesis include loss of the functioning hip joint, which is not recommended in younger patients, shortening of the leg, lack of mobility, and long consolidation times, which means longer periods of rehabilitation and the use of gait support. Hip spica cast immobilization is required postoperatively for approximately 3 months to obtain union of the arthrodesis.

Fusion rates of femoropelvic arthrodeses are <50%. In most patients, a stable and painless pseudarthrosis develops, but with a comparable functional result to that of the alternative reconstruction options. Alternative arthrodesis techniques, such as the tibia–hindfoot rotationplasty with calcaneosacral arthrodesis and the hip transposition, have also been reported after external hemipelvectomies. The tibia–hindfoot rotationplasty with calcaneopelvic arthrodesis is applicable in selected patients with unaffected external iliac and femoral vessels and involves a modified anterior flap hemipelvectomy with resection of the femur and hemipelvis but preservation of structures below the knee. The calf with its vascular supply is rotated by 180º, the fore- and midfoot are resected, and the calcaneus is fixed to the osteotomy site at the sacrum. The hip transposition technique involves refixation of the inferior part of the acetabulum to the preserved bone (ilium or sacrum) after 90º rotation (type I) and wrapping the femoral head (type IIa) or a proximal femoral bipolar megaprostheses (type IIb) into an artificial capsule that is attached to the intact proximal bone (ilium or sacrum) with bone anchors.

Arthroplasty reconstructions are recommended when adequate ilium and pu-
bis remain for fixation of a pelvic allograft composite with a unipolar or total hip megaprostheses. Pelvic allografts should be carefully selected and matched. Large femoral head sizes (≥32 mm) should be chosen, and the periacetabular soft tissues and gluteal fascia should be reattached to maximize postoperative hip stability. Custom-made metallic pelvic prostheses are expensive. The 3 linking areas for the pelvic prosthesis are the remaining of the opposite pubic rami, the joint facet of the sacrum or the remainder of the ilium, and the remaining ischium. With the prosthesis in place, the acetabular prosthesis should be symmetric with the contralateral side in height, lateral distance, and orientation. Saddle prostheses provide good cosmetic result and limb-length equality (Figure 11); however, the eccentric position of the new hip center reduces the range of motion, and loosening, lateral shift, or dislocation of the prosthesis is common. In this regard, artificial ligaments have been used to secure the saddle and conventional proximal femoral megaprostheses until a fibrous pseudocapsule develops.

Reconstructions for Type IV Resections

Sacral resections below S1 are structurally stable and seldom require reconstruction; stability is preserved because the conventional S2-S3 partial sacrectomy does not disrupt the sacroiliac articulations and lumbopectoral structure. Conversely, sacral tumors at the S1 level alter the biomechanics at the lumbosacral junction, and therefore may require stabilization.

After total sacrectomy, the lumbar spine usually migrates inferiorly and remains between the ilia. The muscles and the scar between the pelvis and spine form a biological sling, eventually stabilizing the spine. Most patients are able to walk with a brace, with only slight back or leg pain.

In this setting, some surgeons do not advocate reconstruction of the osseous defect after total sacrectomy because of the risk of major wound complications (especially deep wound infection) after reconstruction and the acceptable ambulatory status of the patients without reconstruction. However, most authors recommend lumbar pelvic stabilization after total sacrectomy, partial sacrectomy involving >50% of the sacroiliac joint on each side, and sagittal and high transverse partial sacrectomy that essentially obliterates the sacroiliac articulation unilaterally or bilaterally and destabilizes the lumbopectoral segment.

Spinopelvic stabilization after major spinopelvic resections has been attempted using various constructs with combinations of screws, wires, bars, and plates. Spinal fixation using sacral bars and Luque rod constructs (Zimmer, Inc, Warsaw, Indiana) with combinations of hooks, wires, and pedicle screws, and the Luque-Galveston technique (segmental spinal instrumentation through the use of sublaminar wiring and iliac fixation to the pelvis) have fueled the evolution of reconstruction techniques in the past. However, although fixation to the pelvis improved, proximal fixation was tenuous, and stability was difficult to achieve.

The current instrumentation used in spinopelvic reconstruction is the pedicle screw–rod construct. Pedicle screw instrumentation is performed into at least the lowest 3 segments of the lumbar spine, and screw fixation is obtained in the bone stock of the remaining ilium, avoiding the hip joint. Rods are placed in the spinal pedicle screws and the iliac screws connecting the lumbar and pelvic segments. A part of the femur (usually the femoral condyles) of the amputated limb that is tumor free is saved sterile and used as strut graft to bridge the gap between the remaining lumbar spine and pelvis on the retained side. The pedicle screw–rod construct for spinopelvic reconstruction is easier to place safely, and the fixation is more rigid than that of previous constructs. However, long-term follow-up is still not available.

Wound Closure

In the past, the defects created by these procedures were closed primarily, resulting in wounds subjected to considerable tension and high rates of complications, such as wound dehiscence, hematoma formation, and infection. To overcome these problems, pedicled or free myocutaneous flaps have been used for wound closure, and polytetrafluoroethylene mesh (Gore-Tex) and acellular dermal matrices GraftJacket (Wright Medical Technology, Arlington, Tennessee) are used to repair retroperitoneal defects and prevent hernias.
However, regardless of the level of ligation of the iliac vessels, the factor that determines the viability of the posterior flap is whether the gluteus maximus is left attached to the flap. In this case, adequate blood supply to the gluteus maximus and the posterior flap is provided from branches entering the gluteus maximus at its sacral origin; these branches derive from the middle sacral, iliolumbar, and other arteries independent of the blood supply provided by the internal iliac vessels. Tumor contamination, previous surgery, or tumor arising from the gluteus muscle preclude the use of the posterior gluteus maximus myocutaneous flap.

The anterior thigh flap is a modified version of the posterior gluteus maximus myocutaneous flap that has allowed for the treatment of difficult buttock and pelvic tumors in which the posterior flap was involved or contaminated by a tumor. The anterior thigh flap consists of skin, subcutaneous fat, and the quadriceps muscle. With the quadriceps femoris muscle attached to the flap, the dominant blood supply is provided through the lateral femoral circumflex branches of the deep femoral artery. Although the superficial femoral vessels may provide additional blood supply when they can be preserved, their presence is not necessary for the viability of the anterior thigh flap. This flap cannot be used in patients with tumor contamination of the anterior thigh compartment.

The medial thigh adductor myocutaneous flap is an option for hemipelvicomy closure in patients with tumors involving the buttock and anterolateral upper thigh. Another option is the axial thigh fillet flap, which is based on the spare parts concept that uses residual tissue from amputated limbs for complex soft tissue reconstructions, thereby limiting donor-site morbidity by not further involving healthy structures. The free fillet lower leg flap is a free flap raised from the calf and is supported by the popliteal artery anastomosed to the cut end of the internal iliac artery in an end-to-end fashion. Free microvascular flap transfer should be considered only when use of local flaps is contraindicated. However, the use of free flaps is often restricted as a result of the limited availability of recipient vessels.

**Complications**

Initially, overall complications in sarcoma patients after pelvic resections were reported in 75% of patients, with 25% to 35% having a 5-year survival rate. More recently, overall complication rates have decreased to <2%, the 5-year survival rate increased to 37%, and the local recurrence rate and perioperative mortality have decreased to 17% and almost 0%, respectively. The most common complications were intraoperative hemorrhage; sciatic and femoral nerve injuries on the opposite side; ureter, bladder, and bowel injuries; wound-healing complications; infection and dislocation of prostheses; infection and fracture of allografts; lower-quadrant hernia; bowel ischemia; and late venous thrombosis. Sacrectomies have been associated with wound complications requiring flap closure, mechanical instability requiring spinopelvic reconstruction and fusion, stress fractures, and long-term neurological deficits.

Patients with sacral resections distal to S3 generally have limited deficits, with preservation of sphincter function in the majority and some reduced perineal sensation and sexual ability. The highest variability in functional results is seen for transverse resections above S3. Preserving both S1 nerve roots is important for normal gait and foot plantarflexion. Sectioning of the S1 roots may result in clinically relevant motor deficits (walking with external support), and almost uniformly results in total loss of sphincter control and sexual ability. Unilateral resection of sacral roots leads to unilateral...
deficits in strength and sensitivity; however, sphincter control may be either preserved or only partially compromised. Patients with bilaterally preserved S2 roots will retain bowel and bladder function; in those patients in whom only 1 S2 root is preserved, bowel and bladder function will likely be lost. Patients with resection of 1 to all 4 S2 and S3 roots have saddle anesthesia and significant reduction in sphincter control.14,50

Reconstruction procedures have increased the rates of infection and mechanical complications because of the lengthy surgical procedure and the poorly vascularized residual region. Despite technological advances, reconstructions using pelvic prostheses have been associated with complication rates as high as 60%, with 40% of patients needing ≥1 repeat surgeries.14,71 Following sacroiliac resection and spinoepic resections, postoperative infection and mechanical failure rates range from 14% to 60% and 12% to 27%, respectively.7,11,14,15,17,71 Psychological effects and depression are common after major operations, especially in patients with sarcomas, and should be treated adequately by a psychiatric specialist.12

CONCLUSION

The use of limb-salvage pelvic resections has increased with the advances in imaging and surgical techniques and instrumentation. However, pelvic surgery for sarcomas remains challenging because of the complex anatomy and the extent of tumor growth. Reconstruction options have also evolved. However, they remain difficult, especially when the acetabulum is involved, and complications are frequent. External hemipelvectomy is often the only option.

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