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Principles and Rehabilitation after Limb-sparing Surgery for Cancer

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OVERVIEW

Until around 1970 amputation was the principal operation performed for bone and soft-tissue sarcomas of the extremities, shoulder, and pelvic girdle. Today 85% of these tumors are treated by limb-sparing surgery (LSS), a procedure that involves reconstruction of bones, joints, and soft tissues using endoprostheses, allografts, autografts, and composites. With proper evaluation and surgical management about 60% of these patients are cured of their underlying disease.

This progress creates new opportunities for rehabilitation medicine. The purpose of this chapter is to describe major considerations associated with the rehabilitative care of patients who have undergone LSS. Specific information on surgery, principles of rehabilitation, and incidence of complications is presented for LSS surgery of the distal femur and knee joint, proximal femur and knee joint, proximal humerus and glenohumeral joint, proximal femur and hip joint, and pelvic girdle. The chapter concludes with information on LSS in children and its role in palliative care.

INTRODUCTION

Until the 1970s amputation was the treatment of choice for primary high-grade malignant bone and soft-tissue tumors of limbs. The management of these lesions has changed dramatically since that time. Today about 85% of these patients undergo LSS. Instead of amputating part or all of the limb, the surgical team reconstructs the bony and soft-tissue defects using custom or modular endoprostheses, allografts, autografts, or composite materials.[1,2] The procedure is performed in conjunction with chemotherapy and/or radiation therapy (neoadjuvant and/or adjuvant).[1,2] Although LSS can enhance the quality of life it does cause a variety of functional impairments, and creates a need for early intensive rehabilitative intervention.[1,2]

Rush[2] defined medical rehabilitation as "maximal preservation of physical, psychological, social, occupational, creative and economical function in conjunction to malignant disease and its treatment". It is a way to restore the patient's function to the highest possible level without considering the basic pathology.

For many years it has been assumed that investing in extensive rehabilitation efforts for patients with poor prognoses and short life expectancies could not be justified from an economic perspective.[3] Now that cure rates among patients who have undergone LSS are 60–80%, this assumption is clearly no longer correct.[3] It is no less important to rehabilitate patients with metastatic bone disease. Patients with pathological fractures or pending fractures are currently treated aggressively with internal fixation techniques that permit immediate weightbearing and full functionality. The goal is to avoid pain and maximize mobility for the remainder of the patient's lifetime, regardless of its length.[4] The implication is clear: rehabilitation must become an integral part of the team approach to LSS.

This chapter describes the rehabilitation of patients who have undergone LSS. Because most of the authors' experience is with the use of endoprostheses, different aspects of this type of reconstruction are stressed.

LSS VERSUS AMPUTATION SURGERY

LSS can result in survival rates and disease-free periods that equal those achieved with amputation.[2] The presumed functional and psychological advantages of LSS over amputation, however, have yet to be established. LSS appears to offer the possibility of better psychological functioning and an intact body image, but it is more complex and demanding than amputation and is associated with more morbidity. The duration of surgery is longer, and infection, pain, and other postoperative complications are more common.[1,5–7]

Otis *et al.*[8] compared energy cost during gait in osteosarcoma patients after resection of the distal femur and knee joint and replacement with an endoprosthesis with that of patients who had undergone an above-knee amputation. The former had a lower energy cost during gait than the latter. Eiser *et al.*[6] noted that one of the disadvantages of LSS is that additional hospitalizations may be necessary in the case of complications such as infections or loosening of the endoprosthesis. In children, repeat procedures are necessary for elongation of an extendable prosthesis.

It is important to emphasize that, in order to justify LSS, the procedure must provide limb function equal or superior to that provided by an external prosthesis after amputation. At the same time the tumor must be resected according to principles of oncologic surgery (i.e. there must be free margins and minimal damage to major neurovascular bundles and muscles). Despite the disadvantages, nearly all patients believe that an attempt to salvage a limb is worth the time and effort.[5]

PROBLEMS ASSOCIATED WITH LSS

LSS is an extensive procedure involving huge masses of soft tissues, bones, and joints, and resulting in long and deep scars. In contrast to ordinary general orthopedic procedures, in which the goal is to solve a local problem with minimal exposure of and damage to surrounding anatomic structures, LSS deliberately damages many anatomic areas and may cause the following problems.

Bone and Joint Damage

- Resection of bone with no replacement: in non-weightbearing (NWB) areas such as pelvic girdle, or dispensable bones such as the fibula, clavicle, or scapula. There is not need to replace or reconstruct them.
- Resection of bone and joint with replacement: this means the need for using endoprostheses (customized or modular), improvised internal implants/fillers such as nails, plates, and cement; allografts, and composites/combinations of the above.

Muscle Damage

- Resection of part of a muscle or group of muscles because tumor involvement.
- Damage to muscle innervation because the nerve was involved in the tumor or had to be mobilized for tumor excision.
- Local transfer of muscles in order to cover implants or free microvascularized flaps.

Skin Damage

- Resection of skin areas involved by tumor, previous biopsy scars, or scars of other surgical procedures (in cases of local recurrence).
- Extensive use of skin grafts taken from other body parts.

Nerve Damage

- Excision of a nerve that is involved by tumor.
- Neuropraxia as a result of the need to mobilize major nerves during LSS.
- Local pressure on nerves during long surgical procedures.
- Direct nerve damage resulting from nonsurgical treatments such as radiotherapy and effects of neurotoxic agents.

Vascular Damage

- Excision of major vessels because of tumor involvement.
- Vascular damage during surgical exploration.
- Vascular spasm due to extensive mobilization of the bundle.
- Limb edema due to venous system damage.

Damage to the Lymphatic System

- Chronic swelling due to the long, deep, and extensive surgical exposures and scarring.

Scars

- Pain, dysesthesias, restricted range of movement (ROM) of joints, active muscle contractions, and blockage of lymphatic drainage can be caused by scars.

Infections

- Infections of bones, implants, and soft tissues are common because of the large areas exposed, the use of large implants, and the fact that many patients are immunocompromised as a result of radiotherapy.

Oncological Treatments

- *Radiotherapy* damages the skin, subcutaneous tissues, and muscles and causes fibrosis, decreased tissue elasticity, and contractures, resulting in joint stiffness. The consequence is delayed wound healing and limb edema. Osteonecrosis or osteopenia causes fragility and risk of fractures that do not heal.
- *Chemotherapy* causes chronic weakness and fatigue; it requires repeated hospitalizations, which make it difficult to maintain the intensity and continuity of a rehabilitation program.

The effects of ILP with TNF on the limb tissues are similar to those of radiotherapy. Although they are more acute, they are also more easily reversible.

THE REHABILITATION PROCESS

Rehabilitation of LSS patients is performed by a multidisciplinary team that includes an orthopedic oncologist, nurses, social workers, dietitians, physiotherapists, occupational therapists, and orthopedic technicians. To plan the pre- and postoperative management the team must understand the surgical procedure and its implications.

Steps in the rehabilitation process include a preoperative physical evaluation of limb function and disability, and pretraining the patient to reduce the rehabilitation time and emotional stress following surgery.

From the time the patient can leave his or her hospital bed to discharge home, the goal is to bring the patient as close as possible to independence in everyday life. Unlike many postsurgical patients, individuals who undergo LSS are not transferred to rehabilitation centers; instead they must return as soon as possible to chemotherapy or radiation therapy. Therefore, it is essential to distribute information about the surgery to the appropriate supporting medical teams in the community while closely following these patients for extended periods (see the Appendix).

TREATMENT TECHNIQUES FOR ACCESSORY AIDS

The following techniques are useful at different stages of the rehabilitation process.

- *Improving ROM*. This is done manually by the therapist and with slings, continuous passive motion (CPM), and pulleys.
- *Muscle contraction*. This entails static contractions by manual actions. In advanced stages, open-chain exercises against gravity, springs, and weights are used, as are closed-chain exercises with weight lifting.
- *Pain-relief techniques*. These include electrotherapy, heat, massage, hydrotherapy, joint movements, and mobilization.
- *Soft-tissue treatment*. Surgery and radiation therapy damage tensile strength (TS) which is the ability of the tissue to stretch. The goal of treatment after soft-tissue injury is to encourage the tissue to regain its tensile strength as soon as possible.

The treatment principles are altered according to the healing stage of the tissue. There are four stages: injury, inflammation, regeneration, and remodeling. In the inflammation stage, for example, manual techniques are avoided because they influence the arrangement of the collagen fibers and there is a risk of breaking the fibrin network.[9]

Therapeutic Techniques

- Passive psychological stretching. This involves applying a longitudinal stretch to the tissue by using passive physiological joint movement.

Mobilization of Specific Soft Tissues

Scar Treatment

LSS leaves long and deep scars that cause adhesions of the skin and soft tissues. This limits ROM and causes pain. Mobilization of the scar is very important. Methods include deep friction and stretching, which make the scar soft and flexible. Ultrasound can be used to soften the scar.

Lymph Drainage

The lymphatic system is a fine drainage network that returns proteins and fluids into the circulation. It functions in only one direction. It begins in the intracellular space and gradually joins vessels that pass through the lymph nodes, finally draining into the main veins. Edema develops when fluids (rich in protein and fat) collect in the intracellular space after damage to the lymphatic system. Surgical wounds, especially deep ones, damage to the lymphatic system. In addition, the deep scars of LSS impede lymphatic drainage.

The goal of lymph damage is to reduce edema by influencing the superficial network. This is done by applying fine and accurate manual movements in a certain pressure that activate the lymphatic system and produce a pumping action in the tissue.

Treatment also includes the use of special pressure bandages that help to maintain skin elasticity and prevent additional fluid congestion.

The pressure bandage is the main way to soften an extant edema. Treatment should not be introduced until about 6 weeks after surgery, when the wound has healed and the patient's status is clear. Treatment should not be given during radiation therapy.[10] In advanced stages of the treatment it is possible to use a Jobst pressure bandage (Jobst Ireland Ltd., Tipperary, Ireland). An accurate measurement is made to adjust a sleeve to the extremity.

Hydrotherapy

After completion of chemotherapy or radiation therapy, and considering the condition of the immune system, the skin, and the wound, it is possible to treat the patient with hydrotherapy. The buoyancy effect and relative lack of gravity. As well as the analgesic influence of warm water allow easy performance of physical therapy requirements. On the other hand, water resistance can be used as a means of reinforcement of muscle strength.

Orthoses and Splints

Upper extremity orthoses are indicated when the extremity needs a mechanical support to prevent a fracture; there is a need to stabilize a joint in a functional position in order to prevent movement; or there is a neurological impairment.

Orthoses may be static or dynamic:

- *Statis orthoses* include the cock-up splint, used for keeping a functional wrist position.
- *Dynamic orthoses* include a device used for radial palsy.

Lower extremity orthoses include the static *peroneal splint*, which keeps the dorsiflexion in 90° after damage to the peroneal nerve, and the *foot positioner*, which resembles a peroneal splint.

REHABILITATION CONSIDERATIONS OF SPECIFIC ANATOMIC SITES

Distal Femur and Knee Joint

The distal femur is the most common location for benign and malignant primary bone tumors. It is the site where the most experience has been gained with LSS.[11] The following details are relevant for the rehabilitation team:

1. The surgical approach depends on the tumor location (lateral or medial).
2. Extent of resection of the distal femoral bone (1/3, 1/2, or 2/3).
3. Resection of the muscle ends: vastus intermedius muscle (always resected), vastus medialis, vastus lateralis, rectus femoris, medial hamstrings (semitendinosus, semimembranosus), lateral hamstrings (biceps femoris), gracilis, sartorius, medial and lateral gastrocnemius muscles (the origin is always resected).
4. Replacement of the distal part of the femur by an endoprosthesis/allograft and stabilization of the stem (cemented/noncemented).
5. Replacement of the knee joint, including the tibial surface (usually not including the patella).

6. Type of endoprosthesis. Two types of endoprosthesis are used at the knee joint: a constrained (hinged) device, which enables movement in one plane (flexion/extension), and a semiconstrained (rotating hinge) device, which enables movements in two planes (rotation and flexion/extension). The rotating hinge provides varus–valgus and anteroposterior stability but allows rotation between the femur and the tibia. The constrained joint is more stable and is widely used in patients with large resections or in patients with a poor prognosis.
7. Local muscle flap transfer to cover the endoprosthesis (transferring the gastrocnemius muscle anteriorly to cover the endoprosthesis) or transferring the muscle to reinforce the loss of major quadriceps mass (suturing the hamstrings anteriorly).
8. Nerve impairment: peroneal nerve palsy (in the lateral approach) is quite rare; femoral nerve and tibialis posterior nerve impairment are rare.
9. Leg-length discrepancy: Up to a 2 cm shoe insert can be given; when more is required it is necessary to raise the shoe.

Principles of Rehabilitation

1. A knee immobilizer is used for 3–6 weeks or until the soft tissues are satisfactorily healed and the quadriceps muscle is strong enough to stabilize the knee while walking.
2. ROM: knee flexion with CPM (Figure 36.1) is started 5–7 days after surgery, if the wound is healed. Afterwards, the patients starts performing assisted active and active flexion exercises. The range of extension should be monitored by the therapist.
3. Muscle strengthening: extension (quadriceps) and flexion (hamstrings, gastrocnemius) are supported by static contraction, assisted active, and active exercises (e.g. open- and closed-chain exercises).

While the degree of quadriceps resection is an important factor influencing the knee extension strength and the functional outcome, it is not the only one. Other factors are history of deformity, details of the surgical technique leading to changes in muscle fiber orientation and length–tension properties, postoperative perioprosthetic scar tissue, prosthetic design, and the rehabilitation program.[12,13]

4. Ambulation: the goals in terms of activities of daily living include: independence in transfers (e.g. bed to chair) and, in cases of peroneal palsy, the use of a peroneal splint, in order to facilitate correct stepping. In cases where a cemented endoprosthesis is used, walking with weightbearing using crutches is permitted and, if the custom prosthesis is not cemented, weightbearing should be deferred for at least 6 weeks.

Figure 36.1 A CPM machine is utilized following distal femoral replacement only if the wound is well healed. In general this does not begin until postoperative day 5–7.

Complications

Patellar dislocation is rare and observed only after resection of the vastus lateralis.[11]

PROXIMAL TIBIA AND KNEE JOINT

This is the second most common site for primary benign and malignant bone tumors. LSS in this site is more difficult than in most other anatomic sites because of the lack of soft-tissue covering.[14] The following details are relevant for the rehabilitation team:

1. The surgical approach depends on the tumor location (lateral or medial).
2. Extent of resection of the proximal tibial bone (1/3, 1/2, 2/3).
3. Extent of resection of the proximal part of the fibula (tibiofibular joint only, fibular head, or proximal third of the fibula).
4. Detachment or complete resection of the patellar tendon.
5. Surgical options for reconstruction of the extensor mechanism (a) suturing the patellar tendon to the hook on the endoprosthesis with Dacron tape; or (b) suturing the gastrocnemius muscle above and to the patellar tendon stump to reinforce the extensor mechanism. The transposing of the medial gastrocnemius muscle, lateral gastrocnemius muscle, or both, with a skin graft is used also to cover the endoprosthesis.

6. Detached muscles: biceps femoris muscle, pes. anserinus muscles and the popliteus muscle (always resected).
7. Detachment and transfer of muscles to cover the endoprosthesis: medial/lateral gastrocnemius muscles.
8. Partial muscle resection: all the attached muscles to the resected proximal tibia (anterior tibialis, extensor digitorum longus, extensor hallucis, soleus, flexor digitorum longus).
9. Replacement of the proximal part of the tibia by an endoprosthesis and stabilization of the stem (cemented/noncemented).
10. Replacement of the knee joint. This procedure resembles that used for the distal femur. In addition, there is a hook on the tibial body that is used for attachment of the reconstructed patellar tendon (pseudotibial tuberosity).
11. Peroneal palsy (deep and/or superficial peroneal nerve) is more common in these operations because of the proximity of the nerve to the operating area or the tumor itself.
12. Leg-length discrepancy (same as the distal femur).

Principles of the Rehabilitation Program

The knee is kept in extension using a brace for 4–6 weeks to permit healing of the new joint capsule and the patellar tendon, and to enable the establishment of a good extensor mechanism.[14]

1. Muscle strengthening: during this period, which lasts from 4–6 weeks, the patient strengthens the knee muscles and the extremity muscles. Static, assisted active, active, and weightbearing exercises are used.
2. ROM: after removal of the brace the patient stars gradually flexing the knee using CPM and active exercises.
3. Ambulation: partial weightbearing with a walker or crutches is used for the first 4–6 weeks and full weightbearing is used thereafter. A peroneal splint is used in patients with peroneal palsy.

Complications

These patients experience varying degrees of extension lag and late extensor mechanism rupture.[14] There are several ways to reconstruct the extensor mechanism:

1. Gore-Tex reinforcement: using the middle third of the quadriceps muscle tendon, together with part of the patellar surface, and creating a "new" patellar tendon reinforced with Gore-Tex (W.L. Gore and Associates, Inc., Flagstaff, Arizona, USA) implants.[15]
2. Fibula transposition: the proximal fibula is ventralized and medialized, and the patellar ligament is sutured to the stumps of the tendon of the biceps femoris muscle and the lateral collateral ligament on the fibular head.[16]
3. Transposition of the gastrocnemius muscle: reconstruction is accomplished using a strap of fascia and transferring the femoral insertion of one or both heads of the gastrocnemius muscle.[16]
4. A combination of the above.[16]

PROXIMAL HUMERUS AND GLENOHUMERAL JOINT

The shoulder girdle consists of the proximal humerus, scapula and clavicle as well as the surrounding muscles. The proximal humerus and the scapula are the third most common sites of primary bone sarcomas. Tumors at this site are likely to involve the deltoid muscle and the axillary nerve, and they are almost always sacrificed when the proximal humerus is resected. In most cases shoulder function is severely damaged but extremity function is close to normal.[17] From a rehabilitation perspective, LSS in the shoulder offers a superior functional outcome to forequarter amputation or shoulder disarticulation.[1] The following details are relevant for the rehabilitation team:

1. Extent of resection of the proximal humerus (1/3, 1/2, 2/3).
2. In many cases resection of the lateral part of the clavicle and parts of the scapula (the acromion, coracoid process, glenoid fossa, or all of these).
3. Detachment and/or resection of muscles: the deltoid muscle and the long head of the biceps brachii muscle are almost always resected. Insertions of the three muscles of the coracoid process, rotator cuff, pectoralis major and minor, teres major, latissimus dorsi, triceps brachii, and trapezius muscles are almost always excised.
4. Replacement of the proximal humerus with an endoprosthesis and stabilization with a cemented/noncemented stem.
5. Creating a concave surface on the lateral border of the scapula as a pseudoglenoid when needed.
6. Suturing the remaining muscle stumps to each other and to the endoprosthesis (pseudo greater tuberosity).
7. Nerve resection (mostly the axillary nerve).

Principles of the Rehabilitation Program

For the first 3–4 days the hand is stabilized to the body (bulky, Dessaut-like dressing). At this stage the patient moves the elbow, wrist, and hand. After the bulky dressing is removed only a pendular movement in the "shoulder joint" is permitted for 3–4 weeks. Active and passive movements in the scapula (elevation, depression, protraction, retraction) are permissible. As a result of the surgical procedure (i.e. muscle detachment, lack of joint stability, weight of the extremity with the endoprosthesis, pain), the patient's ability to posture the head, neck and the shoulder girdle is impaired. It is important to instruct the patient on proper posture, after which passive and assisted active exercises are initiated.

The active exercises should be focused on enhancing the patient's functional ability. Occupational therapy has a very important role in training the limb to be a usable "helping hand". During rehabilitation it may be necessary to use accessory aids: a simple *sling* in the first stages to help overcome the weight of the limb, a *band* that holds the limb adducted to the body so that the limb will stay attached while the patient changes position in bed, and a *shoulder mold* that improves the contour of the cosmetic deformity in the shoulder caused by the lack of muscle tissue.

PROXIMAL FEMUR AND HIP JOINT

The proximal femur is the fourth most common location for primary bone sarcomas. Most tumors of the proximal femur can be managed by LSS. The femoral vessels, femoral nerve and sciatic nerve are rarely involved by tumor. Rehabilitation may take up to 1 year.[18] The following details are relevant for the rehabilitation team:

1. The surgical approach is almost always lateral (anterolateral or posterolateral shift).
2. Extent of the proximal femur (1/3, 1/2, etc.).
3. Resection of all the muscle insertions that are attached to the proximal femur (i.e. iliopsoas, external rotators, gluteus medius/minimus, and (sometimes) part of the glueteus maximus, adductors, and quadriceps muscles). The tensor fascia lata muscle and the iliotibial band (ITB) are almost always damaged during the surgery.
4. Replacement of the proximal femur with an endoprosthesis/allograft (cemented/noncemented). A bipolar cup is used whenever possible. This is better than total hip arthroplasty because it gives greater stability and has less risk of dislocation.[18]
5. Suturing most of the muscle stumps to each other in order to cover the implant and create a pseudocapsule that will protect the implant from dislocations and infection.
6. Attachment of the abductors into a hook on the endoprosthesis (pseudo greater trochanter).
7. Leg-length discrepancy.

Principles of the Rehabilitation Program

1. For 6–8 weeks the patient should avoid adduction, flexion over 90°, and internal rotation about the hip joint.
2. The leg has a tendency to fall into external rotation because the adductors and the external rotators of the hip are "attached" in a shorter position during the surgical procedure. The leg should be kept in a neutral position within a splint (see Figure 36.2).
3. Exercises to improve ROM of the hip and knee joints.
4. Muscle strengthening: gradually exercising to improve active mobility of the hip joint and strengthening the muscles gravity is recommended for the first 4–6 weeks (within the limits of pain). The gluteus medius and tensor fascia lata muscles are attached to the ITB. The surgical wound damages the ITB and causes a scar, which shortens the band; therefore the hip tends to be in abduction. The gluteus medius is in its inner range, which leads to weakness. As a result it is important to strengthen the gluteus medius and stretch the ITB.[19]
5. Ambulation: the patient walks with a walker or crutches for 6–12 weeks, then switches to a cane. Except for the elderly, most patients are eventually free from ambulatory aids. Some have a Trendelenburg gait because of weakened abductors.

Figure 36.2 Postoperatively it is essential that the extremity is kept in the neutral position and not allowed to rotate externally. Following a distal femur or proximal tibial replacement there is a normal tendency for the knee component to rotate externally due to gravity until the muscles are strong enough to maintain the leg in a neutral position. Therefore, an external foot splint is utilized as shown.

Complications

Hip dislocation and a Trendelenburg gait.

PELVIC GIRDLE

The pelvic anatomy is complex, and resection and reconstruction of bony tumors and defects in this area are more difficult than LSS of cylindrical long bones. The pelvis is covered by a large mass of muscles that usually restrict the tumor from reaching the adjacent vessels and nerves; however, there is occasional damage of the nerves (sciatic or femoral).[20] Moreover, involvement of internal organs in the pelvic space (uterus, bladder, bowel) may require excision or reconstruction.

There are four types of pelvic resection:[20]

Type I – ilium: usually includes resection of the gluteus medius, gluteus minimus, and iliacus muscles. The sartorius, tensor fascia lata and abdominal muscles are detached.

Type II – periacetabulum: the major muscle detached is the rectus femoris.

Type III – ischium and pubis: the detached muscles include the hamstrings, external rotators, adductors, and gracilis.

Type IV – perisacroiliac joint: the major detached muscle is the gluteus maximus.

Types of reconstruction include: (a) various improvisations using nails, plates and cement, and bone graft; (b) saddle prosthesis – fixed distally to the femoral diaphysis (the head and neck of femur are resected) and proximally hinged under the remaining ilium; (c) custom-made implants or allografts, and (d) arthrodesis. Not all pelvis resections require reconstruction.

Principles of the Rehabilitation Program

1. The patient remains in bed for 4–7 days, depending upon the extent of surgery.
2. The patient is taught to mobilize in bed (e.g. use of the other limb, the torso).
3. When getting out of bed the patient starts partial weightbearing (PWB) with ambulatory aids.
4. Occasionally there is a need to teach some special techniques and to use aids to help in ambulation (e.g. hiking of the nonoperated side to help in moving the operated leg, raising the shoe of the nonoperated leg).
5. General strengthening of the muscles of the lower extremities.

Complications

These include a Trendelenburg gait, dislocations, and fractures around the hip or pseudohip, surgical damage to the sciatic or femoral nerve, and visceral injuries (e.g. to the bladder, rectum).

LSS IN CHILDREN

The most common primary malignant bone tumors in children are osteosarcoma and Ewing's sarcoma. They develop in the same anatomic locations as in adults, namely the knee and shoulder joint areas.

Children who undergo LSS, in contrast to adults, need to be hospitalized repeatedly for lengthening procedures. This prolongs rehabilitation and causes repeated cycles of functional regression because of soft-tissue stretching and stiffening that follow each procedure.

During LSS the operated leg is lengthened by up to 2 cm if possible. When the adjuvant chemotherapy and/or radiation therapy has ended, and the child has grown, the procedures for lengthening the extremity begin. Each lengthening operation extends the extremity between 1.5 and 2 cm. The procedure is carried out once or twice a year, according to the individual rate of growth. Once the skeleton reaches maturity the endoprosthesis is changed to its final form.

In children, endoprostheses are usually noncemented. As a result of the repeated lengthening procedures, various complications may develop. These include higher rates of infections, thick scarring that limits ROM of the adjacent joint, stiffness of soft tissue because of the repeated stretching, higher chances for vascular and nerve damage, skin problems, lack of muscular cover, and a frequent need to lengthen tendons.

After each lengthening procedure the child needs to return to the rehabilitation program and learn to cope again and again with the above problems.

Principles of Rehabilitation

The aims of rehabilitation include enhancement of ROM of joints, muscle strengthening, scar treatment, soft-tissue mobilization, and provision of ambulatory aids (e.g. crutches) if needed.

Many children experience psychological problems during the course of the disease. Frequent hospitalizations for surgery, chemotherapy, or radiotherapy necessitate lengthy absences from school. Young children feel frustrated by being isolated from their environment. 'There is a loss of opportunity for play, feelings of inadequacy due to impaired mobility, problems at school and fears of separation and death' according to Frieden *et al.*[5] The child might feel victimized. Depression or bad moods can influence the rehabilitation process and the child's ability to cope. The issues affecting teenagers are often related to their body image. They may have difficulties coping with disfigurement and physical disability. In addition, there are problems in identifying with their peer group and concern as to how patients are perceived by members of the opposite sex. Their families might experience guilt or be overprotective.

It is the therapist's duty to deal with all these problems, acquire the child's trust, bond with the family, and accompany the patient and family throughout this period.

REHABILITATION IN PALLIATIVE ONCOLOGY

Rashleigh[4] described palliative care as having a holistic focus; that is, it refers to the active interdisciplinary care, including an effort to meet the physical, social, psychological, and spiritual needs of the patient and his or her family or caregivers.[4] Many cancers metastasize to bone (spine, pelvis, ribs, and long bones). Metastases weaken the bones and increase the risk of pathological fractures. The patients are operated upon for pending fractures, fractures, and intractable pain.[4] The aims of palliative treatment are to control pain, increase mobility, reduce dependence, and enhance the quality of life. The complex issue of physical palliation of the terminally ill involves aspects of musculoskeletal, neural, respiratory and circulatory therapeutic management, as well as education.[4]

The components of rehabilitation treatment in the palliative setting include:

1. Mobilization and ambulation prevent the patient from becoming bedridden and developing bedsores, osteopenia, hypercalcemia, and respiratory and urinary tract infections.[4]
2. Pain relief by electrotherapy (TENS), hydrotherapy, and medications, including opiates.
3. Respiratory therapy (toilet of airways).
4. Accessory aids and modification of the patient's surroundings.

An essential element of a home visit assessment is the education of palliative care patients and their caregivers to utilize energy conservation strategies and employ mechanical aids to cope with limited physical resources.[4]

Despite the short period of time that the patient will survive, intensive rehabilitation can improve the quality of life, enable the patient to return to his or her familiar surroundings, bring optimal independence of function, and help avoid dependence.[4,21]

APPENDIX: RESECTION OF THE DISTAL FEMUR AND KNEE JOINT (A SAMPLE PROTOCOL FOR THE COMMUNITY REHABILITATION TEAM)

Surgical Procedure

- Surgical approach (lateral/medial)
- Resection of the distal femoral bone (1/3, 1/2, or 2/3)
- Resection of muscle ends: vastus intermedius, vastus medialis, vastus lateralis, rectus femoris, medial hamstrings, lateral hamstrings, gracilis, sartorius, medial and lateral gastrocnemius.
- Replacement by an endoprosthesis/allograft/autograft composite. Stabilization of the stem (cemented/noncemented)
- Replacement of the knee joint (constrained/rotating hinge)
- Muscle flap transfer: ____________________
- Nerve impairment (Yes/No)? Which? __________
- Leg-length discrepancy: ______ cm
- Comments

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Hospitalization

Days 1–5 after surgery
- Resting cast/splint for 3 days
- Quadriceps muscle – static contraction
- Out of bed to the armchair: 2–3 days after surgery
- After cast removal: exercises to improve flexion and ROM using CPM; deferred until wound is well healed, 5–7 days.
- Passive movement of the ankle in cases of peroneal palsy.

5 days after surgery until discharge from hospital
- Walking PWB/NWB with walker/crutches for 6 weeks
- Knee immobilizer
- Exercises: climbing stairs
- Peroneal splint as needed
- Raising of shoe as needed
- Knee muscle strengthening: start with assisted active exercises in supine, prone, and sitting positions (using slings, pullies, or springs without weightlifting for the first few weeks)
- Electrotherapy if needed
- Ankle dorsiflexion when needed
- Patient's condition at time of discharge:

After discharge (±2–6 weeks)
- Ambulation: gradual exercise to improve weightbearing; stop use of the accessory aids, including the knee mobilizer
- Continuation of muscle strengthening: add closed-chain exercises (while standing) to strengthen the quadriceps muscle, stair climbing, exercises to improve weightbearing
- Treatment of the scar after removal of the sutures

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