Complications in Treatment of Spinal Cord Tumors and Prevention Surgical Strategies

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25.1   Introduction

Both extramedullary and intramedullary intradural spinal cord tumors (SCTs) will often create early neurological signs and symptoms due to the infiltration and/or compression of neural structures in small spatial compartments, such as the spinal dural sac or a vertebral canal. Gross total tumor resection, whenever possible, is the goal in surgical treatment in order to relieve symptoms and preserve or improve neurological function, as well as to avoid tumor recurrence and repeated surgery. However, in cases of malignant or infiltrative tumors, radical resection may not be possible and may not prolong survival [1, 2]. In their classic work, Yasargil et al. [3] reported a successful radical removal of intramedullary spinal tumors using microsurgical techniques with favorable neurological outcomes. Since then, there have been many other studies of SCT reporting satisfactory outcomes [4–21].

Postoperative functional outcome mainly depends on tumor histology, molecular biology, genetic basis, tumor size and location, preoperative neurological status, utilized surgical technique, and postoperative care [12, 16, 22, 23]. Patients with severe preoperative neurological deficits may not recover functioning after surgery;

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their functioning may even worsen. Good results with better postoperative recovery and better functional outcome are more common in patients with short-term neurological deficits [11]. Upper thoracic lesions, for example, are associated with the highest rate of surgery-related complications and unfavorable postoperative functioning, possibly due to the anatomically narrow canal and relatively poor "transitional" blood supply in this region of the spine [12, 13]. With spinal nerve sheath tumor surgery, surgical complications are more common in cervical and lumbosacral tumors than in thoracic lesions [17].

Intraoperative imaging and neuronavigation are helpful tools to precisely localize lesions, lessen exposure, and preserve of normal spinal function. Bony exposure and extent can be optimized before dural incision, which may also be tailored to reduce the incidence of complications, such as leakage of cerebrospinal fluid (CSF) or accidental neural tissue damage.

Careful microsurgical technique is necessary to avoid postoperative neurological complications and infections. Despite precise techniques, a number of the patients may report sensory symptoms, such as dysesthesia after surgery due to surgical manipulation and dissection of the cord's posterior columns. Sensory disturbances may last a long time, but will usually improve postoperatively after a few months. They can often be persistent, which can interfere with early postoperative rehabilitation. They also may not respond to medical treatment. Residual symptoms may reduce patients' quality of life in a long-term. To avoid this, patients should receive neurophysiologic monitoring throughout surgery. Postoperative neurologic deficits after SCT surgery can also happen due to nerve root injury or avulsion, removal of a functional nerve root, or spinal cord manipulation with glial scarring (Fig. 25.1) [18].

Kalakoti et al. analyzed surgical risk factors and postoperative complications following resection of benign intradural spine tumors in adults in both low volume and high volume centers [24]. The study showed that there was a decreased risk for the most unfavorable outcomes for patients who underwent surgery at high volume centers. Inpatient postoperative risks included mortality (0.3%), wound complications (1.2%), cardiac complications (0.6%), deep vein thrombosis (1.4%), pulmonary embolism (2.1%), and neurological complications, including dural tears (2.4%).

Fisahn et al. analyzed readmission, reoperation, and complication rates of spinal cord tumor surgery highlighting how it is still involved with morbidity even in experienced and specialized centers [25]. In an analysis of National Surgical Quality Improvement Program (NSQIP) registry, Karhade et al. reported that 10.2% of patients undergoing surgery for spinal tumors were readmitted within 30 days, 5.3% underwent a reoperation, and 14.4% experienced a major complication [26]. The most common complications were surgical site infections (3.6%), systemic infections (2.9%), and venous thromboembolism (VTE) (4.5%). The strongest predictors of adverse events were comorbidities, preoperative steroid use, and a higher American Society of Anesthesiologists (ASA) classification [26]. Weber et al., reported a 50% increase in the mean hospital cost per patient with cerebrospinal fluid (CSF)-related postoperative complications after elective spinal surgery.

Fig. 25.1 Postoperative T-2 weighted sagittal MRI showing progressive degenerative changes—spondylosis and herniated cervical disk at C5/6 with kinking of the spinal cord—and MRI signal intensity change after removal of intradural intramedullary tumor and 2 level laminectomies 2 years after surgery

Furthermore, these complications may lead to additional complications, creating a vicious circle and even lethal outcomes [27].

In this chapter, we discuss different surgical complications, and their prevention and treatment.

25.2 CSF Dissemination, Seeding and Metastasis

SCT can disseminate through CSF pathways and cause metastases along the neural axis, albeit infrequently (Fig. 25.2). This is common in malignant and more aggressive SCT, such as grade III and IV astrocytomas and intradural chordomas, but has been reported also in myxopapillary ependymomas and meningiomas [28–30]. Surgical or secondary seeding of myxopapillary ependymomas after surgery is relatively uncommon—but usually occurs after subtotal resection—with recurrence at the site of resection in adults, and more often in the pediatric population, together with the disseminated disease. However, primary seeding of myxopapillary ependymoma has been reported both in adult and pediatric population [30]. Arnautović and Al-Mefty found a case of cervical spine chordoma with surgical seeding as a consequence of the implantation of tumor cells along the surgical route in the neck muscles and subcutaneous tissue [28]. Ito et al., reported a case of intraspinal meningioma with malignant transformation from atypical to anaplastic meningioma with distant hematogenous metastasis [29]. Careful postoperative craniospinal magnetic resonance imaging (MRI) evaluation and surveillance with and without contrast should
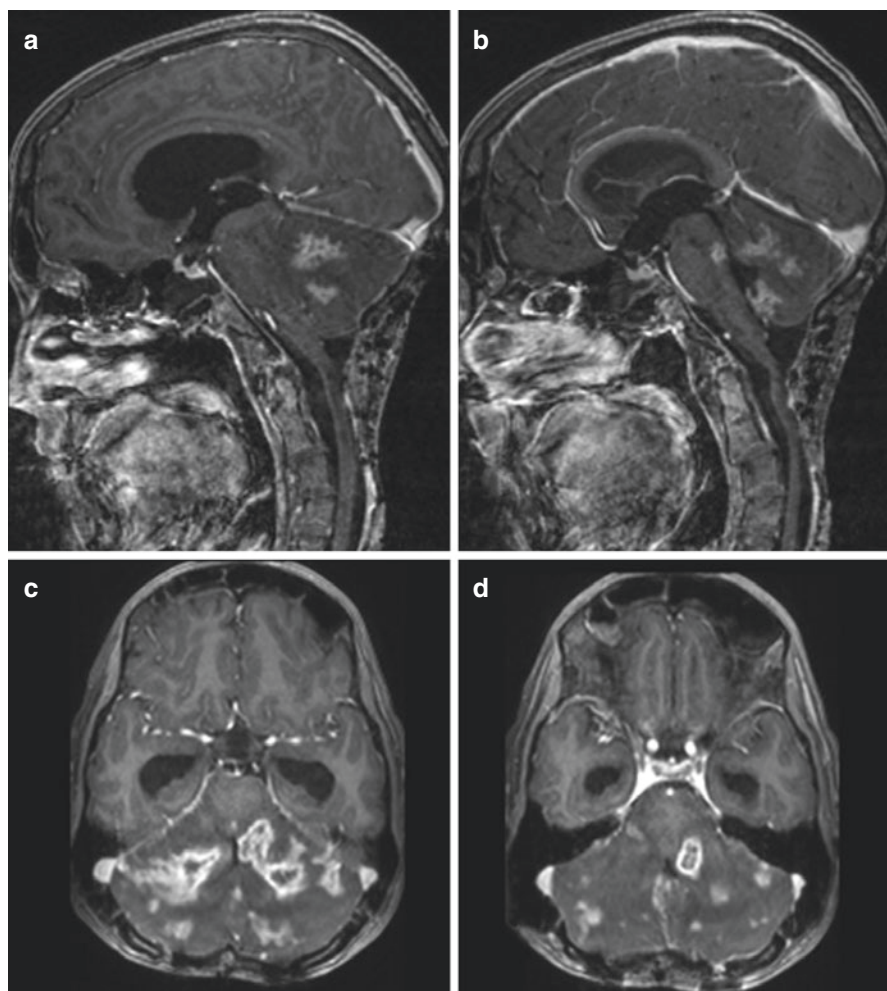
Fig. 25.2 Postoperative T-1 weighted MRIs with contrast. (**a**, **b**) Sagittal and (**c**, **d**) axial views showing diffuse enhancing cerebellar metastases 2 years after resection of pediatric primary spinal intramedullary embryonal tumor with multilayered rosettes (former PNET)

be considered regularly during follow up and in case of unexpected or unexplained neurological deterioration.

These complications can be provoked by surgical manipulation and/or partial resection and will need to be treated with additional surgery, irradiation, and/or chemotherapy. However, radiation therapy after subtotal resection of spinal cord tumors may complicate future surgery since the spinal cord can be damaged with effective radiation doses. Additionally, it can create spinal column deformity and produce a secondary malignancy as well [31, 32].

Introduction of radiosurgery helped to minimize these concerns. Promising results with low rates of complications have been shown with stereotactic radiosurgery treatment for benign tumors, but further studies are needed to determine the indications and outcome profile of stereotactic radiosurgery for intradural spinal tumors [33].

25.3   Spinal Column Deformities

Spinal column deformities are a possible postoperative complication of early or late intradural spinal tumor surgery (Fig. 25.3). Adequate approach to such tumors may require extensive laminectomies which may result in spinal instability that may require further surgical treatment involving spinal instrumentation and fusion [32, 34, 35]. Advancement of preoperative spinal column degenerative changes and/or development of the new changes during the follow-up can be exaggerated or caused by inadequate or extensive bone decompression for the removal of SCT (Figs. 25.1 and 25.3). Careful preoperative planning, analysis of MRI scans, computerized tomography (CT) scans in sagittal, coronal, and axial reconstruction (including bone windows and anterior-posterior, lateral, dynamic, flexion and extension X-rays) are essential in planning the extent and type of operative bone resection and the possible need for simultaneous instrumented fusion.

Fig. 25.3 Postoperative T-1 weighted sagittal pre-contrast MRI showing kyphotic deformity in a 16-year-old patient after multiple laminectomies in the upper cervical spine
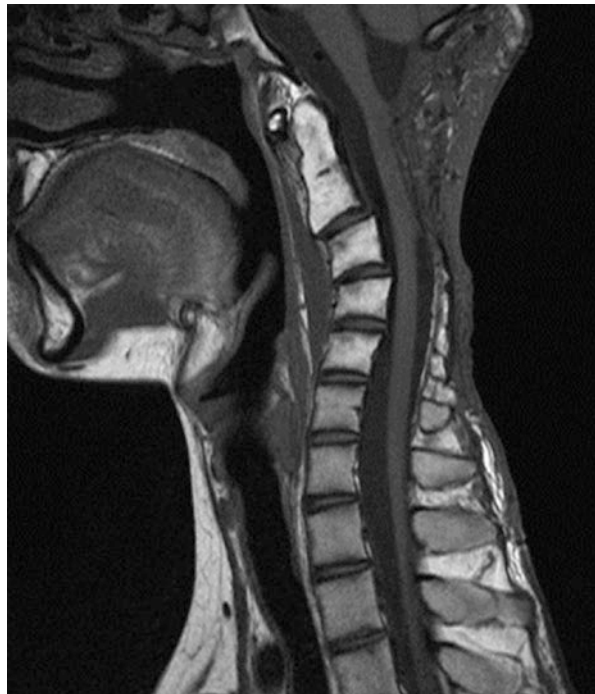
Papagelopoulos et al. found that 28% of children and young patients treated with lumbar or thoracolumbar multisegment laminectomy for intraspinal tumors exhibited spinal column deformity and instability [35]. Laminoplasty for prevention of spinal deformity after spinal intradural tumor surgery is a strategy used by many authors [36]. In 1989, Chiou et al., reported that unilateral approaches were advantageous for spinal tumor surgery with fewer complications, especially for juxtamedullary benign tumors [37]. With a unilateral technique, stability can be preserved due in part to the protection of musculoligamentous attachments and posterior bony elements [38].

Less invasive approaches—or minimally invasive surgical (MIS) approaches—recently have gained popularity in spinal intradural surgery. MIS techniques showed efficacy and safety for the treatment of spinal intradural tumors with no increased complications. Some authors reported a reduced complication rate with a significant decrease in hospital costs [39–42]. Parihar et al., reported a study with endoscopic management of spinal intradural extramedullary tumors in 18 patients with a short follow-up [43]. Although it is a technically demanding procedure, endoscopic management for this kind of pathology was shown to be efficacious and safe. The advantages for spinal intradural tumor MIS may include decreased operative blood loss, shorter hospitalization, and less postoperative pain. Disadvantages include prolonged operative times, decreased surgical exposure, and decreased difficulty with closing the dura due to a limited surgical corridor and a steep learning curve. To date, however, MIS approaches have not gained widespread acceptance in SCT surgery.

25.4   Complications Related to Anesthesia

In order to obtain the best surgical results, it is necessary to optimize the management of preoperative and perioperative anesthesia. Any potential health problem and preoperative risk factors should be evaluated and any comorbidity that arises should be addressed. For surgeries expecting blood loss, 1 or 2 blood doses should always be reserved for transfusion. (Anesthetic considerations will be discussed in a separate chapter of this book.)

25.5   Surgical Positioning Complications

Correct positioning of the patient for spine surgery is imperative and of great importance. Complications associated with surgical positioning are rare, and therefore tend to be underreported in the literature. The risk for these complications can be minimized with careful surgical planning and close detailed attention during the patient's positioning, using prevention strategies to avoid complications.

25.5.1 Pressure Injuries

Decubitus ulcers, or pressure sores, are local skin and underlying tissue injuries resulting from prolonged pressure during a surgical procedure due to inappropriate positioning. Prone positioning places pressure on the forehead, chin, shoulders, thorax, pelvis, knees, and ankles. Prolonged pressure lasting for a few hours can cause tissue ischemia and resulting necrosis. The risk factors for the development of ulcers are older age, obesity, diabetes, and the administration of steroids, although the duration of surgery may be the biggest risk factor. Appropriate padding and attention during positioning should be given to protect bony prominences and joints (e.g., the facial area, elbows, anterior superior iliac spines, knees, and feet). External genitals must be free of pressure or traction caused by urethral catheters.

Compartment syndrome after spine surgery is rare, albeit anterior thigh and anterior tibial compartment syndromes have both been reported. Two cases of anterior thigh compartment syndrome after lumbar spine surgery have been reported [44]. Both patients were obese and positioned on a Jackson table with well-padded bony prominences, but the thigh and iliac crest pads were switched in order to increase lumbar lordosis. Postoperatively, the patients complained of moderate quadriceps weakness with pain and stiffness in their thighs. In one case, the patient improved and postoperative MRI of the thighs revealed local muscle necrosis. In the other case, the patient had severe pain and thigh swelling. Consequently, fasciotomy was performed on postoperative day 2. In spite that, the patient developed rhabdomyolysis and acute kidney injury [44].

25.5.2 Hemodynamic Complications

Prone positioning during spinal tumor surgery can seriously affect the patient's vascular system. If the abdomen is not free of compression during the surgery, this can restrict the blood flow through the inferior vena cava, which then results with swelling of the epidural veins. Consequently, the blood stasis in the spinal canal can cause excessive bleeding in the surgical field, which can aggravate the operation, significantly extend the time of the procedure, and increase blood loss. There is a risk of hypovolemia with postural hypotension and reduced cardiac function in the prone position combined with the excessive blood loss can deteriorate hypoperfusion to multiple organ systems, leading to acute kidney failure. Abdominal compression during surgery in the prone position and increased intraabdominal pressure should be avoided with proper positioning on the surgical table using appropriate frames and supports. Although rare, complications following peripheral arterial and vein compression during surgical positioning can also be avoided with properly secured pressure points (i.e., carotid/jugular, femoral).

25.5.3 Ophthalmologic Complications

The incidence of perioperative visual loss after spine surgery ranges from 0.02–0.2% with an increased risk related to prone positioning and comorbidities like diabetes mellitus and coagulopathies. Various causes of perioperative visual loss have been described, including direct compression, anterior and posterior ischemic optic neuropathy, central retinal artery or vein occlusion, cortical blindness, acute closed-angle glaucoma, and amaurosis [45].

Ischemic optic neuropathy is the most common cause of perioperative visual loss. Risk factors include anemia, diabetes, obesity, male gender, Wilson frame use, microvascular pathology, prolonged operative time, longer anesthetic duration, increase in orbital venous pressure due to Trendelenburg positioning and placement of the head below the heart, intraoperative hypotension, and extensive blood loss. Patients usually notice prodromal blurred vision or immediate vision loss upon waking from general anesthesia, which can result in complete blindness with no effective treatment available.

Central retinal artery occlusion (headrest syndrome) is the second-most common cause of perioperative visual loss after spine surgery in prone position. Suggested etiology includes thromboembolism or increased intraocular pressure from direct compression of the ocular bulb, which disrupts perfusion of the retina. Patients usually have unilateral periorbital ecchymosis and visual loss that is irreversible with no effective treatment. A cherry-red spot on the macula can be located with fundoscopic exam.

Cortical blindness is a result of decreased perfusion of the occipital lobe visual cortex. Etiology includes thromboembolism, hypotension, or cardiac arrest. Symptoms are usually barely conspicuous. Fundoscopy is usually normal, but visual field testing will reveal visual field defects. Unilateral cortical blindness is present with contralateral homonymous hemianopia, and bilateral cortical blindness may cause complete peripheral vision loss. After initial ischemic insult, symptoms usually ameliorate without treatment, but full recovery is rare.

Acute angle-closure glaucoma can result from prone positioning in susceptible patients. In 2010, Singer and Salim reported a case of bilateral acute angle-closure glaucoma after spine surgery with eye pain and nausea [46]. Optional treatment is laser iridotomy.

Amaurosis represents the permanent or transient (*amaurosis fugax*) loss of vision without obvious eye lesion. Etiology is proposed to be thrombosis or embolic stroke of the ophthalmic artery. Subconjunctival hemorrhage is an infrequent asymptomatic complication of spine surgery in the prone position with no need for treatment.

25.5.4 Prevention of Ophthalmologic Complications

Strategies to prevent or reduce the risk of ophthalmologic complications are proper positioning with avoidance of ocular bulb compression, neutral-head or slight

head-up position, reverse Trendelenburg positioning and the employment of frames that prevent abdominal compression. Diminishing orbital venous pressure or intra-ocular pressure reduces the risk for perioperative visual loss. Limiting prolonged intraoperative hypotension and the duration of anesthesia is also helpful. Special caution and care should be taken in high-risk patients with obesity and comorbidities like diabetes, vascular disease, anemia, or in patients where excessive blood loss and prolonged operation is expected. Lubrication of the cornea (ocular ointment) and adequate eye occlusion are necessary to avoid direct corneal damage [45]. Using adherent googles for eye protection may help minimize ophthalmologic complications.

25.5.5 Neurological Complications

As a result of inadequate prone positioning, certain neurological complications such as brachial plexus injury, acute cervical myelopathy or spinal cord infarction can occur.

Brachial plexus injury. The brachial neural plexus is under increased risk of traction injury. Postoperative brachial plexus injury and other peripheral nerve injuries are considered common complications due to inadequate positioning during spinal surgery. A neuropraxia or axonotmesis are the most common types of injury. Recovery is expected, but complete improvement is rarely achieved. Hypovolemia, hypothermia, diabetes mellitus, and other adverse conditions increase the risk of nerve injury.

In 2010, Uribe et al. reported a review of postoperative brachial plexus injuries identified in 17 out of 517 patients after spine surgery in prone position [47]. The risk for the injury was higher with the hyper-abduction of the arm, extension and external rotation of the arm, rotation and lateral flexion of neck, and application of shoulder braces. Intraoperative electrophysiological monitoring (SSEPs and MEPs) was used to identify the injury in 15 patients, as well as for the prevention of further injury. No electrophysiological evidence of injury was noticed in the remaining two patients who had transient upper extremity weakness postoperatively that resolved within few weeks [47].

Spinal cord injury. Although a rare complication, injury of the spinal cord can happen during spinal surgery. It may happen indirectly in patients who have concomitant cervical spine disease with severe stenosis or degenerative instability, and can be more common among the elderly population. It is advisable to obtain X-rays of the cervical spine in all patients who may have a suspected cervical spine degenerative disease. It is important to pay attention and carefully manage the neck during intubation, as well as during the positioning of the patient. This injury may result from a combination of neck extension during endotracheal intubation and inappropriate prone positioning, muscle relaxation during anesthesia, and rough manipulation during surgery.

Spinal cord infarction. Following prone positioning, spinal cord infarction is rare but can happen in severe hypotension during surgery, especially when the

patient is hypovolemic. This type of injury occurs during spinal intradural tumor surgery when spinal cord blood supply is endangered due to surgical manipulation. Meticulous surgical technique is necessary to preserve spinal cord vascularization and avoid mechanical damage to the neural tissue.

A rare case of neurologic deterioration after spinal cord tumor surgery was reported due to intradural tension pneumorrhachis [48]. Development of syringomyelia years after removal of benign spinal extramedullary neoplasm may also lead to late neurological deterioration [49].

25.5.6 Other Peripheral Neuropathies

These rare but important perioperative complications can result in significant patient disability and loss of function. In 2009, Welch et al. reported the incidence of perioperative peripheral nerve injury at a single institution during a 10-year period as 0.03–0.1% [50]. The most common perioperative peripheral nerve injury was ulnar neuropathy, which occurred in 0.5% of surgical patients, primarily men between 50–75 years of age. It occurred in 3 out of 7 patients who had developed permanent neuropathy with residual symptoms. The injury had a delayed onset with symptoms developing within a few days postoperatively. The symptoms included the loss of hand grip strength, discomfort, and numbness [50].

Patients with sensory deficits have a better chance for complete recovery compared with those who have combined motor and sensory deficits. Permanent injury leads to a claw-like deformity due to atrophy of the intrinsic muscles of the hand. Injury can occur due to excessive flexion of the elbow or direct pressure on the nerve over the cubital tunnel (or the collateral ulnar artery and vein), or if the arm of the patient accidentally falls off of the arm board during surgery, both of which resulting in reduced perfusion and ischemia.

Cho et al. reported lateral femoral cutaneous nerve neuropathy—or meralgia paresthetica—as a result of direct compression, which accounted for an incidence of up to 24% after spinal surgery in prone position [51]. Compression usually occurs due to the placement of pelvic bolsters near the anterior superior iliac spine. Risk increases with the duration of surgery and degenerative spinal disease with previous damage of the lumbar nerve roots. Patients postoperatively complain of paresthesia in the thigh, although complete resolution is expected within several months.

25.5.7 Intraoperative Neurophysiological Neuromonitoring

The modalities of intraoperative monitoring include somatosensory evoked potentials (SSEP) and motor evoked potentials. SSEP monitoring is used to detect peripheral nerve conduction abnormalities that show peripheral nerve stress and threaten injury. It indicates position modification to protect peripheral nerves from injury under general anesthesia during surgery. The incidence of position related

significant upper extremity SSEP changes during spine surgery ranges from 1.8 to 15% [52].

25.5.8 Airway and Vascular Complications

Some rare airway and vascular complications are associated with prone positioning during spine surgery. Tongue-bite protector devices or strategies should always be considered with patients in the prone position. Miura et al. reported a case of massive tongue swelling, causing airway obstruction after spinal surgery [53]. Orpen et al. reported 2 cases of bilateral avascular necrosis of the femoral head and 1 case of unilateral avascular necrosis after lumbar spine surgery [54]. Signs of early osteoarthritis were seen on preoperative radiographs, which increased probable susceptibility to ischemic insult. Pressure on the inguinal area with artery compression, combined with reduced venous outflow and hypotension, were related to avascular necrosis of the femoral head.

25.6   Wound Complications

Local surgical-site complications are important causes of postoperative morbidity following spinal surgery. Disruption of skin sutures or failure of the wound to heal can lead to rupture of the wound closure, seroma or hematoma formation, wound dehiscence, and wound infection (superficial or deep wound abscess). Risk factors that contribute to wound healing complications are excessive suture tension, poor blood supply, diabetes, steroid treatment, malnutrition, radiotherapy, and immuno-suppressive therapy. All wound complications can lead to wound defects and scarring with poor cosmetic appearance.

Seroma and hematoma are excessive collections of serous fluid or blood in the wound of the surgical site. Hematomas are frequently the result of inadequate primary hemostasis, unrecognized preoperative bleeding diathesis, or increased use of preoperative anticoagulants and prophylactic treatments for deep vein thrombosis. They can cause the skin incision to separate and predispose wound infection since there is no skin barrier against causative bacteria, which can then get into deeper layers of the wound. Clinical manifestations usually appear a few days postoperatively. Seroma or hematoma in the wound may be asymptomatic or manifest with swelling, pain or drainage. Their presence increases the pressure to the wound and compresses surrounding blood vessels, causing wound ischemia and possible tissue necrosis. Hematomas can also cause necrosis due to induction of cytotoxic mechanism by free-radicals. Local erythema, wound induration, fever, and leukocytosis are possible if the collection is infected. Late postoperative hematoma a few days after surgery usually occurs due to the infection that damages vessels at the operation site. Additional diagnostic assessment can be done with ultrasound, CT and MRI to verify the extent of collection, which is especially important in case of possible CSF leak and pseudomeningocele formation. Treating these complications can

sometimes be difficult because it includes fine-needle aspiration, which usually needs to be repeated and carries the risk of infection entering the wound. In many cases the surgical re-exploration is recommended. To prevent seroma and hematoma formation, delicate surgical technique with careful control of bleeding is imperative. Since fluid collects in surgically-created "dead spaces," it is important to diminish or eliminate these potential spaces. Quilting sutures may be used to reduce the "dead space" formation and drains can be inserted for fluid drainage, which is carefully monitored postoperatively, so that the wound layers would close more easily and the body's natural fibrin glue could connect the layers for better wound healing.

Wound dehiscence is a partial or complete disruption of wound closure along the surgical incision. This is a serious complication that may lead to local infection, wound opening, and the possibility of repeated dehiscence. Management includes analgesics, fluid resuscitation, prophylactic antibiotics, early cutting and re-suture of the edges under general anesthesia for clean wounds, or secondary wound closure with frequent sterile dressing changes to the wound and debridement for infected wounds. Prevention is achieved through reducing stress on the wound edges by adequate undermining, avoiding physical stress, adequate nutrition, diabetes control, and certain medications, such as corticosteroids. Sterile strips may be used to reinforce the suture line.

Wound infection is a relatively frequent complication after spinal surgery. These complications significantly increase the length of hospital stay and hospitalization costs. The most common form is a superficial wound infection that occurs during the first week postoperatively and presents with localized pain, redness, and slight discharge or pus draining. It is necessary to make wound culture sampling for appropriate antibiotic treatment according to antibiogram. Wound debridement and cleansing should be regularly done with frequent sterile dressing changes that allow the tissue to granulate. The wound heals by secondary intention over several weeks. Early or delayed closure of infected wounds is not recommended because it is associated with relapse of infection and wound dehiscence.

Cellulitis and abscesses usually present within the first few weeks postoperatively, but can be seen later, even after hospital discharge. They present with pyrexia and local signs of redness and a painful lump due to pressure and inflammation. Cellulitis is treated with antibiotics. An abscess is a collection of pus, bacteria, and debris; treatment—aside from antibiotic use—is surgical incision and drainage. Superficial abscesses can drain spontaneously or require suture removal and probing of the wound, but deeper abscesses require surgical re-exploration for deeper tissues to be inspected for integrity and the source of infection. The wound is left open to heal by secondary intention. Deep chronic abscess can form a wound sinus with possible fistula formation, which requires surgical re-exploration.

To minimize the risk for wound infection, it is important to identify and treat all infections distant to surgical site, as well as to delay elective surgery until the infection is treated. Preoperative hyperglycemia should be avoided and blood glucose level optimized. The night before surgery, patients need to have a shower/

bathe with antiseptic soap. Preoperatively, attention should be given to proper asepsis and surgical site preparation. Commitment to generally accepted surgical principles of delicate and minimal tissue dissection and proper wound closure is important.

Antibiotic prophylaxis for the prevention of wound infection is recommended because the consequences of infection after spinal intradural surgery can be severe. The selected antibiotic should be effective against the predicted pathogens likely to be encountered during the surgical procedure with good tissue penetration and cost effectiveness. Antibiotics are administered intravenously, generally 30–60 minutes prior to surgical incision. The timing of administration is very important because the concentration of the antibiotic should be at therapeutic levels during the time of surgery and for a few hours postoperatively. Usually, the administration of antibiotics is continued postoperatively for the duration of drains *in situ*.

The incidence of antimicrobial resistance has increased over the past few decades and it is of great importance to minimize the continuing emergence of antibiotic pathogen resistance because the current rate of development of new antibiotic treatments is insufficient. It is critically important to avoid unnecessary antibiotic administration and to increase the effectiveness of prescribed antibiotics. Methods of prevention and effective treatment are mandatory to reduce the frequency, morbidity, and costs associated with surgical site infections.

25.7   Other Infective Complications

25.7.1 Meningitis

Meningitis is the most intimidating cause of morbidity and mortality in neurosurgical patients. It can be a serious complication and life-threatening condition after spinal surgery. The reported incidence of postoperative meningitis varies between 0.4 and 7% [55, 56]. In the study by McClelland et al. [56], the incidence of postoperative meningitis was 0.4% out of 492 spinal surgery cases. The most common causative organism was *Staphylococcus aureus*. The incidence of meningitis after spinal surgery is higher in patients with intradural tumors due to dural opening with possible postoperative CSF leak. Every accidental dural tear with CSF leak after spinal surgery increases the chance of developing meningitis. Other risk factors include diabetes, alcoholism, compromised immune system, and immunosuppressive therapy. In case of suspected meningitis, a CSF sample should be taken for gram stain and microbial culture. Antibiotic or a combination of antibiotics should be given empirically or based on sensitivity from gram stain results [57]. Good CSF drug penetration is mandatory. In combination with antimicrobial treatment, corticosteroids reduce the inflammation in the subarachnoid space and improve the outcome of bacterial meningitis. Meningitis is sometimes difficult to treat and without proper prevention, it may become a severe complication that significantly increases the length of hospital stay and the cost of medical treatment, especially in cases with multidrug-resistant infections.

25.7.2 Urinary Tract Infection

Nosocomial urinary tract infections are the most common of all hospital-acquired infections. The risk for developing nosocomial urinary infections increases in patients with urinary catheters, older patients, and those with comorbidities, such as diabetes and obesity. Almost 80% of hospital-acquired urinary tract infections are associated with urinary catheters. Patients with spinal cord tumors or injury have an increased risk for urinary tract infection because of retention and chronic catheter use. The causative organisms usually originate from the patient's endogenous intestinal flora. The most common cause of infection is *Escherichia coli*, although other bacteria or fungi may be the cause of infection, too. Preventive measures include sterile equipment and catheterization using an aseptic technique for insertion. Nosocomial pathogens have a higher antibiotic resistance than simple urinary infections. Urinary tract infections should be treated with targeted antibiotics only after a urine sample microbiological analysis.

25.7.3 Pneumonia

Postoperative pneumonia is a hospital-acquired or ventilator-associated disease after endotracheal intubation. It is the second most common nosocomial infection after urinary tract infection and the leading cause of mortality attributed to infection. Pneumonia is usually bacterial and most infections are caused by gram-negative aerobes like *Pseudomonas aeruginosa, Klebsiella pneumoniae, Enterobacter species, Serratia,* and *Acinetobacter species.* However, *Methicillin-resistant Staphylococcus aureus* (MRSA) is the predominant gram-positive pathogen. Preventive strategies may be nonpharmacological and pharmacological. Major strategies for effective prevention of postoperative pneumonia are good postoperative care, infection-control practice, and surveillance of local nosocomial infection rates.

25.8 CSF-Related Complications after Intradural Spinal Tumor Surgery

The incidence of CSF-related complications after intradural spinal tumor surgery is hypothesized to be underreported, but still remains high nevertheless. It has been reported between 5–18% of patients [1–12, 20, 21, 55]. CSF leak is a potential and common complication after any dural opening, occurring accidentally or during intradural tumor surgery, which can lead to significant morbidity and mortality. It can be asymptomatic or cause intracranial hypotension with persistent headaches, nausea, and vomiting. Neuropathic pain and neurologic deficits can be caused by neural elements' herniation (protrusion) out of dural opening. Locally, it can present with wound swelling or CSF drainage through the skin incision, which can be seen as leakage that creates a central reddish spot with a surrounding halo on

wound-coverage gauze or bed sheets. Consequently, there is a high risk for the development of meningitis, and/or pseudomeningocele and fistula formation.

MRI remains the gold standard in diagnostics of CSF fistulae and their complications (Fig. 25.4). If CSF leak is suspected, additional confirmation can be achieved with the analysis for Beta-2 transferrin, which is a specific protein marker for CSF.

Treating these complications is a vexing problem and often requires prolonged post-operative bed rest, surgical re-exploration, placement of an external lumbar drain, and a prolonged use of antibiotics [12–16, 18–20]. Despite Mayfield and
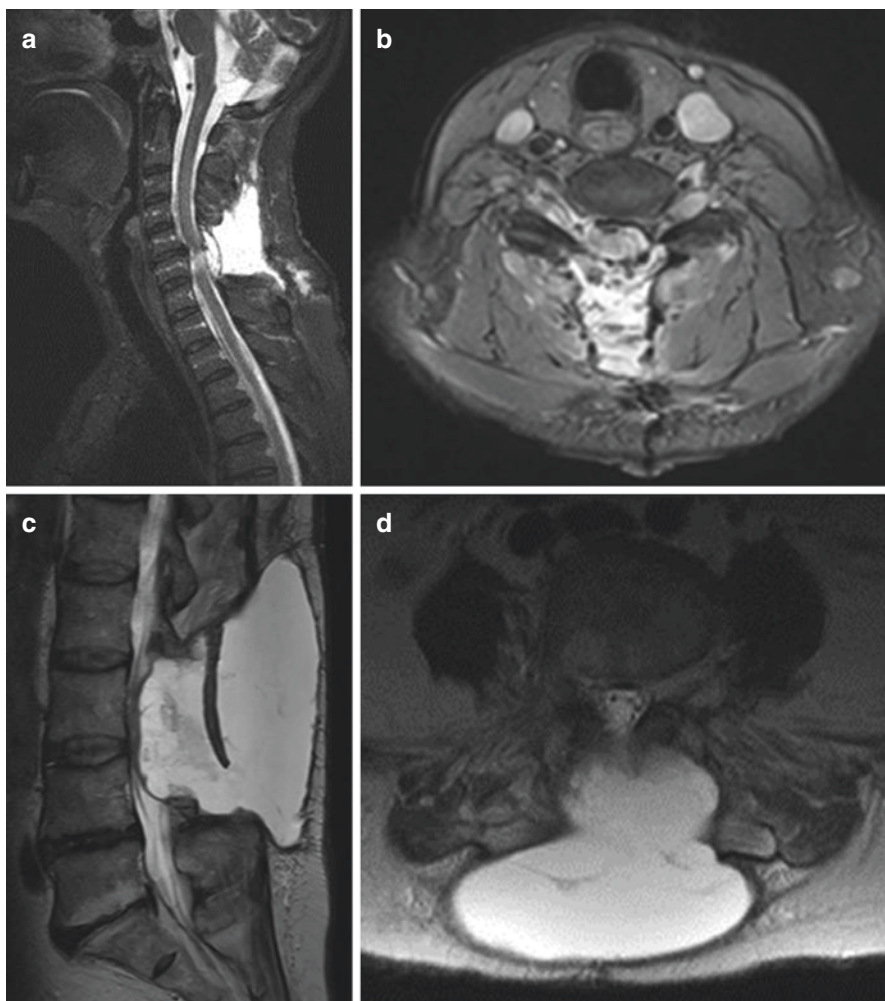

Fig. 25.4 Postoperative T-2 weighted sagittal and axial MRIs showing CSF leak into dorsal tissue with giant pseudomeningocele and fistula formation compressing the thecal sac after intradural tumor surgery in cervical (**a**, **b**) and lumbar spine (**c**, **d**)

Black's recommendation to use a fat graft to prevent spinal surgery CSF complications [58, 59], the current practice has not gained routine use. However, some authors have prospectively adopted the intraoperative use of autologous fat grafting for dural closure. Arnautović reported a case series of 40 consecutive patients treated surgically for spinal intradural tumors with no CSF-related complications postoperatively using this technique [60].

Two recent studies evaluated the efficacy of polyethylene glycol sealants in an attempt to decrease the rate of CSF-related complications after intradural spinal surgery [61, 62]. Goodwin et al. reported that CSF leaks occurred in 5% of patients and meningitis occurred in 1% in their series [61]. Similarly, Wright et al. compared the use of polyethylene glycol sealant with standard dural closure [62]. The rate of complications related to CSF leak requiring re-operation in the sealant treated group was 7% compared with 13% in the standard dural closure cohort. Besides that, each cohort had an additional 4% rate of pseudomeningocele formation that did not require re-operation.

The effect of CSF-related complications on outcomes is particularly important in older patients with medical comorbidities. Such patients may not tolerate the prolonged bed rest required to manage the CSF-related postoperative complications. An increased number of elderly patients with intradural spinal tumors (ISTs) who require surgical treatment have also been reported by Sacko et al. [16]. The additional complications mentioned earlier can also jeopardize an otherwise successful surgery and rehabilitation process.

25.8.1 Prevention Strategies

After tumor resection the dura is usually closed primarily, if possible. Sometimes a dural patch graft may be necessary for dural closure (autologous fascia lata, thoracodorsal fascia patch graft, or artificial dural substitute patches) (Fig. 25.5).
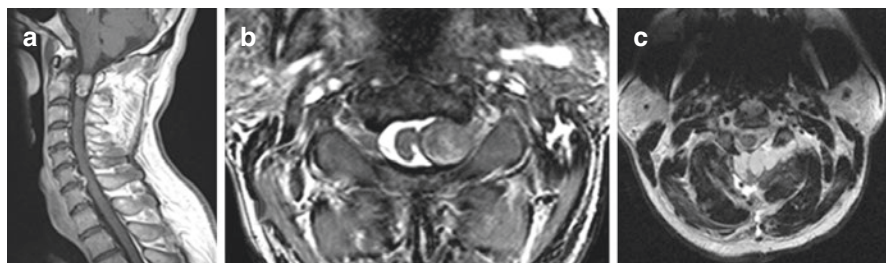

Fig. 25.5 (**a**) Post-contrast sagittal T1-weighted MRI showing the enhancing tumor intradural, extramedullary tumor (schwannoma at C1–C2). (**b**) Axial T2-weighted MRI showing the left-sided tumor involving the C1–C2 intervertebral foramen and compressing the spinal cord. (**c**) Postoperative axial T2-weighted MRI showing the radical tumor resection. Note the fat graft overlying the dura dorsally and reinforcing dural closure

Meticulous closure technique is obligatory, especially for repeated surgeries or a previously irradiated spine. Bed rest is recommended for 24 to 48 hours after surgery to minimize CSF pressure on the dural closure. Thromboprophylaxis is needed during this period, after which gradual mobilization and physical therapy should commence. Any suspicion of CSF leak should be treated early; wound revision is necessary to prevent further complications.

25.8.2   The Technique of Dural Closure by Autologous Fat Grafting

If the dural incision is in the midline after watertight dural closure, the Valsalva maneuver is performed at 30 cm H_2O for 5–10 s to ensure the dura is closed properly. If any area in the suture line leaked CSF, an additional suture is placed and a piece of fat tissue cut and positioned inside the stitch, which is then tightened. This maneuver reinforces the dural closure.

   If the dural incision is T-shaped (i.e., for dumbbell, intra/extradural, or foraminal tumors), or Y-shaped (i.e., for sacral canal/foraminal tumors), the dural incision in the midline and its T or Y-shaped extension over the spinal nerve root are closed in running fashion with 5–0 Prolene stitches. Multiple pieces of fat tissue are then incorporated into single additional dural sutures to achieve watertight closure and reinforce the dural closing. When suturing is complete, a layer of fat tissue 6–8 mm thick is placed over the entire exposed dura to obliterate the dead space remaining after a laminectomy or facetectomy. The fat tissue allograft nicely conforms to the allotted space and serves as filler. The fat graft also creates light pressure on the dural suture line, lessening the chance of CSF seepage and pseudomeningocele formation. In other words, the graft prevents a potential low-pressure space into which CSF may migrate and form a pseudomeningocele, later producing CSF leak. Finally, fibrin glue is applied over the graft to conclude the procedure.

   The spinal dura appears to be the thickest dorsally in the midline and thins laterally, particularly along the dural sleeves of the spinal nerve roots. Therefore, a running dural midline suture is used to achieve watertight closure after the tumor is removed, and then the Valsalva maneuver is used to ensure it. Still, there is no guarantee that the suture line will not weaken or that a leak will not occur after the patient is mobilized postoperatively, when CSF fully replenishes and patient engages in full physiologic CSF pressure challenges on the dural suture line. However, CSF may still seep into the low pressure dead-space created after a laminectomy, leading to a pseudomeningocele formation or CSF leak. Reinforcing the dural suture line with autologous fat is useful, particularly in cases when the Valsalva maneuver revealed CSF seepage. In addition, the fat graft obliterates the dead space created by a laminectomy and muscle dissection, and generates gentle pressure to the dural suture line. After 1 year follow-up, MRI scans of the spine usually show that the fat autograft is totally reabsorbed avoiding any scar formation.

In some cases, it may be impossible to achieve watertight dural closure. These patients are particularly at risk for CSF leak and, therefore, may clearly benefit from the concept of autologous fat grafting. The cases are as follows:

- An intradural spinal tumor in a sacral location
- A craniospinal intradural tumor requiring a Y-shaped dural incision and patch grafting
- When the tumor invades the dura (e.g., meningioma) and necessitates dural excision to achieve radical resection and subsequent dural patching
- If the lesion is a dumbbell intradural extramedullary spinal tumor extending into the intervertebral foramen and beyond

The fat graft is always harvested on the left side of abdominal wall to prevent possible confusion in the case of a future appendectomy or other abdominal surgery on the right side (Fig. 25.6). Fat deposits are abundant in the abdominal wall area even in patients with a low Body Mass Index (BMI). There is no significant time or expense added to surgery, nor complications like infection, hematoma, or cosmetic problems. In addition, fat autograft carries no risk of hypersensitivity reaction or infectious disease transmission. A separate skin incision is favored for the tissue removal, rather than harvesting fat from the subcutaneous tissue in the area of the primary incision. This approach prevents the development of additional tissue pouches in the primary surgical area that may favor a pseudomeningocele or hematoma formation and jeopardize wound healing.

The prospective use of autologous fat grafting ensures watertight dural closure and obliterates the dead space created during surgical exposure, muscle dissection, and bone removal. This technique appears to significantly reduce, if not completely eliminate, postoperative CSF-related complications in patients

Fig. 25.6 Left abdominal wall fat graft harvesting
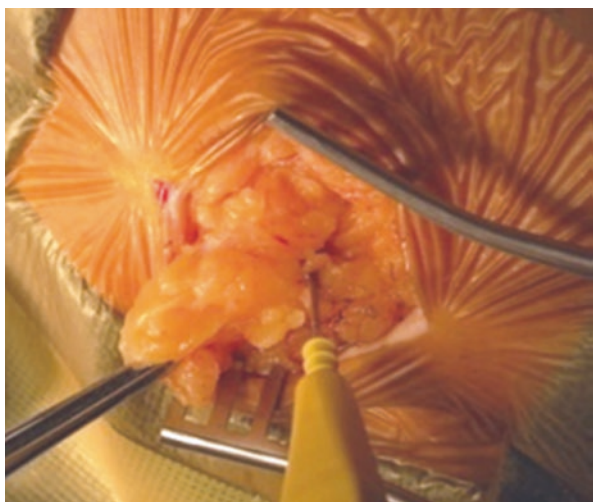
with ISTs, without adding any significant operative time, expenses or complications.

25.9   Deep Vein Thrombosis and Pulmonary Embolism

Spinal surgery is classified as a moderate risk for deep vein thrombosis (DVT), which is a major cause of morbidity but can be prevented with thromboprophylaxis. In terms of SCT surgery, there is a potentially difficult decision between balancing the risk of a thromboembolic accident and the risk of permanent neurological damage from postoperative bleeding in the spinal canal. Yamasaki et al. found that the overall incidence of DVT in patients undergoing lumbar spine surgery was 32.3%, but the incidence depends on the invasiveness of the procedure. Among those patients, 15.8% received anticoagulant therapy and none of them experienced pulmonary embolism (PE) or epidural hematoma. A follow-up vein ultrasonography 3 weeks postoperatively showed resolution of DVT in 86.7% of cases [63].

Dhillon et al. reported data from retrospective analysis of 6869 consecutive patients after spinal surgery and found that the risks of spinal epidural hematoma were low and equivalent to patients who received or did not receive chemoprophylaxis [64]. The authors concluded that anticoagulation therapy is safe for patients at high risk for thromboembolic complications from day 1 to day 3 after surgery. Fawi et al. reported a review of 2181 patients with elective spinal surgery, where a perioperative protocol involving mechanical anti-embolism stockings, adequate hydration, and early post-operative mobilization was effective in significantly reducing the incidence of thromboembolic complications [65]. The addition of low molecular weight heparin (LMWH) was reported safe in patients at higher risk of developing thromboembolic events.

Mosenthal et al. published a systematic review and meta-analysis of 28 articles on thromboprophylaxis in spinal surgery [66]. They found that the incidence of thromboembolic complications after spinal surgery is not well established due to variety of the small number of studies available. The incidence of DVT and PE was relatively low, regardless of prophylaxis type. The authors concluded that the role of thromboprophylaxis in spinal surgery remains undetermined. They also suggested the use of chemoprophylaxis because of the relatively high rate of fatal PE they discovered in 6% of the cases in their series.

Successful management of thromboembolic incidents depends on preoperative risk evaluation, including prophylactic treatment and early diagnosis, in order to avoid PE and other complications.

25.10   Complications of Immobilization and Bed Rest

Prolonged bed rest with inactivity and immobilization inevitably leads to complications, which are often much easier to prevent than to treat. Necessitated bed rest due to illness or recuperation after surgery for intradural and spinal cord tumors,

paralysis, loss of sensation, and immobilization of the spine may complicate primary disease and become an even greater problem. Geriatric patients, those with neurological deficit, and those with different comorbidities have a greater risk of developing these complications.

25.10.1 Cardiovascular Complications

Cardiovascular complications include increased heart rate, decreased cardiac reserve, orthostatic hypotension, VTE, and myocardial infarction.

25.10.2 Musculoskeletal Complications

Muscle weakness and atrophy together with the loss in muscle strength and endurance are commonly caused by prolonged immobilization. Nearly half of normal muscle strength is lost within few weeks of immobilization, which can prevent verticalization and early rehabilitation of the patient. Unfortunately, the rate of recovery for these patients is slow.

25.10.3 Joint Contractures

Contractures are fixed deformities of joints as a consequence of immobilization and are commonly seen in patients with paralysis. Unsuitable bed positioning can result in joint deformities, particularly in the lower extremities. Contractures can be painful, limit positioning, complicate bathing and bed transfers, increase the risk of pressure sores, and lengthen hospital stay. Treatment of contractures is based on prevention with a goal of performing active or passive range-of-motion (ROM) exercises, changing the positions of immobile joints regularly, and using resting splints. Established contractures are treated with passive ROM and terminal stretching for 30 seconds. Contraindications to aggressive management of immobilized or contracted joints include fractures, osteoporosis, acute arthritis, ligamentous instability, and insensitive areas.

25.10.4 Osteoporosis

Disuse osteoporosis is bone loss during long-term immobilization. It can lead to fractures of the spinal vertebrae, resulting in kyphosis and chronic back pain.

25.10.5 Decubitus Ulcers

Pressure sores or decubitus ulcers are localized areas of cellular necrosis over bony prominences subjected to external pressure greater than capillary pressure for

prolonged period of time. These complications occur most often in patients with spinal cord injuries and elderly patients. Obese and comatose patients are at particular risk for pressure sores. Patients in supine position usually get sores on the sacrum and heels, while sitting patients have sores on the ischial tuberosity. In patients who lie on their sides, sores occur on their hips and ankles. The most common problem associated with decubitus ulcers is infection with both aerobic and anaerobic bacteria. Deeper tissue and bone infection can result in sinus formation, periostitis, and osteomyelitis. Draining ulcers can be a source of large daily water and protein loss. Prevention of pressure sores depend on relieving the pressure by means of repositioning the patient every few hours via turning. Meticulous skin care and nursing are of utmost importance in prevention of pressure sores. Factors that interfere with healing include a necrotic ulcer surface, tissue hypoxia, malnutrition, infection, and improper wound care. Treatment is based on blood supply restoration to ulcer tissue by relieving localized pressure. It is essential to surgically remove all necrotic tissue. Granulation can be improved with available ready-made wound dressings that allow better wound healing. Surgery is sometimes indicated for deep pressure sores (Grades 3 and 4) and ulcers larger in diameter. Current surgical practice involves excising the ulcer and covering the defect with skin or myocutaneous flap.

25.11 Conclusion

The gravest complications in the surgical treatment of SCTs—those having high morbidity and mortality rates—are thromboembolism and infections like meningitis. Therefore, preventive measures are the primary concern of every neurosurgeon dealing with such an issue with the goal being improved management outcomes. CSF leak is an important topic when considering surgical strategies to avoid complications since leaks can be easily prevented by executing a meticulous and effective surgical protocol.

The best surgical strategy is prevention, which includes careful preoperative, perioperative, and postoperative surgical planning and anticipation and prevention of all surgical complications. If any occur, complications should be detected and treated as early as possible. Nursing care of the highest standard and daily bedside visits with the patient by neurosurgeon are of utmost importance.

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