The incidence of leptomeningeal carcinomatosis has shifted in recent years due to advanced oncology treatments.

Surgical Treatment for Leptomeningeal Disease
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**Background:** Advancements in cancer treatment have led to more cases of leptomeningeal disease, which requires a multimodal approach.

**Methods:** Treatment modalities are reviewed from a neurosurgical standpoint, focusing on intrathecal chemotherapy and shunting devices. Potential complications and how to avoid them are discussed.

**Results:** The Ommaya reservoir and the chemoport are used for administering intrathecal chemotherapy. Use of ventriculo-lumbar perfusion can efficiently deliver chemotherapeutic agents and improve intracerebral pressure. Shunting systems, in conjunction with all of their variations, address the challenge of hydrocephalus in leptomeningeal carcinomatosis. Misplaced catheters, malfunction of the system, and shunt-related infections are known complications of treatment.

**Conclusions:** From an oncological perspective, the surgical treatment for leptomeningeal disease is limited; however, neurosurgery can be used to aid in the administration of chemotherapy and address the issue of hydrocephalus. Minimizing surgical complications is important in this sensitive patient population.

**Introduction**
Leptomeningeal disease has been traditionally considered an end-stage diagnosis, and the prognosis has been poor; however, progress in chemotherapeutic agents has led to more favorable outcomes. Although there is rarely a solid tumor that exists in leptomeningeal carcinomatosis to resect, there is a role for neurosurgical intervention.

In this paper, we review our understanding of devices used to access to the ventricular system as well as shunt systems. We also provide an overview of the most common complications and discuss techniques such as neuronavigation that help minimize rates of morbidity and mortality from leptomeningeal disease.

**Ommaya Reservoir**
The mainstay of treatment for leptomeningeal disease is intrathecal chemotherapy, which is most commonly applied through an Ommaya reservoir. It is an intraventricular catheter system that encompasses a silicon reservoir on the top. Because silicon is self-sealing, it allows for multiple punctures to be made so that the agent can be intraventricularly administered.

The Ommaya reservoir was invented in 1963 and is synonymous with the Rickham reservoir. Typically, it is placed with the tip of the drain into the frontal horn of the right ventricle in the nondominant hemi-
sphere. The surgical technique for placement of the Ommaya reservoir is similar to that for an external ventricular drain. After a skin incision, which should be straight or horseshoe-like, a burr hole is placed at the Kocher point. This point is approximately 11 cm from the nasion and 2.5 cm from the parasagittal plane, generally 1 cm anterior to the coronal suture at the ipsilateral midpupillary line. A subgaleal pocket for the reservoir is created. After the surgeon identifies the coronal suture, the burr hole is placed 1 cm anteriorly. The dura is coagulated and incised and then a ventricular drain is inserted toward the frontal horn of the ventricle, approximately 5.5 cm deep from the dura. Landmarks that the surgeon should use to insert the drain freehand include the ipsilateral canthus and the external auditory meatus. The catheter is then connected to the Ommaya reservoir and aspiration of cerebrospinal fluid (CSF) is performed to confirm that the drain is intraventricular. The incision is then closed in the standard fashion.

Because chemotherapeutic agents are neurotoxic, it is crucial to ensure that the drain ends in the ventricle, not in the brain parenchyma. Encephalitis has been reported due to a misplaced Ommaya reservoir. Therefore, obtaining computed tomography (CT) is mandatory following the placement of an Ommaya reservoir. Many neurosurgeons advocate for the use of intraoperative navigation for an accurate placement of the drain and to avoid complications. In such cases, the head of the patient is registered with the navigation system and then the trajectory is planned. In our practice, we use a neuronavigation application when the ventricles are small or to perform revision surgery for misplaced ventricular catheters.

**Ventriculoperitoneal Shunt**

Patients with leptomeningeal carcinomatosis can develop elevated intracranial pressure due to communicating or obstructive hydrocephalus, which may warrant intervention in selected cases. Because the prognosis of leptomeningeal disease is generally poor, surgical treatment may not always be appropriate.

Aspiration of CSF through the Ommaya reservoir might be an option to control hydrocephalus, particularly when used as a temporary solution prior to implanting a ventriculoperitoneal shunt (VPS). Generally, a shunt can be palliatively placed to treat hydrocephalus in leptomeningeal disease. The standard of therapy for hydrocephalus in the setting of leptomeningeal disease is VPS; however, third ventriculostomy, which is the placement of a small hole at the bottom of the third ventricle via endoscopy, may be an alternative. Performing third ventriculostomy has 2 advantages: (1) the procedure does not involve implants, so infection risk is minimized, and (2) magnetic resonance imaging (MRI) can be obtained without fear of valve malfunctioning or need for readjustment, as would be the case in VPS placement.

Typically, shunts consist of a valve, a small reservoir, and silicon-reservoir tubing. In a VPS, the valve opens when the intraventricular pressure is greater than the opening pressure, thus allowing for the spontaneous flow of fluid from the ventricles to the peritoneum. When the patient is in the supine position, the shunt will drain less; in the standing position, overdrainage might occur — regardless of the settings — leading to slit ventricle syndrome, subdural hematoma, or headache. Antisiphon devices aim to minimize this siphon-like effect: When the pressure within the shunt decreases beyond a certain point, atmospheric pressure transmitted through the skin pushes the diaphragm down to block any further flow of CSF through the system. Thus, antisiphon devices are implanted below the shunt reservoir as a separate piece or they can be incorporated into the valve.

The surgical technique for shunt implantation is similar to placement of an Ommaya reservoir for the ventricular catheter. The ventricular catheter is connected to the valve, not the reservoir. It is important to place the valve with the arrows toward the gravitational flow of the CSF. The valve is connected to a long catheter, which is tunneled under the skin toward the abdomen. The peritoneum is exposed via a small incision, and the catheter is intraperitoneally inserted through a small opening. Approximately 10 cm or more of the catheter should be within the peritoneum. Some surgeons prefer to make skin incisions at the umbilical area, use trocars to enter the peritoneal cavity, and then insert the catheter intraperitoneally using a Seldinger technique. Another method for intraperitoneal placement of the catheter is via endoscopy. Doing so helps to visualize the placement of the catheter.

High levels of CSF protein related to the disease itself might be of consideration because it is possible that the shunt may not work. According to Stark et al., shunts should work even when the level of CSF protein is as high as 3000 mg/dL. Nonetheless, in our every-day practice, we would typically aspirate the CSF through the Ommaya reservoir for a few days until the protein level drops. A strict cutoff for this does not exist.

The neurosurgeon should also consider the dissemination of disease to the peritoneum after placement of the VPS. The prognosis of leptomeningeal disease is poor, so patients may not survive long enough to experience issues from peritoneal involvement. True incidence of peritoneal seeding could be higher than reported. One article reported the presence of malignant ascites after a subduroperitoneal shunt was placed in a patient with leptomeningeal disease.

When applying a chemotherapeutic agent and reducing the amount extraventricularly diverted, the programmable valve can be placed on its highest set-
tting so that the shunt will — albeit temporarily — underperform. After the chemotherapeutic agent is absorbed, the valve can be reset. Zada and Chen have published a protocol that involves keeping the pressure at 200 mm H2O for 4 hours, then resetting it to baseline. Although this is not an option with the non-programmable shunts used today, these shunts still have advantages: They do not require reprogramming after obtaining MRI, and, when reprogramming a shunt, doing so is easy and reliable.

Chemoport
In 2011, Gwak et al reported on their experience with a device that would deliver intrathecal chemotherapy called the chemoport. The technology is a vascular-access device traditionally used for intravenous chemotherapy. According to Gwak et al, the technique for inserting the chemoport is similar to the Ommaya reservoir. However, the method varies because the chemoport is bulkier than the Ommaya reservoir. Hence, the neurosurgeon must drill the outer table of the skull to fit the chemoport into the skull engraving. The chemoport can be punctured many times without leakage issues, and it can be taped with a hooked needle and then later be connected to a CSF drainage system. In this way the chemoport can function as an extraventricular drainage device. By contrast to the Ommaya reservoir, which cannot be firmly secured, the chemoport sits in the skull engraving.

Use of ventriculo-lumbar perfusion in leptomeningeal carcinomatosis has also been advocated by Gwak et al. The principle of ventriculo-lumbar perfusion is to insert the chemotherapeutic agent via the Ommaya or chemoport reservoir and to simultaneously remove it via the subarachnoid lumbar space. Better control of increased intracranial pressure and improved responses to chemotherapy have been reported with this method.

Complications of Intraventricular Reservoirs and Shunts

Intracranial Hemorrhage
During and after the placement of an Ommaya reservoir, shunt catheter, or both, the neurosurgeon should consider certain intraoperative challenges during the perioperative and postoperative periods. Intraoperatively, the trajectory of the placement of the catheter is important and must be verified by either stereotactic guidance or the precise use of anatomical surface landmarks. Once the catheter is advanced via the intracranial space through the brain parenchyma, the patient will be at risk for vascular or parenchymal injury, which can lead to intracranial hemorrhage (ICH). Such injury may be present if a high degree of brain atrophy is observed and subdural hematoma could develop.

In addition to a patient’s risk of ICH and subdural hematoma, intraventricular hemorrhage (IVH) could also occur if the highly vascularized choroid plexus is damaged. In a retrospective review of 107 patients, Souweidane et al discovered 3 cases of ICH and 1 case of IVH; 2 of the cases of ICH were fatal. Based on other reported series, the overall incidence of ICH ranges from 0.3% to 4.0%. These injuries can be avoided by minimizing the number of passes through the brain parenchyma, using stereotactic guidance, or placing the catheter via endoscopy. In addition to iatrogenic causes of ICH, complications can also arise from patient comorbidities such as coagulopathy due to liver damage. Such conditions put patients at higher risk for certain complications, and this is especially true for patients with cancer. Some patients may develop ICH or IVH due to anticoagulation or antiplatelet therapy that was preoperatively or postoperatively started for various other complications such as spontaneous deep venous thrombosis or pulmonary emboli.

Other patients may already be taking antiplatelet or anticoagulation medications prior to surgery. Platelet-activation assays are not routinely checked; however, during routine checking at our institution, we have found that the results of platelet-activation assays are often elevated, even though patients have stopped taking antiplatelet medications as far back as 10 days prior to surgery. Even after the successful placement of a reservoir or shunt catheter, and sometimes weeks later, the operative site remains vulnerable to hemorrhage. Although debate exists among surgeons at our institution, we tend to place patients on anticoagulation 24 to 48 hours after surgery, utilizing single doses of low-molecular-weight heparin. We typically resume antiplatelet medication 7 to 10 days following surgery, although no standardized regimen has been published.

Hardware Malposition/Migration
During the placement of the intraventricular catheter, the patient is at risk of malposition of the catheter, migration of the catheter, or both. Bleyer et al reported as early as 1978 that 2 of 27 patients treated with intrathecal chemotherapy via an intraventricular reservoir system experienced life-threatening complications due to misplaced catheters. One patient was being treated for meningeal Burkitt lymphoma, and the cause of death was a large mass of tumor cells growing around the tip of the catheter, which was found in the contralateral cerebral peduncle. The tip of the catheter placed in the second patient migrated into the contralateral thalamus.

Souweidane et al reported that the incidence rate of malpositioned catheters was 7.4% for those requiring revision, whereas other centers have reported malposition rates to be between 2.7% and 12.5%. Malpositioned catheters can cause neurological deficits.
due to damage of the eloquent cortex.21-23 Multiple attempts at passing the catheter without any stereotactic guidance or lacking direct visualization can also lead to improper catheter position or postoperative neurological deficits. Although the persistent, continuous return of CSF has a high sensitivity rate for when the catheter is appropriately positioned, CSF may drain into other subarachnoid spaces, not the ventricular system. We do not recommend it, but intraoperative confirmation of the placement of the catheter can be used to minimize the incidence of this complication.

The ventricular system has an anatomical variant called the cavum septi pellucidi, and its presence can deter the catheter from its correct trajectory. If the catheter is placed directly into the defect, then return of the CSF may not be observed, prompting the surgeon to redirect and attempt additional passes. Thus, it is important that all findings on CT and MRI be reviewed prior to surgery to avoid this anatomical variant. In addition to the absence of CSF flow after the catheter is placed into the cavum, successful flow can be observed. However, once the cavum is decompressed, the ventricle in question is unaffected, so it can continue to increase in size and become trapped. This occurs because of the collapse of the leaves of the septum around the draining holes of the catheter.

Sherman and Aygun25 reported on a rare iatrogenic complication in a patient with this anatomical variant. The complication occurred after the catheter was placed near the septum. After the chemotherapeutic agent was injected, findings on subsequent CT demonstrated cavum septi, suggesting that the agent was injected between the leaves of the septum and had created the defect.25 Thus, this report underscores the importance of catheter placement, which should be directed and confirmed within the free CSF space of the ventricle. Furthermore, in patients for whom biventricular catheters or endoscopic fenestrations of the septum may be indicated, these actions should be taken to avoid unnecessary complications.

**Infection**

Infection is a common complication for both intraventricular reservoirs and shunts. As early as 1987, Browne et al26 reported their 10-year experience in 61 pediatric patients, 14 (23%) of whom had infections. Of the organisms isolated, *Propionibacterium acnes* was the most common organism recovered from CSF and other cultures grown (Table 1).26,27 Some patients were asymptomatic, whereas others had symptoms consistent with meningitis.26

At our institution, we have developed and modified a sterile technique for delivering chemotherapeutic agents, using antiseptic preparations, smaller-gauge puncture devices, and, for certain cases, placed the patient on prophylactic antibiotics before and after delivery of the chemotherapeutic agent.

In 2014, Kramer et al28 did not observe any long-term infections in their safety profile of long-term intraventricular-access devices in pediatric patients. Their study involved 143 patients, whom the researchers observed for more than 10 years.28 A total of 143 Ommaya reservoirs and 8 VPSs were included in the study. Kramer et al28 suspected that the risk of infection in these patients was minimized because a filter was used when delivering compartmental, intraventricular, radioimmunotherapy; or, alternatively, they hypothesized that the low risk of infection may have been because of the drug itself, which helped to eliminate microscopic or low-colonized bacteria loads.

At our institution, we use preoperative and subsequent intraoperative antibiotics (vancomycin/gentamycin). We also pack the wound with vancomycin powder and adhere to a strict sterile protocol.

Shunt infection is a common complication of shunt surgery. The incidence rate of shunt infections in adults has been reported to be between 1.6% and 16.7%,22,29 According to Chakraborty et al,29 the majority of shunt infections occur within the first 3 months of shunt surgery. The spectrum of possible clinical manifestations is shown in Table 2.

Hematogenous spread is also common in vascular shunts, and bacteremia can ensue with positive blood cultures.

In the absence of another source, a shunt tap can be performed using a sterile technique to isolate the organism. Shunt infections are often the result of contamination of the proximal end of the shunt with normal skin flora, particular with coagulase-negative staphylococci and *Staphylococcus aureus*.22 Wells and Allen27 noted that infections caused by these species account for 50% and 33% of all shunt infections, respectively. The timing of the infection dictates the pathogen involved. Early shunt infections (within weeks of shunt insertion or revision) are also typically caused by coagulase-negative staphylococci and

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<th>Table 1. — Common Pathogens Associated With VPS-Related Infections</th>
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<td><strong>Early Infection</strong></td>
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<td>Coagulase-negative staphylococci (50%)</td>
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<td><em>Staphylococcus aureus</em> (33%)</td>
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<td><em>Corynebacterium species</em></td>
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<td><em>Propionibacterium acnes</em></td>
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*aApproximately 85% of VPS-related infections usually occur within weeks of VPS placement or revision.  
*bApproximately 15% of VSP-related infections usually occur within several months after VPS placement or revision.  

VPS = ventriculoperitoneal shunt.  
Data from references 26 and 27.
S. aureus.27 However, late infections are typically caused by streptococcal species and gram-negative pathogens such as Pseudomonas aeruginosa.30

The highest rate of infections occurs early after shunt placement or revision.31 Infections may occur 1 month postoperatively, a time considered to be a critical period.32 The infection rate can also increase as the number of revisions increases.26,27,53 As the number of revisions increases, Wells and Allen27 reported that adult patients are 3 times more likely to develop shunt infections than those without prior revisions. It is also important to note that, if radiotherapy has been provided, it will also increase a patient’s risk of infection, because wound healing is protracted following radiotherapy.

### Abdominal Complications

After a VPS is placed, abdominal complications may also occur. Various complications have been described in the literature and include omental clogging, abdominal viscera perforation, and bowel obstruction.54 Visceral perforation can occur at the time of the access attempt to the peritoneal compartment prior to inserting the distal catheter, during the insertion of the catheter into the peritoneum, or even later due to catheter erosion through the abdominal viscera. Over time and with more revisions, as well as additional abdominal surgeries needed unrelated to the placement of VPSs, adhesions can form that may lead to bowel obstruction.

The development of a pseudocyst due to CSF drainage is not a common complication, but it does occur at a rate of 0.33% to 6.8%.34,35 Pseudocysts consist of collections of CSF in the peritoneal cavity at the distal end of the catheter surrounded by a wall composed of fibrous tissues without an epithelial lining.36 Many underlining factors and mechanisms are involved in the formation of pseudocysts; however, the inflammatory process, either sterile or infectious, is usually regarded as the main causative factor.34,35 Other predisposing factors to consider can include peritonitis, prior surgical peritoneal adhesions, distal shunt migration, multiple shunt revisions, malabsorption of CSF, and allergic reactions.34 When a pseudocyst develops, it can harbor an infectious process. The most frequent signs and symptoms associated with pseudocysts are abdominal pain, abdominal distention, and a palpable abdominal mass.37 If there is a high index of suspicion for the accumulation of pseudocysts, ultrasonography is the imaging modality of choice because it is fast and easily attainable. CT of the abdomen will also illustrate similar findings.

### Intra-Abdominal Shunt-Related Seeding

Intra-abdominal metastasis secondary to the divergence of CSF into the abdominal cavity has been described.12,38 Although it is a rare occurrence, it has been reported with various tumor pathologies, particularly germinomas and medulloblastomas.12,38 Typically, germinomas occur in children and are usually proximal to the pineal or suprasellar regions, causing obstructive hydrocephalus as they increase. VPSs can be used to treat the obstruction and relieve symptoms. Because germinomas are radiosensitive, patients with them have a 5-year survival rate of 85%.35

Back et al35 noted that the incidence of metastasis via CSF shunt was 1%. By contrast, after they reviewed 245 pediatric cases requiring VPS for intracranial tumors to treat hydrocephalus, Murray et al53 identified that 27.3% of the abdominal metastases in these patients were directly related to VPS placement. Germ cell tumors were the most common cause. The mean interval between shunt operation and metastatic diagnosis was 17 months for all tumors (range, 5 months [yolk sac tumors] to 29 months [germinomas]).53

Intra-abdominal seeding and dissemination likely occurs due to spillage of the tumor into the ventricles at the time of either stereotactic surgery, open biopsy, or attempted resection of the tumor. Evidence of intra-abdominal metastasis through VPS comes from the lack of metastatic spread in other body locations, and, as evidenced by Back et al55 in their reported case, where gravity-dependent locations of single peritoneal cavity recurrences were adjacent to and around the distal ends of the shunt catheter. In the reported case by Back et al,55 the peritoneal metastases occurred around the distal end of the shunt catheter, because the cancer cells were driven there by gravity to the catheter.

In an attempt to limit shuntborne metastasis, VPS catheters with Millipore filters have been used. However, these catheters have been complicated by a high
rate of obstruction requiring revision and are not considered to be practical. Some have advocated for systemic therapy to prevent seeding, whereas others have suggested a means of CSF diversion at the time of local treatment, such as external ventricular drains, endoscopic third ventriculostomy, or an externalized ventriculo-distal shunt; however, none of these suggestions have been supported with statistically significant evidence.

In adults and children with leptomeningeal carcinomatosis, a condition already known to have metastatic spread, the complication of metastasis may seem trivial. However, patients may present with localized cranial disease and controlled systemic disease requiring CSF diversion, which can potentially cause intrabdominal seeding.

**Overdrainage**

Overdrainage refers to draining more CSF than intended based on the setting adjustments of the valve. This complication is not common, but it has been reported in the literature and is an important complication to acknowledge. Excess drainage of CSF may lead to subdural hematoma, which may lead to significant neurological deterioration that often requires surgical intervention (evacuation). To minimize this risk, serial CT should be obtained (a) during the immediate postoperative period, (b) at subsequent clinic visits, and (c) after any valve adjustments. Patients and their family members should be advised to be aware of any neurological changes from baseline, because such changes may be due to this complication. Cases of subdural hematoma due to overdrainage documented in the literature have generally occurred in the setting of idiopathic normal pressure hydrocephalus (iNPH), a condition in which hydrocephalus is a long-standing problem prior to its diagnosis. It is difficult to compare hydrocephalus due to carcinomatosis with iNPH, because the mechanisms that may lead to overdrainage may not always be attributable to a VPS-related issue but may in fact be due to the rate of change in ventricular compliance, brain compliance, and elasticity. Over time, these trends can change in patients with iNPH. Such changes are not always seen in patients with leptomeningeal disease because of its acuity. Nevertheless, overdrainage can occur and the neurosurgeon should be aware of such complications.

**Conclusions**

The prognosis of leptomeningeal carcinomatosis has significantly changed in recent years. Focus is now on novel chemotherapeutic agents and the ways in which to apply them. From a neurosurgical standpoint, shunt systems should continue to see improvement so that health care professionals can more efficiently address common issues, such as overdrainage, and use standardized techniques to minimize the risk of complications. Shortening operating times by using clinicians experienced in neurosurgery and the advent of future neuronavigation will be helpful.

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