

The Role of Lumbar Drainage in Neurosurgery: Applications in Brain Tumor Resection

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Abstract

Brain tumor resection involving skull base and transsphenoidal approaches carries a high risk of postoperative cerebrospinal fluid (CSF) leakage and requires optimal intraoperative brain relaxation. Effective perioperative CSF pressure management is essential to maximize tumor resection and minimize neurological morbidity. Lumbar drainage (LD) serves both therapeutic and prophylactic roles in brain tumor surgery. Therapeutically, it diverts CSF during dural defect reconstruction. Prophylactically, it facilitates brain relaxation, reducing the need for mechanical retraction and lowering the risk of cerebral edema and tissue ischemia, particularly in sphenoid wing meningioma and pituitary macroadenoma resection. LD functions through controlled CSF diversion from the subarachnoid space, reducing the transmural hydrostatic pressure gradient across the surgical defect and allowing reconstructed tissues, such as the nasoseptal flap, to adhere and heal. From a neuroanesthetic perspective, perioperative challenges include hemodynamic management and intraoperative monitoring of drainage rate to prevent overdrainage-related complications, including tension pneumocephalus, tonsillar herniation, and intracranial hemorrhage. LD is not recommended for routine use; however, it demonstrates clear benefit in appropriately selected patients, particularly those with intraoperative high-flow CSF leaks or comorbidities associated with elevated intracranial pressure, such as obesity. Careful patient selection and precise perioperative management of CSF drainage and intracranial pressure are essential to optimize clinical outcomes and prevent drainage-related morbidity.

Keywords: Brain tumor, brain relaxation, cerebrospinal fluid, lumbar drainage, neuroanesthesia, skull base

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Introduction

Brain tumor surgery, particularly those located at the skull base, sellar, and suprasellar regions, is among the most complex neurosurgical procedures requiring precision. Two primary challenges for the neurosurgical and neuroanesthesia team are achieving adequate operative field exposure and maintaining optimal brain relaxation.^{1,2} A tight brain during surgery not only makes access to tumors surrounding vascular structures and cranial nerves difficult,

but also increases the risk of secondary injury from the use of mechanical retraction.³ Previously, mechanical brain retractors were often the primary modality for achieving tumor exposure. However, excessive retraction can trigger cerebral edema, brain ischemia, and focal perfusion disturbances.^{2,4} These findings drove the evolution of surgical techniques toward more conservative and minimally invasive strategies, with one important innovation being the use of intraoperative lumbar drainage (LD). Initially, LD was predominantly used postoperatively

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to manage cerebrospinal fluid (CSF) leaks; its use has since expanded to serve as a proactive tool from the early stages of surgery.^{5,6} Through controlled CSF diversion using a subarachnoid catheter in the lumbar region, intracranial volume can be reduced, thereby providing additional working space for the surgeon without requiring aggressive brain retraction, a concept known as retractor less surgery.³

In sphenoid wing meningioma or pituitary macroadenoma surgery, LD facilitates relaxation of the frontal or temporal lobe, enabling safer visualization of optic nerve structures and carotid arteries.² Furthermore, in endoscopic endonasal procedures, CSF diversion helps lower the suprasellar tumor component into the surgical field of view while simultaneously reducing the hydrostatic pressure on the dural reconstruction area, suppressing the risk of postoperative CSF leak.¹ Nevertheless, the integration of LD in perioperative management is not without risk, making the role of the neuroanesthesiologist important. Clinical considerations must balance the benefits of CSF diversion against potential neurological complications. Excessively rapid or excessive CSF drainage (over drainage) can cause severe intracranial hypotension, subdural hemorrhage, life-threatening pneumocephalus, and fatal tonsillar herniation.^{4,7}

Other risks include procedure-related complications such as radicular nerve injury, infection (meningitis), and epidural or spinal hematoma.^{5,7} The use of LD in brain tumor surgery requires a thorough understanding of pathophysiology and careful neuroanesthetic monitoring. The decision to place LD must be based on analysis of the patient's risk profile, such as obesity (high Body Mass Index), which is known to increase the risk of postoperative CSF leaks—as well as the complexity of the planned dural reconstruction.⁸ Precise neuroanesthetic management in regulating the drainage rate and maintaining hemodynamic stability is an essential factor in balancing the need for surgical exposure with neurological patient safety. This literature review discusses the use of lumbar drainage in brain tumor resection procedures,

covering clinical indications, patient selection criteria, placement technique, safe intraoperative drainage parameters, and neuroanesthetic management, as well as the prevention and management of perioperative complications. This review is intended to serve as a guide for neuroanesthesiologists in understanding the role of LD in optimizing brain relaxation, minimizing the need for mechanical retraction, and supporting patient safety by reducing the risk of postoperative morbidity, including CSF leaks and neurological complications from over drainage or invasive lumbar procedures.

This review was prepared from a literature search of the PubMed/MEDLINE and Google Scholar databases for articles published between 2015 and 2025. The search used combinations of the keywords “lumbar drain”, “lumbar drainage”, “cerebrospinal fluid diversion”, “brain relaxation”, “brain tumor”, “skull base surgery”, “endoscopic endonasal surgery”, “pituitary adenoma”, “meningioma”, “cerebrospinal fluid leak”, and “neuroanesthesia”, combined with the Boolean operators AND and OR. English-language randomized controlled trials, cohort studies, systematic reviews and meta-analyses, expert practice statements, and narrative reviews relevant to the use of LD in brain tumor surgery were included, and the reference lists of the retrieved articles were screened manually to identify additional relevant sources.

Anatomy and Physiology of the Cerebrospinal System

Cerebrospinal fluid (CSF) is a dynamic component that plays an important role in maintaining the homeostatic environment of the central nervous system (CNS). Physiologically, CSF is actively produced by the choroid plexus within the ventricular system, primarily in the lateral, third, and fourth ventricles. CSF formation involves active ion transport and plasma ultrafiltration regulated by the blood–CSF barrier. The CSF production rate is approximately 0.3–0.4 mL/minute, or roughly 500 mL/day in adults. This is important to understand because it determines the rate at which intracranial volume re-accumulates

after intraoperative diversion or drainage.⁹ After production, CSF circulates from the lateral ventricles through the foramen of Monro to the third ventricle, passes through the aqueduct of Sylvius to the fourth ventricle, then exits through the foramina of Luschka and Magendie into the subarachnoid space surrounding the brain and spinal cord. Primary absorption occurs at the arachnoid villi (Pacchioni granulations), which return CSF to the venous circulation through the superior sagittal sinus. The balance between production and absorption maintains a basal CSF volume of approximately 150 mL in adults.⁹ Understanding intracranial space management is based on the modified Monro–Kellie Doctrine. This doctrine states that the adult cranial cavity is a closed and rigid space with a relatively constant total volume, comprising three main compartments: brain parenchyma (80%), cerebral vascular blood (10%), and CSF (10%).⁴ Under physiological conditions, an increase in volume in one compartment must be compensated by a decrease in another to maintain stable intracranial pressure (ICP).⁵ The primary compensatory mechanism against extrinsic volume addition, such as tumor growth, is the displacement of CSF volume from the intracranial compartment to the spinal subarachnoid space.⁵ LD management utilizes this natural compensatory mechanism in a controlled manner by regulating and facilitating removal of CSF volume from the spinal subarachnoid space, thereby decompressing the intracranial compartment and providing additional space within the rigid cranium.⁴

The presence of a brain tumor, whether a slowly growing skull base meningioma or a progressive glioma, can alter the intracranial elastance curve (volume–pressure curve). In the early phase, tumor mass addition is compensated through CSF displacement to the spinal space. However, once this compensatory capacity is exceeded, even a small volume addition, such as cerebral vasodilation due to transient hypercapnia during anesthetic induction, can trigger an exponential rise in ICP.⁵ Beyond the mechanical effect, tumors often cause local disruption of the blood–brain barrier, leading to extravasation of

protein-rich fluid into the extracellular space, known as vasogenic cerebral edema. A brain with vasogenic edema becomes more vulnerable and is often referred to as a tight brain. Mechanical retraction on edematous brain tissue with elevated ICP can disrupt local microcirculation, causing secondary ischemic cerebral edema, or retraction-induced brain edema.² In this context, the neuroanesthesiologist plays a role in controlling ICP pharmacologically and mechanically through LD to restore brain compliance before surgical manipulation begins.

Basic Principles of Lumbar Drainage (LD)

Lumbar drainage (LD) is a minimally invasive procedure involving the temporary placement of a small spinal catheter—inserted through a large-bore Tuohy needle, typically 14–18G—into the intrathecal or lumbar subarachnoid space, usually at the L4–L5 or L3–L4 level.^{4,5} The catheter is then connected to a closed drainage system equipped with a flow-regulating valve, drip chamber, and collection bag, allowing the neuroanesthesiologist to measure and control CSF removal volumetrically per unit time.⁶ The insertion procedure is generally performed under sterile conditions following general anesthetic induction, and may be assisted by fluoroscopic guidance in patients with complicating factors such as obesity (high BMI) or prior spinal surgery.^{2,8}

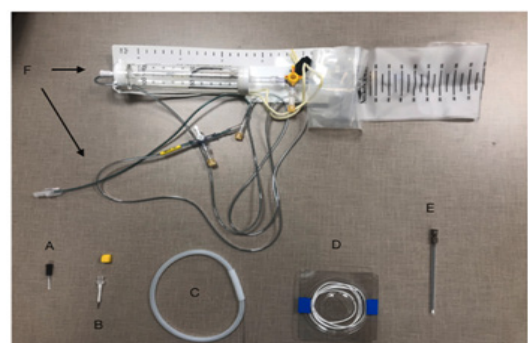


Figure 1. Lumbar Drain (LD) Set. A. Primary adaptor, B. Secondary adaptor, C. Guide wire, D. Lumbar drainage catheter, E. 14G Tuohy needle, F. External drainage system. (image from “Lumbar drains: practical understanding and application for the otolaryngologist”, Livingston et al., 2020)⁴

The primary mechanism of LD is not to address cerebral tissue edema directly, but rather to mechanically alter the intracranial space ratio. Removing 10–30 mL of CSF through LD at the start of the procedure can decompress the basal cisterns and reduce hydrostatic pressure in the subarachnoid space.⁴ This pressure reduction shifts the brain parenchyma away from the cranial fossa or calvaria being opened.

This principle forms the basis of the retractor less surgery technique.² In conventional microscopic surgical approaches, surgeons often require retractor blades to displace brain lobes in order to access tumors located deeper, for example, in the cavernous sinus or clivus. With adequate CSF drainage, the brain relaxes (slack brain) and shifts gravitationally due to the reduced buoyancy provided by CSF.⁴ This condition expands the surgical field of view, minimizes focal ischemic compression from retractors, and helps protect adjacent cranial nerves and major vascular structures.² Brain relaxation management in neuroanesthesia encompasses both pharmacological and mechanical approaches. Standard induction in neurosurgery typically includes administration of osmotic agents such as mannitol (0.5–1.0 g/kg body weight) or hypertonic saline.² Hyperventilation is not part of routine management; when used, it should be mild and brief, reserved as a temporizing measure for a tight brain, and guided by arterial PaCO₂ rather than by a fixed end-tidal CO₂ (EtCO₂) target.

Although osmotherapy is effective, its mechanism of action depends on the formation of an osmotic gradient that draws intravascular fluid from normal brain tissue (normal parenchymal dehydration). This effect requires time, peaking at approximately 15–30 minutes, and has a limited efficacy threshold. Excessive osmotherapy can cause severe systemic dehydration, electrolyte imbalance, and acute renal failure. On the other hand, aggressive hyperventilation reduces cerebral blood volume (CBV) through vasoconstriction but also risks global cerebral ischemia.^{2,3} Lumbar drainage can address some of these limitations by providing rapid mechanical decompression.

LD removes volume from the CSF space without disturbing intracellular fluid composition and, when drainage is controlled, generally without compromising cerebral blood flow (CBF). However, CBF is not always preserved: over drainage may cause intracranial hypotension and downward brain sagging, which can compromise cerebral perfusion.⁴ In suprasellar and skull base tumors, particularly when vasogenic edema limits the response to osmotherapy, LD can be a key intervention to achieve a slack brain.²

Clinical Applications in Brain Tumor Surgery

The use of LD is highly dependent on the anatomical location of the tumor and the surgical approach employed. Resection of skull base tumors, such as sphenoid wing meningioma or anterior skull base tumors, requires wide surgical exposure. Preoperative or intraoperative CSF drainage has been shown to facilitate frontal and temporal lobe relaxation.² In endoscopic endonasal surgery (EES), LD provides dual benefits. Beyond facilitating brain relaxation, LD plays a protective role in prophylaxis against postoperative CSF leakage. Skull base tumor resection often leaves a large dural defect. Even after reconstruction with a vascularized flap such as a pedicled nasoseptal flap, a high intracranial hydrostatic pressure gradient can displace the flap, risking disruption of its adhesion.^{1,10}

Obese patients (BMI >30 kg/m²) have higher intrathoracic and intraabdominal pressures, which can be transmitted to the venous system, increasing jugular venous resistance and potentially contributing to intracranial hypertension. In this high-risk patient group, particularly when high-flow intraoperative CSF leaks are encountered, perioperative LD to maintain CSF diversion significantly reduces the incidence of reconstruction failure and CSF leak.^{11,12} In surgery for large pituitary macroadenomas, LD has a distinctive biomechanical function. In suprasellar tumors, controlled CSF removal, for example, stepwise up to a total of 20 mL, can artificially reduce supratentorial pressure.⁶

This causes the diaphragm sellae and residual

suprasellar mass to descend or prolapse slowly into the sphenoid cavity, enabling gross total resection through an inferior endoscopic approach without requiring additional open craniotomy.^{3,6} Controlling the drainage rate is critical, as excessively rapid fluid removal can exert traction on cortical bridging veins, increasing the risk of acute subdural hemorrhage.⁴ The use of LD in posterior fossa tumors, such as vestibular schwannoma or medulloblastoma, remains controversial and carries high risk. Masses in the infratentorial compartment often obstruct CSF flow at the aqueduct of Sylvius or fourth ventricle, causing obstructive hydrocephalus. In this setting, placement of lumbar LD is contraindicated unless supratentorial pressure has first been secured, for example, through the placement of an External Ventricular Drain (EVD). Removing CSF from the lumbar region in obstructive hydrocephalus can suddenly create a large transmural pressure gradient between the cranial and spinal compartments, potentially triggering tonsillar herniation (brainstem herniation), where the brainstem is pushed toward the foramen magnum.⁴

Intraoperative Management

Intraoperative management of lumbar drainage (LD) is not merely a mechanical act of removing cerebrospinal fluid (CSF), but an intervention requiring continuous monitoring and flow rate control by the neuroanesthesiologist. LD placement is generally performed immediately after general anesthetic induction and endotracheal intubation, but before the patient is positioned definitively for surgery, for example, in the supine position with Mayfield pin fixation for craniotomy, or in a modified position for transsphenoidal endoscopy. Placement after induction reduces patient anxiety, prevents sudden movements that may injure the spinal cord, and allows for safe airway management.⁶ However, in certain cases, such as patients with a history of complex spinal surgery, LD may be placed while the patient is still awake under local anesthesia, to ensure the absence of radicular neurological responses during insertion.¹² Intervertebral level selection requires careful

attention. Insertion must be performed below the conus medullaris, typically at L3–L4 or L4–L5, using a 14G–18G Tuohy needle.^{4,13} The subarachnoid catheter is then advanced 5–10 cm into the intrathecal space. In patients with central obesity (BMI >30 kg/m²)—who represent a target population due to their higher risk of postoperative CSF leak—anatomical landmarks are often difficult to palpate. In such cases, the neuroanesthesiologist may use ultrasound or fluoroscopic guidance to assist with safe insertion.^{8,13}

The procedure must be performed under strict aseptic precautions equivalent to surgical standards, as the catheter creates a direct conduit between the external environment and the central nervous system.¹⁴ Once the catheter is in place and connected to the closed system, the stopcock must be immediately clamped to prevent over drainage at the outset.¹³ The lumbar drainage catheter can also serve as a monitoring tool. By connecting the catheter to a pressure transducer aligned at the level of the foramen of Monro, typically at the level of the tragus or external auditory meatus real-time global ICP monitoring is possible, provided there is no CSF flow obstruction between the cranial and spinal compartments.⁴ Drainage volume monitoring must be performed using a precision-scaled burette (mL).

The neuroanesthesiologist must continuously monitor the drip rate, as rapid and sudden CSF removal, for example, due to changes in operating table position or a Valsalva maneuver, can have serious consequences.^{6,14} Closed-loop communication between the neurosurgeon and neuroanesthesiologist determines the timing of catheter valve opening. The valve must not be opened during skin incision or cranial bone drilling (craniotomy). Premature opening while the dura is still intact may cause the brain parenchyma to retract away from the dura, creating a dead space that stretches the bridging veins and increases the risk of venous laceration when the surgeon exposes the bone.⁶ CSF removal is initiated when the surgeon indicates the need for brain relaxation, typically just before dural opening or during

tumor manipulation at the skull base. Drainage volume is generally limited to 10–20 mL/hour in a gradual stepwise manner, or delivered as controlled small boluses of 10 mL while evaluating the brain relaxation response until a slack brain is achieved.^{6,12} If baseline ICP is very high, drainage must be performed more slowly to prevent a sudden decompression gradient. Once the target volume is reached, for example a total of 20–30 mL, the valve must be promptly closed to allow the intracranial compartment time to reach pressure equilibration.⁶

LD management must be aligned with pharmacological neuroanesthetic strategies. The use of inhalational anesthetic agents such as isoflurane or sevoflurane at Minimum Alveolar Concentration (MAC) >1.0 is cerebral vasodilatory, which can increase cerebral blood volume (CBV) and reduce the expected relaxation effect of CSF drainage. Therefore, total intravenous anesthesia (TIVA) using propofol is often recommended, as it can reduce the cerebral metabolic rate of oxygen (CMRO₂) and facilitate cerebral vasoconstriction, synergistically working with CSF diversion to achieve brain relaxation.¹⁵ The administration of adjunct osmotherapy, for example, 20% mannitol 0.5 g/kg body weight, must be coordinated with the drainage rate to avoid excessive brain shrinkage.¹³

Complications and Risk Mitigation

CSF diversion interventions can alter intracerebral physiological equilibrium, making monitoring essential to mitigate iatrogenic complications. Brain herniation is the most serious complication. Its pathophysiology relates to the formation of a rostrocaudal pressure gradient, a sudden pressure gradient from the cranial toward the spinal compartment. If an obstructive supratentorial or posterior fossa lesion blocks CSF circulation, removal of CSF from the lumbar compartment will rapidly decrease spinal pressure while cranial pressure remains high. Consequently, brain structures such as the cerebellar tonsils or uncus may be pushed toward the foramen magnum, compressing the brainstem.^{4,14} In patients under general anesthesia, intraoperative clinical signs

that can be monitored include the Cushing reflex (Cushing's triad), presenting as sudden hypertension accompanied by marked bradycardia without a clear cause and hemodynamic pattern changes.¹⁴ Primary mitigation includes avoiding rapid diversion in large volumes and not placing LD in obstructive hydrocephalus without securing an External Ventricular Drain (EVD).

Excessively aggressive CSF decompression can result in over drainage or artificial intracranial hypotension. The brain loses its buoyancy within the cranial cavity and is pulled downward by gravity. This positional change causes mechanical stretching of the delicate cortical bridging veins that drain into the superior sagittal sinus. If the elastic limit of these veins is exceeded, laceration can occur, triggering traumatic subdural hemorrhage (SDH).^{4,12} Hematoma may also develop at the puncture site, including spinal epidural hematoma, particularly if the patient's coagulation profile is suboptimal.^{4,5} Meningitis is an important complication reported in 2–7% of patients with lumbar catheters. The risk increases with longer postoperative catheter dwell time and more frequent CSF sampling, as these actions may compromise the integrity of the closed system. Manipulation of the stopcock by nurses or physicians must be minimized. Although the use of specific antibiotic prophylaxis, beyond antibiotics for the neurosurgical procedure itself, remains debated, systemic broad-spectrum perioperative antibiotics are generally recommended while the drain is in place for clean-contaminated procedures such as the endonasal approach.^{5,14}

Pneumocephalus is a complication that often goes unrecognized until the recovery phase. Tension pneumocephalus can occur through a siphoning effect. When surgery involves opening the skull base, for example through the nasal cavity, or extensive dural dissection, the cranial cavity may come into contact with free air. If CSF is drained from the lumbar area at a rate exceeding the brain's ability to re-expand, a negative pressure within the cranium can draw air from the surgical site into the subarachnoid space and intracranial ventricles.¹⁵ Trapped air can expand, particularly

if nitrous oxide (N_2O), which is contraindicated in neuroanesthesia, is used during anesthesia, causing parenchymal compression and sudden neurological deterioration following extubation.¹² Post-dural puncture headache (PDPH) is a relatively common minor complication following surgery, caused by persistent CSF leakage through the needle puncture defect in the spinal dura after catheter removal. The reduction in CSF volume causes traction on pain-sensitive meningeal structures when the patient assumes an upright position. Because LD placement requires a large-bore Tuohy needle (14–18G), the use of smaller atraumatic needles is not feasible; anesthetic prevention therefore relies on minimizing repeated punctures and ensuring adequate wound closure. Management includes bed rest, adequate hydration, intravenous caffeine, and epidural blood patch (EBP) for refractory headache.^{4,5}

Evidence-Based Medicine on the Use of LD in Various Cases

Advances in skull base reconstruction techniques, such as the use of pedicled nasoseptal flaps, position LD not as a routine procedure for every skull base and endonasal tumor operation. Accordingly, the use of LD should be individualized and guided by patient risk stratification.¹⁶ A meta-analysis evaluating endoscopic skull base tumor resection concluded that routine LD in all patients do not significantly reduce the incidence of CSF leak compared to no LD, and may increase the risk of headache and prolong hospital stay.¹ However, in the subgroup analysis of patients with high-flow intraoperative leaks, defined as dural defects $>1\text{ cm}^2$ with ventricular or basal cistern exposure, the use of intraoperative LD through several days postoperatively (3–5 days) significantly reduced dural repair failure and postoperative CSF leak rates.^{1,10} These findings are supported by other studies indicating that mechanical CSF diversion should be integrated into multilayer reconstruction strategies when dural tears are extensive.¹¹

In obese patients ($BMI >30\text{ kg/m}^2$), studies on endoscopic endonasal suprasellar meningioma resection have shown that failed LD placement

is an independent predictor of postoperative CSF leak. Obesity increases intrathoracic and central venous pressure, which can be transmitted as secondary intracranial hypertension. In this high-risk population, particularly in the presence of intraoperative high-flow leaks, intraoperative LD has a protective role in managing perioperative ICP elevation.⁸

A randomized controlled trial in pituitary adenoma surgery showed that the group receiving CSF diversion via LD demonstrated superior operative field exposure.³ Similarly, a retrospective cohort study of 189 patients with pituitary macroadenomas undergoing endoscopic transsphenoidal surgery (119 with LD and 70 without LD) showed that removing 20–30 mL of CSF facilitated descent of the suprasellar mass. This intervention not only significantly reduced the rate of intraoperative CSF leakage (10.1% vs. 31.4%; $P < 0.001$) and postoperative CSF leakage (3.4% vs. 11.4%; $P = 0.035$), but was also associated with a higher gross total resection rate (92.4% vs. 78.6%; $P = 0.006$), achieved without requiring maneuvers that risk injuring the optic nerve.⁶ Postoperative functional outcomes may improve as blunt traction manipulation of healthy brain tissue can be avoided.

Accordingly, the American Rhinologic Society Expert Practice Statement (2024) formulated a consensus that lumbar drainage management is no longer viewed as a blanket policy for all patients, but rather as a targeted adjuvant procedure decided intraoperatively, based on tumor morphology, degree of intraoperative leakage, and patient anatomical comorbidities.¹⁰ This decision requires effective collaboration and comprehensive analysis between the neurosurgeon assessing the operative field directly and the neuroanesthesiologist controlling hemodynamics and the patient's CSF hydrodynamic profile.

Conclusion

The use of lumbar drainage (LD) in neurosurgical procedures—particularly in skull base and transsphenoidal brain tumor resection—has evolved from a modality for managing

postoperative complications to a frequently employed intraoperative instrument. The role of LD extends beyond fluid diversion to become an integral component of the strategy for achieving a slack brain that facilitates retractor less surgery techniques. LD optimizes surgical exposure and brain relaxation: LD provides rapid mechanical decompression of the intracranial compartment through direct CSF volume removal. This significantly reduces the need for aggressive mechanical brain retraction, thereby lowering the risk of post-retraction ischemic cerebral edema, particularly in large suprasellar and skull base region tumors. LD use is not recommended routinely for all cases, but is recommended selectively in high-risk populations.

Patients with high BMI or obesity, as well as cases with intraoperative high-flow CSF leaks, demonstrate the greatest protective benefit from LD in preventing dural reconstruction failure. Successful LD use is highly dependent on precise intraoperative neuroanesthetic management. Decisions regarding catheter valve opening timing—just before dural opening—control of a slow and gradual drainage rate (10–20 mL/hour), and the use of total intravenous anesthesia (TIVA) to support cerebral vasoconstriction are important responsibilities of the neuroanesthesiologist in maintaining CSF hydrodynamic stability. Vigilance regarding serious risks—such as brainstem herniation from a rostrocaudal pressure gradient, subdural hemorrhage from rapid decompression, and tension pneumocephalus—must be a primary monitoring focus.

Neuroanesthesiologists must recognize early signs of intracranial compartment decompensation so that CSF diversion can be stopped before permanent neurological injury occurs. In conclusion, the integration of lumbar drainage in brain tumor surgery represents a multidisciplinary collaboration requiring a solid understanding of pathophysiology. For the neuroanesthesia subspecialist, mastery of this technique provides the ability to dynamically manipulate the intracranial space, with the aim

of increasing the degree of tumor resection, protecting healthy neural tissue, and optimizing patients' postoperative functional outcomes.

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