**Saudi Journal of Medicine and Public Health**

https://saudijmph.com/index.php/pub

https://doi.org/10.64483/202522407

# Craniotomy in Nursing Practice: Perioperative Care, Neurologic Monitoring, and Patient Safety

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## Abstract

**Background:** Craniotomy is a cornerstone neurosurgical procedure that provides direct access to intracranial structures for treating tumors, vascular lesions, trauma, and infections. Despite technological advances, it remains a high-risk intervention requiring meticulous planning and multidisciplinary coordination.

**Aim:** To review craniotomy in nursing practice, emphasizing perioperative care, neurologic monitoring, and patient safety.

**Methods:** This narrative review synthesizes historical evolution, anatomical considerations, indications, contraindications, equipment, personnel roles, preparation, surgical technique, complications, and postoperative management. Sources include contemporary neurosurgical literature and evidence-based nursing guidelines.

**Results:** Craniotomy techniques have evolved from ancient trephination to modern neuronavigation-assisted approaches. Indications span trauma, neoplasms, vascular disorders, and functional neurosurgery. Contraindications are rare but include severe systemic instability and coagulopathy. Nursing interventions are critical across all phases: preoperative optimization, intraoperative sterility and monitoring, and postoperative surveillance for complications such as hemorrhage, infection, and electrolyte imbalance. Enhanced Recovery After Surgery (ERAS) principles and interprofessional collaboration improve outcomes.

**Conclusion:** Craniotomy remains indispensable for managing complex intracranial pathology. Success depends on anatomical precision, technological integration, and coordinated perioperative care. Nursing professionals play a pivotal role in ensuring safety, reducing complications, and supporting recovery through structured protocols and interdisciplinary teamwork.

**Keywords:** Craniotomy, neurosurgery, perioperative nursing, patient safety, neuronavigation, postoperative care.

## Introduction

A craniotomy is a neurosurgical procedure in which a portion of the skull is temporarily removed to provide access to the intracranial contents, enabling surgeons to visualize and treat pathology within the cranial vault.[1] In contemporary practice, craniotomy remains a foundational approach in neurosurgery because it offers direct exposure to the brain and surrounding structures, allowing precise intervention in conditions that would otherwise be inaccessible or unsafe to treat. The most frequently encountered indications include brain tumors, intracranial aneurysms, arterio-venous malformations, subdural empyemas, subdural hematomas, and intracerebral hematomas.[2] These disease processes vary widely in pathophysiology and urgency, ranging from elective tumor resections to time-sensitive operations for hemorrhage or infection. Regardless of indication, the craniotomy framework provides an operative corridor that balances the need for adequate exposure with the imperative to minimize injury to healthy tissue and preserve neurological function. The procedure is characterized by the creation and management of a "bone flap," which is the section of cranial bone removed to expose the dura and brain. Specialized neurosurgical instruments are used to create this flap, typically by forming burr holes and then connecting them to outline the flap before it is elevated. Once



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Receive Date: 01 December 2025, Revise Date: 28 December 2025, Accept Date: 30 December 2025

removed, the bone flap is maintained in a controlled sterile manner—often held at the instrument table—until intracranial work is completed, after which it is typically returned to its original position and secured.[3] The handling of the bone flap is not merely a technical step; it reflects broader clinical goals related to cranial protection, cosmetic outcome, infection prevention, and long-term structural integrity. However, the fate of the bone flap can vary depending on the patient's underlying pathology and the physiologic conditions encountered during surgery. In certain situations, the bone may be discarded, stored temporarily in the abdominal subcutaneous space, or preserved via cryopreservation under cold storage conditions.[3] These alternatives are generally considered when immediate replacement is not advisable, such as when swelling is expected to worsen or when infection risk is high.

When the bone flap is not replaced at the conclusion of the initial operation, the procedure is termed a craniectomy rather than a craniotomy. This distinction has important clinical implications, particularly in the context of decompressive craniectomy, which is performed to treat malignant cerebral edema and reduce intracranial pressure by allowing the swollen brain to expand outward rather than herniate through rigid intracranial compartments.[4][5] In such cases, the bone flap is typically reimplanted weeks later after swelling has resolved and the patient's neurologic status stabilizes.[4][5] The subsequent reconstructive operation to restore the cranial contour and replace the bone flap—or an alternative implant when the original flap is unavailable—is known as cranioplasty.[6] Cranioplasty is not purely cosmetic; it can contribute to cranial protection, normalization of cerebrospinal fluid dynamics, and improved patient rehabilitation, underscoring the continuity between the initial life-saving intervention and longer-term recovery planning.[6] From a historical standpoint, cranial surgery has progressed from the rudimentary technique of trephination—creating a single burr hole—to more extensive approaches such as craniectomy and, ultimately, the tailored craniotomy techniques used today.[1] Trephination is widely recognized as one of the oldest surgical procedures in human history, with reports dating back approximately 2300 years.[7][8] While ancient practitioners lacked modern understanding of neuroanatomy and pathology, archaeological evidence suggests that some civilizations, including the Incas in Peru, possessed practical familiarity with cranial interventions and basic anatomical principles, even if their etiologic explanations for disease were limited.[7][9] The development of modern craniotomy, involving the connection of multiple burr holes to create a controlled bone flap, represents the culmination of incremental surgical innovation. A key historical milestone is attributed to Wilhelm Wagner, whose late 19th-century contributions helped shape the procedural concepts that evolved into present-day craniotomy practice.[1][7][8] This historical trajectory reflects the broader transformation of neurosurgery from empiric cranial opening toward precision-based operative exposure guided by anatomy, imaging, and microsurgical principles.

In contemporary neurosurgery, technological advances have further refined craniotomy planning and execution. Depending on lesion type, pathology, and the intended surgical corridor, craniotomy can be assisted by neuronavigation systems that integrate preoperative magnetic resonance imaging (MRI) or computed tomography (CT) scans.[10] These systems allow the surgeon to tailor the size and location of the incision and bone flap to the lesion's exact coordinates, supporting the goal of maximal therapeutic effect with minimal collateral disruption. Neuronavigation functions through computerized spatial localization, merging craniofacial reference points on the patient with the imaging dataset to provide real-time orientation during the procedure. By enhancing guidance and localization, neuronavigation improves surgical confidence and can contribute to better outcomes, particularly in complex cases where anatomical landmarks are distorted by mass effect, edema, or previous surgery.[10] For perioperative nursing practice, these developments also emphasize the need for familiarity with evolving neurosurgical workflows, specialized equipment, and the interdisciplinary coordination required to maintain safety and sterility while supporting highly technical intraoperative decision-making.

**Historical Background**

The craniotomy approach has a long and complex history that reflects the broader evolution of surgery itself—from ritualistic practices rooted in spiritual beliefs to anatomically informed, technically refined neurosurgical interventions supported by anesthesia, antisepsis, and imaging. Evidence of cranial opening procedures extends back to the Neolithic period, making craniotomy and its earlier forms among the oldest documented surgical practices in human civilization. The earliest and most widely recognized precursor is trepanation or trephination; a term historically associated with creating an opening in the skull using a boring technique. The word "trepanation," meaning "borer," became closely linked with trephination through linguistic and instrumental traditions, including reference to the French instrument "tres fines," translated as "3 ends," which contributed to the terminology that persisted in surgical literature.[11] Although the procedural intent and technique have changed drastically over time, the persistent human attempt to access the cranial vault underscores a long-standing recognition—whether scientifically grounded or culturally interpreted—that intracranial processes could cause illness and that cranial intervention might provide relief. Archaeological findings and historical interpretations suggest that trephination was performed by prehistoric peoples for reasons that were often symbolic, religious, or magical. Historical accounts describe its use in efforts to “release demons and malignant spirits,” and in some contexts, bone fragments removed from the skull were reportedly retained as amulets.[12] While modern clinicians recognize these explanations as pre-scientific, they nonetheless provide insight into early attempts to attribute neuropsychiatric symptoms, seizures, headaches, or behavioral changes to forces believed to be trapped within the body. Importantly, the persistence and geographic diversity of trephination findings indicate that cranial intervention was not isolated to one region or culture, but rather emerged independently across societies, possibly because cranial trauma and neurologic symptoms were common and dramatic, prompting experimentation with interventions that might alleviate suffering.

**Fig. 1:** Decompressive hemicraniectomy.

During the Neolithic era, the technical execution of skull drilling began to show systematic characteristics. Therapeutic drilling was performed with pointed or sharp cutting tools made from silica or obsidian, materials capable of producing the necessary cutting edges despite the limitations of early toolmaking.[13] The refinement of drilling techniques accelerated as mechanical principles were adapted from other human technologies. For example, the concept of bow drilling—derived from fire-making—was utilized by Egyptians around 1400 BC. A sharp rod made of hard stone or metal could be rotated rapidly between the hands, and later the process was improved by using a cord and bow mechanism to increase speed and control. This method created a circle of small holes, after which the remaining bony bridges were broken to complete the opening.[12] Such descriptions are notable because they reveal an early understanding of incremental skull penetration, likely intended to reduce uncontrolled fractures and perhaps to protect deeper structures, even if anatomical knowledge was incomplete. Several historical figures and texts are associated with the development and documentation of cranial surgery. The approach to craniotomy has been attributed to Imhotep, who is believed to have written about such concepts around 2900 BCE, reflecting one of the earliest recorded associations between medicine and organized technical practice.[13] Hippocrates later described therapeutic cranial intervention for fracture management in the fifth century BC, marking a shift toward clinical indication and pragmatic rationale rather than purely ritualistic intent.[12][14] Over the centuries, surgical instruments and methods became increasingly detailed in medical writings. Instruments were described as early as 1518 in Berengario’s “De fractura calvae,” illustrating that by the Renaissance period there was growing emphasis on procedural technique and the mechanics of cranial intervention.[14] The historical narrative was later enriched by scholars such as Broca, who explained archaeological findings related to skull trepanation and helped integrate ancient practices into the evolving understanding of neurosurgical history.[14]

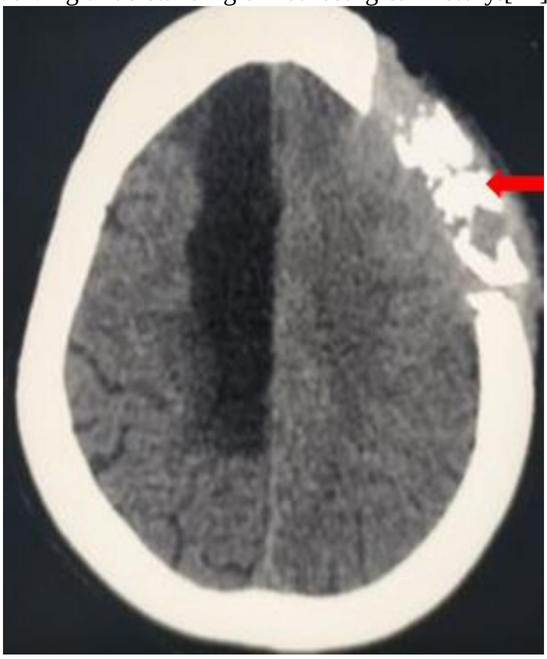

**Fig. 2:** Osteomyelitis.

Classical and early medical writers also contributed procedural nuance. Celso advocated for trephination as a sequential process—working through the external cortex, diploic tissue, and finally the internal cortex—while emphasizing protection of the meninges.[12] Even though modern neurosurgery has vastly more precise anatomical and physiological knowledge, this stepwise approach reflects an early recognition of layered cranial structure and the need to avoid penetrating too deeply too quickly. Such incremental advances in method likely improved survival and may explain why some archaeological skulls show evidence of healing, implying that patients occasionally survived these procedures. By the nineteenth century, cranial surgery expanded from trauma-related interventions to the attempted treatment of intracranial disease. William Detmold's operation on an abscess within the lateral ventricle in 1850 exemplifies this transition toward intracranial pathology management.[12] However, progress was not linear. The Renaissance period, with the rise of firearms and explosive weapons in the sixteenth and seventeenth centuries, increased the burden of cranial trauma, which likely stimulated further refinements in cranial operative techniques and instruments.[12] The introduction of angulated manual trephines equipped with perforating or cutting terminals during this era illustrates an effort to improve control and effectiveness when dealing with complex cranial injuries.[12] In 1889, Wagner's performance of an osteoplastic bone flap represented a pivotal milestone, aligning more closely with modern craniotomy concepts in which bone is removed and later replaced to preserve cranial integrity.[12] The subsequent use of Gigli's saw by Obalinski in 1897 further advanced the technical toolkit available for controlled cranial openings, supporting more refined and reproducible bone flap creation.[12]

Despite these innovations, early nineteenth-century practice experienced a decline in craniotomy primarily due to postoperative infections, with trephining often reserved for exceptional circumstances.[12] This period underscores how surgical ambition was constrained by the absence of effective infection control, sterile technique, and reliable anesthesia. The dramatic transformation occurred with the development and adoption of antisepsis and general anesthesia in the nineteenth century, which catalyzed exponential growth in trephination and craniotomy. These advances enabled surgeons to perform cranial operations with reduced infection risk, improved pain control, and greater procedural precision, extending indications beyond traumatic injury to include nontraumatic intracranial lesions.[12][13][14] In this sense, the historical evolution of craniotomy mirrors the broader story of modern surgery: technical ideas existed for centuries, but widespread safe practice became possible only when supportive scientific foundations—microbiology, antisepsis, anesthesia, and later imaging—allowed surgeons to translate concept into consistently survivable clinical care.[12][13][14]

**Anatomy and Physiology**

Craniotomy is not a single standardized operation but rather a family of approaches tailored to the location of intracranial pathology and the anatomic corridor required for safe access. For that reason, a foundational understanding of cranial anatomy and neurophysiology is essential to performing an adequate craniotomy while minimizing complications. The selection of approach is shaped by the relationship between the skull, meninges, venous sinuses, cranial nerves, vascular territories, and eloquent cortical regions. Although surgical technique and modern technologies such as neuronavigation and intraoperative imaging can enhance accuracy, they cannot substitute for anatomical literacy. In practice, craniotomies are frequently named according to the skull bone or region opened, reflecting both the surgical entry point and the operative trajectory toward the target. The frontal, parietal, temporal, and occipital bones are among the most commonly targeted cranial bones, and each region carries distinct risks and physiologic considerations, such as proximity to major venous channels, functional cortical areas, and arterial branches that supply critical neural tissue. A central physiologic distinction in craniotomy planning is whether the approach is supratentorial or infratentorial. Supratentorial craniotomies access structures above the tentorium cerebelli, including the cerebral hemispheres, basal cisterns, and much of the anterior and middle cranial fossae. Infratentorial craniotomies—often described as posterior fossa approaches—provide access to the cerebellum, brainstem, fourth ventricle, and cranial nerve root entry zones. This distinction is clinically significant because posterior fossa operations occur in a confined compartment where edema, bleeding, or impaired cerebrospinal fluid (CSF) flow can lead to rapid deterioration due to brainstem compression or obstructive hydrocephalus. Conversely, supratentorial approaches must contend with cortical mapping considerations, the risk of seizures, and potential deficits related to motor, language, or sensory cortex depending on the operative region.

One of the most traditional and widely utilized supratentorial approaches is the pterional craniotomy. Anatomically, the pterion region lies near the junction of the frontal, parietal, temporal, and sphenoid bones, providing a versatile corridor to the anterior circulation and parasellar regions. Clinically, the pterional approach is commonly used for aneurysms of the anterior circulation, basilar tip artery aneurysms, and direct surgical access to the cavernous sinus, as well as for tumors involving the frontal and temporal lobes.[15][16][17][18] It is also used for suprasellar tumors, including pituitary adenomas and craniopharyngiomas, which occupy a region densely populated by vital neurovascular structures. The physiologic implications of operating in this territory include risks related to manipulation of the circle of Willis, perforator vessels, optic apparatus, and hypothalamic-pituitary axis—structures that, if compromised, can result in ischemic injury, visual loss, or endocrine disturbance. Thus, the pterional craniotomy exemplifies how an anatomic corridor must be chosen not only for access but also for the ability to protect functionally critical structures while providing adequate visualization. Another important supratentorial approach is the temporal or subtemporal craniotomy. This approach leverages access through the temporal bone and is selected when pathology lies in or near the temporal lobe or the floor of the middle cranial fossa. In clinical practice, it may be used for temporal lobe biopsy, temporal lobectomy, epilepsy surgery, and access to the middle cranial fossa floor.[19][20] The physiologic stakes of temporal operations include potential impacts on language (particularly in the dominant hemisphere), memory circuitry, and the risk of injury to venous drainage pathways. Moreover, retraction and manipulation in the temporal region can influence intracranial pressure dynamics and cerebral perfusion, making anesthetic and surgical coordination essential to avoid secondary injury, especially in cases where edema or vascular compromise is a concern.

Frontal craniotomy represents another common category, frequently employed to access the frontal lobe and anterior skull base. This approach is used for surgical corridors toward tumors of the third ventricle or sellar region, craniopharyngiomas, planum sphenoidale meningiomas, and frontal lobe tumors, and it may also be utilized for repair of anterior CSF fistulas.[21] The anatomy of the anterior cranial fossa brings additional considerations, including proximity to the frontal sinuses and the potential for postoperative CSF leakage or infection if barriers between sterile intracranial spaces and sinonasal cavities are compromised. Physiologically, operations in the frontal region may affect executive function, behavior, and motor pathways depending on lesion location, further reinforcing the need for meticulous planning and neuro-monitoring strategies where appropriate. Beyond these commonly described approaches, other craniotomies—including parietal, occipital, and retrosigmoid—are selected based on lesion location and required operative angles.[21] Each carries characteristic relationships to cortical function, arterial supply, venous sinuses, and cranial nerves. In all cases, the guiding principle remains the same: craniotomy design is an exercise in applied anatomy and neurophysiology, balancing exposure against tissue preservation, and minimizing disruption to cerebral perfusion, CSF dynamics, and functional neural networks. A detailed grasp of these relationships supports safer operative planning and contributes directly to reduced complication rates and improved neurologic outcomes.

**Indications**

Craniotomy is indicated when direct intracranial access is required to diagnose, decompress, repair, remove, or treat lesions affecting the brain, meninges, cranial vasculature, or skull base. Because the cranial vault is a rigid compartment, many intracranial pathologies can rapidly compromise cerebral perfusion, distort neural structures, or precipitate herniation syndromes. In such scenarios, craniotomy is not merely a technical option but a physiologically driven intervention intended to relieve mass effect, control bleeding, eradicate infection, restore anatomic integrity, or enable definitive lesion management. Accordingly, the indications for craniotomy span urgent life-saving emergencies as well as elective procedures aimed at preventing neurologic decline, improving function, or achieving long-term disease control. Trauma remains one of the most time-sensitive indications. Craniotomy may be required for acute extradural (epidural) hematoma, acute subdural hematoma, traumatic intracerebral contusions with mass effect, and depressed skull fractures when there is significant compression, contamination, or neurological deterioration. It is also indicated for removal of intracranial foreign bodies and for repair of cerebrospinal fluid (CSF) leaks, particularly when persistent leakage raises the risk of meningitis or other intracranial infections.[22][23][24][25][26][27][28][29][30][31][32][33][34] In traumatic contexts, the physiologic goal often centers on preventing secondary brain injury by controlling hemorrhage, reducing intracranial pressure, and restoring normal intracranial dynamics as quickly as possible.

Neoplastic disease represents another broad and common indication. Craniotomy enables biopsy, subtotal resection, or gross total resection of tumors and tumor-like lesions, including meningiomas, high-grade and low-grade gliomas, epidermoid tumors, ependymomas, oligodendrogliomas, metastatic lesions, and tumors in complex regions such as the orbit, cerebellopontine angle, and sellar or parasellar compartments.[22][23][24][25][26][27][28][29][30][31][32][33][34] In these settings, craniotomy is frequently performed to establish histopathologic diagnosis, reduce tumor burden, relieve mass effect, and create conditions for adjunctive therapies such as radiotherapy or chemotherapy. Vascular indications encompass both hemorrhagic and ischemic conditions. Craniotomy may be performed for intracerebral hemorrhage evacuation in selected cases, decompression for malignant middle cerebral artery (MCA) territory infarction with life-threatening edema, and management of cortical venous thrombosis with hemorrhagic infarction when mass effect or deterioration is present.[22][23][24][25][26][27][28][29][30][31][32][33][34] It is also indicated for definitive treatment of aneurysms and vascular malformations, including arterio-venous malformations, cavernous angiomas, and arterio-venous fistulas, where microsurgical clipping, resection, or combined strategies may be necessary.[22][23][24][25][26][27][28][29][30][31][32][33][34] These operations are undertaken with the aim of preventing rebleeding, reducing seizure risk, alleviating neurologic deficits, or eliminating high-risk vascular anatomy.

Craniotomy is additionally indicated for microvascular decompression procedures, which are performed to relieve neurovascular compression syndromes affecting cranial nerves. Infectious indications include drainage or excision of intracranial abscesses and evacuation of subdural empyemas, where prompt source control is essential to prevent systemic sepsis, venous thrombosis, or irreversible neurologic injury.[22][23][24][25][26][27][28][29][30][31][32][33][34] Parasitic lesions, such as hydatid cysts and racemose neurocysticercosis, may also require craniotomy when medical therapy is insufficient or when lesions produce mass effect or obstruct CSF pathways.[22][23][24][25][26][27][28][29][30][31][32][33][34] Finally, craniotomy supports a range of miscellaneous and functional neurosurgical interventions. These include epilepsy surgery when seizures are refractory to medication, functional procedures such as deep-brain stimulation and pain-modulating operations (e.g., thalamotomy), and stereotaxic or neuroendoscopic procedures that require intracranial access or precise targeting.[22][23][24][25][26][27][28][29][30][31][32][33][34] Across all categories, the decision to perform a craniotomy is guided by an individualized assessment of pathology, patient physiology, neurologic status, and the anticipated balance between operative benefit and procedural risk.

**Contraindications**

Craniotomy is frequently undertaken because it offers direct access to life-threatening or function-threatening intracranial pathology; therefore, true contraindications are comparatively few and are usually determined by an unfavorable risk–benefit balance rather than a strict technical impossibility. In many emergency settings—such as expanding intracranial hematoma with herniation risk—there may be no practical alternative, and the concept of "contraindication" becomes relative, because the expected outcome without intervention is catastrophic. Nevertheless, in elective or semi-urgent contexts, clinicians must systematically evaluate whether the physiologic burden of anesthesia, the operative stress response, and the potential for perioperative complications outweigh the anticipated neurosurgical benefit. When that balance is unfavorable, postponement, alternative strategies, or palliation may be more appropriate. A common category of contraindications relates to excessively high anesthetic risk. Advanced age alone is not necessarily prohibitive, but when combined with severe medical comorbidities—such as unstable cardiopulmonary disease, advanced hepatic dysfunction, or poor physiologic reserve—the probability of perioperative decompensation increases substantially. Similarly, patients in a moribund state, those with profound functional impairment, or individuals with a high frailty index may have limited tolerance for major cranial surgery and a reduced likelihood of meaningful neurologic recovery even if the intracranial pathology is addressed. Severe systemic collapse, including septic shock, multiorgan failure, or profound hemodynamic instability, is another setting in which craniotomy may be contraindicated unless the intracranial process itself is driving the collapse and emergent neurosurgical source control is the only viable life-saving option. In these cases, the decision often becomes one of triage: determining whether stabilization can reasonably occur before surgery or whether surgery must proceed as a rescue intervention [30][31][32][33][34].

Coagulation disorders constitute an important contraindication category because cranial surgery carries a high consequence for bleeding, including the possibility of postoperative hematoma, brain swelling, and secondary ischemic injury. Patients with major bleeding dyscrasias or significant coagulopathy are at elevated risk of uncontrollable intraoperative hemorrhage and postoperative rebleeding. While many coagulation abnormalities can be corrected preoperatively with targeted therapy, severe or refractory disorders may render craniotomy unsafe, particularly for elective indications. In addition, if the pathology can be adequately managed with a less invasive alternative—such as a single burr hole for selected lesions—then full craniotomy may be contraindicated on the basis of unnecessary invasiveness, because the same therapeutic goal can be achieved with lower operative burden and reduced complication risk.[35] Contraindications become more specific in the context of awake craniotomy, which is typically selected to facilitate intraoperative neurologic testing and mapping while minimizing injury to eloquent cortex. Awake techniques introduce unique airway and cooperation requirements, making patient engagement a core safety prerequisite. Absolute contraindications for awake craniotomy include patient refusal and a noncompliant patient, because inability or unwillingness to cooperate can jeopardize airway safety, disrupt neurologic testing, and compromise operative conditions at critical moments.[36] Even when the intracranial indication is strong, awake surgery cannot be performed safely without informed consent and reliable participation [30][31][32][33][34].

Relative contraindications for awake craniotomy include conditions that increase airway risk or impair the ability to maintain stable spontaneous ventilation. These include obesity, obstructive sleep apnea, and anticipated difficult airway management, where airway rescue during an awake procedure may be more challenging.[36] Chronic refractory cough can similarly compromise surgical precision and increase risk, particularly during delicate cortical manipulation. Lesion-specific factors also matter: highly vascular lesions may pose bleeding risks that complicate awake management, and posterior fossa lesions are relatively contraindicated for awake approaches because of positioning, airway considerations, and the proximity of brainstem structures that can rapidly affect ventilation and hemodynamics.[36] Collectively, these contraindications highlight that craniotomy candidacy is not determined solely by intracranial anatomy, but by an integrated assessment of systemic physiology, coagulation safety, procedural alternatives, and—when awake techniques are considered—the patient's airway profile and capacity for cooperation [30][31][32][33][34][35].

**Equipment**

A craniotomy is a technically demanding intracranial operation that depends on a specialized set of instruments designed to achieve controlled access through the scalp, skull, and dura while minimizing tissue trauma and maintaining meticulous hemostasis. The equipment requirements reflect the layered anatomy encountered during the procedure—soft tissue, periosteum, cranial bone, dura mater, and intracranial contents—and the fact that bleeding control, precision dissection, and safe exposure are critical to neurologic outcome. At the outset, standard surgical instruments are required for scalp incision, soft-tissue handling, and closure, including a scalpel handle with appropriate blades, needle holders for suturing, Adson forceps and bayonet forceps for tissue manipulation, and Gerald forceps for fine dissection. Scalp retractors are used to maintain exposure after the incision, while a periosteal elevator facilitates separation of periosteum from the calvarium to prepare the operative field for drilling and bone flap creation. Throughout these steps, suction tips are indispensable for maintaining a clear field and preventing obscuration of anatomy, particularly as scalp bleeding can be brisk and persistent. Hemostasis is a defining requirement in cranial surgery, and equipment selection reflects this priority. Bipolar cautery forceps enable focused coagulation with reduced lateral thermal spread compared with monopolar cautery, making them especially valuable near delicate neural and vascular structures. Hemostatic clips and clip appliers can be used to control focal bleeding points when indicated. In addition, topical hemostatic agents such as bone wax and oxidized regenerated cellulose (e.g., Surgicel) are commonly employed to control oozing from cancellous bone edges or small soft-tissue bleeding sources, supporting a dry operative field and reducing hematoma risk.[37]

Creating the cranial opening requires dedicated cranial instrumentation. A head-fixation system is central to safe craniotomy because it stabilizes the skull and prevents movement during drilling and microsurgical manipulation, thereby reducing the risk of iatrogenic injury. For bone work, high-speed pneumatic cranial drills (craniotomes) allow controlled cutting of the skull to outline and elevate the bone flap efficiently. Alternative or adjunct techniques include use of a Hudson brace with a perforating bit, supported by a round burr, which can create burr holes manually when needed. Additional attachments—perforating bits, narrow burrs, and extension pieces—expand flexibility based on skull thickness, patient anatomy, and surgeon preference. A Gigli wire saw, with its guide and handles, represents another technique for cutting bone, historically important and still occasionally relevant, particularly in select settings or where specific bone-cutting mechanics are advantageous. Once the flap is elevated, bone curettes and Kerrison bone rongeurs allow controlled bone removal or enlargement of the craniotomy margins, particularly at edges or near foramina, to optimize exposure while respecting underlying structures. Penfield dissectors support gentle separation and dissection, and dural scissors are used for safe opening of the dura mater once bone removal is complete.[37] Collectively, these instruments form a coherent system intended to enable safe access, preserve anatomic integrity, and reduce complications such as bleeding, dural tears, or inadvertent cortical injury.[37]

**Personnel**

Successful performance of a craniotomy requires an interprofessional team because the procedure combines complex surgical execution with intensive anesthetic management, specialized intraoperative technology, and high-acuity postoperative care. The neurosurgeon leads the operative strategy and is responsible for approach selection, bone flap creation, dural opening, intracranial lesion management, and safe closure. However, neurosurgical performance depends heavily on the coordinated expertise of the operating room head nurse and surgical technologist, who ensure sterile setup, instrument availability, and workflow efficiency. The surgical technologist (operating room technologist) anticipates operative needs, manages instrument exchange, and maintains orderly field organization—tasks that are particularly important in neurosurgery where small delays or missing tools can translate into prolonged operative time and increased risk. An anesthesiologist and/or anesthetist is mandatory because craniotomy involves significant physiologic demands, including control of airway and ventilation, blood pressure management to maintain cerebral perfusion, management of intracranial pressure, and coordination of anesthetic depth with neuromonitoring goals. These clinicians must balance brain relaxation and hemodynamic stability while also anticipating complications such as blood loss, venous air embolism in select positions, or acute neurologic changes that may necessitate rapid adjustments in ventilation or pharmacology. The team extends beyond the operating room: intensive care unit nursing personnel are integral because most craniotomy patients require close neurologic and physiologic monitoring postoperatively, including frequent neurologic assessments, hemodynamic surveillance, seizure observation, and early detection of complications such as hemorrhage, edema, infection, or CSF leak. In this sense, craniotomy is not a single-event intervention but a perioperative continuum in which coordinated staffing across intraoperative and postoperative phases directly influences outcomes [37].

**Preparation**

Preoperative preparation for craniotomy aims to optimize patient physiology, reduce preventable perioperative risk, and ensure the surgical team is fully prepared for the anatomic and hemodynamic challenges of intracranial surgery. When feasible, the patient should be in the best possible clinical condition before entering the operating room. Standard preparation includes ensuring the patient is nil per os (NPO), meaning no oral intake, to reduce aspiration risk during anesthesia induction; however, in emergencies such as traumatic hematoma evacuation, strict fasting may not be possible and risk mitigation must rely on airway strategy and rapid-sequence induction techniques. Medication reconciliation is critical, particularly regarding antiplatelet and anticoagulant therapy. Blood-thinning medications are typically discontinued between 3 and 10 days preoperatively depending on the agent, because uncontrolled bleeding in cranial surgery can rapidly lead to mass effect, neurologic deterioration, and the need for reoperation.[38] Where discontinuation is unsafe or time is limited, reversal strategies and transfusion planning become essential components of preparation. A medical clearance process—often involving internal medicine or cardiology—helps quantify perioperative risk and identify modifiable issues such as uncontrolled hypertension, arrhythmia, heart failure, electrolyte abnormalities, infection, or poor glycemic control. Parallel to medical optimization is the procedural planning discussion between neurosurgery and anesthesia teams. Most craniotomies are performed under general anesthesia, but the specific anesthetic plan should reflect lesion type, anticipated blood loss, need for neuromonitoring, and positioning requirements. In selected cases, an awake craniotomy may be performed under local anesthetic techniques to allow intraoperative communication and functional testing, especially for lesions near motor or speech cortex.[39][40][41][42] Awake approaches require careful selection, patient counseling, and a shared plan for airway rescue and conversion to general anesthesia if needed. Importantly, awake anesthesia has been described as comparable to general anesthesia in terms of operative and functional outcomes, emphasizing that the choice should be individualized and guided by surgical goals and patient factors.[44]

Standard safety processes remain foundational. Informed consent must be obtained whenever circumstances allow, including discussion of neurologic risks, bleeding, infection, seizures, and potential need for postoperative intensive care. A formal time-out is required to verify correct patient identity, procedure, and surgical side, as wrong-site neurosurgery is catastrophic yet preventable.[43] Because intracranial bleeding can be clinically consequential, blood availability should be confirmed preoperatively, particularly for vascular lesions, tumor resections with high vascularity, or reoperations where scar tissue increases bleeding risk.[43] Prophylactic antibiotics are typically administered before incision for surgical site infection prevention, and other adjunct medications may be initiated as clinically indicated, such as anticonvulsants to reduce perioperative seizure risk and corticosteroids to limit edema in tumor-related cases. Operational preparation also includes the setup of specialized technology. Neuronavigation, the surgical microscope, and neuromonitoring systems are prepared before incision to avoid delays and to ensure that imaging integration and signal quality meet procedural needs. Finally, postoperative planning is part of preoperative preparation: ICU availability should be confirmed, as many craniotomy patients require high-acuity monitoring immediately after surgery. Anesthetic strategy may influence intracranial dynamics; for instance, propofol-maintained and volatile-maintained anesthesia have demonstrated similar brain relaxation scores, but propofol-maintained anesthesia has been associated with lower mean intracranial pressure and higher cerebral perfusion pressure, considerations that may be relevant when intracranial compliance is limited.[45] In sum, preparation for craniotomy is a structured, interdisciplinary process designed to reduce avoidable complications, support intraoperative precision, and ensure continuity of care through the postoperative critical period.[38][43][45]

**Technique or Treatment**

Craniotomy technique is best understood as a staged, safety-driven workflow that begins before the first incision and continues through closure, postoperative triage, and structured recovery. Although the specific skin incision, bone flap design, and intracranial corridor vary by lesion location and operative goals, the overarching priorities remain consistent: secure positioning, reliable hemostasis, atraumatic skull opening, careful dural management, minimal brain retraction, and an error-resistant transition into postoperative care. The procedure begins once the patient is anesthetized and physiologically stabilized, at which point the head is positioned to optimize the chosen approach while preserving airway patency, venous return, and cervical alignment. For supratentorial work, the head is typically rotated and slightly extended or flexed depending on whether the surgeon is targeting frontal, temporal, parietal, or occipital regions, whereas infratentorial (posterior fossa) approaches often require positioning that facilitates access below the transverse sinus and may demand heightened vigilance regarding venous congestion and brainstem-related physiologic vulnerability. Regardless of approach, meticulous padding of pressure points is mandatory because prolonged surgery can create preventable neuropathies, skin breakdown, and compartment injuries. If a neuronavigation system is used, key craniofacial reference points are verified before incision so that image-to-patient registration is accurate and the planned incision and bone flap correspond to the target pathology. Incision planning is lesion-specific and must account for both surgical exposure and postoperative cosmesis. In supratentorial craniotomy, the skin incision is commonly placed over a single bone—frontal, temporal, parietal, or occipital—or across combined regions when broader exposure is required. In infratentorial surgery, the incision is generally positioned in the posterior scalp below the transverse sinus to permit posterior fossa access. Hair preparation may involve shaving the operative region, and when feasible the incision is placed behind the hairline to improve cosmetic outcome.[37] Once the incision is marked, antiseptic skin preparation and sterile draping are performed according to institutional protocol. A local anesthetic combined with epinephrine is commonly infiltrated along the planned incision to reduce scalp bleeding, improve operative visualization, and support hemodynamic stability during the initial stages of surgery. Scalp bleeding can be substantial, so early hemostatic strategies are not optional; they are integral to maintaining a clear field and avoiding unnecessary blood loss.

After the skin incision, the scalp and underlying soft tissues are dissected to expose the calvarium. Retractors, fishhook systems, or anchoring sutures can be used to maintain exposure and stabilize the scalp flap. The pericranium is separated and preserved, as it may be used later as a dural substitute during closure, particularly when a watertight dural repair is difficult or when dura must be excised. The bone opening is then initiated with burr holes created using a craniotome or high-speed cranial drill.[37] At this stage, the surgeon must exercise strict control of depth and angle to avoid plunging into the intracranial compartment. Following burr hole creation, bone dust and fragments are cleared, and the dura is gently separated from the inner table with instruments such as a Freer elevator or Penfield dissector to prevent dural tears. The burr holes are connected with a craniotome saw to outline the bone flap, which is then elevated after careful dural separation. The bone flap is preserved in sterile conditions—commonly at the instrument table—until the closure phase. Once bone removal is complete, the dura is opened (durotomy) and reflected to expose the brain and enable the intradural portion of the operation. The intradural phase varies widely by indication—tumor resection, hematoma evacuation, aneurysm clipping, infection drainage, or functional intervention—but the key technical aims are consistent with the "dictum of craniotomy." The exposure must be adequate to address the lesion safely, the route to the target should be as short and direct as possible, and retraction of normal brain should be minimized to reduce ischemia, edema, and postoperative neurological deficits. These principles influence incision placement, flap geometry, and patient positioning. For example, positioning should facilitate gravity-assisted brain retraction, which can reduce the need for fixed retractors and thereby decrease focal pressure injury to cortical tissue. Positioning must also preserve cerebral venous drainage—because venous congestion increases bleeding, brain swelling, and postoperative complications—while remaining compatible with surgical ergonomics and airway safety. Rigid head fixation is typically achieved using three-point cranial fixation with a two-pin swivel arm and a contralateral single pin, with recommended limits on pin pressure (maximum allowable pin pressure cited as 80 lbs). Fixation planning must avoid the intended incision line, pneumatized sinuses, cranial sutures, dural venous sinuses, vulnerable neurovascular structures (including superficial temporal vessels and supraorbital or occipital neurovascular bundles), and regions of thin calvaria such as the temporal squamosa or pterion. These precautions reduce risks of bleeding, skull fracture, CSF leak, and iatrogenic injury.

Craniotomy can be performed in several structural variants, including trephine craniotomy, flap craniotomy (free bone flap or osteoplastic), keyhole approaches, and stereotactic craniotomy. Flap design is tailored to lesion location and required corridor. For instance, bicoronal (Souttar) flaps provide broad anterior exposure and can be reflected anteriorly toward the supraorbital rim; frontal flaps—unilateral or bifrontal—support access to anterior interhemispheric or sellar/third ventricular regions; temporal flaps, often designed as linear or question-mark incisions, provide routes to the middle fossa and anterior superior brainstem and may be combined with petrosectomy in select cases.[13] Parietal approaches may be chosen for interhemispheric access to parafalcine or splenial lesions, but must protect motor and sensory cortices through mapping, navigation, or functional MRI integration when appropriate. Pterional (frontotemporal) flaps, developed by Gazi Yasargil, offer access to the Sylvian fissure, opercula, and suprasellar cisterns and can be combined with subfrontal corridors for anterior cranial fossa exposure.[13] Other designs include frontotemporoparietal question-mark flaps, inverted U-shaped horseshoe flaps for convexity exposure, and orbitozygomatic approaches—described by Pellerin and Hakuba—which may be executed as one- or two-piece osteotomies and are used for lesions in paraclinoid, parasellar, cavernous sinus, basal cistern, and upper clival regions.[13] Posteriorly, mitre-shaped occipital flaps, midline suboccipital incisions, and retromastoid or retrosigmoid incisions provide access to occipital lobe, tentorial, cerebellopontine angle, and cerebellomedullary cistern regions; the retrosigmoid approach, popularized as the lateral suboccipital route, is also used for neurovascular decompression.[13] Suboccipital approaches, associated with Rand and Yasargil, can extend from the external occipital protuberance to the C2 level to expose cerebellar structures, medulla, fourth ventricle, craniocervical junction, and foramen magnum.[13] Technical execution of burr holes and bone flaps follows a controlled sequence. Burr holes may be created with a Hudson brace or motorized drill fitted with a perforating bit. The drill is held perpendicular to the skull and advanced with attention to tactile feedback: penetration through outer cortex can be difficult, then easier through cancellous bone, with a distinct resistance change as the inner cortex is engaged. Visual confirmation of inner table breach is essential, after which enlargement is performed using a curette or round burr to reduce plunge risk. Bone wax can be applied to the burr edges to control bleeding from diploic channels.[37] Bone flap creation emphasizes direct access, centering over convexity lesions, careful dural separation with a Penfield dissector, and beveling to prevent postoperative sinking of the flap. When bone cuts approach dural venous sinuses, these cuts are often deferred until last to reduce hemorrhage risk, and dural hitch or tack-up sutures may be applied liberally to minimize epidural bleeding and reduce postoperative epidural hematoma formation.

Durotomy is performed with hemostasis and closure in mind. Epidural tacking sutures are applied, dural flaps are oriented based on sinus anatomy where relevant, and the dura is opened initially with a sharp hook and knife then extended with dural scissors, commonly with a cottonoid beneath to protect cortical tissue. A suitable dural cuff is preserved to enable closure at the end of the operation. Closure aims to restore barriers, obliterate dead space, and distribute tension to preserve scalp perfusion and reduce wound complications. Dural repair should be watertight but not excessively tensioned, bone flap replacement is performed whenever feasible, monofilament sutures are favored for lower bacterial ingress and reduced tissue drag, and closure should eliminate dead space to reduce hematoma and seroma risk. Interrupted suturing can help preserve galeal vessels that supply the scalp, and skin closure is often performed in two layers to optimize healing and cosmetic outcome. At the conclusion of the intracranial portion, the bone flap is reattached with plates and screws, and the surgeon confirms adequate hemostasis before scalp closure. Layered reapproximation of tissues is completed, and a subdural or subgaleal drain may be placed depending on surgeon preference to evacuate accumulating blood products and reduce tension on the wound. In addition, a systematic review supports the use of a regional scalp block (RSB), reflecting a growing emphasis on multimodal, opioid-sparing analgesia strategies in neurosurgical patients.[46]

Modern practice is increasingly influenced by technological augmentation. Manual craniotomy can be physically demanding and time-consuming, and robotic systems may support preoperative path planning and precision drilling or milling.[47] Emerging approaches incorporating deep learning and augmented or virtual reality (AR/VR) have been proposed to supplement, augment, or potentially replace aspects of conventional technique by improving planning fidelity, spatial orientation, and intraoperative guidance.[48][49][50][51][52] While these systems vary in maturity and availability, their inclusion reflects a broader trajectory toward precision neurosurgery that seeks to reduce variability and enhance safety. Postprocedure disposition is determined by patient risk, surgical complexity, and anticipated postoperative needs. Routine ward admission appears safe for many patients, with reports of approximately 2% unplanned ICU admissions, suggesting that careful triage can avoid unnecessary critical care utilization.[53][54] Nonetheless, ICU admission is often appropriate when operations are prolonged, blood loss is substantial, anesthetic risk is high, new neurological deficits occur (including lower cranial nerve deficits), consciousness is reduced, or delayed extubation is anticipated.[53][54] Decision-making should integrate patient-specific factors such as age, baseline neurologic status, comorbidities, frailty index, and anesthesia-associated risks; surgical factors such as lesion location, size, pathology type, approach, procedure duration, emergency status, and intraoperative complications; and anticipated postoperative complications including the need for stringent neurologic and hemodynamic monitoring and management of endocrine or electrolyte disturbances such as syndrome of inappropriate antidiuretic hormone secretion, diabetes insipidus, or cerebral salt wasting. Univariate analyses have associated diabetes, high intraoperative blood loss, transfusion requirement, older age, and longer procedures with ICU need, while multivariate analysis has identified diabetes and age as predictive variables, reinforcing the importance of structured risk models and standardized pathways.[55] A “safe transition pathway” model is therefore recommended to reduce handoff failures and ensure continuity of monitoring intensity.

Postoperative management emphasizes multimodal monitoring and individualized optimization across the perioperative continuum.[56][57] Core recommendations include strict neurologic assessment and monitoring,[58] surveillance of hemodynamic stability, seizure prophylaxis when indicated, and adequate analgesia and sedation using multimodal approaches such as opioids, paracetamol/NSAIDs where appropriate, and regional anesthesia techniques.[59] Fluid and electrolyte monitoring is essential because neurosurgical patients are vulnerable to dysnatremias and endocrine disturbances; respiratory care with chest physiotherapy supports pulmonary function after prolonged anesthesia; nutritional support facilitates healing; and deep venous thrombosis prophylaxis is implemented using strategies such as low-molecular-weight heparin and intermittent compression devices when safe with respect to bleeding risk.[60][61] Enhanced Recovery After Surgery (ERAS) principles applied to neurosurgery incorporate mental status assessment, prophylactic antimicrobial, steroidal, and antiepileptic strategies when appropriate, nutritional evaluation, postoperative nausea and vomiting prophylaxis, regional field or scalp blocks, avoidance and early removal of invasive monitoring, use of absorbable skin sutures, avoidance of wound drains where feasible, early extubation, early mobilization, early de-escalation of intravenous fluids, early initiation of oral intake, and timely postoperative imaging to identify complications early.[56] Across these phases, the craniotomy technique is therefore not limited to a bone opening and lesion treatment; it is a comprehensive perioperative system designed to maintain cerebral physiology, prevent secondary injury, and support neurologic recovery through disciplined surgical execution and coordinated multidisciplinary care.[56][58]

**Complications**

Craniotomy is a high-stakes neurosurgical intervention performed within a confined anatomic compartment where small deviations in technique or physiology can yield disproportionate clinical consequences. Accordingly, complications span the full perioperative continuum: those related to head fixation and positioning, approach- and flap-specific risks, complications arising during skull opening and dural management, and postoperative neurologic, infectious, and systemic sequelae. Appreciating these risks is essential not only for operative planning but also for perioperative surveillance and early intervention, because morbidity is often driven by delayed recognition rather than inevitability of the complication itself. Head fixation devices, while essential for precision and safety, can be a direct source of harm. Complications include scalp laceration, skull fractures, and pin-site infections that may progress to osteomyelitis.[13] These events are not merely local; they can serve as portals for deeper infection, complicate wound healing, and increase the risk of reoperation. In selected circumstances, venous air embolism has also been described as a fixation-related or positioning-associated hazard, particularly when venous structures are exposed and pressure gradients favor air entry. Moreover, fixation and pin placement may contribute indirectly to acute epidural or subdural hematoma formation and even brain contusions, particularly when applied over regions of thin calvaria or when excessive pin pressure is used. Because these complications can occur early and sometimes silently, the surgical team must balance rigid immobilization against tissue integrity, avoid hazardous pin trajectories, and reassess fixation stability throughout long operations.

Complications also vary substantially by flap design and operative corridor. Scalp flap necrosis represents a serious complication because it compromises both cosmesis and the protective barrier over intracranial structures; it is more likely when vascularity is impaired by narrow flap bases, crossed incisions, excessive tension, or prolonged retraction. Frontal flaps may be complicated by cosmetic deformity, cerebrospinal fluid (CSF) leak, superior sagittal sinus injury, and retraction-related bilateral frontal lobe injury.[13] Temporal approaches carry distinct venous and cosmetic vulnerabilities, including injury to the vein of Labbe and postoperative temporal hollowing; preserving temporalis origin and avoiding dissection between leaflets of the deep temporal fascia or intermediate fat pad can mitigate hollowing risk.[62] Parietal flaps may jeopardize the vein of Trolard and overlying cortical veins, with consequences ranging from bleeding to venous thrombosis and ischemic injury; they also risk injury to the motor cortex if localization is imprecise.[13] Pterional approaches are associated with violation of the frontal sinus, potential injury to frontalis branches of the facial nerve, and extension of sphenoid osteotomy toward the optic canal—events that can translate into CSF leak, facial weakness, or visual compromise.[13] Orbitozygomatic flaps intensify these risks: fractures of the orbital roof or rim may injure the optic nerve, and sphenoid or ethmoid sinus fractures can precipitate CSF leakage. Posterior fossa corridors have their own profile. Retrosigmoid flaps can injure the lesser occipital and greater auricular nerves, producing postoperative dysesthesia and headache; they also pose risks of cerebellar retraction injury, venous sinus injury (transverse, sigmoid, torcular, or occipital), cranial nerve or brainstem damage, CSF leak and pseudomeningocele, and substantial bleeding from the mastoid emissary vein, which can additionally serve as a source of air embolism.[13] Injury to the vertebral artery, bone-dust-induced meningitis, and positional vulnerabilities compound the complexity.[13] Suboccipital operations may be complicated by pooling of blood in prone positioning that impairs visibility, pressure-related facial or ocular injury in prone positioning, and increased venous air embolism and hemodynamic instability risk in the sitting position, in addition to CSF leak, pseudomeningocele, venous sinus injury, and cerebellar mutism.[13]

During the cranial opening itself, burr hole creation, craniotomy cutting, and durotomy introduce specific hazards. Breach of an air sinus is a well-recognized risk; management includes mucosal removal, packing (e.g., betadine-soaked materials), and sealing with wax or vascularized flaps to reduce infection and CSF leak risk.[37] Bone bleeding is typically controlled with bone wax, whereas dural venous sinus injury may require packing or repair by suturing.[63] Dural lacerations can predispose to CSF leaks and pseudomeningocele, and injury to cortical draining veins can lead to venous infarction or hemorrhage. A particularly feared mechanical complication is drill perforator plunge into the brain, producing cerebral contusion and potentially catastrophic hemorrhage.[63] Operative and patient factors that increase complication risk include prone or lateral-prone positioning, emergency indications, low depth of anesthesia, prolonged operative duration, and thin scalp.[64] These variables highlight why standardized checklists, careful positioning, adequate anesthetic depth, and time-sensitive decision-making matter as much as technical dexterity. Postcraniotomy complications are numerous and may present immediately or evolve over days. Pain syndromes such as postcraniotomy headache are common,[2] and emergence hypertension can occur and may increase risk of bleeding or edema.[65] Structural complications include extraxial hematomas, intracranial hemorrhage, cerebral edema, cerebral ischemia, vasospasm, pneumocephalus (including tension pneumocephalus), hydrocephalus, and CSF leakage.[67][68] Seizures are a clinically important complication; evidence suggests levetiracetam is superior to phenytoin for de novo seizures following craniotomy.[66] Electrolyte disturbances are frequent, with hyponatremia and hypernatremia particularly common, often reflecting neuroendocrine dysregulation and fluid management challenges. Infectious complications range from superficial soft tissue infection to extradural abscess, empyema, and bone flap infection.[69][70] Postoperative meningitis has been reported with an incidence of 2.2%, commonly due to gram-negative organisms, with an overall mortality rate of 5%, underscoring the seriousness of intracranial infection even when incidence is modest.[69][70] Respiratory complications such as ventilator-associated pneumonia may occur in high-acuity patients, diagnosed via bronchoalveolar lavage and endotracheal aspirate evaluation. Mechanical and procedural complications also exist, including drill bit breakage, incidental dropout of the bone flap, and longer-term musculoskeletal issues such as temporalis muscle atrophy, myositis ossificans, and other postoperative changes affecting function or cosmesis.[71][72][73][74] Additionally, craniectomy itself—when performed rather than bone flap replacement—has been linked to inflammatory responses, inhibited autophagy, and impairment of the blood–brain barrier, suggesting systemic and cellular-level effects beyond mechanical decompression.[75]

Risk stratification for infection has identified several operative predictors, including American Society of Anesthesiologists score greater than 2, concurrent infection elsewhere, operative duration exceeding 4 hours, sinus entry, CSF leak with a notably elevated odds ratio (OR 7.817), CSF drainage, use of surgical drains, greater number of prior operations, and presence of implants.[76][77][78] These findings support a preventative emphasis on meticulous closure, sinus management, minimization of unnecessary drains, and careful handling of revision cases. Importantly, a meta-analysis has shown that prophylactic antibiotics significantly reduce meningitis risk after craniotomy, reinforcing the value of standardized perioperative prophylaxis.[79] Overall complication rates underscore why vigilance is necessary: significant complications have been reported at 8.3%, while minor complications can occur in up to 60% of cases; mortality attributable to major complications has been reported as 22% (compared with 0.5% in minor complications).[78] Variables associated with significant complications include older age, an abnormal neurologic examination at the end of surgery, and intraoperative desaturation, emphasizing that postoperative outcomes reflect both surgical factors and intraoperative physiologic stability.[78]

**Clinical Significance**

Craniotomy occupies a central position in contemporary neurosurgical care because it provides definitive access to intracranial pathology in a way that no external or purely medical therapy can replicate. By permitting controlled exposure of the brain and surrounding neurovascular structures, craniotomy enables timely evacuation of mass lesions, microsurgical repair of vascular abnormalities, targeted tumor resection or biopsy, drainage of intracranial infection, and functional interventions that can meaningfully restore or preserve neurologic capacity. Historically, many of these conditions were uniformly fatal or left survivors with profound disability because clinicians lacked the ability to safely enter the cranial vault. In modern practice, craniotomy has transformed those prognoses by allowing early decompression, precise lesion management, and reduction of secondary brain injury driven by intracranial hypertension, ischemia, or hemorrhage. This impact is most evident in trauma, where rapid surgical intervention for extradural or subdural hematoma can be life-saving, and in neuro-oncology, where tissue diagnosis and maximal safe resection remain foundational to personalized multimodal therapy. Likewise, in vascular neurosurgery, craniotomy supports microsurgical clipping or resection strategies that remain essential in many aneurysms and arteriovenous malformations, even as endovascular options expand. Importantly, craniotomy persists as a primary therapeutic tool despite major advances in endovascular neurosurgery and stereotactic radiosurgery. Endovascular techniques have broadened the armamentarium for aneurysms and some malformations, and radiosurgery has expanded noninvasive options for select tumor and vascular targets. However, these modalities do not eliminate the need for open cranial access; rather, they complement it. Many lesions still require direct visualization, manipulation, decompression, or durable reconstruction that cannot be achieved through luminal catheters or focused radiation alone. Consequently, the contemporary decision to perform craniotomy is individualized, grounded in lesion biology, anatomy, urgency, and the anticipated benefit relative to procedural risk. As neuronavigation, neuromonitoring, microscope optics, ultrasonic aspirators, and minimally invasive “keyhole” strategies mature, craniotomy continues to evolve toward greater precision with less collateral injury—maintaining its relevance and expanding its safety profile.

Because outcomes depend on both disease severity and patient reserve, structured scoring systems are used to anticipate morbidity, mortality, and functional recovery after craniotomy. Preoperative American Society of Anesthesiologists (ASA) physical status classification, Karnofsky performance score (KPS), Charlson comorbidity score, Modified Rankin Scale, and composite tools such as SKALE (sex, KPS, ASA physical status classification, location, and edema) have been employed to stratify risk.[80] Among these, KPS has the strongest evidence base for predicting surgical outcomes, reflecting the importance of baseline functional status in determining the trajectory after major cranial surgery.[80] Evidence also indicates that KPS and ASA classification predict early (≤30-day) morbidity in tumor patients, while Charlson comorbidity score predicts mortality risk in elective aneurysm management, emphasizing that neurologic diagnosis alone is insufficient for outcome forecasting without comorbidity and functional context.[80] In sum, craniotomy's clinical significance lies not only in what it enables surgically, but also in how it has shaped the modern concept of treatable intracranial disease—transforming previously unsurvivable disorders into conditions with realistic pathways to recovery and long-term functional preservation.

**Enhancing Healthcare Team Outcomes**

Optimizing outcomes after craniotomy depends on a coordinated perioperative system rather than isolated surgical excellence. The procedure is intrinsically interdisciplinary: it requires accurate diagnosis and triage, careful medical optimization, high-fidelity intraoperative physiologic control, and vigilant postoperative monitoring to detect complications before they become irreversible. In the preoperative phase, communication among neurosurgeons, emergency physicians, internists, and cardiologists is essential to align urgency with patient readiness. This includes confirming indication and laterality, reconciling medications that influence bleeding risk, stabilizing cardiopulmonary status, and ensuring that imaging, blood products, and intensive care capacity are available when needed. Early, explicit alignment on risk—especially in frail patients or those with major comorbidities—reduces delays, prevents avoidable cancellations, and supports realistic counseling for patients and families. During the intraoperative phase, outcomes are strongly influenced by the reliability of team communication and the discipline of shared situational awareness. Neurosurgeons, neuroanesthesiologists, and neuromonitoring personnel must coordinate continuously to maintain cerebral perfusion, control intracranial pressure, manage blood loss, and respond rapidly to changes such as brain swelling, hemodynamic instability, or neuromonitoring deterioration. The anesthesia team's ability to maintain stable hemodynamics and ventilation is inseparable from surgical success because cerebral oxygen delivery is vulnerable to hypotension, hypoxia, and hypercarbia. Likewise, nursing and technologist performance—ensuring correct instrument readiness, sterile integrity, and rapid availability of hemostatic adjuncts—directly affects operative flow and complication risk, particularly during bleeding or vascular injury scenarios where seconds matter. When neuronavigation or specialized approaches are used, the entire team benefits from a shared understanding of the operative plan, including anticipated critical steps and "failure modes" such as sinus entry or need for conversion to an alternative corridor.

Postoperatively, coordinated care becomes the dominant determinant of safety. Intensive care nurses and intensivists perform frequent neurologic assessments, monitor intracranial and systemic parameters, and escalate concerns promptly for early imaging or intervention when deterioration occurs. Pharmacists contribute by optimizing antiepileptic prophylaxis, analgesia regimens, anticoagulation timing for thromboembolism prevention, and antimicrobial strategies in infection-risk contexts. Rehabilitation professionals—speech pathologists, physical therapists, and physical medicine specialists—support early functional recovery, while respiratory therapists help prevent pulmonary complications in high-risk patients. Discharge planning and social work can reduce readmission risk by ensuring medication access, follow-up, and home support. This end-to-end interprofessional approach strengthens handoffs, reduces preventable complications, and enables earlier mobilization and rehabilitation, translating surgical success into meaningful patient-centered outcomes [79][80][81].

**Nursing, Allied Health, and Interprofessional Team Interventions**

Craniotomy care requires structured, team-based interventions that begin before the patient enters the operating room and continue through recovery and discharge. Preoperatively, collaboration between the neurosurgeon and anesthesiologist is pivotal for aligning the surgical plan with the anesthetic strategy, particularly when the lesion location, anticipated blood loss, or need for neuromonitoring imposes specific physiologic targets. These discussions typically address positioning requirements, expected duration, risks of venous air embolism or major hemorrhage, the need for blood availability, and whether an awake technique may be considered for language or motor mapping. In parallel, coordination with the operating room head nurse ensures that the correct cranial instruments, head fixation systems, hemostatic agents, microscope or endoscope equipment, neuronavigation components, and neuromonitoring supplies are available and functioning. Nursing leadership in equipment readiness and sterility checks reduces workflow interruptions and prevents avoidable safety events, especially in emergencies where time constraints are extreme. Additionally, a pre-incision discussion regarding non-anesthetic agents administered by the anesthetist—such as antibiotics, anticonvulsants, corticosteroids, osmotic agents, vasopressors, or reversal plans—helps avoid dosing errors and ensures the operative team anticipates physiologic shifts related to medication timing. Intraoperatively, nursing and allied health interventions support both technical success and physiologic stability. Circulating nurses maintain environmental control, coordinate specimen handling, document key events, and facilitate closed-loop communication between surgical and anesthesia teams. Scrub personnel contribute by anticipating instruments, maintaining organized operative tables, and enabling rapid response during bleeding or dural repair. Neuromonitoring technologists provide real-time feedback that can prompt immediate changes in surgical manipulation or anesthetic depth. These roles function best when communication is explicit and standardized, particularly during critical steps such as head pin placement, burr hole drilling, durotomy, vascular dissection, and bone flap replacement [81].

Postoperatively, interprofessional interventions shift toward complication prevention, early detection of neurologic change, and rehabilitation planning. Intensive care unit nursing personnel are central to neurologic surveillance, including pupil assessment, motor examination, mental status evaluation, and monitoring for signs of hemorrhage, edema, seizure activity, electrolyte disturbance, or infection. Allied health involvement becomes progressively important as the patient stabilizes: speech pathologists assess swallowing and communication deficits; physical therapists and rehabilitation clinicians guide mobilization and functional recovery; respiratory therapists support pulmonary hygiene and ventilatory weaning; and pharmacists refine analgesia, seizure prophylaxis, and antimicrobial regimens. Practical nurses contribute to continuity of bedside care, while discharge planners and social workers address home safety, caregiver resources, and follow-up adherence, reducing the likelihood of preventable readmissions. In many cases, the quality of the handoff from operating room to ICU and from ICU to the ward determines whether early complications are recognized promptly. For this reason, structured communication tools, shared postoperative goals, and timely escalation pathways are essential components of team-based craniotomy care, ensuring that the technical achievement of intracranial access translates into safe recovery and durable neurologic benefit.[81]

**Conclusion:**

Craniotomy continues to be a vital neurosurgical technique despite the emergence of minimally invasive and endovascular alternatives. Its enduring relevance lies in its ability to provide direct visualization and intervention for life-threatening or function-threatening intracranial conditions. However, the complexity of the procedure demands more than surgical skill—it requires a comprehensive perioperative system integrating neurosurgeons, anesthesiologists, nurses, and allied health professionals. Preoperative optimization, intraoperative vigilance, and postoperative monitoring are essential to mitigate risks such as hemorrhage, infection, and neurologic deterioration. Nursing care is central to this continuum, encompassing medication reconciliation, sterile preparation, hemodynamic stability, and early detection of complications. Evidence-based strategies, including ERAS protocols and multimodal analgesia, further enhance recovery and reduce morbidity. Ultimately, craniotomy exemplifies the intersection of technical precision and collaborative care. By adhering to structured workflows and fostering interprofessional communication, healthcare teams can transform a high-risk intervention into a pathway for meaningful neurologic recovery and improved quality of life.

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