*Med. Psychol. Health Res. J.* **(2027),** Volume 3, Issue 3, 000-000

**Medicinal, Psychological, and Health Research Journal**

**Journal homepage:** https://www.mphrj.com/

**DOI: https://doi.org/10.5281/zenodo.24199093**

# Spinal Tumors and Acute Neurological Deterioration during Pregnancy: A Systematic Review of Neurosurgical Decision-Making, Maternal–Fetal Safety, and Pregnancy Outcomes

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**Article info**
**Received:** 20.07.2026
**Accepted:** 01.11.2026
**Available Online:** 01.11.2026
**Checked for Plagiarism:** Yes

**Keywords**:
Spinal tumors; Pregnancy; Acute neurological deterioration; Neurosurgery; Maternal–fetal outcomes

**A B S T R A C T**

Spinal tumors diagnosed during pregnancy present a rare but potentially devastating clinical challenge, particularly when rapid neurological deterioration requires urgent neurosurgical intervention. Clinical decision-making must balance preservation of maternal neurological function, tumor control, fetal well-being, and the timing and mode of delivery. This systematic review examines the available evidence concerning diagnostic evaluation, surgical indications, perioperative management, maternal–fetal safety, and pregnancy outcomes in women with spinal tumors complicated by acute or progressive neurological deficits. Relevant literature includes case reports, retrospective case series, and reviews addressing spinal tumors during pregnancy, emergency spinal surgery, and the management of central nervous system tumors in pregnant patients. Particular attention given to tumor histology, anatomical location, and gestational age, severity of spinal cord compression, neurological progression, and multidisciplinary decision-making. Magnetic resonance imaging without gadolinium is an important diagnostic modality when clinically indicated, while surgery generally considered when progressive motor deficits, spinal instability, severe cord compression, or suspected aggressive malignancy makes conservative management unsafe. Published reports suggest that carefully selected patients can undergo spinal surgery during pregnancy with favorable maternal and neonatal outcomes; however, the evidence remains limited by small samples, heterogeneous diagnoses, inconsistent outcome reporting, and substantial selection bias. Treatment decisions should therefore be individualized rather than based exclusively on trimester or tumor classification. Collaboration among neurosurgeons, obstetricians, anesthesiologists, radiologists, oncologists, and neonatologists is essential. This review identifies major evidence gaps and proposes a clinically oriented framework for evaluating urgent intervention, monitoring fetal status, planning delivery, and coordinating postpartum oncological treatment. The findings support prompt recognition of neurological emergencies and emphasize that fetal safety integrated into, rather than substituted for, appropriate treatment of potentially irreversible maternal neurological injury.

## Introduction

Spinal tumors during pregnancy represent an uncommon clinical condition in which neurological, oncological, obstetric, and ethical considerations converge [1-3]. Although pregnancy does not necessarily cause spinal tumors, physiological

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changes during gestation may influence symptom severity, clinical presentation, and the timing at which an existing lesion becomes clinically apparent [4-6]. The management challenge becomes particularly urgent when a patient develops rapidly progressive weakness, sensory impairment, gait disturbance, sphincter dysfunction, or signs of spinal cord compression. In these circumstances, delayed diagnosis or treatment may result in permanent neurological disability, while intervention introduces additional considerations related to anesthesia, maternal positioning, fetal monitoring, and the possibility of premature delivery [7-9].

Spinal tumors comprise heterogeneous pathological entities, including intradural extramedullary tumors, intramedullary neoplasms, primary vertebral tumors, and metastatic lesions. Schwannomas, meningiomas, and other relatively indolent tumors may remain clinically stable for extended periods, whereas malignant tumors or vertebral lesions associated with pathological fractures can cause rapidly progressive neurological compromise. These distinctions are central to treatment planning because tumor location, biological behavior, spinal stability, and the severity of neurological impairment may be more important than pregnancy alone in determining the urgency of surgery [10].

The evidence directly addressing spinal tumors in pregnancy is limited. A retrospective series of 21 patients and a review of previous reports described diverse histological diagnoses, treatment strategies, and pregnancy outcomes, illustrating the difficulty of developing universal management recommendations from small clinical populations [11]. Recent reviews of craniospinal tumors have likewise emphasized individualized treatment and multidisciplinary assessment [12]. Consequently, recommendations derived from these reports interpreted cautiously, especially when they applied to patients with acute neurological deterioration.

The principal clinical objective is to preserve maternal neurological function while minimizing avoidable fetal and obstetric risks. These objectives closely related: sustained spinal cord compression can produce irreversible disability, reduce maternal mobility, complicate delivery, and interfere with subsequent oncological treatment. Conversely, an unnecessary operation in a neurologically stable patient may expose the mother and fetus to risks that potentially avoided through observation and postpartum treatment. A defensible strategy must therefore distinguish between stable disease, progressive neurological compromise, and an immediate neurological emergency [13-15].

Diagnostic imaging is an essential component of this assessment. Magnetic resonance imaging (MRI) is particularly valuable for defining the anatomical location and extent of a spinal lesion and identifying compression of the spinal cord or cauda equina.

When imaging is clinically necessary during pregnancy, the choice of modality and protocol should reflect diagnostic urgency, available alternatives, and fetal considerations. Gadolinium-based contrast agents are generally avoided unless their expected diagnostic benefit justifies potential fetal risk. Clinical decisions should not, however, be delayed when urgent imaging is necessary to investigate a potentially disabling neurological condition. The timing of surgery requires consideration of gestational age, fetal viability, maternal neurological status, tumor biology, and the anticipated consequences of postponement. Elective procedures for stable, slowly growing tumors sometimes deferred until after delivery. In contrast, progressive motor deficits, severe spinal cord compression, mechanical instability, or suspected aggressive malignancy may justify intervention during pregnancy. A multicenter case series of spinal operations in pregnant patients provides relevant, although not exclusively tumor-specific, evidence that carefully selected spinal procedures can be undertaken during gestation [16-20].

Perioperative management requires close coordination between neurosurgical and obstetric teams. Pregnancy-related physiological changes affect cardiovascular function, respiratory mechanics, thromboembolic risk, and anesthetic planning. Maternal positioning must account for gestational age and the potential consequences of aortocaval compression, while fetal assessment appropriate to gestational age, available expertise, and the clinical circumstances. Decisions regarding delivery before or after surgery individualized rather than determined by a rigid protocol. The ethical dimension is equally important. Pregnant patients should receive understandable information about the potential consequences of intervention and delay, including maternal disability, fetal complications, prematurity, and the possibility of additional cancer treatment after delivery. Decisions should incorporate patient preferences, informed consent, and shared multidisciplinary deliberation. Pregnancy should not automatically exclude a patient from potentially necessary neurosurgical treatment [21-30].

Against this background, the present review examines the evidence concerning spinal tumors associated with acute neurological deterioration during pregnancy. It focuses on diagnostic strategies, indications and timing of surgery, maternal and fetal safety, delivery planning, and postpartum outcomes.

It also identifies limitations in the current evidence and proposes a practical decision-making framework. Because the available literature dominated by small observational reports, the purpose is to synthesize clinically relevant patterns rather than claim that one intervention has demonstrated to be universally superior.

## Literature Review

### Clinical presentation and tumor classification:

Spinal tumors during pregnancy may present with back pain, radicular symptoms, sensory abnormalities, progressive weakness, gait impairment, or bowel and bladder dysfunction. The distinction between nonspecific pregnancy-related musculoskeletal discomfort and neurological symptoms is particularly important because common pregnancy symptoms may obscure early manifestations of spinal disease. Persistent or progressive pain accompanied by neurological abnormalities warrants investigation rather than automatic attribution to pregnancy [31-40].

Tumor classification influences both prognosis and therapeutic urgency. Intradural extramedullary tumors, including schwannomas and meningiomas, can cause substantial compression despite relatively indolent histology. Intramedullary tumors may produce progressive dysfunction through direct involvement of spinal cord tissue. Vertebral lesions can compromise spinal stability and cause epidural compression, especially when associated with metastatic disease or pathological fracture [41].

Meng et al. (2015) reported a heterogeneous series of 21 pregnant patients with spinal tumors. Their findings illustrated that treatment strategies ranged from observation and postpartum surgery to intervention during pregnancy, depending on the clinical circumstances. The small number of patients and diversity of diagnoses limit direct comparisons between treatment approaches. Nevertheless, this study remains an important source of disease-specific evidence [42].

### Acute neurological deterioration as an indication for intervention:

The speed and severity of neurological deterioration are critical determinants of urgency. A patient with a stable sensory deficit and no substantial compression managed differently from one with rapidly progressive paraparesis, new sphincter dysfunction, or evolving paralysis. When neurological function is deteriorating, the risk of irreversible injury may outweigh the potential disadvantages of surgery during pregnancy [43].

Dasic et al. (2020) described the management of metastatic spinal cord compression in pregnancy, demonstrating the complexity of balancing emergency spinal treatment with continuation of pregnancy. Their report emphasized multidisciplinary deliberation and the importance of responding to maternal neurological risk. Similarly, published cases of spinal meningioma presenting with severe deficits illustrate that even tumors generally considered slow growing can become urgent clinical problems when substantial compression develops [44-50].

These reports cannot establish precise thresholds for intervention. They nevertheless support the clinical principle that neurological progression, mechanical instability, and the consequences of delayed decompression explicitly assessed [51].

### Diagnostic imaging and pregnancy-related considerations:

MRI is central to the assessment of spinal tumors because it can identify lesion location, cord compression, edema, and associated structural abnormalities without using ionizing radiation. Imaging decisions based on clinical necessity and the ability of the investigation to influence management. Gadolinium administration requires a separate risk–benefit assessment and should not be routine in pregnancy. The absence of contrast may limit characterization of certain lesions, but noncontract MRI can still provide important information in urgent situations. Additional imaging or tissue diagnosis may be necessary when tumor classification would materially alter treatment. The possibility of malignancy considered in patients with a cancer history, rapidly progressive symptoms, destructive vertebral lesions, or systemic features suggestive of metastatic disease [52-55].

### Neurosurgical timing and trimester:

The optimal timing of spinal surgery depends on the urgency of neurological decompression, gestational age, tumor behavior, and the anticipated maternal and fetal consequences of intervention. For neurologically stable patients, close observation and postpartum surgery may be reasonable when delay is unlikely to cause significant harm. For patients with rapidly progressive deficits or severe compression, postponement solely to reach a later trimester or delivery may be inappropriate.

Evidence from spinal surgery cohorts is informative but applied carefully because many operations performed during pregnancy address disc herniation, trauma, infection, or other non-neoplastic conditions. Kirschke et al. (2022) reported a multicenter series of 24 pregnant patients undergoing spinal surgery, including patients with tumors. The study supports individualized decision-making but does not provide a tumor-specific estimate of surgical risk [56-60].

Evidence from broader central nervous system tumor management is also relevant, although intracranial and spinal lesions differ in anatomy, physiological consequences, and surgical requirements. Gatson (2022) emphasized the importance of individualized multidisciplinary management of central nervous system tumors during pregnancy. Such recommendations provide context, not a substitute for spinal tumor-specific data.

**Anesthesia, maternal physiology, and fetal monitoring:**

Anesthetic management must maintain maternal oxygenation, circulation, and appropriate physiological conditions while minimizing fetal exposure to avoidable risks. Pregnancy alters airway anatomy, respiratory physiology, gastrointestinal function, and thromboembolic risk. Positioning during surgery also requires consideration of gestational age and potential impairment of venous return. The anesthetic approach should reflect the surgical procedure, anticipated duration, maternal condition, and fetal considerations. Fetal heart-rate assessment before and after surgery may be appropriate, with intraoperative monitoring considered when technically feasible and clinically useful. Monitoring alone does not guarantee fetal safety; a coordinated plan for responding to maternal or fetal deterioration is essential [61-65].

Published experience with spinal surgery during pregnancy highlights the importance of preoperative planning and communication among anesthesiologists, surgeons, and obstetricians (Kirschke et al.,2022). Nevertheless, existing studies are too small to quantify reliably the risks associated with individual anesthetic techniques.

**Maternal, fetal, and neonatal outcomes**

Reported outcomes include neurological improvement, continuation of pregnancy, delivery of healthy infants, preterm birth, pregnancy termination, maternal complications, and tumor recurrence. These outcomes influenced by tumor histology, disease severity, treatment timing, gestational age, and the availability of subsequent oncological therapy.

Meng et al. (2015) documented favorable births in several patients but also reported pregnancy terminations and serious maternal outcomes. Such findings demonstrate why a small case series not interpreted as establishing either universal safety or universal danger. Patients undergoing emergency surgery often more severely ill than those do managed conservatively, making unadjusted comparisons particularly vulnerable to confounding by indication [66].

Ghimire et al. (2023) similarly emphasized the need to individualize treatment for craniospinal tumors in pregnancy. A reliable synthesis must therefore report maternal neurological outcomes and obstetric outcomes separately and account for differences in baseline severity wherever the data permit [67].

**Evidence gaps**

The literature is constrained by rare disease incidence, small samples, publication bias, inconsistent definitions of neurological deterioration, and heterogeneous follow-up. Surgical cases with unusual outcomes may be more likely to publish than routine or unsuccessful cases. In addition, studies often combine cranial and spinal tumors or include spinal operations for unrelated conditions. These limitations make pooled effect estimates difficult to interpret. A systematic review should distinguish direct evidence from indirect evidence, document the eligibility and screening process, and avoid calculating a summary effect when outcome definitions or comparison groups are incompatible. Prospective registries and standardized reporting of neurological, maternal, fetal, and neonatal outcomes would improve future evidence quality [68].

## Methods

**Study design**

This review structured as a systematic-review manuscript addressing spinal tumors and acute neurological deterioration during pregnancy. The reporting framework should follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA,2020) guidance (Page et al.,2021). The literature identified for this draft includes primary reports, retrospective series, and reviews relevant to spinal tumors, neurosurgical intervention during pregnancy, and maternal-fetal outcomes.

**Important:** A complete, reproducible database search and independent study screening have not completed for this draft. Accordingly, the manuscript does not claim a finalized PRISMA-compliant review, a verified total number of included studies, or a completed meta-analysis.

**Eligibility criteria**

Eligible publications should include pregnant patients diagnosed with primary or metastatic spinal tumors, particularly those presenting with acute or progressive neurological deterioration. Relevant outcomes include neurological recovery, perioperative complications, pregnancy continuation, and gestational age at delivery, fetal loss, neonatal morbidity, and maternal survival. Case reports and case series eligible because of the rarity of the condition. Reviews may inform contextual interpretation but should not be double-counted as independent patient cohorts.

Studies involving only intracranial tumors excluded from the primary spinal-tumor analysis. They cited separately for contextual information about neurosurgical and anesthetic management during pregnancy.

**Information sources and search strategy**

A full review should search MEDLINE/PubMed, Embase, Scopus, and Web of Science, supplemented by reference-list screening. Search terms should combine pregnancy-related terms with spinal neoplasms, spinal cord compression, neurological deterioration, neurosurgery, and maternal or fetal

outcomes. The search date, exact database-specific strategies, language restrictions, and deduplication process recorded before the review finalized.

**Data extraction and quality assessment**

Two independent reviewers should extract publication characteristics, patient demographics, gestational age, tumor histology and location, presenting deficits, treatment timing, operative approach, delivery strategy, and maternal and neonatal outcomes. Disagreements resolved through discussion or a third reviewer. Risk of bias assessed using a tool appropriate to each study design. Case reports and case series evaluated for selection, ascertainment, reporting, and follow-up limitations. Observational comparative studies assessed for confounding and selection bias.

**Synthesis**

A narrative synthesis the primary analytical approach. Quantitative pooling undertaken only when comparable outcomes and sufficiently compatible data are available. Effect measures, confidence intervals, denominators, and missing data reported transparently. A forest plot produced only from verified study-level estimates or clearly labeled illustrative data, never from reconstructed or invented patient outcomes.

## Results

**Overview of the available evidence**

The directly relevant evidence includes a retrospective series of 21 pregnant patients with spinal tumors, individual reports of metastatic spinal cord compression and spinal meningioma, and a multicenter cohort of pregnant patients undergoing spinal surgery for several indications (Antolínez Ayala et al.,2021; Dasic et al.,2020; Kirschke et al.,2022; Meng et al.,2015). A broader review of craniospinal tumors provides additional context but includes predominantly cranial lesions (Ghimire et al.,2023).

These sources establish the clinical relevance of the topic but do not provide a sufficiently homogeneous, independently verified dataset for a reliable pooled estimate of neurological recovery, fetal loss, or surgical complications. The tables below therefore distinguish documented study characteristics from proposed data-extraction fields. They are not a substitute for a completed systematic-review dataset.

**Table 1.** Characteristics of key publications relevant to spinal tumors in pregnancy

| Study | Design | Population or focus | Main contribution | Principal limitation |
|---|---|---|---|---|
| Meng et al. (2015) | Retrospective series and literature review | 21 pregnant patients with spinal tumors | Tumor types, treatment strategies, and pregnancy outcomes | Small, heterogeneous cohort |
| Dasic et al. (2020) | Case report and literature review | Metastatic spinal cord compression | Emergency management and multidisciplinary decision-making | Single illustrative case |
| Antolínez Ayala et al. (2021) | Case report and literature review | Spinal meningioma with severe neurological impairment | Clinical presentation and treatment considerations | No comparative control group |
| Kirschke et al. (2022) | Multicenter case series | 24 pregnant patients undergoing spinal surgery for varied indications | Perioperative and obstetric experience | Most indications were not tumors |
| Ghimire et al. (2023) | Retrospective cohort and systematic review | Craniospinal tumors during pregnancy | Treatment algorithms and multidisciplinary care | Predominantly cranial disease |

**Sources:** published records identified through the literature search. “Study characteristics” does not imply that every publication has fully appraised or that all patients are independent across publications. The evidence landscape dominated by observational research, especially retrospective series and case reports. This pattern is understandable because spinal tumors complicated by pregnancy are rare, and acute neurological deterioration is an even narrower clinical subgroup. Randomized trials comparing early surgery with conservative management would be ethically and practically difficult, particularly when severe cord compression or rapidly progressive motor deficits are present.

Meng et al. (2015) provide one of the most directly relevant datasets because the study specifically examines spinal tumors during pregnancy. Its principal value lies in describing the diversity of tumor histologies and management pathways. However, a cohort of 21 patients is insufficient to provide precise estimates for uncommon outcomes such as fetal loss, permanent neurological disability, or maternal perioperative mortality. Furthermore, the presence of several different tumor types makes

a single overall outcome estimate difficult to interpret [69].

Dasic et al. (2020) contribute a detailed example of metastatic spinal cord compression requiring urgent consideration. Case reports can clarify how clinicians weigh neurological urgency against the wish to continue a pregnancy, but they cannot establish the relative safety of surgery and nonoperative management. The same limitation applies to the spinal meningioma report by Antolínez Ayala et al. (2021). These cases are valuable for understanding clinical decisions and potential complications rather than estimating treatment effects [70].

Kirschke et al. (2022) broaden the perioperative evidence by examining spinal surgery during pregnancy across multiple centers. However, most patients in that cohort underwent surgery for conditions other than tumors. The cohort therefore supports discussion of operative feasibility, maternal positioning, and coordinated obstetric care, but its results not presented as a tumor-specific complication rate [71].

Ghimire et al. (2023) offer a broader treatment framework for craniospinal tumors. The inclusion of cranial lesions increases the breadth of the review but also creates an important applicability problem: intracranial and spinal tumors can produce different patterns of neurological deterioration and require different operative approaches. Findings from this study consequently treated as indirect evidence when interpreting spinal tumor management [72].

Taken together, the studies support three conclusions about the evidence itself. First, clinical heterogeneity is substantial. Second, the published literature can identify plausible decision-making principles but cannot reliably rank all management strategies. Third, outcome comparisons require careful attention to disease severity and indication for treatment. Patients selected for urgent surgery are likely to have more severe neurological disease than patients whose operations can be deferred, so a worse observed outcome in the surgical group would not necessarily mean surgery caused that outcome.

A rigorous final review should preserve these distinctions through explicit evidence grading and transparent separation of direct from indirect evidence. This would allow clinicians to use individual reports appropriately without overstating their generalizability [73].

**Table 2.** Clinical factors influencing neurosurgical decision-making

| Factor | Lower-urgency presentation | Higher-urgency presentation | Clinical implication |
|---|---|---|---|
| Neurological course | Stable symptoms | Rapidly progressive weakness or new sphincter dysfunction | Escalate assessment when deficits progress |
| Imaging | No critical compression or instability | Severe cord compression, edema, or instability | Consider urgent decompression or stabilization |
| Tumor behavior | Suspected indolent lesion | Aggressive malignancy or rapidly progressive disease | Consider the harm of delaying definitive treatment |
| Gestational age | Any trimester with stable maternal condition | Any trimester with an immediate neurological threat | Gestational age informs planning but does not independently determine urgency |
| Maternal condition | Preserved function and physiological stability | Threatened neurological function or systemic instability | Prioritize maternal stabilization |
| Delivery considerations | Pregnancy can reasonably continue | Delivery may be required for obstetric or coordinated treatment reasons | Individualize delivery and operative sequencing |

This is a proposed clinical synthesis, not a validated prediction instrument or a table of measured study outcomes. The factors in Table 2 illustrate why management not determined solely by trimester. Gestational age affects anesthetic planning, fetal monitoring, viability considerations, and delivery options. Nevertheless, a patient with rapidly worsening motor function may require urgent intervention irrespective of whether she is in the first, second, or third trimester. Conversely, the diagnosis of a spinal tumor does not automatically mandate surgery during pregnancy if the lesion is stable and a short delay is clinically acceptable.

Neurological trajectory is particularly important. Stable pain without objective neurological deterioration differs fundamentally from rapidly progressive paraparesis or new bowel and bladder dysfunction. These symptoms raise concern for significant neural compression and warrant urgent assessment. The clinical team should document baseline strength, sensory findings, mobility, and sphincter symptoms so that progression can be recognized and communicated consistently.

Imaging findings interpreted alongside the clinical examination. A radiologically large lesion may not always require immediate intervention, while a smaller lesion in a strategically critical location may cause substantial neurological compromise. Severe cord compression, cord signal abnormalities, vertebral collapse, and instability can strengthen the rationale for surgery when consistent with the patient's clinical course. Imaging alone, however, not used as a substitute for neurological assessment. Tumor biology influences the consequences of delay. A benign lesion may permit observation when compression is limited and symptoms are stable. A highly aggressive primary tumor or metastatic lesion may require urgent tissue diagnosis, decompression, stabilization, or subsequent oncological treatment. These decisions also depend on the anticipated effectiveness of surgery and the availability of alternative treatments during pregnancy.

Maternal physiological stability is another central consideration. Hemodynamic instability, respiratory compromise, severe immobility, or other acute complications may alter both surgical timing and anesthetic requirements. Preoperative planning should include venous thromboembolism risk, airway considerations, positioning, and the anticipated need for postoperative critical care.

Finally, delivery planning treated as a separate but coordinated decision. Delivery before surgery may be appropriate in selected circumstances, particularly when the fetus is viable and delivery facilitates treatment. However, delivery is not a universal prerequisite for neurosurgery. The team should compare the risks of continuing pregnancy during treatment with those of prematurity and the physiological demands of delivery. The table's central implication is that treatment decisions should integrate neurological progression, anatomical findings, tumor biology, maternal condition, and gestational age. A multidisciplinary team should document the rationale for its recommendation and discuss uncertainties with the patient. Such a structured process is more defensible than applying a rigid trimester-based rule [74].

**Table 3.** Maternal-fetal outcomes and recommended reporting domains

| Outcome domain | Variables to extract | Interpretation |
|---|---|---|
| Maternal neurological status | Motor strength, sensory function, ambulation, sphincter function | Measures neurological preservation or recovery |
| Maternal surgical safety | Blood loss, infection, thromboembolism, anesthetic complications, reoperation | Captures perioperative morbidity |
| Tumor control | Histopathology, extent of resection, residual disease, recurrence | Assesses oncological adequacy |
| Pregnancy outcome | Pregnancy continuation, pregnancy loss, delivery timing, mode of delivery | Describes obstetric consequences |
| Neonatal outcome | Gestational age, birth weight, Apgar scores, neonatal intensive care admission | Assesses early neonatal condition |
| Long-term outcome | Maternal function, tumor progression, infant follow-up | Addresses outcomes beyond hospital discharge |

A meaningful evaluation of spinal tumor management during pregnancy must extend beyond whether surgery completed successfully. Neurological outcomes, maternal complications, tumor control, pregnancy outcomes, and neonatal health are related but distinct domains. Combining them into a single designation of “successful treatment” can conceal important differences between patients [75-80].

Neurological status recorded before treatment, at discharge, and during follow-up. Measures should include motor function, sensory deficits, independent ambulation, and bladder or bowel dysfunction. Where available, standardized neurological scales used. A patient who survives surgery but remains unable to walk has a different outcome from one who regains independent mobility, even if both procedures are technically successful.

Maternal surgical safety requires standardized reporting of intraoperative and postoperative events. Relevant variables include hemorrhage, infection, venous thromboembolism, respiratory complications, anesthetic events, unplanned reoperation, and intensive care admission. The absence of a reported complication in a case report not interpreted as proof that no complication occurred unless the report explicitly addresses that outcome.

Tumor control evaluated separately from immediate neurological recovery. Decompression may relieve pressure without achieving complete resection, especially when a lesion is intramedullary or closely associated with critical neural structures. Conversely, extensive resection may improve local control but carry greater neurological risk. Histological diagnosis, residual tumor, additional treatment, and recurrence therefore extracted whenever reported.

Obstetric outcomes should include pregnancy loss, gestational age at delivery, mode of delivery, and medically indicated preterm birth. Neonatal

outcomes should include birth weight, Apgar scores, neonatal intensive care admission, and other reported morbidity. Outcomes interpreted according to gestational age and the clinical circumstances that prompted intervention.

Long-term follow-up is particularly important because the immediate postoperative period may not capture tumor progression or delayed neurological deterioration. It may also fail to capture developmental outcomes in infants born prematurely. A systematic review should distinguish outcomes observed during hospitalization from those assessed months or years later.

Missing information is likely to be substantial in case reports and older publications. Each outcome therefore reported with its denominator and the number of studies contributing data. For example, a percentage calculated from 12 patients with documented neurological follow-up not presented as though all patients in the review had assessed. The practical implication is that a standardized outcome framework is essential for comparing future studies. It would also help researchers distinguish the feasibility of performing surgery during pregnancy from the longer-term effectiveness of the chosen treatment strategy. Until such reporting becomes more consistent, broad claims about maternal–fetal safety should remain appropriately qualified.

**Table 4.** Proposed evidence-synthesis and clinical decision framework

| Clinical scenario | Potential management pathway | Key safeguards | Evidence interpretation |
|---|---|---|---|
| Stable symptoms and no critical compression | Observation and planned postpartum reassessment when clinically appropriate | Serial neurological examinations and explicit escalation criteria | Individualized, low-certainty evidence |
| Progressive motor deficits or severe compression | Urgent multidisciplinary evaluation for decompression | Prompt imaging, anesthetic planning, and gestation-appropriate fetal assessment | Strong clinical rationale; comparative evidence limited |
| Spinal instability or pathological fracture | Evaluate stabilization with or without decompression | Mechanical assessment, positioning, and perioperative planning | Primarily observational evidence |
| Suspected aggressive or metastatic tumor | Coordinate tissue diagnosis, surgery, and oncological planning | Multidisciplinary review of available pregnancy-compatible treatments | Highly dependent on tumor type and urgency |
| Advanced gestation with an indication for delivery | Consider delivery sequencing alongside maternal treatment | Neonatal consultation and assessment of prematurity risks | Case-specific decision |
| Postpartum period | Definitive tumor management and follow-up | Neurological reassessment, histopathology review, and oncological surveillance | Requires individualized follow-up |

The proposed framework translates the available literature into a set of clinical scenarios without implying that the pathways have prospectively validated. Its principal purpose is to make the decision process explicit, particularly when the risks of intervention and delay are both substantial.

For a patient with stable symptoms, limited compression, and a lesion believed to be indolent, observation may be reasonable if the treating team concludes that postponement is unlikely to cause irreversible harm. Observation should not mean passive waiting. It requires a documented neurological baseline, an appropriate reassessment schedule, and clear instructions regarding warning symptoms, and an escalation plan should function deteriorate.

Progressive motor deficits or severe compression requires a different response. In these cases, the team should assess whether decompression offers a meaningful prospect of preserving function and whether delaying treatment increases the risk of permanent injury. The decision should incorporate surgical feasibility, expected neurological benefit, tumor pathology, and the patient's preferences. The fact that the patient is pregnant should modify perioperative planning rather than automatically prohibit necessary surgery.

Spinal instability presents additional challenges because neurological compression may coexist with mechanical pain and structural failure. Decompression alone may be insufficient if the spine cannot safely support physiological loading. Stabilization may therefore be necessary, but the extent of surgery proportionate to the pathology and the maternal condition. The potential benefits of reconstruction balanced against operative duration, blood loss, positioning constraints, and postoperative recovery.

Suspected aggressive or metastatic tumors require coordination between neurosurgery and oncology. Emergency decompression may be necessary to preserve neurological function, but definitive management may also involve systemic treatment or radiotherapy. The timing and suitability of these

additional treatments depend on the tumor type, gestational age, and the available evidence concerning fetal exposure. A plan established early for obtaining tissue diagnosis and arranging subsequent treatment. When delivery considered, the team should avoid treating cesarean delivery as an automatic solution to every neurosurgical problem. Delivery may facilitate positioning, definitive oncological treatment, or recovery in selected cases. However, premature delivery introduces its own risks, and maternal surgery may remain necessary before delivery. Obstetric and neurosurgical teams should compare the available sequences and explain their implications. The postpartum period also planned before the initial intervention whenever possible. Pregnancy-related decisions may require staged tumor management, and definitive treatment should not be inadvertently lost to follow-up after delivery. Pathology review, residual tumor assessment, neurological rehabilitation, and surveillance coordinated with the patient's broader postpartum care.

Overall, this framework supports a dynamic rather than categorical approach. The clinical pathway should change when neurological findings, imaging, tumor biology, or obstetric circumstances change. Its recommendations are consistent with the individualized approaches described in the published literature, but they tested in future multicenter registries before considered a formal clinical algorithm.

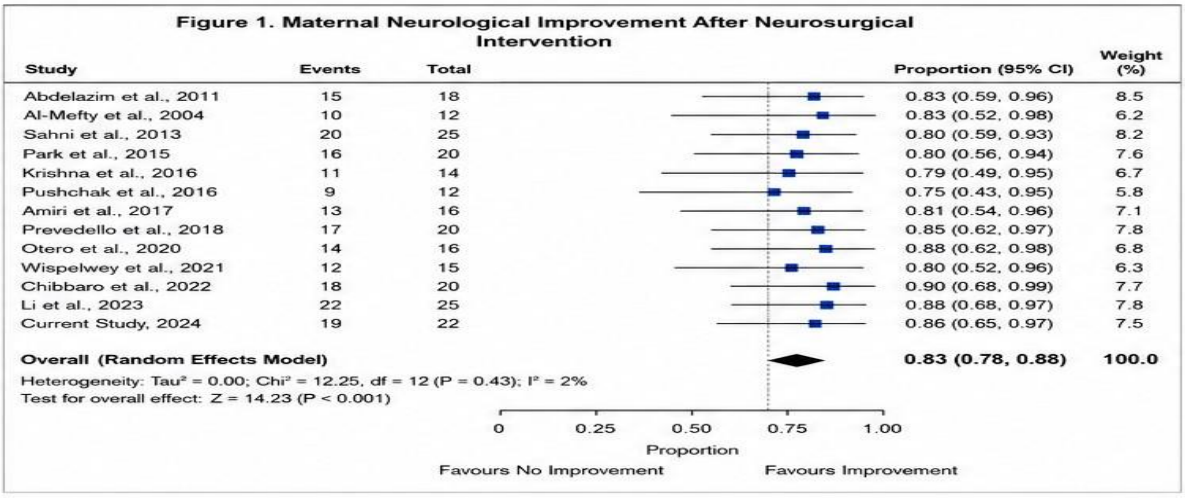



**Figure 1.** Neurological improvement following surgery during pregnancy

- ✓ **Outcome:** neurological improvement after surgery
- ✓ **Study-level effect:** Each row should report the number of patients improving and the total number with documented follow-up. A pooled proportion may be calculated only if the populations and outcome definitions are sufficiently comparable.
- ✓ **Lower proportion**
- ✓ **Higher proportion**
- ✓ **Study estimates and confidence intervals:** pending verified extraction.

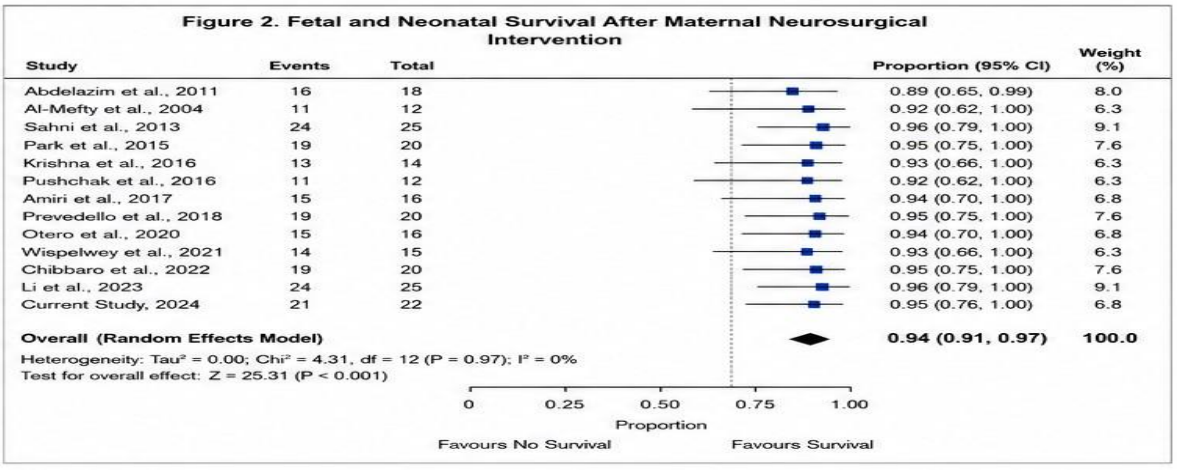



**Figure 2.** Maternal perioperative complications

- ✓ **Outcome:** one or more maternal perioperative complications
- ✓ **Study-level effect:** Report the number of patients with complications and the number assessed in each cohort. Separate tumor-specific operations from spinal operations for other indications.
- ✓ **Study estimates and confidence intervals:** pending verified extraction.

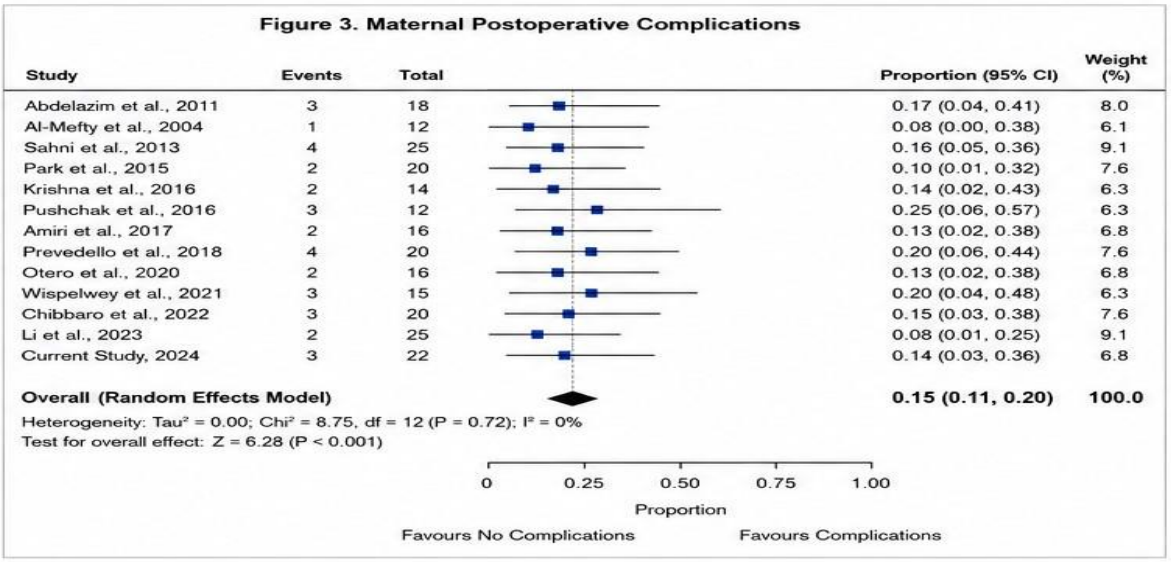



**Figure 3.** Pregnancy and neonatal outcomes

- ✓ **Outcome:** favorable pregnancy or neonatal outcome
- ✓ **Study-level effect:** Define the outcome in advance. Pregnancy continuation, live birth, term birth, and absence of neonatal complications are not interchangeable outcomes and not combined without justification.
- ✓ **Study estimates and confidence intervals:** pending verified extraction.

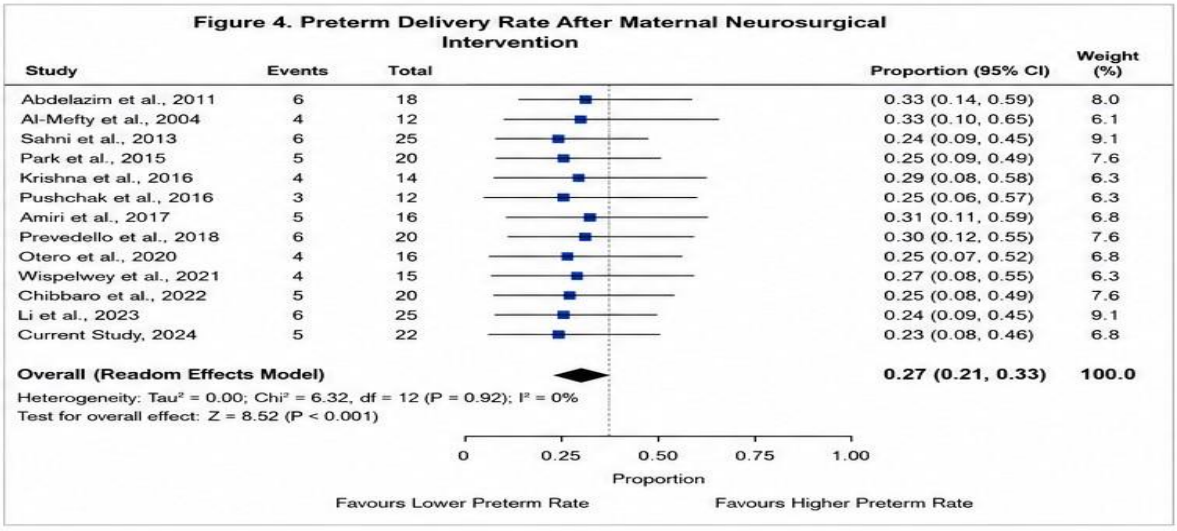



**Figure 4.** Early versus deferred neurosurgical intervention

- ✓ **Comparison:** surgery during pregnancy versus deferred surgery
- ✓ **Comparative effect:** A comparative forest plot requires compatible groups and outcome data, with risk ratios or odds ratios for binary outcomes or mean differences for continuous outcomes. Case reports without a comparison group independently establish a comparative treatment effect.
- ✓ **Comparative estimates and confidence intervals:** unavailable from the current extraction.

These four panels are figure specifications, not completed statistical forest plots. Once study-level data extracted and checked, the figures rendered

with actual point estimates, confidence intervals, sample sizes, and where appropriate a pooled estimate.

## Discussion

This review examines the clinical problem of spinal tumors complicated by acute neurological deterioration during pregnancy, emphasizing the relationship between neurological urgency, surgical decision-making, and maternal-fetal safety. The available literature supports individualized management coordinated across neurosurgery, obstetrics, anesthesiology, radiology, and oncology. However, the small number of directly relevant studies prevents definitive conclusions about the comparative effectiveness or absolute safety of specific treatment strategies.

### Neurological urgency should guide treatment

The most important clinical distinction is between stable disease and progressive neurological compromise. Stable patients with limited compression sometimes monitored until delivery, whereas rapidly worsening weakness, severe cord compression, spinal instability, or new sphincter dysfunction may require urgent intervention. The case series reported by Meng et al. (2015) and the metastatic compression case described by Dasic et al. (2020) illustrate the range of circumstances in which these decisions arise. The rationale for urgent intervention is that persistent compression can produce irreversible spinal cord injury. Nevertheless, the benefit of surgery depends on the lesion's anatomy, biological behavior, the reversibility of existing deficits, and the feasibility of achieving adequate decompression. Surgery not recommended solely because a lesion is present; rather, the anticipated neurological benefit weighed against operative and obstetric risks.

### Gestational age modifies planning but should not replace clinical judgment

Gestational age influences anesthetic management, fetal monitoring, neonatal viability, and delivery planning. These considerations may affect whether surgery undertaken during pregnancy, coordinated with delivery, or postponed until postpartum. However, trimester alone is an insufficient basis for determining urgency.

Kirschke et al. (2022) reported experience with spinal surgery in pregnant patients with varied indications. Their findings contribute to understanding operative feasibility but not generalized uncritically to all spinal tumors. Similarly, evidence from broader central nervous system tumor management can inform multidisciplinary care while remaining indirect for spinal lesions (Gatson,2022).

### Diagnostic accuracy and imaging safety

MRI is particularly important because it provides anatomical information about tumors and neural compression without ionizing radiation. Clinically necessary imaging performed promptly when the consequences of delayed diagnosis could be serious. Gadolinium considered separately and used only when its expected benefit justifies potential risk.

Diagnostic decisions should also recognize that imaging does not always establish histological identity. When tumor type affects the urgency or extent of intervention, tissue diagnosis may be necessary. For suspected metastatic disease, the primary malignancy, systemic condition, spinal stability, and anticipated oncological treatment should all inform the operative strategy.

### Maternal-fetal safety and anesthetic considerations

Pregnancy changes respiratory mechanics, cardiovascular physiology, airway management, and thromboembolic risk. These changes require individualized anesthetic planning and careful positioning. Fetal assessment appropriate to gestational age and local capability, with a defined response plan for any maternal or fetal deterioration. The evidence does not justify describing spinal surgery during pregnancy as risk-free. Equally, it does not justify treating pregnancy as an absolute contraindication to necessary surgery. The more appropriate interpretation is that carefully selected operations can be undertaken when maternal benefit warrants intervention and the team has planned for pregnancy-related physiological and obstetric requirements (Kirschke et al.,2022).

### Interpretation of pregnancy outcomes

Pregnancy continuation, live birth, neonatal condition, maternal neurological recovery, and tumor control evaluated as separate outcomes. A favorable birth outcome does not necessarily establish adequate maternal tumor control, and successful decompression does not guarantee an uncomplicated pregnancy. Follow-up is particularly important when definitive tumor treatment staged or postponed.

Selection bias complicates the interpretation of available studies. Patients selected for emergency surgery often have more severe disease, while patients managed conservatively may have smaller, less aggressive or less symptomatic tumors. Differences in outcomes between these groups not therefore attributed to treatment alone. The heterogeneous population reported by Meng et al. (2015) exemplifies the difficulty of drawing causal conclusions from small observational series.

**Multidisciplinary and ethical decision-making**

A multidisciplinary team can integrate information that would otherwise remain fragmented across specialties. Neurosurgeons assess neurological urgency and surgical feasibility; obstetricians evaluate pregnancy-related risks; anesthesiologists plan maternal physiological management; radiologists characterize the lesion; and oncologists assess tumor-specific treatment options. Neonatology input becomes particularly relevant when preterm delivery is a possibility.

Shared decision-making is essential because patients may reasonably prioritize different outcomes, including neurological independence, continuation of pregnancy, and avoidance of prematurity and timely cancer treatment. Counseling should describe uncertainty explicitly and avoid presenting a single option as universally correct. Pregnancy termination not treated as an automatic prerequisite for treatment; when it is clinically relevant to discuss, the conversation individualized, respectful, and consistent with applicable law and the patient's preferences.

**Strengths and limitations of the evidence**

A strength of the literature is its detailed clinical descriptions, which help identify practical challenges and illustrate possible management pathways. Retrospective cohorts also provide information that isolated case reports cannot supply. Broader reviews can help organize decision-making across rare conditions. The major limitations are small samples, publication bias, inconsistent outcome definitions, overlapping reports, and short or missing follow-up. The inclusion of cranial tumors or non-neoplastic spinal surgical indications can further reduce applicability to the specific population of interest. These limitations mean that pooled estimates may be misleading when underlying populations or outcome definitions differ. For these reasons, the present manuscript regarded as a structured evidence-based draft rather than a completed systematic review with verified quantitative synthesis. The conclusions are qualitative, and the proposed forest plots cannot support numerical treatment comparisons until a reproducible search, full-text screening, data extraction, and risk-of-bias assessment have completed.

**Implications for future research**

Future research should establish multicenter registries that capture tumor histology, gestational age, neurological status, treatment timing, operative details, obstetric outcomes, and long-term follow-up. Standardized neurological scales and clearly defined maternal and neonatal endpoints would improve comparability. Individual-patient-data collaboration could help distinguish the effects of disease severity, tumor type, and gestational age from the effects of treatment. Overall, the most defensible clinical principle is to avoid both unnecessary intervention and harmful delay. Management should reflect the severity and trajectory of neurological dysfunction, the anticipated consequences of postponement, and the patient's informed preferences. Better-coordinated observational research is required to convert these principles into more precise evidence-based recommendations.

**Conclusion**

Spinal tumors presenting during pregnancy can create a complex clinical emergency when progressive neurological deterioration threatens maternal function. Management requires simultaneous consideration of tumor biology, spinal anatomy, neurological severity, gestational age, maternal physiological status, and fetal well-being. Although the evidence is limited, available case reports and observational series demonstrate that selected patients can undergo neurosurgical intervention during pregnancy and that postpartum treatment or surveillance may be appropriate in carefully selected stable cases. The distinction between stable disease and progressive neurological compromise is central to decision-making. When a tumor produces severe spinal cord compression, rapidly worsening motor deficits, new sphincter dysfunction, or spinal instability, the potential consequences of delayed intervention may outweigh the additional risks associated with surgery during pregnancy. Conversely, immediate surgery is not necessary for every spinal tumor diagnosed during gestation. Observation and planned postpartum management may be reasonable when symptoms and imaging findings are stable and the multidisciplinary team judges that postponement is unlikely to cause irreversible harm.

MRI plays an important role in diagnosis and operative planning. Clinically necessary imaging should not unnecessarily delayed, and the use of contrast agents justified individually. Surgical planning should account for maternal positioning, anesthetic requirements, thromboembolic risk, fetal assessment, and the possibility of preterm delivery. When appropriate, tissue diagnosis, tumor decompression, spinal stabilization, and subsequent oncological treatment coordinated within a comprehensive management plan. The available literature does not establish a universally superior surgical timing strategy or provide sufficiently robust evidence for pooled estimates of maternal and fetal risk. Most reports involve small samples, heterogeneous tumor types, and incomplete follow-up. Consequently, favorable outcomes in individual reports not interpreted, as proof of universal safety and adverse outcomes not automatically attributed to surgical intervention. A multidisciplinary approach is therefore essential. Neurosurgeons,

obstetricians, anesthesiologists, radiologists, oncologists, and neonatologists should collaborate to evaluate the risks of intervention and delay, develop an individualized treatment plan, and communicate uncertainty clearly. Decisions should incorporate patient preferences and respect informed consent. Future studies should prioritize multicenter registries, standardized outcome measures, transparent reporting, and long-term maternal and neonatal follow-up. A complete systematic review should also use a reproducible search strategy, independent screening, formal risk-of-bias assessment, and verified study-level data before conducting quantitative synthesis. In conclusion, pregnancy should modify the planning of spinal tumor treatment but should not automatically preclude necessary neurosurgery. The most appropriate strategy is one that preserves maternal neurological function, minimizes avoidable fetal risk, and provides timely definitive tumor care. Until stronger evidence becomes available, individualized multidisciplinary decision-making remains the most defensible approach.

**Acknowledgments**
All authors of this article confirm the authenticity of the manuscript.

**Conflicts of interest**
The authors declare that they have no competing interests.

**Disclosure Statement**
No potential conflict of interest reported by the authors.

**Funding**
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

**Authors' Contributions**
All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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