



POSTOPERATIVE DAY 1 VERSUS DELAYED EARLY MAGNETIC RESONANCE IMAGING AFTER INTRADURAL SPINAL TUMOR SURGERY

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ABSTRACT

Objective: Postoperative magnetic resonance imaging (MRI) is important after intradural spinal tumor surgery, but the optimal timing of early postoperative imaging is not standardized. This study compared postoperative day 1 (POD1) MRI with delayed early MRI in detecting residual tumor.

Materials and Methods: This retrospective single center cohort included patients who underwent surgery for intradural spinal tumors between June 2020 and December 2025. Patients who underwent gadolinium-enhanced POD1 MRI and delayed early gadolinium-enhanced MRI (performed within POD30-60) were analyzed. Patient-level timing of delayed early MRI was recorded. Two blinded, spine-focused neurosurgeons reviewed MRI studies using predefined criteria.

Results: Ninety-six patients from a 112-patient intradural spinal tumor cohort had paired imaging. Sixteen patients were excluded because of missing MRI studies. A delayed early MRI was obtained a median of 48 days after surgery (interquartile range, 41-56; range, 33-60). POD1 and delayed early MRI were concordant with respect to the presence of residual tumor in 95 of 96 patients. With delayed early MRI as the paired imaging comparator, POD1 MRI demonstrated 93.3% sensitivity, 100.0% specificity, 98.8% negative predictive value, 99.0% accuracy, and a kappa coefficient of 0.959. Progression occurred in 7 of 13 patients (53.8%) with POD1 residual tumor and in 1 of 81 patients (1.2%) without POD1 residual tumor ($p<0.001$).

Conclusion: POD1 gadolinium-enhanced MRI showed very high agreement with delayed early MRI in detecting residual tumor after intradural spinal tumor surgery and may serve as a reliable early baseline for residual tumor assessment. However, cerebrospinal fluid (CSF) collection and T2 signal change were more time-dependent findings, supporting selective delayed imaging when early findings are equivocal or postoperative symptoms or CSF-related concerns persist.

Keywords: Spinal cord neoplasms, magnetic resonance imaging, postoperative period, residual neoplasm, disease progression

INTRODUCTION

Postoperative magnetic resonance imaging (MRI) is used after intradural spinal tumor surgery to document extent of resection (EOR), establish a surveillance baseline, and support follow-up or adjuvant treatment decisions in selected patients^(1,2). Accurate residual tumor assessment is particularly relevant for tumor types in which subtotal resection is associated with recurrence or progression, including spinal ependymomas, myxopapillary ependymomas, meningiomas, and other intradural lesions⁽²⁻⁴⁾. However, the timing used to define postoperative EOR after intradural spinal tumor surgery remains inconsistent. In both intradural extramedullary (IDEM) and intramedullary (IM) tumor literature, some studies use early postoperative MRI within 72 hours, whereas others rely on delayed first follow-up MRI obtained approximately 3-6 months after surgery⁽⁵⁻⁸⁾.

This variation limits comparison between surgical series and leaves a practical question: whether immediate postoperative MRI provides the same residual tumor information as delayed early imaging.

In cranial glioma surgery, postoperative MRI timing has been studied more extensively. Early postoperative MRI is used to assess residual enhancing tumor before surgically induced enhancement becomes more prominent, although interpretation may be confounded by blood products, ischemia related diffusion restriction, reactive enhancement, and postoperative T2 or fluid attenuated inversion recovery changes⁽⁹⁻¹¹⁾. Comparable evidence is limited for intradural spinal tumor surgery, where the imaging problem may differ from cranial intra-axial tumors because many IDEM lesions are extra-axial, well circumscribed, and contrast enhancing, whereas IM tumors may involve intrinsic cord tissue and may be more difficult to distinguish from postoperative neural tissue changes⁽¹²⁻¹⁴⁾.

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Postoperative day 1 (POD1) and delayed early MRI may also differ according to the postoperative feature being assessed. Residual enhancing tumor may be a relatively stable finding, whereas cerebrospinal fluid (CSF) collection, postoperative hematoma, residual compression, syrinx, and T2 signal change may evolve over the first postoperative weeks⁽¹⁵⁾. Therefore, POD1 MRI may be reliable for residual tumor but less reliable for dynamic postoperative findings.

The primary objective of this study was to compare POD1 gadolinium-enhanced MRI with delayed early postoperative MRI after intradural spinal tumor surgery for residual tumor detection. Delayed early MRI corresponded to the institutional 6-week postoperative control MRI and was defined as contrast-enhanced MRI obtained between POD30 and 60. Secondary objectives were to compare agreement for selected dynamic postoperative MRI findings and to assess the association between POD1 residual tumor and subsequent radiological progression.

MATERIALS AND METHODS

Study Design and Patient Selection

This retrospective single-center cohort study was performed at a tertiary neurosurgical center after approval by the University of Health Sciences Türkiye, Başakşehir Çam and Sakura City Hospital Local Ethics Committee (approval no: KAEK/04.02.2026.78, date: 24.02.2026). The requirement for individual informed consent was waived because of the retrospective design and anonymized analysis.

Patients who underwent surgery for intradural spinal tumors between June 2020 and December 2025 were reviewed. The eligible intradural spinal tumor cohort consisted of 112 patients. Patients were eligible for the paired imaging analysis if both POD1 gadolinium-enhanced MRI and delayed early postoperative gadolinium-enhanced MRI were available. Delayed early MRI was defined a priori as MRI performed between POD30 and 60. Sixteen patients were excluded because delayed early MRI was unavailable within this predefined window, leaving 96 patients in the final paired MRI cohort. Patient-level delayed early MRI timing was recorded for all included patients.

During the study period, the institutional postoperative imaging protocol included routine POD1 MRI to document immediate postoperative findings and an outpatient control visit with delayed early MRI at approximately 6 weeks after surgery.

Surgical Treatment and Clinical Variables

All operations were performed using standard microsurgical techniques. The surgical approach and EOR were selected according to tumor level, compartment, preoperative imaging, suspected pathology, and intraoperative findings. The operative goal was maximal safe resection. Subtotal resection was accepted when further removal was considered unsafe because

of IM location, adherence to functional neural tissue, vascularity, or intraoperative neuromonitoring change.

Demographic, clinical, operative, pathological, and outcome variables were extracted from the institutional dataset. Clinical variables included age, sex, American Society of Anesthesiologists physical status score, comorbidities, preoperative and postoperative neurological status, operative duration, transfusion, length of stay, readmission, reoperation, and follow up duration. Neurological status was recorded using the modified McCormick scale⁽¹⁶⁾.

Histopathological diagnoses were grouped as meningioma, schwannoma/peripheral nerve sheath tumor, non-myxopapillary ependymoma, myxopapillary ependymoma, congenital/cystic lesions, glial or malignant tumors, vascular lesions, and other rare tumors. Tumor compartment was classified anatomically as IDEM or IM according to the imaging and operative record. For pathology grouping, ependymal tumors with IM location were classified as non-myxopapillary ependymomas, whereas ependymal tumors with non-IM location were classified as myxopapillary ependymomas.

MRI Protocol and Image Assessment

All examinations used for residual tumor assessment included gadolinium-enhanced sagittal and axial T1-weighted sequences. Sagittal and axial T2-weighted images were used for anatomical correlation and for assessment of syrinx, cord signal change, and postoperative fluid collection. Residual tumor was assessed only on contrast-enhanced MRI.

Preoperative tumor length, maximal axial diameter, foraminal extension, syrinx, dural tail, and T2 hyperintensity were recorded using predefined criteria. Ventral relationship was classified on axial images according to the dominant anterior-half relationship of the lesion to the dural sac or spinal canal for IDEM tumors, or the anterior-half epicenter within the cord for IM tumors. Borderline cases were resolved by consensus review.

POD1 MRI variables included residual tumor, postoperative hematoma, residual compression, T2 signal change, and CSF collection. Delayed early MRI variables included residual tumor, syrinx, T2 signal change, and CSF collection.

Residual Tumor Definition

Residual tumor was defined as nodular, mass like, or anatomically persistent enhancing tissue at the surgical level that was compatible with the preoperative tumor and spatially concordant with the original tumor location. Linear dural enhancement alone, non-specific granulation tissue, hemostatic material, blood products, collapsed tumor capsule, postoperative packing, and simple CSF or fluid collection were not classified as residual tumor. Equivocal enhancement was adjudicated by consensus after review of preoperative morphology, operative level, and multiplanar postcontrast sequences.

Postoperative hematoma was defined as a blood-product collection at the operative level on POD1 MRI. Residual

compression was defined as persistent mass effect on the spinal cord, conus, or cauda equina after surgery. T2 signal change was defined as IM hyperintensity at or adjacent to the operative level. CSF collection was defined as an extradural, subfascial, or paraspinal postoperative fluid collection compatible with CSF accumulation or pseudomeningocele.

MRI Review and Interrater Reliability

MRI features were independently reviewed by two spine-focused neurosurgeons using the predefined criteria. Reviewers were blinded to clinical outcomes, tumor progression, reoperation status, pathology, and each other's ratings. When reviewing POD1 MRI, reviewers were also blinded to the delayed early MRI result. Preoperative images were available for anatomical correlation and to confirm the original tumor level and morphology, but operative reports and later clinical outcomes were not used for the primary residual tumor classification. Discrepancies were resolved by consensus review.

Interrater reliability was assessed in a random subset of 45 patients using exact agreement. For POD1 MRI, exact agreement was 44/45 for residual tumor (97.8%), 43/45 for hematoma (95.6%), 45/45 for residual compression (100.0%), 44/45 for T2 signal change (97.8%), and 43/45 for CSF collection (95.6%). For delayed early MRI, exact agreement was 45/45 for residual tumor (100.0%), 45/45 for syrinx (100.0%), 44/45 for T2 signal change (97.8%), and 44/45 for CSF collection (97.8%). Because the archived reliability dataset preserved exact agreement counts but not the full rater-level contingency tables, kappa statistics were not calculated for the interrater subset.

Outcomes

The primary outcome was agreement between POD1 and delayed early MRI for residual tumor detection. Delayed early MRI was treated as a comparator, not as an absolute gold standard.

Secondary imaging outcomes were agreement between POD1 and delayed early MRI for CSF collection and T2 signal change. Secondary clinical outcomes included radiological tumor progression, tumor reoperation, any reoperation, readmission, and composite postoperative morbidity.

Progression analysis included only patients with postoperative surveillance beyond delayed early MRI. Two patients without adequate follow-up imaging beyond delayed early MRI were excluded from the progression analysis. Progression was defined as radiological enlargement of residual tumor compared with POD1 or delayed early MRI, or new recurrent tumor after no residual tumor had been identified on POD1 or delayed early MRI.

Composite postoperative morbidity was defined as any reoperation, lumbar drain placement for CSF fistula, or postoperative neurological worsening during the index postoperative period.

Statistical Analysis

Continuous variables were summarized as medians and interquartile ranges (IQRs). Categorical variables were summarized as counts and percentages. Agreement between POD1 and delayed early MRI findings was evaluated using paired 2×2 contingency tables, McNemar tests, and Cohen kappa. Diagnostic performance of POD1 MRI was calculated using delayed early MRI as the comparator and included sensitivity, specificity, positive predictive value, negative predictive value, and accuracy. These metrics therefore describe agreement relative to delayed early MRI rather than diagnostic accuracy against a pathological gold standard.

Associations between residual tumor status and categorical clinical outcomes were evaluated using Fisher's exact tests. Continuous variables were compared using Wilcoxon rank-sum tests. Logistic regression was considered exploratory but was not emphasized because of sparse event counts and complete or quasi-complete separation in some models. A two-sided p-value <0.05 was considered statistically significant. Statistical analyses were performed using R software (version 4.5.2).

RESULTS

Cohort Characteristics

Of the 112 patients in the eligible postoperative imaging cohort, 96 had both gadolinium-enhanced POD1 MRI and delayed early MRI within POD30-60 and were included in the paired imaging analysis. Sixteen patients were excluded because delayed early MRI was unavailable within the predefined window. Delayed early MRI was obtained at a median of 48 days after surgery (IQR, 41-56; range, 33-60).

The median age was 49.5 years (IQR, 38.0-59.0), and 58 patients (60.4%) were female. Median tumor length was 18.5 mm (IQR, 13.8-27.6), median axial diameter was 10.8 mm (IQR, 9.0-13.4), median operative time was 240 minutes (IQR, 188-311), and median length of stay was 4 days (IQR, 3-6). Median follow-up was 13.1 months (IQR, 6.9-24.9). Pathological and anatomical distributions are summarized in Table 1.

Residual Tumor Agreement Between POD1 and Delayed Early MRI

POD1 MRI identified residual tumor in 14 of 96 patients (14.6%), whereas delayed early MRI identified residual tumor in 15 of 96 patients (15.6%). Residual tumor classification was concordant in 95 of 96 patients. One patient had no definite residual tumor on POD1 MRI but had residual tumor on delayed early MRI (Figure 1). No patient had residual tumor on POD1 MRI that was absent on delayed early MRI.

Using delayed early MRI as the comparator, POD1 MRI showed 93.3% sensitivity, 100.0% specificity, 100.0% positive predictive value, 98.8% negative predictive value, and 99.0% accuracy for residual tumor detection. Cohen's kappa was 0.959, and

Table 1. Baseline characteristics of the paired POD1/delayed early MRI cohort

Variable	Value
Cohort and imaging timing	
Patients, n	96
Delayed early MRI timing, POD	48 (41-56); range 33-60
Delayed early MRI POD30-39	18 (18.8)
Delayed early MRI POD40-49	36 (37.5)
Delayed early MRI POD50-60	42 (43.8)
Demographic and operative characteristics	
Age, years	49.5 (38.0-59.0)
Female sex	58 (60.4)
Tumor length, mm	18.5 (13.8-27.6)
Axial diameter, mm	10.8 (9.0-13.4)
Operative time, min	240 (188-311)
Length of stay, days	4 (3-6)
Follow-up, months	13.1 (6.9-24.9)
Postoperative imaging and progression	
POD1 residual tumor	14 (14.6)
Delayed early MRI residual tumor	15 (15.6)
Progression among patients with available data	8/94 (8.5)
Pathology	
Meningioma	34 (35.4)
Schwannoma/PNST	28 (29.2)
Non-myxopapillary ependymoma	6 (6.3)
Myxopapillary ependymoma	18 (18.8)
Glial/malignant	5 (5.2)
Congenital/cystic	3 (3.1)
Other rare	1 (1.0)
Vascular	1 (1.0)
Tumor compartment and level	
IDEM	86 (89.6)
IM	10 (10.4)
Thoracic	37 (38.5)
Cervical	28 (29.2)
Lumbar	21 (21.9)
Conus	8 (8.3)
Other/sacral or lumbosacral	2 (2.1)

Values are presented as median (interquartile range) or n (%), unless otherwise indicated. Two patients without adequate follow-up imaging beyond delayed early MRI were excluded from the progression analysis. IDEM: Intradural extramedullary, IM: Intramedullary, MRI: Magnetic resonance imaging, PNST: Peripheral nerve sheath tumor, POD: Postoperative day

the McNemar test was not significant ($p=1.000$). Paired MRI classification matrices and diagnostic performance metrics are summarized separately in Figure 2A and Table 2.

Secondary MRI Findings

Agreement was lower for dynamic postoperative MRI findings than for residual tumor. For CSF collection, findings were concordant in 84 of 96 patients; discordance occurred in

both directions, with collections resolving after POD1 MRI in some patients and becoming apparent on delayed early MRI in others. For T2 signal change, findings were concordant in 82 of 96 patients, with most discordance reflecting early POD1 signal change that was no longer present on delayed early MRI. Diagnostic performance for these secondary MRI findings is shown in Table 2.

Pathology and Compartment Specific Findings

Pathology and compartment specific findings are summarized in Table 3. POD1 residual tumor was observed most frequently among glial/malignant, congenital/cystic, and vascular lesions, although these subgroup findings were descriptive because of limited event counts. Among 86 IDEM tumors, residual tumor classification was concordant in 85 patients (98.8%). Among 10 IM tumors, residual tumor classification was concordant in all patients.

POD1 Residual Tumor and Clinical Outcomes

Progression data were available for 94 patients. Radiological progression occurred in 8 patients (8.5%). Progression was observed in 7 of 13 patients (53.8%) with POD1 residual tumor and 1 of 81 patients (1.2%) without POD1 residual tumor ($p<0.001$; Figure 2B). Using delayed early MRI residual tumor status, progression occurred in 7 of 14 patients (50.0%) with residual tumor and 1 of 80 patients (1.3%) without residual tumor ($p<0.001$).

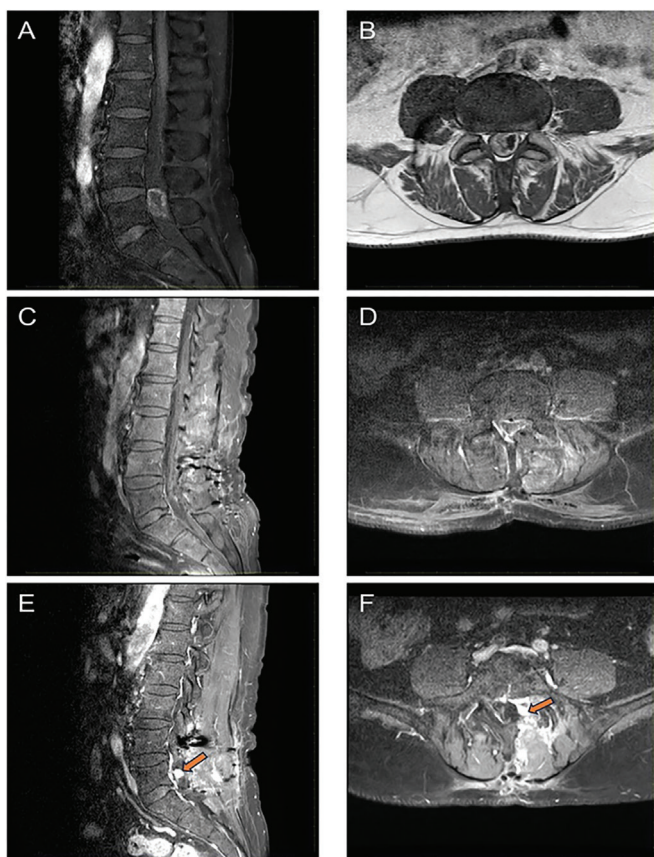


Figure 1. Illustrative discordant paired postoperative MRI case. Preoperative sagittal and axial contrast-enhanced images demonstrate the index intradural lesion (A, B). POD1 sagittal and axial images show postoperative change without definite residual tumor (C, D). Delayed early sagittal and axial images demonstrate a small enhancing residual focus at the operative level, indicated by arrows (E, F). This case illustrates the single discordant residual-tumor classification between POD1 and delayed early MRI. MRI: Magnetic resonance imaging, POD1: Postoperative day 1

POD1 residual tumor was associated with a higher rate of any reoperation and showed a numerically higher rate of tumor reoperation. Readmission and composite postoperative morbidity were also numerically higher but did not reach statistical significance. Clinical and imaging outcomes according to POD1 residual tumor status are summarized in Supplementary Table 1. In retrospective chart review, no patient with negative POD1 MRI for residual tumor had documentation indicating that delayed early MRI alone prompted reoperation, readmission, adjuvant-treatment referral, or a change in surveillance strategy.

DISCUSSION

This study found that POD1 gadolinium-enhanced MRI classified residual tumor almost identically to delayed early MRI after intradural spinal tumor surgery. Among 96 patients with paired imaging, residual tumor classification was concordant in 95 patients, with a kappa of 0.959. POD1 MRI missed one small residual focus that was visible on delayed early MRI, and no POD1 residual-tumor finding disappeared on the delayed early study. These findings support POD1 MRI as a reliable early baseline for residual tumor and EOR assessment.

The timing of postoperative MRI after intradural spinal tumor surgery is not standardized. Ependymal tumor guidance and contemporary spinal tumor series recognize postoperative MRI as important for residual disease assessment and surveillance, but the imaging time point used to define postoperative residual tumor varies substantially, ranging from early MRI within 24-72 hours to first follow up MRI obtained approximately 3 months after surgery^(1,5,8). In the present cohort, delayed early MRI was defined a priori for analysis as POD30-60, and patient level scan timing confirmed a median postoperative timing of 48 days. This timing transparency is important because EOR is frequently analyzed as a prognostic variable, yet the imaging time point used to define it may differ between cohorts.

The main novelty of the study is not the observation that residual tumor is associated with progression, which is biologically and clinically expected in several intradural tumor types. Rather, the important finding is that POD1 MRI already captured nearly the same residual tumor classification as delayed early MRI and identified the same clinically relevant residual tumor group. Progression occurred in 53.8% of patients with POD1 residual tumor compared with 1.2% of patients without POD1 residual tumor. This finding is consistent with the general literature linking residual disease and EOR to recurrence or progression risk in several intradural tumor groups, including ependymoma, myxopapillary ependymoma, and meningioma^(1-4,8). However, this association should be interpreted as supportive clinical correlation rather than independent prognostic modeling because progression events were sparse, pathology specific risks differed across the heterogeneous cohort, adjuvant treatment was variable, and follow up intensity may have differed according to postoperative findings.

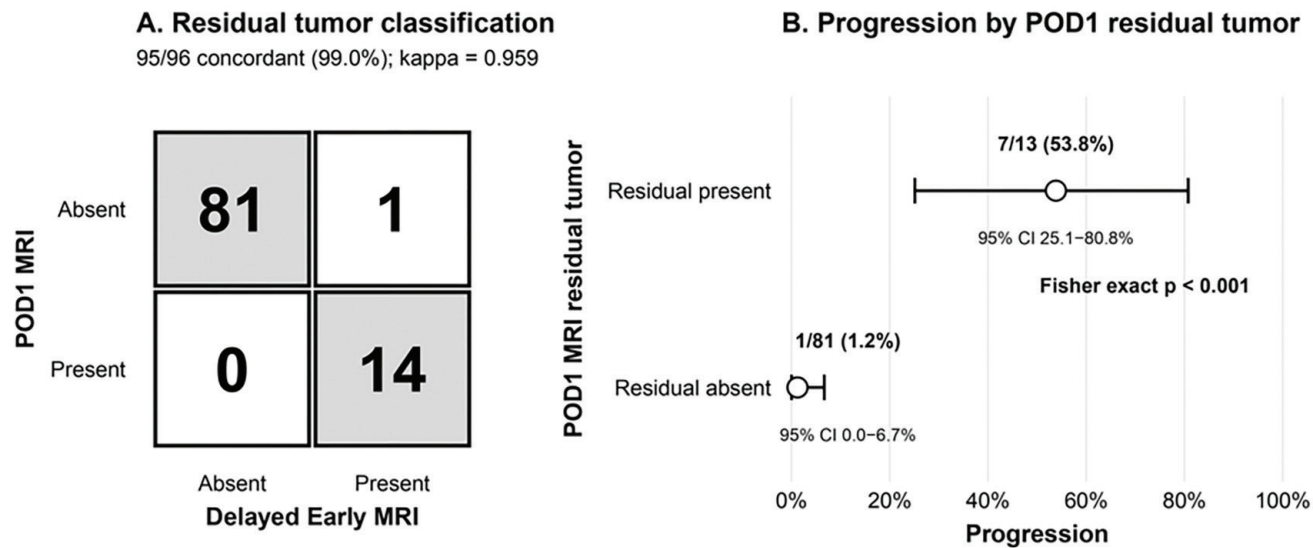


Figure 2. POD1 residual tumor assessment: agreement with delayed early MRI and association with progression
(A) Paired residual tumor classification on POD1 and delayed early gadolinium-enhanced MRI. The delayed early MRI refers to the MRI obtained within postoperative days 30-60. Residual tumor classification was concordant in 95 of 96 patients (99.0%; kappa=0.959). Kappa refers to agreement between POD1 and delayed early MRI classifications, not interrater reliability. (B) Progression according to POD1 residual tumor status among patients with surveillance beyond delayed early MRI. Points indicate observed progression risk, and horizontal bars indicate exact binomial 95% CIs. Progression occurred in 1 of 81 patients (1.2%; 95% CI, 0.0-6.7%) without POD1 residual tumor and 7 of 13 patients (53.8%; 95% CI, 25.1-80.8%) with POD1 residual tumor ((Fisher's exact p<0.001). MRI: Magnetic resonance imaging, POD1: Postoperative day 1, CI: Confidence interval

Table 2. Agreement-derived performance of POD1 MRI using delayed early MRI as comparator

MRI finding	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, % (95% CI)	NPV, % (95% CI)	Accuracy, % (95% CI)	Kappa	McNemar p
Residual tumor	93.3 (68.1-99.8)	100.0 (95.5-100.0)	100.0 (76.8-100.0)	98.8 (93.4-100.0)	99.0 (94.3-100.0)	0.959	1.000
CSF collection	50.0 (23.0-77.0)	93.9 (86.3-98.0)	58.3 (27.7-84.8)	91.7 (83.6-96.6)	87.5 (79.2-93.4)	0.467	0.774
T2 signal change	91.3 (72.0-98.9)	83.6 (73.0-91.2)	63.6 (45.1-79.6)	96.8 (89.0-99.6)	85.4 (76.7-91.8)	0.652	0.013

Diagnostic performance metrics use delayed early MRI as the paired imaging comparator, not as an absolute pathological gold standard. Sensitivity, specificity, PPV, NPV, and accuracy are presented as percentages with exact binomial 95% confidence intervals (CIs). CSF: Cerebrospinal fluid, MRI: Magnetic resonance imaging, PPV: positive predictive value, NPV: Negative predictive value, POD1: Postoperative day 1

The reliability of POD1 MRI did not extend equally to dynamic postoperative findings. Agreement for CSF collection and T2 signal change was lower than agreement for residual tumor. POD1 MRI had only 50.0% sensitivity for CSF collection visible on delayed early MRI, and discordance occurred in both directions. This pattern is clinically plausible because postoperative CSF collections may enlarge, resolve, or become more apparent after discharge. T2 signal change also evolved between time points, with some early signal changes resolving and a smaller number appearing or becoming more visible later. These findings support a practical distinction between relatively stable residual enhancing tumor and more dynamic postoperative imaging findings.

The cranial tumor literature provides an important analogy but should not be directly extrapolated to spinal intradural tumors. In glioma surgery, early postoperative MRI timing is critical because surgically induced enhancement, ischemic

change, and evolving T2/fluid-attenuated inversion recovery abnormalities can affect residual tumor assessment⁽⁹⁻¹¹⁾. Intradural spinal tumors differ anatomically and radiologically. Many IDEM lesions are extra axial, well circumscribed, and contrast enhancing, which may make residual tumor more distinguishable from postoperative change on early imaging. In contrast, IM tumors involve intrinsic cord tissue, and infiltrative or poorly demarcated lesions may create interpretive difficulties more similar to intra axial brain tumors⁽¹²⁻¹⁴⁾.

These findings have practical implications for postoperative workflow. POD1 MRI provides immediate documentation before discharge, establishes a baseline for future surveillance, and may allow earlier multidisciplinary discussion when residual tumor is present. Among patients without residual tumor on POD1 MRI, chart review did not identify any documented treatment, reoperation, readmission, or surveillance plan change that was attributed solely to the delayed early MRI. This does not mean that

Table 3. Pathology and compartment specific residual tumor agreement and progression

Subgroup	n	POD1 residual tumor	Delayed early MRI residual tumor	Concordant residual classification	Progression
Meningioma	34	4/34 (11.8)	4/34 (11.8)	34/34 (100.0)	2/34 (5.9)
Schwannoma/PNST	28	3/28 (10.7)	4/28 (14.3)	27/28 (96.4)	2/28 (7.1)
Non-myxopapillary ependymoma	6	0/6 (0.0)	0/6 (0.0)	6/6 (100.0)	0/6 (0.0)
Myxopapillary ependymoma	18	1/18 (5.6)	1/18 (5.6)	18/18 (100.0)	1/17 (5.9)
Glial/malignant	5	3/5 (60.0)	3/5 (60.0)	5/5 (100.0)	3/5 (60.0)
Congenital/cystic	3	2/3 (66.7)	2/3 (66.7)	3/3 (100.0)	0/2 (0.0)
Other rare	1	0/1 (0.0)	0/1 (0.0)	1/1 (100.0)	0/1 (0.0)
Vascular	1	1/1 (100.0)	1/1 (100.0)	1/1 (100.0)	0/1 (0.0)
IDEM	86	10/86 (11.6)	11/86 (12.8)	85/86 (98.8)	6/84 (7.1)
IM	10	4/10 (40.0)	4/10 (40.0)	10/10 (100.0)	2/10 (20.0)

Values are presented as n (%), unless otherwise indicated. Subgroup findings are descriptive and were not intended for inferential comparison because of limited event counts. The glial/malignant category comprised glioblastoma (n=1), diffuse midline glioma, H3K27-altered (n=1), diffuse astrocytoma (n=1), high-grade diffuse glial tumor (n=1), and a neuroendocrine tumor reported as paraganglioma versus metastasis (n=1). The congenital/cystic category comprised mature teratoma (n=1), mature cystic teratoma (n=1), and dermoid tumor (n=1). The other rare category comprised extranodal Rosai-Dorfman disease (n=1). The vascular category comprised hemangioblastoma (n=1). IDEM: Intradural extramedullary, IM: Intramedullary, MRI: Magnetic resonance imaging, PNST: Peripheral nerve sheath tumor, POD: Postoperative day

delayed early MRI is unnecessary for all patients. Rather, POD1 MRI appears most useful for residual tumor and EOR documentation, whereas delayed early MRI may be reserved for equivocal early imaging, evolving symptoms, suspected CSF related complications, or unresolved postoperative cord-signal questions.

Study Limitations

Several limitations should be considered. First, the study was retrospective and single center. Second, only patients with paired POD1 and delayed early MRI within the predefined POD30-60 window were included in the main analysis, which may introduce selection bias. Third, although patient-level delayed early MRI timing was available for all included patients, the cohort was not large enough to meaningfully assess whether agreement differed across narrower timing intervals within the POD30-60 window. Fourth, the cohort included heterogeneous tumor pathologies and both IDEM and IM tumors, reflecting real world intradural spinal tumor practice but limiting pathology specific inference. Fifth, delayed early MRI was used as a comparator rather than an absolute gold standard. Sixth, residual tumor was analyzed as a binary variable rather than volumetrically. Seventh, although both reviewers were spine-focused neurosurgeons familiar with postoperative intradural tumor imaging, independent neuroradiology review was not performed. Finally, progression events were relatively few, limiting multivariable modeling, and the association between residual tumor and progression should be considered descriptive and exploratory.

CONCLUSION

POD1 gadolinium-enhanced MRI showed very high agreement with delayed early MRI for residual tumor detection after

intradural spinal tumor surgery. These findings support POD1 MRI as a reliable early baseline for residual tumor and EOR assessment. However, agreement was lower for CSF collection and T2 signal change, indicating that delayed early MRI remains useful when early findings are equivocal or when postoperative symptoms, CSF related concerns, or cord-signal abnormalities require further evaluation. The association between POD1 residual tumor and later radiological progression should be interpreted descriptively because of sparse events and pathology heterogeneity.

Ethics

Ethics Committee Approval: This retrospective single-center cohort study was performed at a tertiary neurosurgical center after approval by the University of Health Sciences Türkiye, Başakşehir Çam and Sakura City Hospital Local Ethics Committee (approval no: KAEK/04.02.2026.78, date: 24.02.2026).

Informed Consent: The requirement for individual informed consent was waived because of the retrospective design and anonymized analysis.

Footnotes

During the preparation of this manuscript, the authors used ChatGPT (OpenAI, San Francisco, USA) only for language editing and structural refinement during manuscript preparation. All content, data interpretation, statistical analyses, and conclusions were reviewed and verified by the authors, who take full responsibility for the final manuscript.

Authorship Contributions

Surgical and Medical Practices: A.T.B., M.B., Concept: A.T.B., Design: A.T.B., Data Collection or Processing: A.T.B., M.B.,

Analysis or Interpretation: A.T.B., M.B., Literature Search: A.T.B., M.B., Writing: A.T.B., M.B.

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Supplementary Table Link: <https://d2v96fxpocvxx.cloudfront.net/6548c443-00ef-4a8c-a306-c0848f02b51f/content-images/846d5144-ed95-4dd8-a9e2-1123c5d6bbb5.pdf>

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