Rim and Flame Signs: Postgadolinium MRI Findings Specific for Non-CNS Intramedullary Spinal Cord Metastases

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ABSTRACT

BACKGROUND AND PURPOSE: No highly specific MR imaging features distinguishing ISCMs from primary cord masses have been described. Our purpose was to retrospectively compare peripheral enhancement features on postgadolinium MR imaging of ISCMs with primary intramedullary cord masses.

MATERIALS AND METHODS: A consecutive group of patients with firmly diagnosed ISCM (45 patients with 64 ISCMs) and a comparison group with consecutive pathologically proved primary intramedullary spinal cord masses (64 patients with 64 primary spinal cord masses: ependymoma, astrocytoma, hemangioblastoma, ganglioglioma, and cavernous malformation) were included. MR images were evaluated for 2 specific signs on postgadolinium images: a “rim” sign (more intense thin rim of peripheral enhancement around an enhancing lesion) and “flame” sign (ill-defined flame-shaped region of enhancement at the superior/inferior lesion margins). The frequency of rim and/or flame signs in ISCMs and primary cord masses was compared (χ² test). For ISCMs, the maximal dimension of the enhancing lesion was correlated with the presence of rim or flame signs (t test).

RESULTS: Rim and flame signs, alone and in combination, were seen more frequently in ISCMs than in primary cord masses (P < .0001 for each). Specificity and sensitivity, respectively, for diagnosing ISCMs among spinal cord masses on a per-patient basis were the following: rim sign, 97%, 47%; flame sign, 97%, 40%; at least 1 sign, 94%, 60%; and both signs concurrently, 100%, 27%. In the ISCM group, the presence of either a rim or flame sign correlated with a larger measured maximum enhancing lesion size (P = .0065 and P = .0012, respectively).

CONCLUSIONS: The rim and flame signs are common in and specific for ISCM and are rare in primary spinal cord masses.

ABBREVIATIONS: ABR = American Board of Radiology; ISCM = intramedullary spinal cord metastasis; WHO = World Health Organization

ISCMs are rare. Postmortem series report a prevalence of 0.9%–2.1% in patients with cancer.1,2 However, ISCMs are being observed more commonly than in the past, with contributing factors including the increasing use and availability of MR imaging and more effective cancer therapies.3–5 MR imaging is the diagnostic imaging technique of choice for ISCMs, yet large case series with detailed descriptions of MR imaging features of these lesions are lacking.

To our knowledge, no highly specific MR imaging features of ISCMs that could distinguish them from primary cord masses have been described. Even in the MR imaging era, these lesions are occasionally biopsied for diagnostic purposes. We have anecdotally observed 2 potentially distinguishing postgadolinium MR imaging features at the peripheral aspects of ISCMs. The purpose of the current study was to retrospectively compare the peripheral enhancement features on postgadolinium MR imaging of ISCMs and primary intramedullary cord masses.

MATERIALS AND METHODS

Institutional review board approval with waived consent was obtained for this Health Insurance Portability and Accountability Act–compliant retrospective research study.

Subjects

The radiologic, clinical, surgical, and pathologic data bases at our single institution were searched for a group of consecutive patients with ISCMs (n = 58, 1999 to 2011). Patients with lack of available gadolinium-enhanced pretreatment digital MR imaging examinations, and patients in whom alternative diagnoses were being considered clinically and in whom ISCM was never formally diagnosed were excluded. For any patient with pathologi-
cally proved ISCM, the primary reason (diagnostic or therapeu-
tic) for cord mass biopsy/resection was determined on the basis of
the clinical documentation, and whether the radiologist’s report
favored a primary cord mass or an ISCM was ascertained.

For the comparison group, the pathologic data base at our
institution was searched for patients with pathologically proved
primary spinal cord intramedullary masses (n = 84) with 1 of the
following histopathologies: ependymoma (consecutive from
2009 to 2011), astrocytoma (consecutive from 2006 to 2011),
hemangioblastoma (consecutive from 2000 to 2011), ganglioglioma
(consecutive from 2006 to 2011), and cavernous malformation
(consecutive from 1998 to 2011). The varying date ranges were
chosen so that the final size of the comparison group was approx-
imately the same as the ISCM group. Patients lacking available
pretreatment MR imaging were excluded.

**MR Imaging Review**

Two radiologists reviewed the MR imaging examinations of all
patients in consensus at an electronic workstation: one (F.E.D.), a
neuroradiology faculty member with an ABR certification and a
Certificate of Added Qualification in neuroradiology and in full-
time neuroradiology practice; and the other (J.B.R.), a current
neuroradiology fellow with an ABR certification. The examina-
tions included MR imaging from predominantly our and several
outside institutions. All available pulse sequences were reviewed,
with the typical examination including sagittal T1- and T2-
weighted, axial T2-weighted, and postgadolinium sagittal and ax-
ial T1-weighted images. The presence or absence of the following
imaging features was analyzed by using pre- and postgadolinium
T1-weighted images: 1) gadolinium enhancement, 2) rim sign,
and 3) flame sign. The rim sign was defined as a complete or
partial thin peripheral rim of gadolinium enhancement more in-
tense than the central enhancement of a noncystic/necrotic lesion
(Fig 1). When present, it was rated as either partial or complete/
near-complete. The flame sign was an ill-defined flame-shaped
region of gadolinium enhancement at the superior and/or inferior
margin of an otherwise well-defined lesion (Fig 2). Both the rim
and flame signs can be present in the same lesion (Fig 3). For
ISCMs, the maximum size of the enhancing lesion (including
the flame sign, if present) was measured in millimeters, by using
the superior-inferior dimension on sagittal T1-weighted post-
gadolinium scans in all cases.

**Histopathologic Review**

The histopathologic slides of the 5 patients in whom the ISCM
had been biopsied/resected were reviewed by a board-certified neu-
ropathologist (C.G.). The neuropathologist was asked to assess the
margins of the tumor for any possible correlates of the rim and
flame signs.
Clinical Review
The electronic medical records were reviewed to identify those patients with an ISCM in whom: the cord lesion was identified before a diagnosis of systemic metastatic disease, radiation therapy for their primary malignancy had included the region of spinal cord in which the ISCM developed, and/or systemic steroid therapy was ongoing at the time of MR imaging.

Statistical Analysis
The frequency of rim and/or flame signs in ISCMs and primary cord masses was compared by using the χ² test. We calculated the sensitivity of the rim and/or flame signs for diagnosing ISCM, assuming ISCMs with these signs to be true-positives and those without, false-negatives. We calculated the specificity of these signs for diagnosing ISCM, assuming primary cord masses with these findings to be false-positives and those without, true-negatives. For the ISCMs, a t test, assuming unequal variances, was used to analyze the correlation between the presence of rim and/or flame signs and mean enhancing lesion maximum size; and the χ² test was used to analyze the correlation between the presence of rim and/or flame signs and either radiation therapy for primary malignancy or systemic steroid therapy. Statistical significance was set at a P value of < .05, and analysis was conducted by using JMP Software, Version 7.0 (SAS Institute, Cary, North Carolina).

RESULTS
Histopathologic Characteristics of ISCM
Nine (16%) of the 58 patients with potential ISCMs were excluded due to lack of available gadolinium-enhanced pretreatment digi-
Table 1: Enhancement characteristics of intramedullary spinal cord metastases and primary masses (per-lesion basis)

|                        | Intradural Spinal Cord Metastases (n = 64) | Primary Spinal Cord Masses (n = 64) | Ependymoma (n = 21) | Astrocytoma (n = 21) | Hemangioblastoma (n = 11) | Ganglioglioma (n = 5) | Cavernous Malformation (n = 6) |
|------------------------|-------------------------------------------|-------------------------------------|---------------------|----------------------|----------------------------|-----------------------|-----------------------------|
| No enhancement         | 1 (2%)                                    | 10 (16%)                            | 0                   | 6 (29%)              | 0                          | 1 (20%)               | 3 (50%)                     |
| Rim sign               | 21 (33%)                                  | 2 (3%)                              | 0                   | 0                    | 2 (18%)                   | 0                     | 0                           |
| Flame sign             | 19 (30%)                                  | 2 (3%)                              | 1 (5%)              | 1 (5%)               | 0                          | 0                     | 0                           |
| Rim without flame sign | 9 (14%)                                   | 2 (3%)                              | 0                   | 0                    | 2 (18%)                   | 0                     | 0                           |
| Flame without rim sign | 7 (11%)                                   | 2 (3%)                              | 1 (5%)              | 1 (5%)               | 0                          | 0                     | 0                           |
| Only rim or flame sign | 16 (25%)                                  | 4 (6%)                              | 1 (5%)              | 1 (5%)               | 2 (18%)                   | 0                     | 0                           |
| Both rim and flame signs | 12 (19%)                                 | 0                                  | 0                   | 0                    | 0                          | 0                     | 0                           |
| At least rim or flame sign | 28 (44%)                                | 4 (6%)                              | 1 (5%)              | 1 (5%)               | 2 (18%)                   | 0                     | 0                           |

*a Sum of the 2 preceding rows (lesions that demonstrated only 1 of the 2 signs).

*b Sum of the 2 preceding rows (lesions that demonstrated at least 1 of the 2 signs, whether alone or in combination with the other sign).

Table 2: Rim and flame signs in intramedullary spinal cord metastases (per-patient basis)

|                        | Rim Sign Only | Flame Sign Only | Both Signs | Neither Sign | At Least One Sign |
|------------------------|---------------|-----------------|------------|--------------|------------------|
| All ISCMs (n = 45)     | 9 (20%)       | 6 (13%)         | 12 (27%)   | 18 (40%)     | 27 (60%)         |
| Lung carcinoma (n = 22)| 6 (27%)       | 3 (14%)         | 8 (36%)    | 5 (23%)      | 17 (77%)        |
| Breast carcinoma (n = 6)| 0            | 0               | 1 (20%)    | 2 (100%)     | 0                |
| Melanoma (n = 5)       | 0             | 1 (20%)         | 1 (20%)    | 3 (60%)      | 2 (40%)         |
| CNS origin (n = 4)     | 0             | 0               | 0          | 4 (100%)     | 0                |
| Renal cell carcinoma (n = 2)| 0           | 1 (50%)         | 1 (50%)    | 0            | 2 (100%)       |
| Other (n = 6)          | 3 (50%)       | 1 (17%)         | 1 (17%)    | 1 (17%)      | 5 (83%)         |
| ISCM identified prior to systemic metastatic disease diagnosis (n = 10)| 3 (30%) | 2 (20%) | 4 (40%) | 1 (10%) | 9 (90%) |
| Radiation therapy for primary malignancy included relevant spinal cord (n = 5)| 0 | 1 (20%) | 3 (60%) | 1 (20%) | 4 (80%) |
| Ongoing systemic steroid therapy at time of MRI (n = 12) | 2 (17%) | 2 (17%) | 3 (25%) | 5 (42%) | 7 (58%) |

Histopathologic Characteristics of Primary Spinal Cord Masses

For the comparison group of patients with pathologically proved primary spinal cord intramedullary masses, 20 (24%) of 84 patients were excluded for lack of available pretreatment MR imaging. The final primary spinal cord mass group consisted of the remaining 64 (76%) of 84 patients, distributed as follows: ependymoma in 21 (33%) (20 WHO grade II and 1 grade I [myxopapillary] that involved the conus), astrocytoma in 21 (33%) (10 pilocytic astrocytomas, 11 infiltrating astrocytomas [5 grade II, 5 grade III, and 1 grade IV]), hemangioblastoma in 11 (17%), ganglioglioma in 5 (8%) (4 grade I; 1 anaplastic ganglioglioma [anaplastic astrocytoma, grade III, arising in a background of low-grade ganglioglioma]), and cavernous malformation in 6 (9%).

Rim and Flame Signs in ISCM

Sixty-three (98%) of the 64 ISCMs enhanced with gadolinium. Table 1 demonstrates the per-lesion prevalence of the rim and flame signs in ISCMs compared with primary cord masses. On a per-patient basis (Table 2), the rim sign was present in 21 (47%) of 45 patients with ISCMs and in isolation without the flame sign in 9 (20%) of 45 patients (Fig 1). The flame sign was present in 18 (40%) of 45 patients and in isolation without the rim sign in 6

Table 3: Rim and flame signs in intramedullary spinal cord metastases (per-patient basis)

|                        | Rim Sign Only | Flame Sign Only | Both Signs | Neither Sign | At Least One Sign |
|------------------------|---------------|-----------------|------------|--------------|------------------|
| All ISCMs (n = 45)     | 9 (20%)       | 6 (13%)         | 12 (27%)   | 18 (40%)     | 27 (60%)         |
| Lung carcinoma (n = 22)| 6 (27%)       | 3 (14%)         | 8 (36%)    | 5 (23%)      | 17 (77%)        |
| Breast carcinoma (n = 6)| 0            | 0               | 1 (20%)    | 2 (100%)     | 0                |
| Melanoma (n = 5)       | 0             | 1 (20%)         | 1 (20%)    | 3 (60%)      | 2 (40%)         |
| CNS origin (n = 4)     | 0             | 0               | 0          | 4 (100%)     | 0                |
| Renal cell carcinoma (n = 2)| 0           | 1 (50%)         | 1 (50%)    | 0            | 2 (100%)       |
| Other (n = 6)          | 3 (50%)       | 1 (17%)         | 1 (17%)    | 1 (17%)      | 5 (83%)         |
| ISCM identified prior to systemic metastatic disease diagnosis (n = 10)| 3 (30%) | 2 (20%) | 4 (40%) | 1 (10%) | 9 (90%) |
| Radiation therapy for primary malignancy included relevant spinal cord (n = 5)| 0 | 1 (20%) | 3 (60%) | 1 (20%) | 4 (80%) |
| Ongoing systemic steroid therapy at time of MRI (n = 12) | 2 (17%) | 2 (17%) | 3 (25%) | 5 (42%) | 7 (58%) |

Histopathologic Characteristics of Primary Spinal Cord Masses

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Rim and Flame Signs in ISCM

Sixty-three (98%) of the 64 ISCMs enhanced with gadolinium. Table 1 demonstrates the per-lesion prevalence of the rim and flame signs in ISCMs compared with primary cord masses. On a per-patient basis (Table 2), the rim sign was present in 21 (47%) of 45 patients with ISCMs and in isolation without the flame sign in 9 (20%) of 45 patients (Fig 1). The flame sign was present in 18 (40%) of 45 patients and in isolation without the rim sign in 6
of 45 patients (Fig 2). The rim and flame signs were present concurrently (Fig 3) in 12 (27%) of 45 patients, and at least 1 of the 2 signs was present in 27 (60%) of 45 patients. Eighteen (40%) of 45 patients did not exhibit either imaging sign, including the 1 patient with the completely nonenhancing ISCM. When present, the rim sign was complete/near-complete in 13 (62%) of 21 and partial in 8 (38%) of 21 lesions. When present, the flame sign was seen superiorly only in 1 (5%) of 19 lesions, inferiorly only in 4 (21%) of 19, and at both ends in 14 (74%) of 19. None of the 4 CNS-origin ISCMs demonstrated either the rim or flame sign (Table 2).

Regarding the 5 (11%) of 45 solitary ISCMs that were directly pathologically proved, 2 (40%) of 5 demonstrated the rim and flame signs; 2 (40%) of 5, the rim sign only; and 1 (20%), the flame sign only. Thus, all 5 (100%) of 5 of these lesions demonstrated at least either the rim or the flame sign. In 1 (20%) of these 5 lesions, the surgical resection was performed primarily for therapeutic effect. In 4 (80%) of these 5 lesions, it was performed primarily for diagnostic purposes: The rim sign was present in 2 cases, and both the rim and flame signs in the other 2 (Fig 4). In 3 (60%) of the 5 lesions, the radiologist’s MR imaging report favored primary cord neoplasm over ISCM (Fig 4): One demonstrated a rim sign; 1, a flame sign; and 1, both signs. No histopathologic correlates to the rim or flame signs were identified in these 5 patients, including no evidence for a tumor capsule. This analysis was limited because all 5 tumors appeared highly fragmented. Thus, the tumor margins and relationship to the surrounding cord parenchyma could not be assessed.

In 10 (22%) of the 45 patients with ISCMs, the cord lesion was identified before a diagnosis of systemic metastatic disease. Five (11%) of the 45 patients with ISCMs had undergone radiation therapy for their primary malignancy that included the region of the spinal cord in which the ISCM developed. Twelve (27%) of the 45 patients with ISCMs were on systemic steroid therapy at the time of MR imaging. The frequencies of the signs in these clinical subgroups are displayed in Table 2. Neither radiation therapy for the primary malignancy involving the relevant region of spinal cord nor steroid therapy at the time of MR imaging statistically correlated with the frequency of the rim and/or flame signs ($P$ values all $\geq .05$).

**Rim and Flame Signs in Primary Cord Masses**

Fifty-four (84%) of 64 primary cord masses enhanced with gadolinium. Table 1 demonstrates the per-lesion prevalence of the rim and flame signs in primary cord masses compared with ISCMs. In the 2 primary cord lesions with the rim sign, both hemangioblastomas, the rim sign was partial (2 of 2; 100%) (Fig 5A, -B). In both of the primary cord lesions with the flame sign, 1 an ependymoma and 1 an astrocytoma, the flame sign was present at only 1 margin of the lesions (2 of 2; 100%) (Fig 5C, -D).

**Diagnostic Utility of Rim and Flame Signs**

The rim and flame signs, alone and in combination, were seen more frequently in ISCMs than in primary cord masses ($P < .0001$ for each). The sensitivities of the rim and flame signs on a per lesion basis for the diagnosis of ISCM were the following: rim
sign, 33% (21/64); flame sign, 19% (19/64); at least 1 sign, 44% (28/64); and both signs concurrently, 19% (12/64). The sensitivities of the rim and flame signs on a per-patient basis were the following: rim sign, 47% (21/45); flame sign, 40% (18/45); at least 1 sign, 60% (27/45); and both signs concurrently, 27% (12/45). The specificities of the rim and flame signs on a per-lesion (and per-patient) basis for the diagnosis of ISCM were the following: rim sign, 97% (62/64); flame sign, 97% (62/64); at least 1 sign, 94% (60/64); and both rim and flame signs concurrently, 100% (64/64).

**FIG 5.** Rarity of rim and flame signs in primary cord masses. Only 4 primary cord masses demonstrated 1 of the signs, all shown here; none displayed both signs. Axial postcontrast T1-weighted image (A) in a 70-year-old man with a hemangioblastoma with a partial rim sign (arrows). Sagittal postcontrast T1-weighted images in a 20-year-old woman (B) with a thoracic hemangioblastoma with a partial rim sign (arrows), a 26-year-old man (C) with a thoracic WHO grade II ependymoma with a flame sign superiorly (arrow), and a 21-year-old man (D) with a cervicothoracic WHO grade I pilocytic astrocytoma with a flame sign inferiorly (arrow).

**Maximum ISCM Size and Correlation with the Presence of the Rim or Flame Sign**

Among the ISCM group, the rim sign and the flame sign each individually positively correlated with the mean measured enhancing lesion size (superior-inferior direction), with statistical significance ($P = .0065$ and $P = .0012$, respectively). The mean enhancing lesion sizes for ISCMs with-versus-without these signs, respectively, were 31 versus 14 mm for the rim sign and 34 versus 14 mm for the flame sign.
DISCUSSION
We describe 2 peripheral enhancement features on MR imaging specific for non-CNS-origin ISCMs compared with primary cord masses: a more intense thin rim of peripheral enhancement around an enhancing lesion and an ill-defined flame-shaped region of enhancement at the superior/inferior margins. These rim and flame signs were prevalent in ISCMs and rare in primary cord masses. Among spinal cord masses, the rim and flame signs thus have high specificity for spinal cord metastases. These signs were not seen in any of the 4 ISCMs of CNS origin.

These results have clinical relevance for several reasons. We expect that knowledge of these specific findings will improve the radiologist’s confidence in diagnosing ISCM. This could enable earlier clinical diagnosis and appropriate treatment, which, according to some literature studies, can improve survival in patients with ISCM. In our study, at least 1 sign was present in almost all (90%) patients with ISCMs, who at the time of MR imaging had not yet been diagnosed with systemic metastatic malignancy. In addition, recognition of the rim and/or flame signs may help avoid diagnostic resection, which is performed in some ISCM cases. Supporting this notion is the fact that of our 5 patients who underwent ISCM resection, resection was performed not for therapeutic purposes but primarily because of diagnostic uncertainty. In 3 of these 5 patients, the radiologist’s MR imaging report favored primary cord neoplasm over ISCM, despite the presence of at least 1 of the 2 signs in each case.

Our study adds to the existing literature on ISCMs. To our knowledge, this is the largest series of ISCMs analyzing post-gadolinium MR imaging findings of these lesions. The largest currently available series consists of 40 patients (only 25 imaged with gadolinium-enhanced MR imaging). The next largest series include studies with 19 patients, 12 patients, 12 patients (only 6 imaged with unenhanced MR imaging), and 7 patients. Most interesting, in 1 of these prior studies a “ring-enhancing” ISCM (their Fig 2) actually demonstrated apparent flame and possible rim signs. In fact, on the basis of our review of the relevant literature, other examples of unreported apparent flame and rim signs are evident. We believe that this finding lends further validity to our findings that the rim and flame signs are common in ISCMs.

A limitation of this study is that the MR images were interpreted by a neuroradiology staff member and fellow in consensus. However, in doing so, it was our goal to simulate clinical academic neuroradiology practice and report on the initial observation of new imaging findings; these 2 scenarios have been proposed to be suitable situations in which consensus review can be justified. The limitations of our study also include its retrospective nature, the heterogeneity in the MR imaging technique given that the MR images were from several different decades and from different institutions, the fact that the reviewers were not blinded to histopathology, and not all potential cord mass pathologies being considered. However, prospective studies of the rare entity of ISCM with a standardized MR imaging technique would prove difficult. The readers of our study carefully scrutinized all cases for these findings, regardless of lesion type. We believe that our comparison group of pathologically proved primary cord masses was representative of the lesions that could most commonly be confused on MR imaging for ISCMs. Our primary cord lesions consisted mostly (42 [66%] of 64) of the 2 most common types of primary cord tumors, ependymomas and astrocytomas. It also included several nonenhancing primary cord tumors, which are known to occur, particularly among astrocytomas.

Future work could include surgical and additional radiologic-pathologic correlation of both the rim and flame signs. Histopathologic analysis in ISCM cases with less fragmented tumor samples might be more revealing with regard to microscopic findings at the tumor margins. Because there are various degrees of resectability encountered by neurosurgeons attempting to remove ISCMs, it would also be interesting to analyze whether the rim sign predicts the presence of a cleavage plane and, in turn, an easier, more complete resection. The degree to which varied pathologic processes, such as ischemia, demyelination, and tumor infiltration, contribute to the flame sign would also be of interest and could be studied specifically at postmortem in future cases. Indeed, the pathologic findings in 3 of 5 ISCM cases in 1 series included “central ischemic infarction...cephalad and caudal to the tumor metastasis.”

CONCLUSIONS
We describe 2 peripheral enhancement features on MR imaging specific for non-CNS-origin ISCM compared with primary cord masses: a more intense thin rim of peripheral enhancement around an enhancing lesion (rim sign) and an ill-defined flame-shaped region of enhancement at the superior/inferior margins (flame sign). The prevalences of these signs in ISCMs and primary cord masses in this series, respectively, were the following: rim sign, 33% (21 of 64) and 3% (2 of 64) ($P < .0001$); and flame sign, 30% (19 of 64) and 3% (2 of 64), respectively ($P < .0001$). The prevalences were even higher in cases of ISCMs in which the cord lesion was identified before a diagnosis of systemic metastatic disease: 70% (7 of 10) with a rim sign, 60% (6 of 10) with a flame sign, and 90% (9 of 10) with at least 1 of the signs. Knowledge of these findings should increase radiologists’ confidence in diagnosing ISCMs, thus enabling earlier diagnosis and treatment. Diagnostic biopsy/resection, which is still performed even in the MR imaging era for some ISCMs, may be obviated in some cases.

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