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Different Signal Intensities between Intra- and Extracranial Components in Jugular Foramen Meningioma: An Enigma

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BACKGROUND AND PURPOSE: The purpose of this study was to evaluate retrospectively differences in MR signal intensity and contrast enhancement between intra- and extracranial components of jugular foramen meningioma (JFM).

METHODS: MR studies of eight patients who underwent surgery for histologically confirmed JFM were reviewed retrospectively. Signal intensity differences between intra- and extracranial components of all eight JFMs on axial T1-, T2-, and postcontrast T1-weighted images were evaluated visually. In six of the eight JFMs, quantitative signal intensity evaluations were also performed by using relative signal intensity ratios of the intra- and extracranial components of JFM to CNS tissue at the same level. Paired *t* tests were used to evaluate differences in relative signal intensity ratios in each JFM between intra- and extracranial components.

RESULTS: Both visual and quantitative signal intensity evaluations revealed that signal intensities of the intracranial component of JFM were significantly higher than those of the extracranial component on T1-, T2-, and postcontrast T1-weighted images. Results of relative signal intensity ratios were 0.89 ± 0.04 versus 0.77 ± 0.02 on T1-weighted images ($P = .002$); 1.66 ± 0.28 versus 0.88 ± 0.14 on T2-weighted images ($P = .003$); and 2.16 ± 0.29 versus 1.77 ± 0.26 on postcontrast T1-weighted images ($P = .01$).

CONCLUSION: Intra- and extracranial components of JFM display different signal intensity and enhancement patterns. These differences may be related to histologic composition, and in particular, collagen content.

Jugular foramen meningioma (JFM) comprises one of the smallest subgroups of meningioma, with <60 cases reported in the literature (1–4). These tumors may extend both intra- and extracranially into the cervical and parapharyngeal space through the jugular foramen (4–9). In the series of 371 intracranial meningiomas reported by Nager et al (8), 20% of tumors eventually extended directly into the extracranial space. Although the most common sites are the orbit (8%) and external table of the calvaria (7%), cervical (parapharyngeal) extension is rare, account-

ing for only 1.4% of all intracranial meningiomas. The most frequent pathway to the parapharyngeal space is through the jugular foramen.

JFM presumably arises from arachnoid villi associated with the jugular bulb (9). Tekkok et al (2) reviewed 33 cases of JFM and summarized that these tumors were more frequent in women (2:1) and mean age was 32 years (range, 7–60 years). Among the 33 cases, the most common initial symptoms were mass in the neck ($n = 10$), hearing loss ($n = 9$), and hoarseness ($n = 6$).

Some articles have described CT and MR imaging appearances of JFM (1–5, 7, 9–11). Meningioma tends to take either a circumscribed globular form or an en plaque form that spreads along bony structures. The globular type is the most common lesion within the temporal bone, including the jugular foramen. On CT scans, JFM may display some erosion or cause sclerosis of adjacent bone. Nearly all JFMs enhance strongly with contrast material on both CT and MR images. On MR images, signal intensity is iso- to hypointense on T1-weighted images relative to brain tissue, with variably increased signal intensity on T2-

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weighted images, depending on histologic composition (4, 10, 11).

To the best of our knowledge, no articles have discussed MR imaging characteristics between intra- and extracranial components of JFM. The goal of our study was to evaluate retrospectively differences in MR signal intensity and contrast enhancement between intra- and extracranial components of JFM.

Methods

Subjects

Review of medical records at two referring institutions between January 1994 and December 2003 identified eight patients with surgically and histologically confirmed JFM extending both intra- and extracranially. All patients were women, with a mean age of 47 years (range, 37–67 years). Each patient had only one JFM. MR images were obtained in all patients. Images were obtained within the guidelines of the research committees of the referring institutions, and informed consent was obtained from patients' authorized representatives and patient anonymity was maintained. Although JFM was surgically and histologically confirmed in every patient, histopathological examinations of surgical specimens from both intra- and extracranial components were available in only two cases.

MR Imaging Technique

All patients underwent MR imaging by using 1.5T systems from the referring institutions, and imaging techniques varied, including the use of different types of MR systems. At a minimum, results of axial T1-, T2-, and postcontrast T1-weighted images were obtained.

Spin-echo pulse sequences were employed in every case, with the use of settings considered optimal for routine head and neck imaging on each system. Noncontrast and postcontrast T1-weighted conventional spin-echo images were obtained by using a TR of 400–600 ms and TE of 9–20 ms. T2-weighted fast spin-echo images were obtained with TR of 3500–6200 ms and TE of 88–120 ms. In each sequence, two signals were acquired, with an image acquisition matrix of 256×256 or 192×256 , FOV of 22 cm or 25 cm, and section thickness of 4–6 mm, depending on the imaging system used.

Signal Intensity Evaluation and Measurements

Signal intensity differences between intra- and extracranial components of all eight JFMs on axial T1-, T2-, and postcontrast T1-weighted images were assessed visually by two experienced neuroradiologists (M.K., Y.F.) who were blinded to clinical information for subjects. Each neuroradiologist made an initial assessments independently, and any disagreements over final conclusions were resolved by consensus. No significant disagreements in assessment were encountered.

In each JFM, signal intensity of the intracranial component of JFM on T1-, T2-, and postcontrast T1-weighted images was classified as "hyperintense" when higher than the signal intensity of the extracranial component, "isointense" when equal to that of the extracranial component, and "hypointense" when lower than that of the extracranial component.

In addition to visual assessments, quantitative signal intensity measurements were performed. Quantitative measurements were available for six of the eight JFMs. Images were electronically transferred to a PC workstation. ExaVision LITE (version 1.1.0.) software (ZIO Software, Tokyo, Japan) was used for image display and quantitative measurements.

Visual assessments and relative signal intensity ratios of jugular foramen meningioma (JFM) to central nervous system (CNS) tissue at the same level

Patient No.	Age (y)/Sex	Visual Assessment on T1WI	Visual Assessment on T2WI	Visual Assessment on CET1WI	Relative Signal Intensity Ratio* on T1WI		Relative Signal Intensity Ratio on T2WI		Relative Signal Intensity Ratio on Postcontrast T1WI	
					Intracranial	Extracranial	Intracranial	Extracranial	Intracranial	Extracranial
1	46/F	hyperintense**	hyperintense	hyperintense	0.92	0.75	1.24	0.78	2.24	1.49
2	51/F	hyperintense	hyperintense	hyperintense	0.89	0.78	1.68	1.01	1.97	1.86
3	47/F	hyperintense	isointense	hyperintense	0.94	0.76	1.45	1.05	2.54	2.04
4	41/F	hyperintense	hyperintense	hyperintense	0.88	0.75	1.69	0.91	2.26	2.04
5	67/F	isointense***	hyperintense	hyperintense	0.82	0.79	1.91	0.83	1.69	1.44
6	46/F	hyperintense	hyperintense	hyperintense	0.88	0.76	1.99	0.69	2.26	1.75
7	48/F	isointense	hyperintense	hyperintense	N/A****	N/A	N/A	N/A	N/A	N/A
8	37/F	hyperintense	hyperintense	hyperintense	N/A	N/A	N/A	N/A	N/A	N/A

* "Relative Signal Intensity Ratio" denotes relative signal intensity ratio of intra- and extracranial components of JFM to CNS tissue at the same level.

** "hyperintense" denotes that signal intensity of the intracranial component of JFM is higher than that of the extracranial component.

*** "isointense" denotes that the signal intensity of the intracranial component of JFM is equal to that of the extracranial component.

**** N/A denotes not applicable.

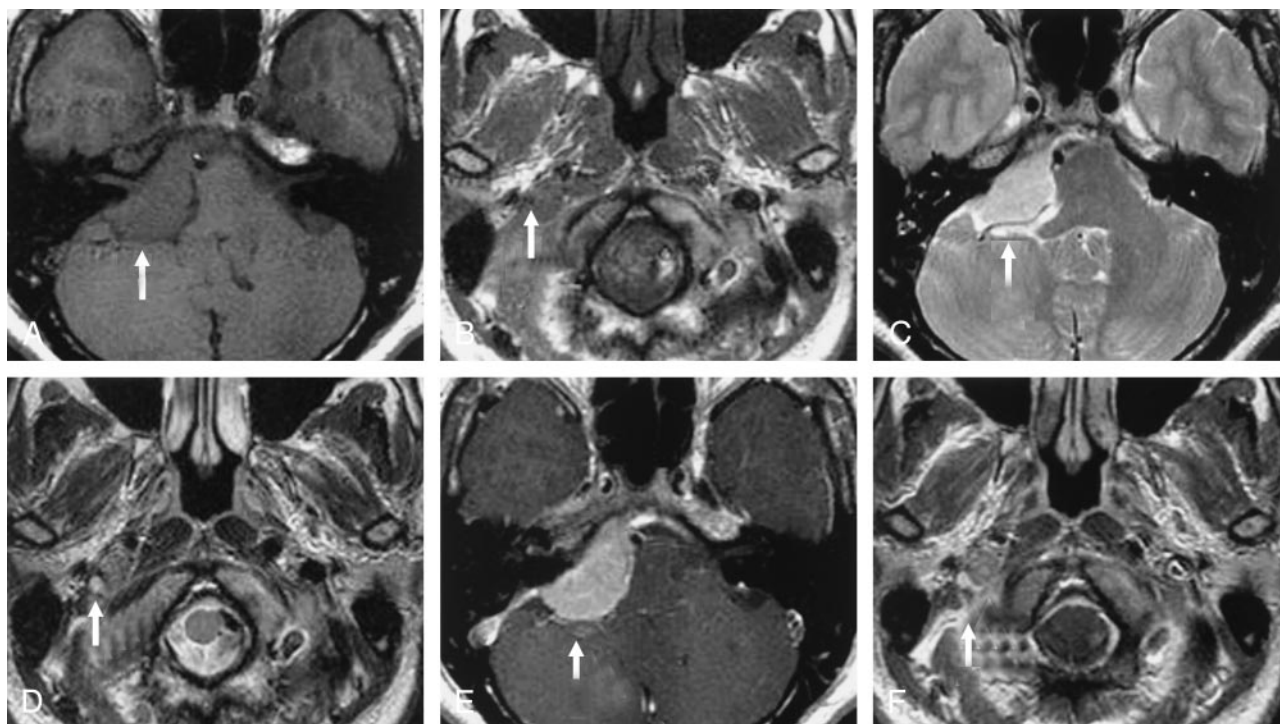


FIG 1. MR images of right JFM obtained in a 46-year-old woman (patient 6).

A, B, Transverse T1-weighted images (400/9).

C, D, Transverse T2-weighted images (4,100/90).

E, F, Transverse postcontrast T1-weighted images (400/20).

MR signal intensity of the intracranial component (arrow in A, C, and E) for JFM is higher than that of the extracranial component (arrow in B, D, and F) on T1-, T2- and postcontrast T1-weighted images.

To eliminate the influence of coil sensitivity differences, signal intensities of the intra- and extracranial components of JFM were evaluated by using relative signal intensity ratios of the intracranial component of JFM to CNS tissue at the same image section level (i.e., level of the pons) and of the extracranial component to CNS tissue at the same image section level (i.e., level of the medulla) on axial T1-, T2-, and postcontrast T1-weighted images (12), because signal intensities of brain stem tissues are not considered to differ significantly in each patient. Mean signal intensities on T1-, T2-, and postcontrast T1-weighted images for the intracranial component of JFM with CNS tissue at the same level and for the extracranial component with CNS tissue at the same level were measured by using the region of interest program. The size of these regions of interest was fixed at 30 mm², because this size was considered small enough to set within the target regions. Measurements were performed by an independent observer (A.Y.) who was blinded to clinical information of subjects.

Statistical Analysis

All data regarding relative signal intensity ratios of the intra- and extracranial components of JFM were presented as mean \pm SD. Paired *t* tests were used to evaluate differences in relative signal intensity ratios for each JFM between intra- and extracranial components. In each analysis, a value of *P* < .05 was considered statistically significant. All statistical tests were performed by using JMP statistical software version 5.0.1 (SAS Institute, Cary, NC).

Results

The Table shows all data from visual assessments and relative signal intensity ratios of JFMs.

On visual assessment of signal intensity differences between intra- and extracranial components of all eight JFMs, trends of “hyperintense” were noted.

On T1-weighted images, six of the eight JFMs (75%) were “hyperintense,” two (25%) were “isointense,” and none was “hypointense.” On T2-weighted images, seven lesions (87.5%) were “hyperintense,” one (12.5%) was “isointense,” and none was “hypointense.” On postcontrast T1-weighted images, all eight JFMs (100%) were “hyperintense,” with no “isointense” or “hypointense” results.

In six of the eight JFMs, relative signal intensity ratio of the intracranial component of JFM to CNS tissue at the same level was significantly higher than that of the extracranial component to CNS tissue at the same level: 0.89 ± 0.04 versus 0.77 ± 0.02 on T1-weighted images (*P* = .002); 1.66 ± 0.28 versus 0.88 ± 0.14 on T2-weighted images (*P* = .003); and 2.16 ± 0.29 versus 1.77 ± 0.26 on postcontrast T1-weighted images (*P* = .01). Examples of MR images are illustrated in Figures 1 and 2.

In two cases, histopathological examinations of the surgical specimens for both intra- and extracranial components of JFM were reviewed. In both cases, although the specimens of intra- and extracranial component represented the same meningotheelial-type meningioma, the intracranial component displayed abundant meningioma cells with sparse interstitial bundles of collagen, while the extracranial component showed sparse meningioma cells with

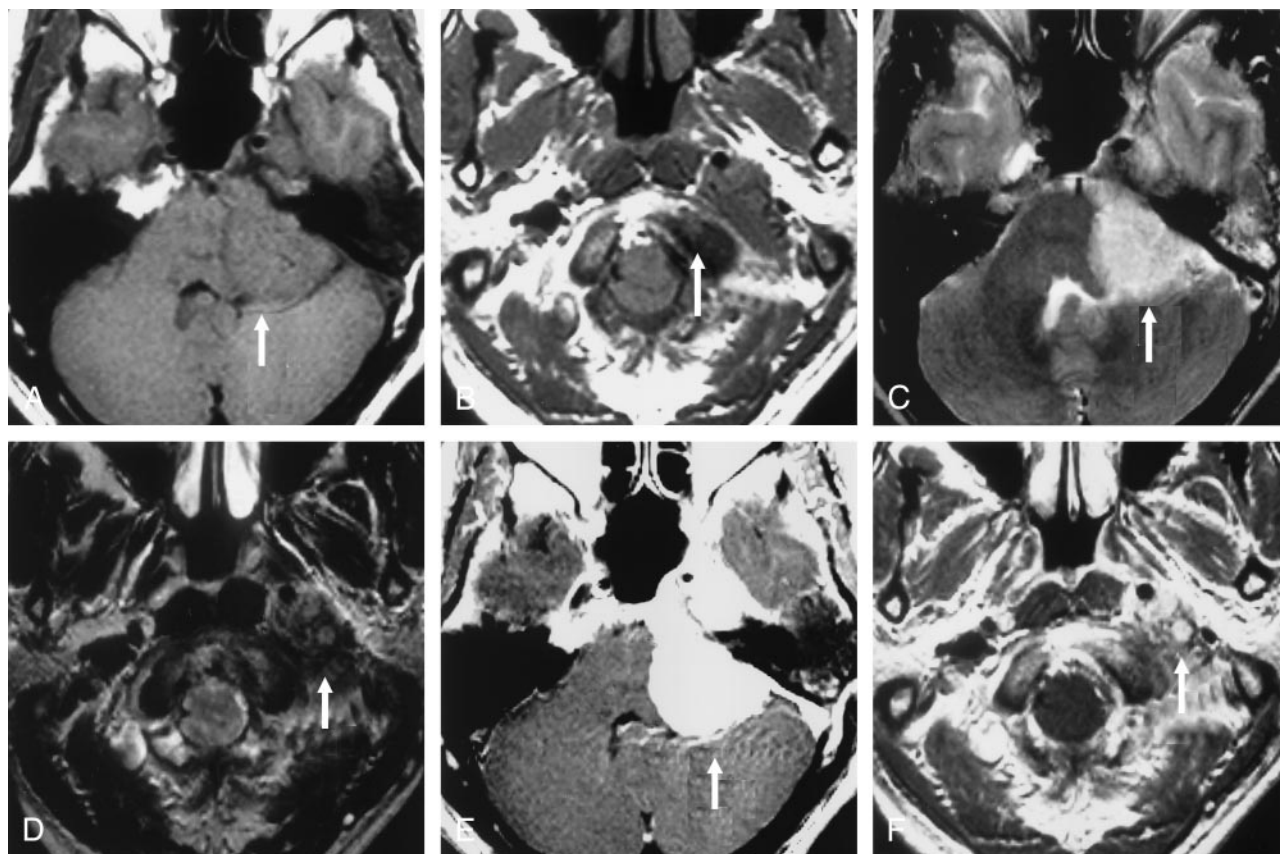


FIG 2. MR images of left JFM obtained in a 48-year-old woman (patient 7).

A, B, Transverse T1-weighted images (500/15).

C, D, Transverse T2-weighted images (4,000/100).

E, F, Transverse postcontrast T1-weighted images (500/15).

MR signal intensity of intracranial component (arrow in A, C, and E) for JFM is higher than that of the extracranial component (arrow in B, D, and F) on T1-, T2-, and postcontrast T1-weighted images.

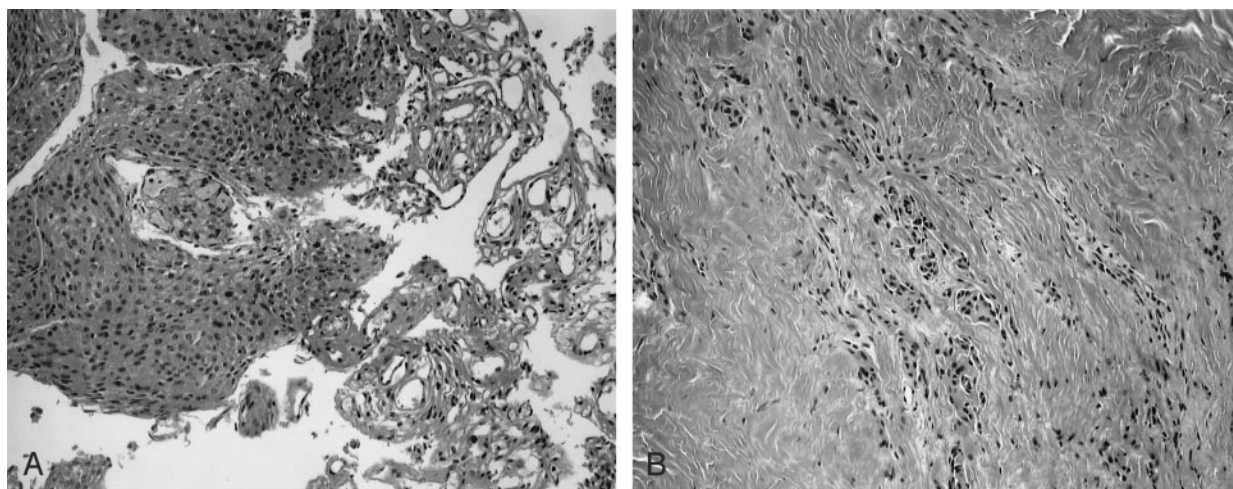


FIG 3. Microscopic specimens from left JFM obtained in a 48-year-old woman (patient 7, same patient as Figure 2; hematoxylin-eosin; original magnification $\times 20$).

A, Histologic examination of intracranial component of JFM shows densely packed tumor cells with sparse interstitial collagen bundles.

B, Histologic examination of extracranial component shows isolated tumor cells surrounded by matrix rich in collagen fibers.

abundant interstitial collagen bundles (Fig 3). Neurosurgeons (F.A. and others) had noted intraoperatively that the intracranial component was softer than the extracranial component in both cases.

Discussion

Lesions of the jugular foramen are rare in clinical practice. In light of the presence of osseous, muscular,

neural, vascular, dural, and connective tissue elements in this region, a wide spectrum of disease processes may arise. These conditions are broadly classified into intrinsic and extrinsic or neoplastic and nonneoplastic. The most common neoplastic jugular foramen lesions are paraganglioma, schwannoma, meningioma, and metastasis. The most common nonneoplastic jugular foramen lesions comprise asymmetric enlargement of the jugular bulb, high jugular bulb, and thrombosis of the internal jugular vein (4, 10, 11, 13).

Uncommon neoplastic and nonneoplastic jugular foramen lesions include neurofibroma, primitive neuroectodermal tumor, hemangioblastoma, choroid plexus papilloma, hemangiopericytoma, squamous cell carcinoma, chordoma, chondrosarcoma, plasmacytoma, lymphoma, Langerhans cell histiocytosis, cavernous hemangioma, rhabdomyosarcoma, fibrosarcoma, endolymphatic sac tumor, salivary gland tumor, malignant tumor of the temporal bone, jugular bulb diverticulum, ectopic carotid artery, aneurysm, arteriovenous malformation, sarcoidosis, abscess, osteomyelitis, cholesteatoma, epidermoid tumor, and cholesterol granuloma (1, 10, 11, 13–16).

CT and MR imaging appearances and differentiating features among the most common neoplastic jugular foramen lesions have been discussed elsewhere (4, 10, 11, 13), and some articles have discussed findings on MR imaging in JFMs (1–5, 7, 9–11). In these reports, signal intensity of JFMs yielded variable results on T1- and T2-weighted images depending on histologic composition, and signal intensity characteristics may be indistinguishable from other jugular foramen lesions.

To the best of our knowledge, no studies have described differences in MR signal intensity and contrast enhancement between intra- and extracranial components of JFM. The current study demonstrated that signal intensity and enhancement of the intracranial component of JFMs was significantly higher than signal intensity of the extracranial component on T1-, T2-, and postcontrast T1-weighted images. Although the available number of histopathological specimens for both intra- and extracranial components of JFM was small in the current study, the ratio between meningioma cells and interstitial bundles of collagen differ between intra- and extracranial components of JFM. Some investigations have examined relationships between MR imaging and histopathologic features in meningioma and have concluded that signal intensity on T2-weighted images of fibrous-type meningioma is significantly lower than those of other types, with differences attributed to varying collagen content (17–20). We therefore speculated that differences in signal intensity and enhancement between intra- and extracranial components in JFM are related to histologic composition, particularly with regard to collagen content and fibrosis. The impressions of neurosurgeons during surgery for the two cases with specimens suggested that the intracranial component of JFM was softer than the extracranial component, supporting this speculation. Of course, this

speculation has not been verified from our limited number of cases, and other speculations may be possible (e.g., higher intensity on T2-weighted images and higher degree of enhancement of the intracranial components may relate to more highly vascular intracranial components *per se*). It is, however, difficult to prove differences in vascularity between intra- and extracranial components by using our fragmented specimens.

Further investigation is needed to clarify the reasons and mechanisms behind differences in histologic composition between intra- and extracranial components of JFM, but similar tendencies have been reported in pituitary adenoma with invasion of the sphenoid sinus (21). Ishii et al (21) reviewed T1-, T2-, and postcontrast T1-weighted images in six patients with pituitary adenoma extending into the sphenoid sinus and correlated imaging and histologic findings. The portion of each adenoma involving the sphenoid sinus and sellar floor was less intense on T1-, T2-, and postcontrast T1-weighted images, when compared with sellar and suprasellar solid portions of adenoma. Histologic examination of adenoma specimens taken from sphenoid sinus demonstrated abundant collagen fibers between adenoma cells, whereas tumor tissue from suprasellar tissues showed no significant fibrosis. Ishii et al (21) also explained the mechanisms of differences in histologic composition in pituitary adenoma as follows: when pituitary adenoma invades the sphenoid sinus and comes into contact with fibroblasts in the sinus mucosa, fibrotic changes may occur secondary to migration of fibroblasts into the tumor. Similar mechanisms may be involved in JFM. When JFM at an intracranial space or intrajugular foramen invades temporal bone and mastoid air cells in an extracranial direction and comes into contact with fibroblasts in those structures, fibrotic changes may increase secondary to migration of fibroblasts into the extracranial component of the tumor.

Conclusion

Different signal intensities and contrast enhancements were noted between intra- and extracranial components of JFM. These differences may be related to histologic composition, and collagen content in particular. Although signal intensity characteristics of JFMs have been considered indistinguishable from other lesions of the jugular foramen (4, 10, 11), the present findings suggest that JFM can be readily diagnosed. In fact, associated bony changes are as important in conjunction with the signal intensity characteristics to make a diagnosis. And the present findings may predict tumor hardness before surgical intervention.

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