Agreement between magnetic resonance imaging, myelography, and surgery for detecting recurrent, thoracolumbar intervertebral disc extrusion in dogs

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Keywords
Magnetic resonance imaging, MRI, thoracolumbar intervertebral disc disease, dogs, myelography, recurrent

Summary
Objectives: Although magnetic resonance imaging (MRI) is reported to be superior to myelography to determine the location and site of first time disc herniation, comparison of these diagnostic methods in cases of recurrent intervertebral disc disease (IVD) herniation after a first surgery has not been evaluated. The objective was to compare the diagnostic accuracy of MRI and myelography in a series of dogs undergoing repeat surgical decompression for recurrent IVD extrusion when compared to the gold standard of surgery.

Methods: Ten dogs with recurrent IVD herniation underwent MRI and myelography followed by surgical decompression. Three observers reviewed the images to determine the site and side of the first surgery and the recurrent lesion. Agreement was determined by calculating a kappa (κ) score.

Results: Substantial interobserver agreement was noted for recurrent lesion site using MRI and myelography (κ = 0.77 vs. 0.73) and when comparing MRI and myelography to the reported surgical site (κ = 0.73 vs. 0.67). Interobserver agreement was greater with MRI for circumferential location compared to myelography (κ = 0.76 vs. 0.43), similar to what was found when comparing to surgical side (κ = 0.82 vs. 0.49). The previous surgical site in this study had no effect on ability to identify the new lesion.

Clinical significance: Despite the limitations of MRI, there was greater agreement between observers using MRI for both the recurrent and first lesion.

Introduction
Thoracolumbar intervertebral disc (IVD) extrusion is a common cause of neurological dysfunction in dogs. Surgical decompression of the spinal cord with removal of the compressive disc material from within the spinal canal is indicated for dogs with severe neurological deficits, and for dogs with milder clinical signs including spinal hyperesthesia alone (1, 2). Decompressive surgical techniques including hemilaminectomy, mini-hemilaminectomy and pediculectomy require accurate identification of the affected disc space and circumferential location to allow removal of the extruded material and limit surgical time and morbidity. Survey radiographs, myelography, computed tomography (CT), and magnetic resonance imaging (MRI) have been described to determine the site and circumferential location of disc extrusion (3–13). The individual advantages and disadvantages of these imaging modalities are well recognized with MRI being reported as superior to myelography and CT to determine the site and circumferential location of disc material in both human and veterinary medicine (10, 14, 15). A recent clinical study comparing MRI and myelography in small breed dogs with first time IVD extrusion concluded that multi-sequence MRI is more accurate than two-view myelography to determine the site and circumferential location of the lesion (10).

Recurrent IVD herniation is reported to occur in 2.7 to 41.7% of cases at a mean time of eight to 14 months after the first surgery (16–22). Most confirmed recurrences that occur four weeks or more after the initial lesion are at a different disc space from the first extrusion, but 87.5% of recurrences reportedly occur at a disc space adjacent to or one disc away from the initial lesion (17-19). Imaging of patients that have had previous spinal decompressive surgery can be complicated by the presence of haemorrhage, residual disc material, scar or granulation tissue at the site of the previous surgery as well as metal artefact related to the first surgery. Haemorrhage, the...
presence of gelatin sponge or a fat graft in the early postoperative period, or scar and granulation tissue later on, can also cause compressive lesions which may be difficult to differentiate from herniated disc material (21, 23–26). In fact, a recent study evaluating the amount of residual disc material immediately postoperatively using CT found that 100% of dogs had residual disc material at the site of decompression and some dogs had more than 100% the initial amount of compression which was attributed to the presence of haemorrhage at the surgical site (21). Surgery leads to inflammation and subsequent scar tissue formation, which may also influence the ability to detect recurrent lesions at the same site or at new disc space when using MRI, since contrast enhancement can be detected for months following surgery (27–29). Studies evaluating advanced imaging and myelography for recurrent lesions in humans have shown that contrast enhanced MRI and CT could differentiate between granulation tissue and new disc material, whereas myelography could not separate what portion of the compressive lesion was caused by disc or by granulation tissue (26, 30). In contrast, it has been previously suggested that myelography may be more accurate in determining the active lesion in the face of multilevel spinal disease in humans (31). Alternate MRI sequences, including MR myelography (heavily T2 weighted images) or the use of gadolinium contrast MRI, have been described to help differentiate recurrent lesions from previous chronic lesions or haemorrhage (29, 30, 32).

Another possible confounding factor is the presence of MRI artefacts following a previous surgery, which is well documented in the human literature and has been reported in the veterinary literature (33-37). The presence of artefact is thought to be associated with microscopic metal fragments from the use of burrs and other instruments at surgery, although in some cases it may be due to presence of paramagnetic suture material or previous haemorrhage (37). Metal artefact may preclude diagnostic MRI, necessitating the use of myelography or CT. Alternate image acquisition protocols have been reported to reduce or eliminate magnetic susceptibility artefacts (34).

To the author’s knowledge, there is no information in the literature that compares MRI and myelography as imaging modalities in cases of recurrent IVD extrusion in dogs, and the influence of the previous surgical site on localizing the new lesion. The objective of this study was therefore to compare the diagnostic accuracy of MRI and myelography in a series of dogs undergoing repeat imaging to guide surgical decompression for recurrent IVD extrusion when compared to the gold standard of surgery.

Materials and methods

Small breed dogs presented to the Ontario Veterinary College Health Sciences Center (OVC HSC) for suspected acute recurrent thoracolumbar IVD extrusion, were prospectively enrolled in this study. Enrolment criteria were that dogs had a complete medical record, that they had previously undergone decompressive surgery for thoracolumbar IVD extrusion at the OVC HSC, had improved clinically and were discharged to the owner prior to recurrence, that each patient was imaged sequentially using MRI and lumbar myelography within the same anaesthetic period or within 48-hours (but prior to surgical decompression), and that the studies were available for review. Owner consent for entry into the study was obtained prior to imaging. The research protocol was approved by the OVC HSC Animal Care Committee and followed the OVC HSC Council for Animal Care guidelines.

The medical files were reviewed and the following information was recorded: age, sex, breed, body weight, time between original surgery and recurrence, details of previous and most recent surgical procedure (site and side of surgery and surgical confirmation of extrusion by removal of extruded disc material), neurological status at recheck and at recurrence. Neurological grade was determined using an accepted grading system: Grade 1) back pain with no deficits; Grade 2) ambulatory paraparesis; Grade 3) non-ambulatory paraparesis; Grade 4) paraplegia with positive deep pain perception; and Grade 5) paraplegia with loss of both bladder control and deep pain perception. (20)

Dogs were anaesthetized using various anaesthetic induction protocols, intubated and maintained on isoflurane in 100% oxygen. A 1.5 Tesla MRI unit was used with an 8-channel phased array surface coil. The contrast agent, gadolinium diethylenetriaminepentaacetic acid (Gd-DTPA) (0.1 mmol/kg) was administered intravenously following the initial sequences in six dogs. Dogs were positioned in dorsal recumbency and T1-weighted fast spin echo (T1W-FSE) transverse (TR = 550-657 milliseconds [MS], TE = 10.5-13.3 ms, 3 mm slice thickness), T1W-FSE sagittal (TR = 450-650 ms, TE = 9.1-27.2 ms, 2 mm slice thickness), T2-weighted fast spin echo (T2W-FSE) transverse (TR = 3150-5500 ms, TE = 85-94.3 ms, 3 mm slice thickness), T2W-FSE sagittal (TR = 3000-4000 ms, TE = 86.3-93.4, 2 mm slice thickness), T2W-FSE coronal (TR = 3000-4750 ms, TE 86.6-93.6 ms), T1W-FSE with Gd-DTPA transverse (TR = 450-700 ms, TE = 10.5-13.3 ms) and T1W-FSE with Gd-DTPA sagittal (TR = 550-667 ms, TE = 9.1-15 ms) were obtained from the ninth thoracic vertebrae to the sacrum.

Orthogonal survey radiographs of the thoracic and lumbar vertebral column were obtained on film, after which a lumbar spinal puncture was performed at the L5-6 subarachnoid space. Iohexol (240 mg I/mL, 0.2-0.6 mL/kg) was injected under fluoroscopic guidance. Ventrodorsal and lateral radiographs of the thoracic and lumbar vertebral column were performed after sufficient contrast was injected.

All dogs underwent a mini-hemilaminectomy at the site determined based on the MRI and myelogram results by a radiologist and the surgeon on clinics at the time the dog was admitted (independent of the study). Subjective descriptions of the composition and circumferential location (i.e. right, left, ventral, or some combi-
nation of these) of the extradural material were obtained from the surgical records. Surgery was considered the gold standard for determination of the site and side of extradural IVD extrusion in this study.

At a later date, all MRI and myelograms were reviewed independently by the three authors (a second year surgery resident, a board certified surgeon with seven years of MRI experience, and a board certified radiologist with 12 years of MRI experience) who were unaware of the identity of the dog, the surgical findings from the current lesion, number of previous surgeries or previous site of lesion. All MRI images were assessed using the same computer station to determine the following: the site and side of first surgery, the site and circumferential location of the recurrent lesion, anatomical anomalies, presence of any other lesions and evidence of disc degeneration or mineralization.

All radiographs and myelographic images were reviewed on a back-lit radiographic viewer by the three independent reviewers. The lateral and ventrodorsal survey radiographs and myelographic projections were reviewed to determine the site and side of previous disc surgery, suspected site and side of the recurrent extradural compression. The subarachnoid space was assessed for evidence of attenuation, obstruction of contrast flow or deviation of the contrast column.

The consensus for all findings was based on the majority (2/3) or complete (3/3) agreement of reviewers. Agreement between observers was determined by calculating a kappa (κ) score for each modality to the documented recurrent and first surgical site and side using SAS software. Kappa values <0.2 were interpreted as slight agreement, 0.2 - <0.4 as fair agreement, 0.4 - <0.6 as moderate agreement, 0.6 - <0.8 as substantial agreement, and values ≥0.8 as near perfect agreement. All estimates of agreement are provided with 95% confidence intervals (CI). Accuracy of a given modality was defined as a percentage when 2/3 or 3/3 observers agreed with findings found surgically. Bias was assessed using a fortran program that was written, employing the formulas and methods discussed in Fleiss et al. (38).

### Results

Ten small breed dogs that had undergone a previous decompressive surgery at this institution met the inclusion criteria for the study. Dog breeds included Dachshunds (n = 5), Shih Tzu (n = 3), Bichon Frisé (n = 1), and a Bichon Frisé cross (n = 1). Eight dogs were male (1 entire) and two were female. Median weight was 8.4 kg (range 4.3-12.3 kg). Median age at the time of first surgery was 4.2 years (range 3.25 to 8 years) and the median age at the time of recurrence was 6.2 years (range 3.25 to 9.5 years). The median interval between initial surgery and recurrence was 404.5 days (range 25-1559 days). Nine of ten dogs recovered a fully ambulatory status with either no neurological deficits (grade 0) or mild proprioceptive deficits (grade 1) following the first surgery. The last dog (dog 10) initially improved to a minimally ambulatory status one week following the first surgery followed by a slow deterioration and was represented for suspected recurrence 25 days postoperatively. Neurological grade on presentation for recurrence ranged from Grade 2 to 4 out of 5.

Following surgery for the recurrent disc herniation, the median time to the follow-up evaluation was four weeks (range 0-58 weeks) with six of the 10 dogs having no residual deficits or minor proprioceptive deficits. Of the four dogs with grade 2 neurological status, two were lost to follow-up after discharge from the second surgery and two had their final evaluation at four weeks following the second surgery. Dog 8 was readmitted for a third episode of IVD herniation six months after the second surgery. It underwent surgical decompression at a disc space that was not previously affected or fenestrated and was ambulatory with mild proprioceptive deficits at the six-week postoperative follow-up evaluation.

Nine dogs had MRI followed by myelography (7 during the same anaesthetic period and 2 within 24-48 hours of each other) and one case had myelography followed by MRI (48 hour delay). Nine of ten dogs had surgery immediately following the last imaging modality; one dog had surgery 72 hours after MRI and myelography. None of the dogs had complications related to MRI or myelography.

For the recurrent site, consensus (all 3 observers agreed) was obtained on the site and side of the lesion using MRI in 70% and 70% of the cases respectively, and using myelography in 70% and 50% of the cases respectively. The majority (2 or more) of the observers agreed on the site and side of the lesion when compared with the reported surgical site using MRI in 90% and 90% of cases respectively, and using myelography in 90% and 70% of cases respectively. Table 1 shows the interobserver agreement (κ with 95% CI) when the majority of observers agreed on the site and side of the lesion for both MRI and myelography. The interobserver agreement among observers and agreement with surgical findings when evaluating the initial surgical site and side using MRI and myelogram are shown in Table 2.

### Table 1

<table>
<thead>
<tr>
<th></th>
<th>MRI site κ (95% CI)</th>
<th>MRI side κ (95% CI)</th>
<th>Myelogram site κ (95% CI)</th>
<th>Myelogram side κ (95% CI)</th>
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<tbody>
<tr>
<td>Interobserver agreement</td>
<td>0.77 (0.69 - 0.85)</td>
<td>0.76 (0.52 - 0.99)</td>
<td>0.73 (0.64 - 0.82)</td>
<td>0.43 (0.16 - 0.71) *</td>
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<td>Agreement with surgery</td>
<td>0.73 (0.66 - 0.79)</td>
<td>0.82 (0.65 - 0.98)</td>
<td>0.67 (0.60 - 0.74)</td>
<td>0.49 (0.27 - 0.71) *</td>
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* Bias may be present with observers often unable to record side using myelography.
When directly comparing MRI to myelography, for both recurrent and previous surgery, more than two observers found that the site determined as the lesion was in the same location in 76.6% of cases, and the side determined was to be the same in 66.6% of cases. In one case (dog 4), the site of the recurrent surgery documented in the medical record was one disc space away from the site recorded by the three observers using both MRI and myelography. The site recorded in the radiologist’s report was the same as the three observers. Since a large amount of disc material was reportedly removed at the time of surgery, the dog improved and no anatomical abnormalities were evident on the images, one assumes that the site reported in the surgical report was incorrect. In the case that had a recurrent lesion 25 days after the initial surgery (dog 10), none of the observers agreed on the site or side of the lesion, with multiple sites recorded by all observers.

Five of the 10 dogs had a recurrent lesion at a disc space immediately adjacent to the previous surgical site. Four of the dogs in this study underwent recurrent surgery at two sites, while one dog underwent recurrent surgery at three sites (dog 10). The multiple sites were correctly identified by all three observers in only two of the five dogs. Extruded disc material was removed from both surgical sites in two of the patients. In 1 case (dog 2), a mini-hemilaminectomy was performed bilaterally at L4-5 with no disc retrieved, but a Type II disc was identified at L3-4. In this case, all observers identified the lesion at L4-5 as the new lesion on both MRI and myelography, as well as a mild protrusion on MRI at L3-4. All patients had seven normal lumbar vertebrae. Two of the patients had a transitional 13th thoracic vertebrae (dog 2 and 6). Multiple calcified or degenerate discs were evident in all patients, which were often associated with the site of the recurrent lesion. No dogs in this study had evidence of magnetic susceptibility artefacts on MRI or radio-opaque fragments on myelography.

Table 2: The agreement, $\kappa$ (95% confidence interval [CI]) among observers for the initial surgical site when using magnetic resonance imaging (MRI) or myelography, and the agreement with the surgical findings when two or more observers agreed using MRI or myelography.

<table>
<thead>
<tr>
<th></th>
<th>MRI site $\kappa$ (95% CI)</th>
<th>MRI side $\kappa$ (95% CI)</th>
<th>Myelogram site $\kappa$ (95% CI)</th>
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<tr>
<td>Interobserver agreement</td>
<td>0.64 (0.35 - 0.94)</td>
<td>0.29 (0.10 - 0.67)</td>
<td>0.41 (0.15 - 0.66)</td>
<td>0.02 (0.00 - 0.32)*</td>
</tr>
<tr>
<td>Agreement with surgery</td>
<td>0.72 (0.49 - 0.95)</td>
<td>0.40 (0.08 - 0.72)</td>
<td>0.43 (0.21 - 0.65)</td>
<td>0.13 (0.00 - 0.39)*</td>
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* There was clear observer bias with observers unable to record side using myelography.

**Discussion**

Although direct statistical comparison between the two imaging techniques was not possible in this study, the data suggests that, similar to what was seen with first time IVD extrusions, MRI is more accurate than myelography to determine both the site and circumferential location of extruded disc material in small breed dogs that have recurrent thoracolumbar disc lesions (10). A difference was not found in this study between MRI and myelography when determining the site of lesion with two or more observers detecting the same site in 90% of the cases. However, the side or circumferential location of the extruded disc material was more frequently correct when using MRI (90%) compared to myelography (70%). The accuracy of MRI over myelography for determining the location of the lesion in spinal disease has been well described, with more lesions detected using MRI than myelography in the cervical and thoracolumbar spine (10, 39). Although radiographs have better spatial resolution, MRI has superior contrast resolution and is not limited by the superimposition of structures, allowing more accurate circumferential location of lesion (40).

The timing of recurrence in this study (median 404 days) was consistent with the previously reported median recurrence time of 14 months (17–20). The elapsed time between initial surgery and recurrence may have improved the ability to detect the new lesions in a majority of the dogs compared to early recurrences since the postoperative oedema and haemorrhage would have had time to resolve. Furthermore, any residual extruded disc material may become encapsulated allowing vessel ingrowth and slow disc resorption through macrophage activity (41).

In this study, only dogs that had undergone surgery at the same institution were eligible for enrolment to ensure the details of the first surgery were available. In the clinical setting, information regarding the previous location of disc extrusion and surgery is not always available from the patient’s records or the owners and could affect the decision-making process at the time of recurrence. The decision as to which modality used to evaluate recurrent IVD lesions is often based on availability, on the expectation of differentiating between residual compression or scar tissue at the at the site of first surgery, chronic protrusions, new extrusions, and the concern for possible metal or other artefacts (33–37). This is especially important since recurrences occur most commonly at a disc space that is adjacent to or one space away from the initial lesion, however this did not appear to be a problem in the five dogs of this study where the recurrent lesion was located immediately adjacent to the first surgical site.

Postoperative magnetic susceptibility artefacts at the site of previous surgical decompression have been noted in cases presenting at this institution for recurrent IVD herniation. In such cases, the presence of a signal void made MRI impossible to interpret at the level of previous surgery and sometimes beyond making myelography a more suitable diagnostic test in those cases. Such susceptibility artefacts have recently been reported in the veterinary literature and are suspected to be caused by the presence of microscopic paramagnetic metal fragments from the surgery, the presence of haemorrhage or possibly suture material.
(37). Magnetic susceptibility artefacts were not seen in the cases in this study. We cannot confirm why susceptibility artefacts were not seen in the cases presented here, but given such artefacts have been associated with accidental drilling of the suction tip or wound retractor we assume it is likely surgeon dependent and will vary depending on the technique used.

The agreement between observers as to the initial site was only fair for myelography and fair to slight for side for both modalities. Only MRI had moderate agreement when determining the site of initial lesion. The inability to detect the initial lesion did not seem to impact the ability of the observers to identify the recurrent lesions in any case except case 10 which was reimaged only 25 days following initial surgery. Repeat MRI in this case showed evidence of haemorrhage at the initial surgical site and evidence of extruded disc material at two adjacent sites. Myelography did not provide additional information that would help to differentiate the recurrent from the initial lesion in this case due to interruption of the contrast material over several disc spaces. The inability of myelography to differentiate between residual disc and scar tissue in recurrent lesions has been previously documented in the human literature (26).

In several cases, the lack of agreement between the myelogram and the surgical side was due to a suspected ventral location of the lesion on the myelogram. Previous studies have shown that 45-60% of cases required oblique views to determine the circumferential location of the extruded disc material within the spinal canal (11–13). In one study, the circumferential location of the disc extrusion was 100% accurate when oblique as well as orthogonal myelographic views were evaluated (11). Oblique views were not performed routinely in all cases in this study and were therefore not used to determine the circumferential location of the disc extrusion when reviewing the images.

As with previous clinical studies, surgical findings were used as the gold standard to determine the actual site and side of disc extrusion in this study (3, 4, 6, 9, 10, 42, 43). Surgery has been criticized as a gold standard, since disc material can sometimes be retrieved from the side opposite to the lesion or from the edges of a long laminectomy performed one site cranial or caudal to the actual herniation site (23, 44). In the study presented here, the lesion location was confirmed based on the surgery report documenting removal of disc material at a specific site and side. All patients in this study improved postoperatively.

Only one case presented for what could be deemed as an early recurrence in this study. In this case, recurrence occurred at 25 days and it is unclear whether or not this was an early recurrence caused by further disc extruding through the ruptured annulus or by residual disc material not removed at surgery, or if this was caused by a second extrusion at an adjacent disc in the early postoperative period. Fenestration of the affected disc space has been shown to reduce the rate of early recurrent extrusion and was performed in all cases (17, 45). The fact that a moderate amount of disc material was retrieved from the spinal canal at the time of first surgery and that the dog improved prior to subsequently deteriorating 18 days postoperatively also supports re-herniation rather than residual disc material. Rates of early postoperative recurrence of neurologic signs are reported between one and 5.8% (23, 24). The myelographic images from the first incidence in this patient revealed a single contrast obstructing lesion at T13-L1 on the right, which is consistent with the site and side of surgery. A mild protrusion was also present at L1-2 and L2-3, with calcification of discs at T11-12, T12-13, T13-L1. None of the investigators in this study agreed regarding the site of the recurrent lesion using MRI and myelography in this patient. The medical record reports that the second surgery extended from T11 to L1 on the left side and that a moderate amount of soft and mineralized disc material and haemorrhage was retrieved over the entire laminectomy. Advanced imaging modalities such as CT or MRI have been recommended in cases of early recurrence, to provide better localization of the compressive material in the canal (24). The difficulty encountered in determining the site and side of the lesion at the time of recurrence may have been due to postoperative swelling and inflammation related to the first lesion/surgery or perhaps to the extent of the lesion which was over three disc spaces. Regardless, neither imaging modality used in this study appeared to be more informative in this particular case.

Limitations of this study include the small number of cases, multiple observers with various experience, the fact that surgery was used as the gold standard for confirming the site and circumferential localization of the disc, and that follow-up imaging was not performed after surgery to determine that the documented surgical site was accurate and that complete removal of disc had occurred. Although multiple observers with varying degrees of experience reading MRI and myelograms were used in this study, this is representative of the clinical situation in a large number of clinical cases. The site of surgery was not determined by consensus of the observers in the study (review of the images occurred later) but rather by the radiologist and surgeon on duty at the time the case was presented. Using surgery as the gold standard does have its limitations since although disc material was reportedly retrieved at surgery and the dogs improved postoperatively, exploration of the other disc space and the opposite side of the spine was not performed to document that there was no extrusion of other disc material.

An additional limitation of this study is the limited MRI sequences performed at the time of the study (T1W, T2W, and with gadolinium enhanced MRI in only 6 dogs). It has been previously shown that gadolinium enhanced MRI sequences are superior in reimagining patients with recurrent lesions or scar tissue formation (29, 30). In a previous study evaluating gadolinium enhanced MRI sequences for identifying disc protrusions in dogs, it was found to provide 93.3% accuracy in lesion localization in the small number of cases (15 cases) compared to between 66.7 and 70.8% (24 cases) when using T1W or T2W imaging respectively (10). It has also been suggested that other sequences that can be used to differentiate new lesions from previous scar tissue or chronic lesions are heavily T2 weighted MR images that produce a MRI myelographic image which may be beneficial in documenting compressive lesions.
Further studies evaluating the use of contrast enhancement and MR myelography in recurrent disc herniation should be performed to determine if they increase the ability to accurately identify recurrent lesions.

Despite the potential limitations of MRI, there was greater agreement between observers using MRI for both the new and previous lesions in this study. Artefacts from the previous surgery did not influence the identification of lesions in this study. Although further studies involving larger numbers of cases would be ideal, based on the results of this study, it can be concluded that MRI is more frequently accurate in determining the site and side of recurrent IVD lesions in small breed dogs.

Acknowledgements

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Conflict of interest

None declared.

References

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