



ORIGINAL ARTICLE

Effects of age on accuracy of advanced imaging modalities in identifying intervertebral disc extrusions in Dachshunds

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Objective The aim of this study was to ascertain whether patient age was a significant factor for the accurate identification of compressive intervertebral disc extrusions (IVDE) in Dachshunds using non-contrast computed tomography (CT).

Methods This retrospective analysis encompassed 150 Dachshunds evaluated for suspected IVDE at a referral hospital in south-eastern Queensland, Australia. Each case underwent diagnostic evaluation by CT, either with or without myelography, or magnetic resonance imaging (MRI), followed by surgical intervention for an intervertebral disc extrusion.

Results In the <9-year dog cohort, 94.7% (71/75) were diagnosed with IVDE via non-contrast CT and proceeded to surgery. In contrast, the ≥9-year dog cohort, only 56% (42/75) were diagnosed via non-contrast CT, with the remaining 44% (33/75) necessitating CT myelography or MRI for diagnosis. The odds of requiring CT myelography or MRI increased 13.95-fold (95% CI, 4.62–42.13) in Dachshunds aged 9 years or older. Furthermore, each additional year of age was associated with a 0.60 increase in the odds of undergoing these advanced imaging modalities (CT myelography or MRI) (95% CI, 0.49–0.74).

Conclusions Age significantly affected the efficacy of non-contrast CT in diagnosing IVDE in Dachshunds. Dogs aged 9 years and above were substantially more likely to require CT myelography or MRI due to the reduced visibility of disc extrusions on non-contrast CT. Veterinarians performing advanced imaging on older Dachshunds for suspected IVDE should be aware of the limitations of non-contrast CT in obtaining an accurate diagnosis and localisation of IVDE, and be prepared to perform either CT myelography or MRI if required.

Keywords CT; CT myelography; intervertebral disc disease; intervertebral disc extrusion; MRI

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Intervertebral disc extrusion (IVDE) is a well-documented disease in dogs.^{1–3} IVDE, particularly in a thoracolumbar location, has been recognised in dogs since the 1880s, and is recognised as a common cause of acute paraparesis and paraplegia in dogs; often attributed to the popularity of chondrodystrophic dog breeds.¹ In a 1977 study the Dachshund breed comprised approximately

45%–65% of all canine patients presenting with intervertebral disc disease. More recently it has been estimated that Dachshunds have a relative risk for IVDE 9.9–12.6 times higher than for all other canine breeds.^{2–4} A 2019 study found that 100% of extruded intervertebral discs in Dachshunds contained degenerate and mineralised intervertebral disc material.⁵

There are numerous studies that compare different imaging modalities for the diagnosis of IVDE across multiple breeds.^{1,3–8} Many studies compare myelography, non-contrast computed tomography (CT), CT myelography and/or magnetic resonance imaging (MRI) for the diagnosis of IVDE in various breeds.^{3–10} A 2010 study comparing the outcomes in dogs with respect to the choice of imaging modality utilised found that there was no significant difference in patient outcome when comparing myelography to MRI, except for the cost of hospitalisation.⁹ Note that this 2010 study included non-ambulatory dogs at the time of diagnosis. In 2018 a study of 555 dogs found that in Dachshunds, non-contrast CT successfully diagnosed IVDE in 96.4% of cases.¹¹

This investigation examined the influence of age, sex, neurolocalisation and specific disc extrusion sites on the diagnostic imaging requirements for IVDE in Dachshunds, comparing these variables against findings from the 2018 study. It is the experience of the referral hospital in which the study was conducted, that as Dachshunds age, non-contrast CT is less likely to positively identify a compressive IVDE, particularly in cohorts over 9 years of age. It was postulated that Dachshunds aged 9 years or older would exhibit a significantly higher propensity for requiring either CT myelography or MRI for the accurate identification of IVDE necessitating decompressive surgery, attributed to the reduced detectability of these conditions on non-contrast CT.

Materials and methods

The practice database (Rx Works; Henry Schein Veterinary Solutions) was retrospectively searched for the terms ‘Dachshund’, ‘Miniature Dachshund’ or ‘Dachshund Miniature’ and those charged for a ‘burr’, a surgical item used in all spinal surgeries, and 62,656 results were retrieved. The search was then further refined, and patients were excluded if they did not have spinal surgery for a compressive intervertebral disc extrusion, if the imaging modality/s and disc extrusion were not clearly described in the medical record, if they were a Dachshund cross-breed or if they did not have surgery in the last 5 years. A total of 150 results were retrieved.

The dataset was processed according to a sequence randomly generated by the practice’s database management system and subsequently divided into two cohorts based on the age at the time of diagnosis

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and surgical intervention: Dachshunds aged under 9 years and those aged 9 years or older. Each group was limited to a maximum of 75 dogs to maintain uniformity in sample size. In instances where a patient's data recurred within the generated list, only the initial occurrence was considered for analysis, with all subsequent entries being excluded to prevent data duplication. Key variables, including age, sex and the precise site of disc extrusion, were documented for each case. While a neurolocalisation was determined after clinical exam at the time of presentation, this was not always available for retrospective review. For the purpose of statistical analysis, neurolocalisation was determined based on the definitive site of disc extrusion, categorised into four anatomical regions: C1-C5 (cervical), C6-Th2 (cervicothoracic), Th3-L3 (thoracolumbar) and L4-S3 (lumbosacral).

Standard practice at the hospital where the study was undertaken was that any Dachshund presenting with a suspicion of IVDE would have a full body non-contrast CT (Go.Up 64 slice; Siemens, Erlangen, Germany). The dog was then positioned in dorsal recumbency and scanned from the C1 vertebral body through to the sacrum, regardless of neurolocalisation at the time of the physical exam. The images were assessed in-house by a Fellow of the Australian and New Zealand College of Veterinary Scientists in Small Animal Surgery, a Diplomate of the European College of Veterinary Surgeons, a surgical registrar and/or a Fellow of the Australian and New Zealand College of Veterinary Scientists in Veterinary Radiology. A study was deemed positive if the primary interpreter determined that it was possible to identify an appropriate site for decompressive surgery. If the IVDE could not be positively identified, a CT myelogram or MRI (1.5 T Magnetom Sempra; Siemens, Erlangen, Germany) was performed.

Myelography was performed with radiographic guidance of a spinal needle into the subarachnoid space at L5-L6 or L4-L5. A unit of 0.3 mL/kg of iohexol (Omnipaque, GE Health Care, Australia) was slowly injected into the subarachnoid space, with serial radiographs (FDR D-EVO; Fujifilm Corporation, Tokyo, Japan) used to confirm flow, positioning and appropriate opacification. Once there was appropriate opacification of the subarachnoid space, the patient was moved back to CT, and a CT myelogram was performed, with the patient again positioned in dorsal recumbency and scanned from the C1 vertebral body through to the sacrum. Magnetic resonance imaging was performed using a 6-channel spinal coil. The patient was scanned in dorsal recumbency, and either the cervicothoracic or thoracolumbar region was imaged based on the neurolocalisation at the time of the physical exam.

The CT myelography and MR images were again reviewed in-house by the same assessors, and a decision was made by the primary interpreter on the site of extrusion, with the dog immediately transferred to the surgical suite for surgical decompression.

The choice between CT myelogram and MR imaging was made depending on the availability of the MRI. Dogs presenting out-of-hours did not have MR imaging performed, and a CT myelogram was utilised instead. Additionally, if the MR unit was in use and the affected patient was already anaesthetised, a CT myelogram was performed to minimise anaesthetic time. In all other instances an MRI was performed. All patients had surgery for the compressive IVDE,

Table 1. Imaging modalities by age and descriptive statistics of age

Age	CT		CT myelogram		MRI
<9 years	71/75 (94.7%)		2/75 (2.6%)		2/75 (2.6%)
≥9 years	42/75 (56%)		25/75 (33.3%)		9/75 (12%)

Age	Range				
	Mean	SD	Median	Minimum	Maximum
	7.9	2.8	8.5	2	15
					N
					150

CT, computed tomography; MRI, magnetic resonance imaging; N, number of dogs; SD, standard deviation.

and surgery was used for confirmation of the extrusion site. Imaging and surgical reports were recorded either immediately or at a later date, particularly if the imaging study was performed on an emergency basis.

A power-sample size estimation was performed based on the expectation that 96.4% of Dachshunds would be able to have their IVDE diagnosed on non-contrast CT. We estimated that 62 dogs would be required in the two age groups to achieve a power of 0.8 with an alpha error probability of 0.05. Due to a large number of available dogs, 75 dogs were used in the two age groups, increasing the power of the study to 0.96 with the same alpha error probability.

Statistical analyses were performed using SAS® OnDemand for Academics (SAS Institute Inc., Cary, NC, USA). Descriptive statistics of age were described by mean (\pm SD) and median (min-max), and sex by frequency and per cent (Table 1). The odds (95% confidence interval) of having CT myelogram and/or MRI as a function of age were estimated twice by binary logistic regression model with backward elimination, once with age as binary predictor (age < 9 vs. age \geq 9) and the second time with age as a continuous predictor. Sex, neurolocalisation and the specific disc extrusion site were predictors in the initial model but were removed from the final model as they did not have a significant effect. Model significance was determined by the Likelihood Ratio Chi Squared statistic. Model fit was evaluated by the Area Under the Curve (AUC) of the Receiver Operating Characteristic Curve (ROC) and the Hosmer and Lemeshow Goodness-of-Fit Test. For all calculations, the alpha error probability was <0.05.

Results

Of the 150 Dachshunds found on searching the practice database, there were three intact females, 42 spayed females, 21 intact males and 84 castrated males. Neurolocalisation identified 19 dogs with lesions at C1-C5, one at C6-Th2, 114 at Th3-L3 and 16 at L4-S3, with the Th12-Th13 intervertebral disc being the most frequently affected site for IVDE (35 dogs). Sex ($P = 0.767$), neurolocalisation ($P = 0.447$) and specific disc extrusion site ($P = 0.877$) did not significantly contribute to the predictive model of whether a Dachshund with a suspected disc extrusion would need advanced imaging beyond a non-contrast CT scan. Conversely, age (years) emerged as

a significant predictor, both when categorised dichotomously (i.e., < 9 or ≥ 9 ; $P < 0.001$) and as a continuous variable ($P < 0.001$).

In the cohort of Dachshunds younger than 9 years, 94.7% (71/75) were diagnosed with IVDE on non-contrast CT and proceeded to surgical treatment. In comparison, for dogs aged 9 years of age or older, only 56% (42/75) were diagnosed with IVDE on non-contrast CT, with the remaining 44% (33/75) requiring either a CT myelogram or MRI for accurate diagnosis prior to surgery. Notably, one patient in the older age group necessitated both diagnostic modalities. This was due to the disc material being in an intra-foraminal location, and not being well defined on myelography.

Statistical analysis revealed that Dachshunds aged 9 years or older had 13.95-fold increased odds of requiring a CT myelogram or MRI for IVDE diagnosis (95% CI 4.62–42.13). Additionally, for each incremental year in age, the odds of necessitating these advanced imaging techniques increased by 0.60 (95% CI 0.49–0.74).

Discussion

Intervertebral disc extrusion is a serious condition requiring prompt diagnosis and treatment. Dachshunds are a chondrodystrophic breed with a high incidence of IVDE.^{2–4,11,12} While thoracolumbar extrusions are the most frequent affected site, extrusions within the cervical and lower lumbar spinal regions also commonly occur.^{1,4,6,11–14} Studies are lacking in the specifics of diagnosis of IVDE within the Dachshund breed specifically, especially considering the known high incidence. It is the clinical experience of the authors that as Dachshunds age, there is a significant decrease in the likelihood that a non-contrast CT will be diagnostic and allow the clinician to diagnose an intervertebral disc extrusion and proceed with confidence to a decompressive spinal surgery. Sex, neurolocalisation and specific disc extrusion sites were not significant factors in the model. It is important to note that although the thoracolumbar region is the most common site,^{1,4,6,11–14} neurolocalisation does not alter the recommendations made regarding the choice of advanced imaging modality.

Numerous studies have been conducted comparing myelography, non-contrast CT, CT angiography, CT myelography and/or MRI in dogs. Plain film myelography was not examined in this study as it has largely been superseded by other imaging modalities. CT angiography has not been shown to add any additional information when compared to non-contrast CT¹¹ and was not examined in this study. CT with or without myelography and MRI are currently used most widely and have become the focus of most contemporary studies when looking at IVDE in both dogs and cats.¹⁵ While non-contrast CT, CT myelography and MRI are all viable options for the diagnosis of IVDE, there are advantages and disadvantages for all three options.

Non-contrast CT is a quick and non-invasive way to achieve a diagnosis in Dachshunds presenting with suspected IVDE. Moreover, in our hospital, it is approximately two thirds the price of MRI. In our study, the IVDE site was identified by non-contrast CT in 94.7% of Dachshunds < 9 years of age, resulting in the dog having decompressive surgery: This is in line with previous studies.^{1,11} On CT an acute IVDE predominantly has the following characteristics: hyperattenuating material within the vertebral canal, loss of epidural

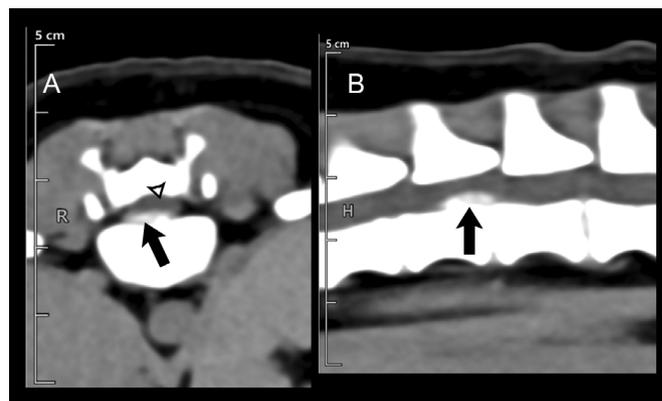


Figure 1. A non-contrast CT from a 4-year-old, entire male Dachshund presenting with a Th3-L3 myelopathy; viewed in a soft tissue algorithm. (A) A transverse image at the level of the Th12-Th13 intervertebral disc space. There is mineral and soft tissue attenuating disc material within the right ventral vertebral canal (arrow), resulting in severe ($>50\%$) compression of the spinal cord (arrowhead). (B) A sagittal image of the same patient depicting the same intervertebral disc extrusion (arrow) as seen in (A).

fat and distortion of the spinal cord (Figure 1). The reason the material is hyperattenuating on CT is because it is commonly mineralised. Extruded disc material may also be admixed with acute haemorrhage (which is also hyperattenuating).^{6,16–18}

While myelography has the potential for an adverse event, the recent literature notes this to be an uncommon finding.¹⁵ The clinical records of the Dachshunds that received CT myelography within our study were examined, and there were no recorded adverse events, consistent with that reported previously.¹⁵ Two 2009 studies showed that both non-contrast CT and CT myelography had similar specificities and sensitivities.^{7,19} In our study, CT myelography allowed identification and characterisation of IVDE in cases that were not definitive on non-contrast CT (Figure 2). However, notwithstanding that in experienced hands a myelogram is typically a relatively quick and low-risk procedure, it does increase anaesthesia time and procedure cost.

MRI is considered the standard of care for diagnostic imaging in intervertebral disc disease in humans and veterinary patients alike.^{1,8,10,13,20–24} MRI has a longer acquisition time when compared to CT and is less readily available within the veterinary community. The resolution of bone on MRI is also less than that on CT. However, disc extrusions that are not mineralised and do not contain haemorrhage, and hence may not be visible with non-contrast CT, will be visible on MRI due to the superior soft tissue resolution. It should be noted that imaging with low field MR units is less sensitive than that with high field MR units. As such, the likelihood of a negative finding with MRI is much lower.^{1,21–24} Imaging of IVDE with MRI will show extradural compression of the spinal cord that is centred over, or closely associated with an intervertebral disc (Figure 3). The disc material may be T2W hypo-intense, hyper-intense or heterogeneous when compared to the spinal cord. It is often T1W iso-intense to the spinal cord. The material can also be further classified as dispersed or non-dispersed, based on the spread of disc material and haemorrhage throughout the epidural space.^{15,22–24} MRI also has the additional benefit of prognostication;

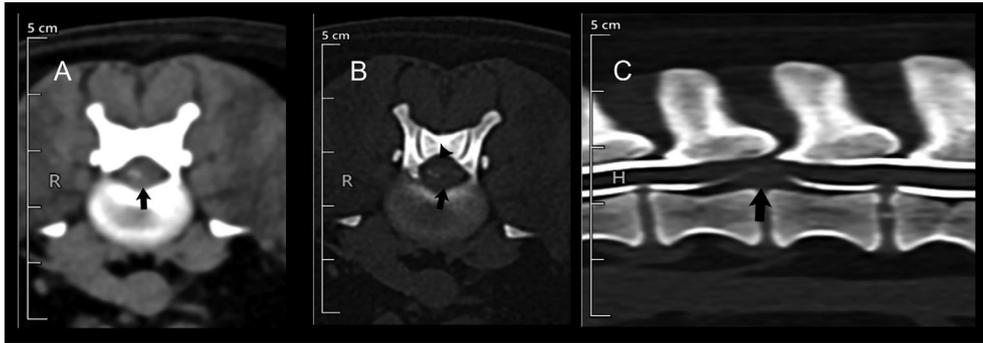


Figure 2. A non-contrast CT and CT myelogram from a 7-year-old, male entire Dachshund presenting with a Th3-L3 myelopathy. (A) A transverse image of a non-contrast CT viewed in a soft tissue algorithm at the level of the L1-L2 intervertebral disc space. The intervertebral disc extrusion is faintly visible (arrow) as mildly hyperattenuating soft tissue material within the vertebral canal; however, further imaging was required to confirm localisation, the extent of compression, and lateralisation. Note that initially, the extruded disc material appears to be slightly lateralised to the right. (B) A transverse image of the same patient, post-myelographic enhancement of the subarachnoid space. Depicted is an L1-L2 mildly left lateralised intervertebral disc extrusion (arrow) with severe (>50%) spinal cord compression (arrowhead). (C) A left para-sagittal image from Th13-L3 of the same patient. There is post-myelographic enhancement of the subarachnoid space. The same intervertebral disc extrusion is depicted (arrow).

T2W hyperintensity within the spinal cord parenchyma has been variably associated with worse locomotor outcome and the development of progressive myelomalacia.^{1,8,10-14,20,21,24} As previously stated, CT has poorer soft tissue resolution, and as such MR imaging can also identify and aid in diagnosing other causes of myelopathies such as neoplasia, inflammatory diseases, spinal empyema and infectious diseases.^{10-14,20,21,24}

Further studies would be required to determine what changes occur within the intervertebral disc that alters how conspicuous the extrusion appears on non-contrast CT. A 1996 study of Dachshunds at 1 and 5 years of age found that in 12 individual dogs, 29 intervertebral discs that were identified as radiographically mineralised at the first examination were not mineralised at the second examination.¹⁷ The 1996 study did not examine the cause for this change. One hypothesis explaining this involves de-mineralisation of previously mineralised intervertebral discs, altering the attenuation of the extruded disc material. This hypothesis is supported by a 2009 study,¹⁹ in which histopathology was performed on extruded disc material from Dachshunds. The study found that disc extrusions not

seen on non-contrast CT were not as calcified as those that were readily seen.¹⁹ Further studies would be required to prove this hypothesis, as well as investigate what determines the degree of mineralisation.

This study has shown that for every one-year increase in Dachshund age, there was 0.602 increased odds of needing other imaging modalities beyond a non-contrast CT. The cut-off of 9 years was chosen for this study based on the authors' experience and was shown to be a significant factor. Dachshunds equal to or over this age have 4.62-42.13 times more odds of needing other imaging modalities beyond a non-contrast CT when compared to those ≤9 years of age.

This study has several limitations. The first, and perhaps most important, is the retrospective nature of the study. Many cases were evaluated by different attending clinicians, meaning standardisation was not possible. It is possible that clinician experience also played a factor in whether or not the non-contrast CT imaging findings were deemed definitive enough to proceed to surgical intervention. IVDE in Dachshunds is a common presentation at our hospital, with

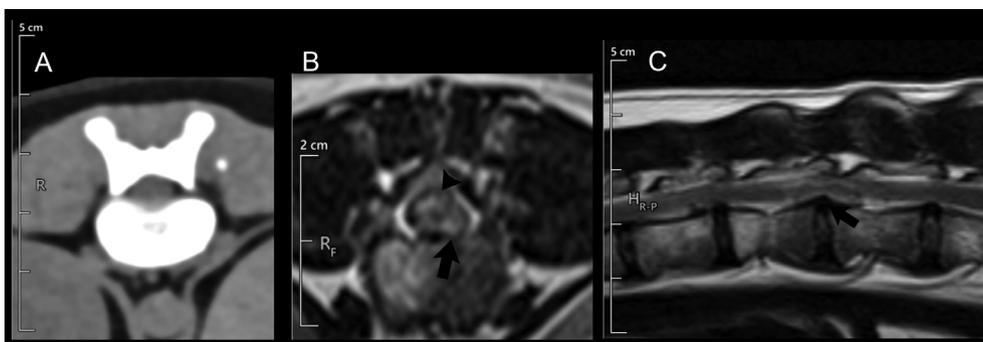


Figure 3. A non-contrast CT and MRI from a 10-year-old male neutered Dachshund presenting with a Th3-L3 myelopathy. (A) A transverse image of a non-contrast CT viewed in a soft tissue algorithm at the level of the Th13-L1 intervertebral disc space. No extruded intervertebral disc material is visible. (B) A transverse T2W MR image of the same patient depicting a Th13-L1 left-sided intervertebral disc extrusion (arrow) with moderate (>25% but <50%) spinal cord compression (arrowhead). The disc material is heterogeneously T2W hyperintense. (C) A T2W sagittal MR image of the same patient depicting the same intervertebral disc extrusion (arrow).

approximately 150 surgical cases seen per year. Less experienced clinicians may have been less likely to elect for surgical intervention based on the non-contrast CT images, and instead opted for CT myelography or MRI. Dogs without clinical signs of spinal cord disease were not included in the study and did not have imaging performed. Additionally, dogs that were taken to surgery for an intervertebral disc extrusion identified on non-contrast CT did not proceed to CT myelogram or MR imaging and there is the possibility other intervertebral disc extrusions were not identified. Therefore, it is not possible to estimate the sensitivity and specificity of the imaging modalities utilised in the study. However, it should be noted that the incidence of negative surgical exploration was zero. Monitoring of patient outcomes, examining onset of clinical signs to time of presentation and imaging and whether myelopathy grade makes a difference in imaging choice were all beyond the scope of this study, and further studies would be needed to determine if these factors are significant.

This positive finding of extruded disc material may be affected by bias, as the surgeon was not blinded to the results of the imaging prior to surgery. As with other studies,^{7,8,13,22,24–26,28} surgical findings were considered definitive in characterising the site and side of disc extrusion in this study; however, the authors acknowledge that this approach has been criticised.²⁷ This is because the surgical site is small, visualisation may be limited by intraoperative haemorrhage and the extrusion may extend cranially or caudally beyond the bony window created (which may result in incomplete and/or inadequate decompression). The extruded material may also extend toward the contralateral side. Despite these criticisms, we and others use surgery as the standard for confirmation of IVDE,^{7,13,25} as the alternatives are impractical in the clinical setting. Bias may also arise within this study as patients with multiple intervertebral disc extrusions were only taken into account for their first presentation, and older presentations were excluded. In doing so, patients whose disc extrusions may differ in appearance from their first presentation may be missed. Whether the appearance of subsequent intervertebral disc extrusions differs on non-contrast CT should be examined in future studies.

A further limitation is that due to an information technology incident in 2022, not all images within the study are available for retrospective review and analysis. As clear imaging and surgical records in the patient history were available, this was not deemed necessary; however, it prevents any blind, retrospective analysis of the data for this and any future studies.

Conclusion

Dachshunds ≥ 9 years of age, presenting with suspected IVDE have significant odds of requiring a CT myelogram or MRI for diagnosis. For every one-year increase in Dachshund age, there is 0.602 increased odds of needing imaging modalities such as CT myelogram or MRI for a definitive diagnosis of IVDE and treating clinicians should attempt to plan accordingly.

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Conflicts of interest and sources of funding

The authors declare no conflicts of interest or sources of funding for the work presented here.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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