



# Otitis media and interna with or without polyps in cats: association between meningeal enhancement on postcontrast MRI, cerebrospinal fluid abnormalities, and clinician treatment choice and outcome

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## Abstract

**Objectives** The aim of this study was to evaluate the association between meningeal enhancement (MgE) and cerebrospinal fluid (CSF) analysis results, their individual association with bacteriology results from affected ear samples and whether these test results influenced clinicians' therapeutic choice in cats with otitis media and interna (OMI).

**Methods** This was a multicentre retrospective study carried out over an 8-year period. Cats diagnosed with OMI, with or without a nasopharyngeal polyp, leading to peripheral vestibular signs were included. Only cats for which MRI with postcontrast T1-weighted sequences and CSF analyses available were included. Cats with intra-axial MRI lesions or empyema were excluded.

**Results** Fifty-eight cats met the inclusion criteria. MgE was reported in 26/58 cases, of which nine had an abnormal CSF result (increased total nucleated cell count [TNCC] or total protein); 32/58 cases had no MgE, of which 10 showed abnormal CSF results. There was no association between bacteriology results (external ear canal or bulla) and MgE or abnormal CSF results. CSF abnormalities were statistically significantly more common in acute cases ( $n = 16/37$ ) than in chronic cases ( $n = 3/21$ ; Fischer's test  $P = 0.04$ ). Prednisolone was prescribed in 10/16 cases with increased TNCC. Among the 42 cases with normal TNCC, 15 received prednisolone and 13 received non-steroidal anti-inflammatory drugs. Various antimicrobial drugs were prescribed in 53/58 cats. Duration of antimicrobial treatment was similar, regardless of positive bacterial culture (5.58 vs 4.22 weeks), abnormal CSF (5.83 vs 4.76 weeks) or MgE (5.33 vs 4.90 weeks).

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**Conclusions and relevance** No association was found between the CSF and MgE results. Furthermore, no association was found between MgE, CSF or bacteriology findings. In addition, abnormal CSF results might lead the clinician to treat with corticosteroids, but they did not have any impact on duration of antimicrobial treatment. CSF abnormalities were seen significantly less frequently in chronic cases. The outcome tended to be poorer when MgE was detected on MRI.

**Keywords:** Otitis media and interna; peripheral vestibular signs; MRI meningeal enhancement; cerebrospinal fluid

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## Introduction

Otitis media and interna (OMI) has been reported to be the cause of vestibular signs in 43–63% of cats with peripheral vestibular signs (PVS).<sup>1,2</sup> OMI in cats is most commonly associated with inflammation caused by upper respiratory infection that has extended through the auditory tube or a nasopharyngeal polyp.<sup>1,3,4</sup> It occurs less frequently as a consequence of an otitis externa or neoplasia. Bacterial isolates from OMI include *Staphylococcus* species, *Streptococcus* species, *Pasteurella multocida*, *Escherichia coli*, *Enterococcus* species and, less frequently, *Mycoplasma* species, *Corynebacterium* species and other bacterial species.<sup>1,4–8</sup> Apart from bacteria, other infectious agents can be involved in cats, especially fungi (*Malassezia* species).<sup>8</sup> Occasionally, a nasopharyngeal polyp – a non-neoplastic, inflammatory growth that arises from the middle ear or auditory tube – can be responsible for OMI.<sup>1,2,9,10</sup> Diagnosis of otitis media and bacterial infection in the bulla can be achieved via cytological and/or bacterial culture of material retrieved via myringotomy or a surgical procedure such as bulla osteotomy.<sup>1,8,9</sup> Cats with PVS are clinically recognised with the presence of at least one of the following clinical signs: ipsilateral head tilt; jerk nystagmus; tight circling; positional strabismus and/or vestibular ataxia; as well as the absence of any neurological signs suggestive of intracranial disease.<sup>11–13</sup> PVS reflect the involvement of the inner ear, while the presence of facial nerve deficit and/or Horner syndrome indicates involvement of the middle ear.<sup>11–13</sup>

MRI is a sensitive method with which to diagnose OMI, particularly for inner ear visualisation.<sup>1,7,14</sup> The fluid composition of endo- and perilymph allows for good visualisation of this inner ear part in a fluid-sensitive sequence such as T2-weighted (T2W) images or in fluid-attenuated inversion recovery (FLAIR).<sup>14,15</sup> A marked hyperintensity compared with adjacent structures is present on T2W images, while suppression is visible in FLAIR.<sup>14,15</sup> Postcontrast T1-weighted (T1W) images may show an abnormality consistent with inflammatory changes in the inner ear.<sup>1</sup> Typical changes raising the suspicion of OMI include isointense material in the bulla on T1W images and hyperintense on T2W images. On postcontrast T1W images, a peripheral enhancement along the inner surface

of the tympanic bulla can be observed.<sup>7,16</sup> A laminated appearance of the mucosa of the tympanic bulla on T2W images has also been described.<sup>17</sup> A reduced signal intensity on T2W or an increased signal intensity on FLAIR images from the intralabyrinthine fluid is an MRI finding suggestive of otitis interna.<sup>14,16,18</sup> Owing to the anatomical proximity, intracranial extension of OMI can lead to a meningeal enhancement (MgE) on MRI after intravenous administration of paramagnetic contrast medium.<sup>19</sup> Anatomically, perilymph and cerebrospinal fluid (CSF) are connected via the cochlear aqueduct.<sup>20</sup> Therefore, CSF analysis is another important diagnostic tool for cats with OMI and is reported to be more sensitive than MRI in identifying intracranial inflammatory processes.<sup>7,15,21</sup> Thus, an abnormal MRI and/or CSF analysis can provide useful clinical information on the presence of a concurrent meningitis and may influence treatment.

The relationship between MgE and abnormal CSF in cats with OMI has not yet been investigated; their association with bacteriology results and therapeutic management has also not been studied. The aims of this study were to describe the association between MgE and CSF analysis results, their individual association with bacteriology results from affected ear samples and the influence of the above with therapeutic choice in cats with OMI. We hypothesised that: (1) MgE is associated with CSF abnormalities; (2) positive bacteriology is more common if MgE and/or CSF abnormalities are present; and (3) positive bacteriology is associated with the choice and length of antimicrobial and/or anti-inflammatory treatment.

## Materials and methods

### Selection criteria

Data were retrospectively collected from six different referral centres across Europe (Vetsuisse-Faculty, University of Bern; University of Veterinary Medicine Hannover; Royal Veterinary College London [RVC]; School of Veterinary Medicine, University of Glasgow; Queen's Veterinary School Hospital, University of Cambridge; and Royal [Dick] School of Veterinary Studies, University of Edinburgh) over an 8-year period (January 2012–December 2020). Only client-owned cats with PVS that underwent MRI (with postcontrast images)

and CSF analysis as part of the diagnostic work-up were selected for this study. Inclusion criteria were: (1) clinical signs consistent with peripheral vestibular lesion localisation; (2) a diagnosis of OMI with or without the presence of a nasopharyngeal polyp based on MRI findings; and (3) the absence of an intra-axial abnormality or imaging findings consistent with empyema on MRI.

Retrospective information collected from the medical records included signalment, history, treatment prior to and after referral, right-, left-sided or bilateral PVS, MRI and CSF findings, bacteriology results from the affected ear and outcome.

### MRI

MRI of the skull was obtained under general anaesthesia, using anaesthetic protocols at the discretion of the anaesthesiologist in charge. High-field MRI was used at all institutions (except for one cat) and varied between centres: a Philips Panorama HFO 1.0 T (Philips Medical Systems Nederland) for Bern; a Philips Achieva 3.0 T (Philips Medical Systems) for Hannover; 1.5T (Intera; Philips Medical Systems) for RVC; 1.5T (Magnetom Essenza; Siemens) for Glasgow, 0.27 T (Esaote VetMR Grande) or 1.5 T (Phillips Achieva; Phillips Healthcare) for Cambridge; and 1.5 T (Intera; Philips Medical Systems) for Edinburgh. Although MRI protocols varied between centres, at least T1W and T2W postcontrast images were available in all cats (gadoteric acid 0.2 mmol/kg IV [Dotarem; Guerbert Laboratories] for Bern and Hannover; gadoterate meglumine 0.1 mmol/kg IV [Dotarem; Guerbet] for RVC; gadobutrol 0.1 mmol/kg [Gadovist; Bayer] for Glasgow and Cambridge; and gadopentate dimeglumine 0.1 mmol/kg IV [Magnevist; Bayer] for Edinburgh). All MRIs were evaluated by a board-certified veterinary radiologist or a board-certified veterinary neurologist. Information about OMI with or without nasopharyngeal polyp and MgE were collected directly from MRI reports.

### CSF analysis

Abnormal CSF was defined as a total nucleated cell count (TNCC)  $\geq 5$  leukocytes/ $\mu$ l and/or increased total protein  $>0.3$  g/l for cisterna magna samples and  $>0.45$  g/l for lumbar samples. Albuminocytological dissociation was defined as an increase in total protein without an increased TNCC. Neutrophilic (respectively monocytic) pleocytosis was identified if neutrophils constituted  $>70\%$  (respectively monocytes) in CSF with an abnormal TNCC.<sup>22</sup>

### Medical treatment

Antimicrobials were categorised as the first or second line of treatment. First-line treatment included amoxicillin-clavulanic acid, cephalosporin, metronidazole, clindamycin and doxycycline. Second-line treatment contained marbofloxacin, enrofloxacin, cefovecin, pradofloxacin and cefixime.<sup>23</sup>

Anti-inflammatory drugs were categorised as steroidal (eg, prednisolone and dexamethasone) or non-steroidal (eg, meloxicam and robenacoxib).

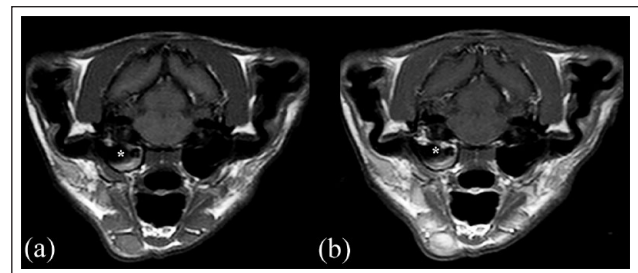
### Statistical analysis

The presence or absence of MgE on MRI, CSF results and bacteriology culture results were compared using a  $\chi^2$  test. The choice of treatment based on MgE, CSF and bacteriology results were compared using a  $\chi^2$  test or a Fisher's exact test if a group contained fewer than five cats. Duration of treatment was compared using a Student's *t*-test. Test values were performed in a two-sided manner and a *P* value  $\leq 0.05$  was considered statistically significant. All analyses were performed using R version 3.6.3.

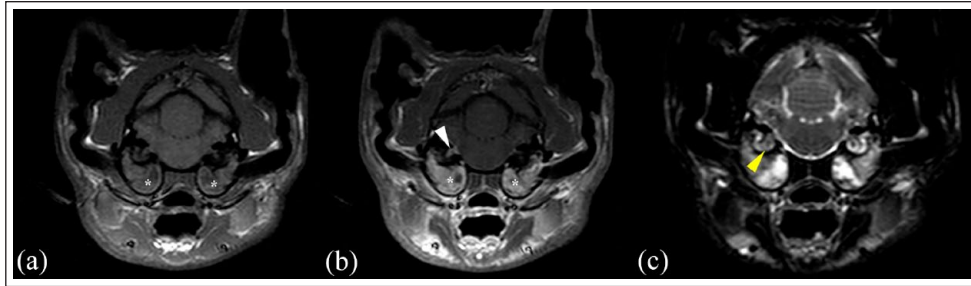
## Results

A total of 58 cats met the inclusion criteria. Domestic short-hair was the most common breed ( $n = 32$ ). Other breeds included Maine Coon ( $n = 9$ ), Siamese ( $n = 4$ ), British Shorthair ( $n = 2$ ), Burmese ( $n = 2$ ), Russian Blue ( $n = 2$ ), Bengal ( $n = 1$ ), Egyptian Mau ( $n = 1$ ), Norwegian Forest Cat ( $n = 1$ ), Ocicat ( $n = 1$ ), Persian ( $n = 1$ ), Ragdoll ( $n = 1$ ) and Snowshoe ( $n = 1$ ). There were 27 females (four intact, 23 spayed) and 31 males (four intact, 27 castrated; male: female sex ratio = 1.15). The mean age of the cats was 6.9 years (median 7.3, range 3.7 months to 14.7 years). Half of the cases had left vestibular signs at time of presentation. Clinical signs were acute ( $\leq 14$  days) in 37 cats and chronic ( $>14$  days) in 21 cats. Before presentation, 32 cats were given medical treatment. Nine cases received antimicrobial treatment alone, eight had antimicrobial treatment with non-steroidal anti-inflammatory drugs (NSAIDs), nine had an antimicrobial treatment with corticosteroids, and two had an antimicrobial treatment, NSAIDs and corticosteroids. Five cats received only corticosteroids and one only an NSAID. All clinical information is available in the table in the supplementary material.

Forty-five cats (78%) were diagnosed with OMI alone (without a nasopharyngeal polyp) (Figures 1 and 2); three



**Figure 1** MRI (Philips Panorama HFO 1.0 T) transverse images in (a) T1-weighted (T1W) sequence and (b) T1W postcontrast sequence of a cat presented with otitis media interna without polyp (\*) and without meningeal enhancement



**Figure 2** MRI (Philips Panorama HFO 1.0 T) transverse images in (a) T1-weighted (T1W) sequence, (b) T1W postcontrast sequence and (c) T2W sequence of a cat presented with bilateral otitis media interna without polyp (\*), with meningeal and vestibulocochlear nerve enhancement (white arrowhead) and otitis interna (yellow arrowhead)

based on histology of material obtained from bulla osteotomy, three based on findings during bulla osteotomy, 26 based on otoscopy and cytology results obtained through myringotomy, and 13 were suspected on MRI only. The remaining cats ( $n = 13/58$  [22%]) were diagnosed with OMI secondary to a polyp (Figures 3 and 4): six based on histology of material obtained from bulla osteotomy, two based on findings during bulla osteotomy, two based on otoscopy and/or cytology results obtained through myringotomy, and two were suspected on MRI only.

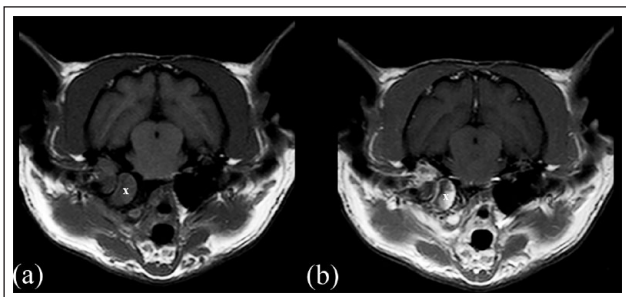
Meningeal contrast enhancement was present in 26 cases (45%; Figure 2b and Figure 4b), while 32 cases (55%) did not show MgE (Figure 1b and Figure 3b). CSF analysis was abnormal in 19 cats (33%): 11 with only increased TNCC, five with both increased TNCC and total protein, and three with albuminocytological dissociation. Increased TNCC ranged between five and 1205 leukocytes/ $\mu\text{l}$  (median 12); increased total protein in CSF ranged between 0.34 and 0.77 g/l (median 0.56). Neutrophilic pleocytosis was seen in nine cases, monocytic pleocytosis was seen in one case and mixed-cell pleocytosis in six cases.

Nine cats (16%) presented with both MgE and abnormal CSF (five with only increased TNCC, two with both increased TNCC and total protein and two with

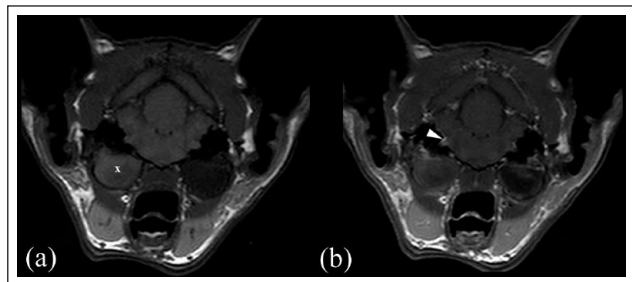
albuminocytological dissociation). MgE was detected in 17 cats (29%) with normal CSF. Abnormal CSF was seen in 10/32 cats (31%) without MgE: six with only increased TNCC, three with both increased TNCC and total protein, and one with albuminocytological dissociation. No significant association ( $\chi^2$  test,  $P = 0.79$ ) was found between the CSF results and MgE findings (Table 1).

CSF abnormalities were more statistically significantly detected more often in acute cases ( $n = 16/37$ ) compared with chronic cases ( $n = 3/21$ ; Fisher's test,  $P = 0.04$ ), while MgE was similar in acute ( $n = 15/37$ ) and chronic ( $n = 11/21$ ) cases. Furthermore, none of the chronic cases presented with abnormal CSF without MgE (Table 2). No association was found between the use of anti-inflammatory drugs before MRI and CSF analysis (Table 3), or the presence or absence of a polyp (Table 4) and MgE or CSF abnormalities.

Bacterial culture was performed in 45/58 cases. Samples were collected from bulla osteotomy in 13 cases, myringotomy in 28 and the external ear canal in four. Negative bacterial culture was observed in 33/45 cases, of which 13 (39%) received antimicrobial treatment before sampling. The percentages of negative bacterial culture was 70% in acute (21/30) and 73% in chronic ( $n = 11/15$ ) cases.



**Figure 3** MRI (Philips Panorama HFO 1.0 T) transverse images in (a) T1-weighted (T1W) sequence and (b) T1W postcontrast sequence of a cat presented with otitis media interna associated with a polyp (X) and without meningeal enhancement



**Figure 4** MRI (Philips Panorama HFO 1.0 T) transverse images in (a) T1-weighted (T1W) sequence and (b) T1W postcontrast sequence of a cat presented with otitis media interna associated with a polyp (X) and with meningeal and vestibulocochlear nerve enhancement (white arrowhead)



**Table 1** Association between cerebrospinal fluid (CSF) and meningeal enhancement (MgE) findings ( $\chi^2$  test,  $P = 0.79$ )

	CSF+	CSF-
MgE+	9	17
MgE-	10	22

CSF+ = abnormal CSF analysis; CSF- = normal CSF analysis; MgE+ = presence of meningeal enhancement; MgE- = absence of meningeal enhancement

**Table 2** Association between cerebrospinal fluid (CSF) and meningeal enhancement (MgE) findings divided between acute and chronic cases

	Acute		Chronic		P value*
	CSF+	CSF-	CSF+	CSF-	
MgE+	6	9	3	8	0.42
MgE-	10	12	0	10	
P value*	0.04				

CSF+ = abnormal CSF analysis; CSF- = normal CSF analysis; MgE+ = presence of meningeal enhancement; MgE- = absence of meningeal enhancement  
\*Fisher's test

**Table 3** Association between cerebrospinal fluid (CSF) and meningeal enhancement (MgE) findings according to the presence or absence of anti-inflammatory treatment before presentation

	Anti-inflammatory		No anti-inflammatory		P value*
	CSF+	CSF-	CSF+	CSF-	
MgE+	3	8	6	9	0.91
MgE-	4	10	6	12	
P value	0.5				

CSF+ = abnormal CSF analysis; CSF- = normal CSF analysis; MgE+ = presence of meningeal enhancement; MgE- = absence of meningeal enhancement  
\* $\chi^2$  test

Twelve cases showed a positive bacterial culture: six for *Staphylococcus* species, three for *Pasteurella* species, one for *Streptococcus canis*, one for *Actinomyces pyogenes* and one with both *Streptococcus equi* subspecies *zooepidemicus* and *Staphylococcus felis*. Of these, seven (58%) received antimicrobial treatment before sampling.

The results of the bacterial culture depending on presence/absence of MgE and normal/abnormal CSF findings are summarised in Table 5. No statistical association was found between a positive bacterial culture and

**Table 4** Association between cerebrospinal fluid (CSF) and meningeal enhancement (MgE) findings according to the presence or absence of a polyp

	Polyp		No polyp		P value*
	CSF+	CSF-	CSF+	CSF-	
MgE+	1	5	8	12	0.91
MgE-	4	3	6	19	
P value†	0.74				

CSF+ = abnormal CSF analysis; CSF- = normal CSF analysis; MgE+ = presence of meningeal enhancement; MgE- = absence of meningeal enhancement

\* $\chi^2$  test  
†Fisher's test

MgE ( $\chi^2$ ,  $P = 0.82$ ) or CSF results ( $\chi^2$  test,  $P = 0.15$ ). One observation was that if no MgE was seen on MRI and no abnormality was detected on CSF analysis, the likelihood of getting a negative ear sample bacterial culture from myringotomy or bulla osteotomy was only about 12% ( $n = 2/17$ ). One cat had a positive culture from CSF (*Clostridium beijerinckii* and *Enterococcus faecalis*), despite no positive bacterial culture ear sample from myringotomy and clindamycin treatment for 3 days.

Twenty-five cats received corticosteroids and 13 received NSAIDs after diagnosis. The choice of anti-inflammatory drugs according to MgE, CSF or bacteriology findings is summarised in Table 6. No statistically significant difference (MgE:  $\chi^2$  test,  $P = 0.53$ ; CSF: Fisher's test,  $P = 0.08$ ; bacteriology: Fisher's test,  $P = 0.62$ ) was identified, although corticosteroids seem to have been chosen more often in the case of abnormal CSF results (11 cases vs 1 case). Fifty-four cats (93%) received antimicrobial treatment after diagnosis. Twenty-six of 54 (48%) had started antimicrobial treatment prior to referral, while it was started by the referral centre after diagnosis in 28 cases (52%). Thirty-nine received first-line antimicrobials, seven received second-line and eight received both. The duration of antimicrobial treatment depending on MgE, CSF or bacteriology findings are summarised in Table 7. Duration of antimicrobial treatment tended to be longer in the case of positive cultures (5.58 vs 4.22 weeks) or when CSF findings were abnormal (5.83 vs 4.76 weeks), although this difference was not statistically significant (Student's *t*-test).

The association between the CSF results, MgE and outcome are provided in Table 8. A good outcome was defined as an improvement of clinical signs (and euthanasia unrelated to the disease after several months). A poor outcome was defined by a lack of improvement or euthanasia. Although cases with MgE tended to have a poorer outcome ( $n = 5/18$ ) than those without MgE ( $n = 3/26$ ), the difference was not statistically significant (Fisher's test,  $P = 0.24$ ). No statistically significant association was

**Table 5** Association between meningeal enhancement (MgE) and cerebrospinal fluid (CSF) results and bacterial culture results from ear canal, myringotomy or bulla osteotomy

	MgE <sup>+</sup>	MgE <sup>-</sup>	CSF <sup>+</sup>	CSF <sup>-</sup>
Culture positive	5 (1 EC + 2M + 2 BO)	7 (2 EC + 4M + 1 BO)	6 (3 EC + 3M)	6 (3M + 3 BO)
Culture negative	15 (10M + 5BO)	18 (1 EC + 12M + 5 BO)	9 (7 M + 2 BO)	24 (1 EC + 15 M + 8 BO)
P value*	0.82		0.15	

MgE<sup>+</sup> = presence of meningeal enhancement; MgE<sup>-</sup> = absence of meningeal enhancement; CSF<sup>+</sup> = abnormal CSF analysis; CSF<sup>-</sup> = normal CSF analysis; EC = ear canal; M = myringotomy; BO = bulla osteotomy

\* $\chi^2$  test

**Table 6** Choice of anti-inflammatory drug depending on the meningeal enhancement (MgE), cerebrospinal fluid (CSF) and bacterial culture (right) results

	MgE <sup>+</sup>	MgE <sup>-</sup>	CSF <sup>+</sup>	CSF <sup>-</sup>	Culture positive	Culture negative
Corticosteroids	10	15	11	14	7	13
NSAIDs	5	8	1	12	2	8
None	11	9	7	13	3	12
P value	0.53*		0.08 <sup>†</sup>		0.62 <sup>†</sup>	

MgE<sup>+</sup> = presence of meningeal enhancement; MgE<sup>-</sup> = absence of meningeal enhancement; CSF<sup>+</sup> = abnormal CSF analysis; CSF<sup>-</sup> = normal CSF analysis; NSAIDs = non-steroidal anti-inflammatory drugs

\* $\chi^2$  test

<sup>†</sup>Fisher's test

**Table 7** Comparison of antibiotic treatment duration (in weeks) based on meningeal enhancement (MgE), cerebrospinal fluid (CSF) or bacterial culture results

	Positive	Negative	P value*
Culture	5.58	4.22	0.27
CSF	5.83	4.76	0.17
MgE	5.33	4.90	0.80

\*Student's *t*-test

found between outcome and CSF abnormalities (Fisher's test,  $P = 1$ ). Bulla osteotomy was performed in 14 cases (eight with polyps and six with OMI), between 1 and 78 days after diagnosis (median 5). Delayed bulla osteotomies were due to the absence of improvement or relapse of clinical signs after initial medical management. Improvement of neurological signs after surgical management was seen in 11 cases (length of follow-up varied between 1 and 104 weeks, including five cases with >8 weeks of follow-up), relapse in one (3 months postoperatively) and three cases were lost to follow-up. None of the surgical cases was euthanased for reasons related to OMI. Medical management resulted in improvement in 23/44 cases (duration of follow-up varied between 1 and 78 months, including 12 cases with >8 weeks of follow-up). Two cases improved and were euthanased for unrelated reasons 4 months (carcinoma) and 17 months (polyarthrititis) after the diagnosis of OMI, respectively. Three cases did not improve after 1 month, but their owners declined

**Table 8** Association between cerebrospinal fluid (CSF) results, meningeal enhancement (MgE) and outcome in 44 cats\*

	Good <sup>†</sup>		Poor <sup>‡</sup>		P value <sup>§</sup>
	CSF <sup>+</sup>	CSF <sup>-</sup>	CSF <sup>+</sup>	CSF <sup>-</sup>	
MgE <sup>+</sup>	5	8	2	3	0.24
MgE <sup>-</sup>	9	14	1	2	
P value <sup>§</sup>	1				

CSF<sup>+</sup> = abnormal CSF analysis; CSF<sup>-</sup> = normal CSF analysis

MgE<sup>+</sup> = presence of meningeal enhancement; MgE<sup>-</sup> = absence of meningeal enhancement

\*Eleven cats were lost to follow-up

<sup>†</sup>Improvement or euthanasia unrelated to the disease

<sup>‡</sup>No improvement or euthanasia

<sup>§</sup>Fisher's test

surgery. Four cases were euthanased following diagnosis or several weeks after, with no improvement on medical treatment. One case showed intermittent vestibular signs and was euthanased 20 months after diagnosis owing to seizure-like episodes. Eleven cases were lost to follow-up.

## Discussion

The findings of this study show that in a cohort of 58 cats with PVS diagnosed with OMI, MgE is seen in approximately 50% of cases; however, only 27% of these cases had an abnormal CSF result. There was no association between MgE and abnormal CSF results. Chronic cases

had significantly fewer abnormal CSF findings. When a treatment was given, its duration was similar regardless of a positive bacterial culture, abnormal CSF analysis or MgE. Cases with MgE tend to have a poorer outcome.

The use of MRI to investigate the cause of PVS is common practice in clinical neurology, particularly if concurrent meningitis is suspected. Administration of a gadolinium-based contrast medium in MRI has been demonstrated as a more sensitive method to diagnose experimental bacterial meningitis in dogs vs MRI without contrast or postcontrast CT.<sup>23</sup> However, only severe meningeal inflammation at necropsy was correlated with MRI findings, while mild inflammation was not detected in MRI, leading to the conclusion that the absence of meningeal enhancement does not rule out bacterial meningitis.<sup>24</sup> False-positive results of diffuse MgE on MRI without CSF abnormalities have also been described previously.<sup>25</sup> MRI also allows for a better evaluation of fluid-containing inner ear structures than CT, and otitis interna can be assessed on T2W images.<sup>16,26</sup> More recently, Keenihan et al and d'Anjou et al compared MR sequences for detecting MgE in dogs.<sup>27,28</sup> Postcontrast T1W and T1W fat suppression were found to be the sequences of choice to detect meningeal inflammation. In previous studies in cats with OMI, only one case with focal meningitis resembled our population of cats with MgE, without intra-axial lesions or empyema. This case had an abnormal CSF analysis.<sup>1</sup> In dogs, few studies describe naturally occurring OMI leading to meningeal enhancement in T1W images after gadolinium administration, but no large study focusing on this aspect has been carried out; therefore, its clinical consideration remains unknown.<sup>16,29,30</sup>

Despite the first hypothesis that MgE is associated with abnormal CSF findings, a discrepancy between MgE and CSF results was found in 47% of cases. Indeed, MgE was seen more frequently in cases with unremarkable CSF analysis (65%), and abnormal CSF can be found without MgE in up to 31% of cases. To the best of our knowledge, no previous report of cats with OMI has evaluated the association between MRI findings and CSF analysis. In previous reports of cats diagnosed with OMI and intra-axial lesions or empyema on MRI, abnormal CSF was detected in 22/25 cases in which CSF analysis was performed.<sup>1,7,31</sup> MgE was specifically described in one of these studies, where none of the five cats with chronic vestibular clinical signs had MgE, while all of the six acute or subacute cases did.<sup>7</sup> The prevalence of MgE is in contrast with our results, in which 11/21 chronic cases and 15/35 acute cases showed MgE. When available, abnormal CSF analysis was detected in all acute or subacute cases (5/5) and only in 1/4 chronic cases.<sup>7</sup> These results reflect our findings with significantly fewer CSF abnormalities in chronic cases. Previous treatment with anti-inflammatory drugs or the presence of a polyp did not affect the presence/absence of MgE or CSF results.

The second hypothesis was that there would be an association between MgE and/or CSF abnormalities and a positive bacteriology culture. In the case of absent MgE and normal CSF, the likelihood of a positive bacterial culture from myringotomy or bulla osteotomy was low (~12%). Even if this result is not statistically significant, it raises awareness in the clinician of the possible need to alter antimicrobial treatment after receiving culture results. Bacteriology results between acute or chronic cases did not differ significantly.

Finally, we hypothesised that a positive bacterial culture would influence the choice and duration of antimicrobial and/or anti-inflammatory treatment. Owing to the retrospective and multicentric aspect of our study, medical management was variable, making investigation of the final hypothesis difficult. Generally, long-term (4–8 weeks), broad-spectrum antimicrobial treatment or, ideally, a treatment based on an *in vitro* antimicrobial sensitivity profile, is recommended to treat OMI in cats and dogs.<sup>8</sup> In this study, the duration of treatment was slightly longer in cases of positive bacterial culture than in cases of negative bacterial growth (5.58 weeks vs 4.22 weeks), although the difference was not statistically significant. The similar duration of treatment may be due to the initial prescription, with no improvement in clinical signs or a lack of short-term follow-up by the referring centre. Also, if anti-inflammatory drugs were to be implemented after abnormal CSF results, clinicians tended to use corticosteroids more frequently. These results could reflect a clinician's preference for corticosteroids in the case of central nervous system inflammation. However, clinicians need to remember the lack of CSF abnormalities in chronic cases, despite meningeal inflammation.

Culture results from samples taken from the external ear canal have to be interpreted with caution. Common microorganisms can be detected in the tympanic bulla of healthy cats in up to 25% of cases.<sup>32</sup> Bacteria have been previously cultured from 48% of healthy canine external ears.<sup>33</sup> Moreover, up to 67% of myringotomies performed via video-otoscopy might be contaminated, even if microorganisms were detected in only 15.4% of samples.<sup>34</sup> The presence or absence of bacteria on culture should not be considered as critical in formulating a treatment plan as the type of bacteria that are cultured (ie, whether they are likely of external ear canal origin and/or possible iatrogenic contaminants vs a likely cause of middle-ear infection). The lack of a cultured infectious agent in our case series with the presumed presence of OMI raises the question of a purely inflammatory mechanism leading to otitis interna.

The age of the cats, uni- or bilateral vestibular signs of distribution, proportion of OMI with or without polyps, and type of bacteria cultured were similar to previously published literature.<sup>1,2,13,35</sup> In this cohort, cases with identified MgE tended to have a poorer prognosis than those without MgE; however, this difference was

not statistically significant, and an abnormal CSF result was not associated with any difference in outcome. This finding might help clinicians to anticipate and adapt the treatment for such cases. Surgical treatment with bulla osteotomy was performed in 14 cats (24%), including four in which it was performed several weeks after diagnosis. This is different to other published studies in which none of the cases with vestibular signs underwent surgery, and up to 30% of otitis media cases without neurological signs received bulla osteotomy.<sup>1,4</sup> In another study focusing on OMI in cats with intracranial complications, ventral bulla osteotomy was performed more often (12/18 cases [67%]).<sup>31</sup> Surgical management led to an improvement in neurological status in all cases (n = 13/13), while medical management showed an improvement in 23/31 cases (74%). These results are slightly better than those for cats with OMI and intracranial complications.<sup>31</sup>

There are several limitations to this study. Firstly, its retrospective nature is associated with incomplete data and did not allow for the long-term follow-up of cases. A multicentre study with different MRI equipment, clinicians and protocols will result in differences in the evaluation of MRI and the clinical management of cases. Concerning recruitment, cases without MRI and/or CSF analysis were excluded, which may have biased the study population towards potentially more severely affected cases. Clinicians may decide against CSF analyses in those cases where clear MgE is seen on MRI, biasing the population towards a higher number of cases without MgE. A similar bias could also have affected the choice of treatment in the cases included in the present study. Moreover, the use of medication prior to presentation might have affected the results. We decided to exclude all cases that presented with intra-axial lesions or empyema on MRI, despite presumed peripheral vestibular lesion localisation as brainstem signs may not be clinically obvious in the neurological examination and might have affected the CSF results.<sup>36,37</sup> In dogs, it has been shown that bacterial culture obtained via myringotomy can be contaminated by bacteria from the external ear canal, which could be one limitation to our bacteriology results.<sup>34</sup> The time of acquisition in dogs and higher dose of gadolinium in humans may induce false-negative MgE.<sup>28,38</sup> False-positive MgE may also occur.<sup>25</sup>

## Conclusions

In this study, no association was found between MgE and CSF results. Nearly half of cases (47%) showed a discrepancy between MRI and CSF findings. Additionally, the lack of MgE in MRI does not rule out the presence of a meningitis pathologically. Hence, CSF analysis may be useful to detect the presence of possible concurrent meningitis in cats with OMI. CSF findings and MgE results were not associated with the likelihood of a positive or negative middle-ear bacterial culture. Abnormal CSF results seemed to influence the clinicians' choice

of anti-inflammatory drugs with a preference for glucocorticoids over NSAIDs. Abnormal CSF results were seen less frequently in chronic cases than in acute cases. Additionally, the identification of an abnormal CSF analysis did not seem to influence the duration of antimicrobial treatment, which remains the mainstay for this presumed infectious disease. Outcome tended to be poorer when MgE was detected on MRI.

**Supplementary material** The following file is available online:

Table of cases.

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