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Case Report
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Successful Treatment of Disseminated Nocardiosis Caused by Nocardia veterana in a Dog

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A 5-year-old male castrated Lhasa Apso cross was evaluated for a 1-month history of inappetence, lethargy, gagging, and progressive right thoracic limb lameness. Synovial fluid analysis revealed nonseptic suppurative inflammation, and a diagnosis of immune-mediated polyarthritis (IMPA) was made. After 3 months of treatment with prednisone and later cyclosporine, the dog developed multiple firm cutaneous and subcutaneous masses and a focal mass within the jejunum. Cultures of blood, urine, skin lesions, and the jejunal mass identified *Nocardia veterana* by matrix-absorption laser desorption ionization-time-of-flight mass spectrometry (MALDI-TOF MS) and allowed for earlier identification of the organism compared to more traditional *secA1* gene sequencing. Immunosuppressive drug treatment was discontinued, and the dog was treated for 3 months by administration of trimethoprim-sulfamethoxazole (TMS). No recurrence of clinical signs was reported 1 year later. This case report highlights the clinical utility of MALDI-TOF MS, particularly for the rapid identification of slow-growing, fastidious organisms.

Key words: Actinomycetales; Antimicrobial treatment; Bacteremia; Immunosuppression; MALDI-TOF MS.

A 5-year-old male castrated Lhasa Apso cross from Northern California was evaluated at the William R. Pritchard Veterinary Medical Teaching Hospital (VMTH) at the University California, Davis, for a 1-month history of decreased appetite, lethargy, intermittent gagging, and progressive right thoracic limb lameness. Five months previously, a T13-L1 right hemilaminectomy had been performed because of intervertebral disk disease with complete recovery. There was no travel outside of Northern California. The dog hiked weekly before the hemilaminectomy and was known to chew sticks. When examined for the lameness and gagging at the referring veterinarian's clinic, a CBC, serum biochemistry panel, SNAP 4DX Plus Assay,[a] thoracic and abdominal radiographs, and abdominal ultrasound examination revealed no abnormalities except for evidence of right elbow dysplasia. A respiratory PCR panel[b] on an oropharyngeal swab specimen for canine influenza virus (H3N8), canine adenovirus type 2, canine herpesvirus, canine parainfluenza virus, canine respiratory coronavirus, H1N1 and H5N1 influenza viruses, canine distemper virus, *Bordetella bronchiseptica*, *Mycoplasma cynos,* and *Streptococcus equi* subsp. *zooepidemicus* was positive only for *Mycoplasma cynos*. Treatment with subcutaneous administration of fluids, sucralfate (30 mg/kg PO q8h for 14 days), cefovecin[c] (8 mg/kg SQ once), azithromycin (5.2 mg/kg PO q24h for 14 days), tramadol (2.5 mg/kg PO q8h as needed for pain), and omeprazole (1 mg/kg PO q24h) was followed by a decreased frequency of gagging but progressive lameness and pain, so the dog was referred.

Abbreviations:

IMPA	immune-mediated polyarthritis
MALDI-TOF	MS matrix-absorption laser desorption ionization-time-of-flight mass spectrometry
MIC	minimum inhibitory concentration
PAS	periodic acid Schiff
TMS	trimethoprim-sulfamethoxazole
VMTH	veterinary medical teaching hospital

On initial evaluation at the VMTH (day 0), the dog was febrile (103.7°F) and had a moderate right thoracic limb lameness. Pain was elicited on palpation of the caudal thoracic vertebral spine, dorsal and lateral flexion of the cervical spine, and on elbow extension bilaterally. Mild joint effusion was noted in the tarsi, carpi, and elbows. A CBC was performed, and the only hematologic abnormality was leukocytosis (38,350 cells/uL, reference range, 6,000–13,000 cells/uL) characterized by a mature neutrophilia (36,433 cells/uL, reference range, 3,000–10,500 cells/uL). Arthrocentesis of the carpus, tarsus, elbow, and stifle revealed mild-to-moderate nondegenerate neutrophilic inflammation (neutrophils comprised 44–75% of total nucleated cells present). No microorganisms were observed. Examination of CSF obtained from the cisternal space revealed no abnormalities. No other diagnostics were performed. A diagnosis of primary immune-mediated polyarthritis (IMPA) was made, and an immunosuppressive dose of prednisone (1.1 mg/kg PO q12h) and tramadol (2.8 mg/kg PO q8-12h as needed) were prescribed at the time of discharge (day 2).

Over the next 7 days, there was marked improvement in the severity of lameness but persistent mild

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neutrophilic inflammation in multiple joints was detected when the dog was re-evaluated 1 and 2 months after starting prednisone treatment (days 26 and 54, respectively). Therefore, treatment with cyclosporine[d] (5.1 mg/kg PO q12h) was also commenced. One month later (3 months after starting immunosuppressive drug treatment and 85 days after initial evaluation at the VMTH), the dog was re-evaluated for a 10-day history of lethargy, recurrent right thoracic limb lameness, and multiple skin masses. On physical examination, the dog was lethargic, febrile (102.6°F), and had severe right thoracic limb lameness and hepatomegaly. Multiple firm cutaneous and subcutaneous nodules measuring 0.25–1.5 cm were palpated on the head, interscapular region, and caudal dorsum, some of which were ulcerated. There was marked soft tissue swelling and pain in the region of the right carpus.

A CBC revealed a mild normocytic (MCV 72 fL, RR 65–75 fL), normochromic (34.4 g/dL, RR 33–36 g/dL), nonregenerative anemia (HCT 37.5%, RR 40–55%), neutrophilic leukocytosis with left shift and slight toxicity (neutrophils 48,059 cells/μL, RR 3,000–10,500 cells/μL; band neutrophils 1,056 cells/μL), and a monocytosis (3,169 cells/μL, RR 150–1,200 cells/μL). A serum biochemical profile revealed increased activity of serum ALP (4,422 IU/L, RR 14–91 IU/L), GGT (339 IU/L, RR 0–5 IU/L), ALT (421 IU/L, RR 21–72 IU/L), and AST 69 IU/L (RR 20–49 IU/L). Total bilirubin concentration was increased at 1.4 mg/dL (RR 0.0–0.2 mg/dL), and mild hypoalbuminemia was present (3.3 g/dL, RR 3.4–4.3 g/dL). A urinalysis revealed isosthenuria (USG 1.008), proteinuria (25 mg/dL), and mild bilirubinuria (3 mg/dL).

Thoracic radiographs showed a diffuse bronchointerstitial lung pattern. On abdominal ultrasound examination, there was a focal, eccentric, nonobstructing mural mass within the jejunum that was associated with loss of intestinal wall layering. The mass was surrounded by mildly hyperechoic mesentery. The liver was mildly enlarged and hyperechoic. Echogenic debris was present within the gall bladder, but there was no evidence of biliary obstruction. Radiographs of the right carpus revealed marked soft tissue swelling of the antebrachium, carpus, and forefoot without osseous lesions. Aspirates and punch biopsies of the skin nodules revealed marked pyogranulomatous inflammation that included neutrophils that were mildly to moderately degenerated and activated macrophages with both intracellular and extracellular filamentous branching bacteria that morphologically resembled *Actinomyces* spp. or *Nocardia* spp. The skin biopsies were submitted for culture for aerobic and anaerobic bacteria, fungi, and mycobacteria. Smears of the biopsies revealed gram-positive filamentous bacteria. Specimens were inoculated onto sheep blood agar plates, MacConkey agar plates, and tryptic soy broth and incubated at 35°C in 5% CO_2 until bacterial colonies were observed (48 hours). Treatment with cyclosporine was discontinued, the dose of prednisone was decreased (0.6 mg/kg PO q24h for 5 days), and treatment with ampicillin-sulbactam[e] (50 mg/kg IV q8h) was initiated. Subsequently, the results of special staining of the biopsy smears and biopsies became available. The biopsy smears contained filamentous organisms that stained positive with gram stain and Kinyoun stain, and negative with Ziehl-Neelsen stain. On histopathology, the intralesional bacteria stained positive with Kinyoun stain, weakly positive with Gomori's methenamine silver, but negative with Ziehl-Neelsen and periodic acid Schiff (PAS). The Brown and Brenn gram stain revealed abundant gram-positive, filamentous, and beaded organisms. The history of immunosuppression, together with the positive Kinyoun stain, supported a diagnosis of disseminated nocardiosis rather than actinomycosis, so ampicillin-sulbactam was discontinued and trimethoprim-sulfamethoxazole (TMS) (30 mg/kg IV q8h) was commenced. A Schirmer tear test performed before initiating treatment with TMS revealed mildly decrease tear production (14 mm OD, 10 mm OS).

On day 87, an exploratory laparotomy confirmed the presence of a mid-jejunal mass. Two additional masses were present within the mesentery adjacent to the jejunal mass. Histopathology of the resected jejunal mass revealed severe pyogranulomatous inflammation with intralesional filamentous bacteria. Filamentous bacterial organisms that were suspected to be *Nocardia* were visualized by light microscopy after staining with gram stain (gram positive), Ziehl-Neelsen (negative), and Kinyoun's acid fast stains (positive). Culture of the jejunal mass for aerobic bacteria, anaerobic bacteria, and fungi yielded very small numbers of *Lactobacillus acidophilus*, 2 colonies of *Candida albicans,* and small numbers of *Nocardia veterana*. The *Candida* isolate was identified by conventional phenotypic bacterial identification methods as well as matrix-absorption laser desorption ionization-time-of-flight mass spectrometry [MALDI-TOF MS] by comparison with the manufacturer's database.[f] The *Lactobacillus acidophilus* and *Nocardia veterana* isolates were also identified by MALDI-TOF MS. According to the manufacturer, scores <1.7 indicate no reliable identification, scores 1.7 to 1.999 indicate probable genus identification, scores between 2.0 and 2.299 indicate secure genus information and probable species identification, and scores between 2.3 and 3.0 indicate secure genus and species identification. For MALDI-TOF MS, a portion of the colony was spotted onto the manufacturer's stainless steel target plate and allowed to dry. The spot was treated with 70% formic acid in water and allowed to dry before the matrix (α-cyano-4-hydroxycinnamic acid) was applied (extended direct transfer method). The MALDI-TOF MS score values were 2.2, 2.3, and 2.2, for *Candida*, *Lactobacillus*, and *Nocardia* isolates, respectively. Aerobic bacterial culture of the skin biopsies that had been obtained before antimicrobial drug treatment also yielded *Nocardia* via MALDI-TOF MS (score value 1.6), and the isolate was confirmed to be *N. veterana* by sequencing of the *secA1* gene[g] (100% homology).[1] Additionally, aerobic bacterial culture of a urine specimen obtained by cystocentesis yielded growth of 100 colony-forming units/mL of *N. veterana* as identified by MALDI-TOF MS (score value 1.7). Three consecutive

blood samples were each obtained for aerobic and anaerobic blood cultures before antimicrobial drug treatment, which yielded growth of *N. veterana* as identified by MALDI-TOF MS (score value 2.1) in 1 aerobic and 1 anaerobic bottle. *Staphylococcus pseudintermedius* was grown in another aerobic bottle, identified through both conventional phenotypic identification methods and MALDI-TOF MS (score value 2.0), and was thought to represent a contaminant. Antimicrobial susceptibility testing of *Nocardia* isolates from the skin biopsy by broth microdilution according to Clinical and Laboratory Standards Institute methodology[h] revealed susceptibility to TMS [Minimum inhibitory concentration (MIC) ≤0.25/4.75 μg/mL], imipenem (≤2 μg/mL), clarithromycin (≤0.06 μg/mL), and amikacin (≤1 μg/mL).

The dog was treated in hospital for 10 days with TMS (30 mg/kg IV q12h), prednisone (0.6 mg/kg, PO q24h for 5 days and then 0.3 mg/kg PO q24h), methadone (0.17 mg/kg IV q6h) postoperatively, and maropitant[i] (1 mg/kg IV q24h). Four days after anesthesia, clinical signs suggestive of esophagitis developed that included gagging and odynophagia. Treatment with pantoprazole[j] (1mg/kg IV q12h) and sucralfate (60mg/kg PO q8h) were initiated with complete resolution of clinical signs within 2 days. The dog was discharged from hospital with instructions to the owner to treat with TMS (29 mg/kg PO q12h) and to taper the course of prednisone (0.3 mg/kg PO q48h for 7 days then discontinue). Trimethoprim-sulfamethoxazole was continued for a total of 3 months with gradual improvement in the right thoracic limb lameness, skin lesions, the inflammatory leukogram, liver enzyme activities and hyperbilirubinemia. During this time, serum cholesterol concentrations were markedly elevated (at peak, 931 mg/dL, RR 139–353 mg/dL) despite discontinuation of prednisone. Within 1 month of TMS discontinuation, all biochemical variables had returned to within normal limits. Aerobic and anaerobic bacterial blood cultures were performed 1 month after discontinuing TMS and were negative. Two months after discontinuation of antimicrobial drugs, the dog was re-evaluated for an acute onset of reluctance to walk and lumbosacral pain. An MRI revealed a right-sided L3-4 intervertebral disk herniation. There was complete recovery after a second hemilaminectomy. No other clinical signs of disseminated nocardiosis or IMPA have developed in the year since discontinuing antimicrobial and immunosuppressive drugs.

Discussion

This is a detailed description of the use of MALDI-TOF for identification of *Nocardia veterana* in a dog in North America. It also describes successful treatment of *Nocardia veterana* bacteremia in a dog with antimicrobial drugs and discontinuation of immunosuppressive drug treatment. *Nocardia* are filamentous branching gram-positive bacteria found in soil and plant matter. Disseminated nocardiosis is a relatively uncommon disease in dogs and cats and is most often reported in immunocompromised animals or in individuals on immunosuppressive medications such as cyclosporine.[2,3] With the more widespread application of gene sequencing and MALDI-TOF MS for bacterial identification, novel species of *Nocardia* have been identified, including *N. veterana*, which was first discovered in 2001 in human bronchoalveolar lavage fluid.[4] Initially, the role of *N. veterana* in clinical disease was poorly understood, but it was subsequently isolated from a mycetoma in a woman with systemic lupus erythematous (SLE).[5] Phylogenetically, *N. veterana* is closely related to *N. nova*, *N. africana*, and *N. vaccinii* and until recently had been indistinguishable from these species based on antimicrobial susceptibility testing and restriction fragment length polymorphism (RFLP) analysis.[6,7]

Historically, 16S rRNA gene sequencing has been used most commonly for identification as the 16S rRNA gene is highly conserved among *Nocardia* species.[8] However, in the case of a newer *Nocardia* spp., *N. kruczakiae*, and *N. veterana*, 16S rRNA gene sequencing could not differentiate between these 2 distinct species.[9] New techniques using *secA1* gene were able to discriminate between different *Nocardia* spp. better than 16S rRNA gene and therefore may be more clinically useful for *Nocardia* spp. identification.[1] These techniques, however, are not readily available at most clinical laboratories, and with results taking up to several days to return, implementation of appropriate treatment can be delayed. MALDI-TOF MS has recently emerged as a rapid and reliable method of species identification.[10] Within minutes, MALDI-TOF MS analyzes the protein composition of a bacterial or fungal isolate and compares it to a library of mass spectrometry profiles, which is unique for each species. The ability of this technology to rapidly determine the identity of a bacterial isolate makes this technology particularly useful for identification of slow-growing, fastidious organisms such as *Nocardia*.[11] Some of the isolates made from the dog reported here had low identity score values. Recently, it has been shown that repeat extraction, duplicate spotting on the target plate, and addition of other libraries can increase genus-level and species-level identification significantly.[12]

Since it was first isolated, fewer than 20 cases of *N. veterana* infection have been reported in the human literature.[5,7,13–18] Inhalation is thought to be the most common route of transmission, and in the few reported cases of human *N. veterana* infections, pulmonary manifestations predominate.[6,7,13] However, a wide variety of other clinical manifestations of *N. veterana* infection have been reported in humans including urinary tract infections, brain and bowel abscesses, endogenous endophthalmitis, nodular lymphangitis, mycetomas, and bacteremia.[5,14–19] In veterinary medicine, reports of *N. veterana* infection have been limited to bovine mastitis resulting from direct inoculation, and a puppy from Germany with disseminated *N. veterana* infection and concurrent canine distemper virus infection.[20,21] In the latter case, diagnosis

was made at necropsy and as in the study reported here, bacterial isolates from lung tissue were identified by MALDI-TOF MS and confirmed with 16S rRNA gene sequencing.

In this dog, it is unclear whether disseminated *N. veterana* infection led to a secondary IMPA or whether the immunosuppressive drugs used to treat primary IMPA predisposed the dog to nocardiosis. In people with disseminated nocardiosis, approximately 65% have underlying immunodeficiency, so it may be more likely in this case that combination immunosuppressive drug treatment was responsible.[22] In addition, the dog was clinically stable for 3 months after initiation of immunosuppressive drug treatment, so it seemed unlikely that nocardiosis contributed to the clinical signs of IMPA. However, after treatment for *Nocardia* and discontinuation of immunosuppressive drug treatment, there has been no relapse in clinical signs for IMPA. In this case, cyclosporine treatment was instituted despite clinical improvement because of persistent mild neutrophilic joint inflammation. More evidence is required to determine whether decisions about immunosuppressive drug treatment should be based on serial monitoring of synovial fluid. In light of the risks of opportunistic infections, perhaps treatment with multidrug immunosuppressive treatment should be reconsidered in dogs that develop clinical resolution of IMPA despite cytologic evidence of persistent joint inflammation.

Infection with *N. veterana* might have followed inhalation in this dog, or alternatively, it might have followed ingestion of a contaminated penetrating foreign body, especially as the dog had a history of chewing sticks. The latter could also have explained the gagging behavior that was initially observed, which was otherwise unexplained. Additionally, culture of the focal jejunal mass grew *Lactobacillus acidophilus* as well as *Candida*, suggesting the possibility of perforation secondary to direct trauma or the inflammatory lesion itself. Histopathology of the jejunal mass revealed no evidence of plant or foreign material. Finally, it is possible that the organism was introduced by direct cutaneous inoculation, such as from a plant awn or other penetrating organic matter.

Identification of the *Nocardia* species involved is important because it can predict susceptibility to antimicrobials, which differs among *Nocardia* species, and can be difficult to determine accurately through in vitro susceptibility testing.[23] *Nocardia veterana* tends to be resistant to many antimicrobial drugs.[24] In this case, the *N. veterana* isolate was susceptible to TMS, imipenem, amikacin, and clarithromycin. The TMS was chosen because of its recognized activity against *Nocardia* spp., low cost, and oral formulation, despite the breed predisposition to keratoconjunctivitis sicca and the history of IMPA. No adverse effects of TMS were noted during treatment, although there was concern that the profound hypercholesterolemia that developed after discontinuation of prednisone could have resulted from sulfonamide-induced hypothyroidism. When nocardiosis is severe or refractory to monotherapy, combination antimicrobial treatment can be instituted.[8] The optimal duration of treatment is not known but is generally recommended for at least 6 months in people with disseminated nocardiosis, and recurrence of disease is common.[25] In this case, treatment with TMS was only for 3 months, but the granulomatous masses in the small intestinal tract were surgically excised and the underlying immunosuppression was reversible, which likely also facilitated elimination of the pathogen. Additionally, early intervention with appropriate antimicrobial treatment with the aid of MALDI-TOF MS may have played a role in the successful treatment of this dog. In this case, identification of *Nocardia* spp. by MALDI-TOF MS occurred 7 days before results of *secA1* gene sequencing were available. The decision to discontinue treatment early was due to resolution of skin lesions, lameness, and hematologic abnormalities within about 6–8 weeks. The absence of clinical relapse 1 year after discontinuing antimicrobial treatment suggests infection was eliminated.

Conclusion

Early detection and intervention is critical for patients with opportunistic infections secondary to immunosuppression. The identity of the organism to the species level in this dog was facilitated by MALDI-TOF MS and led to initiation of appropriate antimicrobial treatment sooner than traditional gene sequencing methods. The clinical utility of MALDI-TOF MS could have broader applications, particularly in animals with uncommon infections that are slow-growing and fastidious. In this case, successful treatment of disseminated *N. veterana* infection was possible with proper antimicrobial treatment and might be facilitated if underlying immunosuppressive drug treatment can be discontinued.

Footnotes

[a] SNAP 4Dx Plus Test, IDEXX Laboratories Inc., Westbrook, ME
[b] Fastpanel PCR Canine Respiratory Panel, Antech Diagnostics, Irvine, CA
[c] Convenia, Zoetis LLC., Parsippany, NJ
[d] Atopica, Elanco Animal Health, Greenfield, IN
[e] Unasyn, Pfizer Inc., New York, NY
[f] MALDI Biotyper® CA System, Bruker Daltonics Inc., Billerica, MA
[g] *secA1* Gene Sequencing Identification Test, University of Texas Health Center at Tyler, *Mycobacteria/Nocardia* laboratory at Tyler, TX
[h] Performance Standards for Antimicrobial Disk and Dilution Susceptibility Tests for Bacteria Isolated from Animals, 4ed., Clinical Laboratory and Standards Institute, Wayne, PA, clsi.org.
[i] Cerenia, Zoetis LLC., Parsippany, NJ
[j] Protonix, Pfizer Inc., New York, NY

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Conflict of Interest Declaration: Authors declare no conflict of interest.

Off-label Antimicrobial Declaration: Authors declare no off-label use of antimicrobials.

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