PEER REVIEWED

Mycoplasma Infection in Cattle. I. Pneumonia – Arthritis Syndrome

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Abstract

Mycoplasma spp. are unique microorganisms associated with several disease entities, including a pneumonia-arthritis syndrome in cattle. One of the challenges in determining the role of *Mycoplasma* spp. in bovine disease is that this organism has been isolated from both normal and diseased animals. When dealing with field cases of mycoplasma pneumonia, it is common to find mixed infections. Additionally, observations from research studies and clinical experience have indicated that the presence of mycoplasma increases the severity of respiratory disease. There are no pathognomonic signs for mycoplasma infections. Clinical signs associated with respiratory infections include tachypnea, dyspnea, ocular and nasal discharge, depression, decreased appetite, arched stance and fever. Clinical signs associated with joint infections include stiffness, lameness, difficulty when rising, swollen joints and tendon sheaths, decreased appetite and weight loss. The organism requires special growth media and conditions to be cultured in the laboratory. If a practitioner wants to confirm a diagnosis with a positive culture, he/she must specifically request a mycoplasma culture when samples are submitted to the laboratory. Besides determining the significance of *Mycoplasma* spp. in disease, the practitioner is faced with recommending appropriate and effective treatments. Response to therapy, both experimentally and under field conditions, is variable and frequently unrewarding. Since mycoplasma organisms are resistant to several therapies, sound biosecurity and biocontainment programs that minimize stress and exposure to the organism are the best recommendations that practitioners can discuss with producers for prevention and control.

Résumé

Les mycoplasmes sont des microorganismes particuliers associés à plusieurs types de maladies incluant le syndrome de pneumonie-arthrite chez les bovins. L'un des défis pour déterminer l'implication des mycoplasmes dans les maladies bovines réside dans son isolation chez des sujets autant sains que malades. En pratique, lors de pneumonie à mycoplasme, il n'est pas rare de retrouver des infections mixtes. De plus, les observations en clinique et en recherche ont indiqué que la présence des mycoplasmes augmentait la sévérité des maladies respiratoires. Il n'y a pas de signes pathognomoniques des infections à mycoplasme. Les signes cliniques associés aux infections respiratoires incluent la tachypnée, la dyspnée, l'écoulement nasal et oral, la dépression, la perte d'appétit, une posture cambrée et la fièvre. Les signes cliniques associés à l'infection des articulations incluent la raideur, la boiterie, la difficulté à se lever, l'enflure des articulations et des gaines tendineuses et la perte d'appétit et de poids. L'organisme requiert des conditions et un milieu de culture spécifiques pour sa croissance en laboratoire. Si le praticien veut confirmer un diagnostic avec une culture positive, il devra demander spécifiquement d'inclure une culture de mycoplasmes lorsque les échantillons sont soumis au laboratoire. Au-delà de l'implication des mycoplasmes dans la maladie, le praticien doit aussi recommander des traitements appropriés et efficaces. La réaction au traitement, aussi bien expérimentalement que sur le terrain, est variable et souvent négative. Comme les mycoplasmes sont résistants à plusieurs types de traitements, l'élaboration d'un bon programme de biosécurité pour diminuer la transmission et minimiser le stress et l'exposition aux

organismes sera la meilleur recommandation du praticien lors des discussions avec les producteurs sur la prévention et le contrôle.

Introduction

Preventing and treating infectious diseases are concerns and challenges for producers and practicing veterinarians. Bovine Respiratory Disease (BRD) is a major concern to all segments of the cattle industry. *Mycoplasma* spp. have been associated with the BRD complex, specifically a pneumonia-arthritis syndrome. Information from the recent National Animal Health Monitoring System (NAHMS) Beef '97 study indicated the percentage of beef calf deaths was unchanged from the Cow/Calf Health and Productivity Audit (CHAPA) of 1992-93. However, deaths attributed to respiratory problems increased.[53]

Practitioners are aware of the many contributors to the BRD complex, also commonly known as shipping fever. Viruses such as infectious bovine rhinotracheitis virus (IBRV), bovine viral diarrhea virus (BVDV), parainfluenza type 3 virus (PI_3), bovine respiratory syncytial virus (BRSV), as well as stressors including changes in weather and nutrition, transport times and commingling, all play a role in predisposing cattle to BRD.[30,35] *Mannheimia haemolytica* (formerly *Pasteurella haemolytica*), *Pasteurella multocida* and *Haemophilus somnus* are the major bacterial components in the BRD complex.[30,35] Other organisms, including *Mycoplasma* spp., have been isolated from the respiratory tract of cattle suffering from BRD. However, the role of the *Mycoplasma* spp. in this complex is controversial, especially regarding whether it is a primary or secondary pathogen. This paper summarizes the literature regarding the pneumonia-arthritis syndrome in cattle caused by *Mycoplasma* spp.

Organism

Mycoplasma spp. are unique organisms belonging to the family *Mycoplasmataceae* and the genus *Mycoplasma*. Although *Ureaplasma* spp. are members of the same family, *Ureaplasma* spp. produce a urease enzyme while *Mycoplasma* spp. do not. *Acholeplasma* spp. are in yet a separate family, *Acholeplasmataceae*, and do not require sterol for growth.[18,32] *Mycoplasma* spp. are relatively host-specific; they can infect other animals, but primarily produce disease in a particular host. Those that infect cattle are classified into groups 1 to 8. *Acholeplasma laidlawii*, formerly known as *Mycoplasma laidlawii*, is in group 6.[32]

These microorganisms have unique features and characteristics, including a small genome and lack of a characteristic cell wall, compared with commonly encountered pathogenic bacteria of cattle. Instead of a typical cell wall, they possess a limiting membrane. Special culture media, growth substances and conditions are necessary to isolate these microorganisms. Culture of *Mycoplasma* spp. requires longer incubation times than other bacterial pathogens. In a laboratory, typical colony growth on agar is described as having a "fried egg" appearance. Laboratories must use serological tests to perform species differentiation on the isolated colonies. Species identification determines the organism's potential significance in the disease process. Because of the special conditions involved, the practitioner must wait longer for results of *Mycoplasma* spp. cultures than for routine bacterial cultures.

Other known pathogens in the *Mycoplasmataceae* family are frequently recovered from the respiratory system and other tissues of diseased animals.[3,10,11,21,25,31,51,55] Isolation of more than one organism has made it difficult to determine the significance of the role of *Mycoplasma* spp. Isolates from diseased animals include *M. dispar*, *M. bovirhinis*, *Ureaplasma diversum*, *M. bovis*, *Aceholeplasma laidlawii*, *M. alkalescens*, *M. arginini*, *M. canis*, *M. bovigenitalium* and *M. bovimastitidis*.[1,2,3,7-11,14,17,19,21,24,26,31,33,37-45,47,48,49,50,51,52] *M. bovis* is frequently isolated from cattle with the pneumonia-arthritis syndrome, and is generally considered the most pathogenic mycoplasma organism in cattle for this syndrome.[2,3,7,11,17,19,21,23,26,31,37,40,45,51,55]

Amies or Modified Stuarts transport media culture swabs are recommended for submission of antemortem samples. Aseptic collection of postmortem tissue specimens is necessary to minimize contamination. For best results, specimens should be refrigerated and submitted with ice packs to the laboratory as soon as possible after sample collection. Since most diagnostic laboratories do not routinely culture for *Mycoplasma* spp., practitioners must specifically request these tests.

Prevalence

Contagious Bovine Pleuropneumonia (CBPP), caused by *Mycoplasma mycoides* subspecies *mycoides*, is highly contagious and causes significant economic losses in cattle. The disease still occurs in some developing areas in the world, but fortunately has been eradicated from many countries, including the United States. There are several reports from around the world involving *Mycoplasma* spp. and BRD.

In a 1978 report from Northern Ireland, 34 outbreaks of respiratory disease in two- to six-month-old calves were investigated. Both home-raised dairy calves and purchased beef calves were involved. Of 43 calves examined, 42 had extensive pneumonic lesions. *Pasteurella* spp., *Mycoplasma* spp. and PI_3 were the most common isolates from the lungs. Addition-

ally, in nine of the calves, more than one *Mycoplasma* spp. was isolated.[10]

In Scotland, 10 Hereford crossbred six- to-eight-week-old calves were involved in an acute outbreak of severe pneumonia. Two of the 10 calves were selected for necropsy examination and diagnostic tests. *Mycoplasma bovis* and *Mycoplasma bovirhinis* were cultured from the first calf, and *Mycoplasma bovis*, *Acholeplasma laidlawii* and *Streptococcus bovis* were cultured from the second calf. No viruses were isolated from either calf. Although other calves recovered in two to three weeks, specific therapies were not mentioned in the article.[3]

A survey from the Netherlands reported that *Mycoplasma bovis* was detected in 59 of 83 herds. Samples examined in this study of 20% dairy herds and 80% fattening herds included respiratory tract specimens and cultures of calves with respiratory disease.[48]

A total of 322 heifers and steers from five Ontario feedlots were examined serologically at arrival and again approximately 28 days later. Indirect hemagglutination titers were performed for both *M. bovis* and *M. dispar*. Titers to *M. bovis* increased in cattle at all five locations and to *M. dispar* in cattle at four of the five locations. The study also showed that cattle with increased *M. dispar* titers were at significantly greater risk of treatment for respiratory disease. These findings suggested the organisms, especially *M. dispar*, were components of BRD.[39]

The Texas Veterinary Medical Diagnostic Laboratory in Amarillo reported culture results of 435 lungs of feedlot heifers and steers from a four-state area that died of BRD. Of the 435 lungs cultured, 409 were positive for *Mycoplasma* spp. According to histories that accompanied the samples, slightly over 50% of the cattle had received antibiotics. The most common isolate was *Mannheimia haemolytica,* with a relative incidence of 49.7%. *Mycoplasma* spp. were the second most common isolates with a relative incidence of 33.3%.[55]

Clinical Signs and Observations

There are no pathognomonic clinical signs to help the practitioner specifically identify respiratory disease caused by *Mycoplasma* spp. Some of the signs observed include tachypnea, dyspnea, ocular and nasal discharge, depression, decreased appetite, arched stance and fever. Episodes of BRD also cause these clinical signs, making it difficult for practitioners to make an accurate etiologic diagnosis without laboratory confirmation. Historical information may be helpful in suggesting mycoplasma's role in an outbreak of respiratory disease. A common history is that clinical signs of pneumonia started in the cattle three to four weeks after arrival, and the infected animals failed to respond to routine therapy.[2,31,33,38] Field reports from practitioners in North America, however, indicate that clinical signs occur earlier, at two-to-three weeks after arrival. Additionally, cattle may exhibit lameness due to arthritis-synovitis or polyarthritis. Large rotatory joints such as the shoulder, elbow, carpal, hip, stifle and hock joints are most frequently described in reports and anecdotally from practitioners.[2,23,31,36,38,45,50] In one report involving feedlot cattle in Canada, 25 of 29 lung specimens yielded *Mycoplasma bovis*. Samples from arthritic joints of 12 of these animals also yielded *M. bovis*.[31]

Necropsy findings reflect the consequences of a suppurative bronchopneumonia with some degree of pleural involvement. Although most of the lesions are distributed in the cranial lobes, the caudal lobes can also be involved in severe, complicated cases.[3,10,17,38] Abscesses can be identified in the lung parenchyma, and if pressure is applied to the lung tissue, purulent material and fluid exude from the bronchi on cut surface of the lung.[1,2,3,10,17,38] Affected areas of the lungs are firm, and red or purple in color due to consolidation and hemorrhage.[10,19,37,38,50] The interlobular septa may be easily identified and edematous.[10,51]

Experimental infections in calves with *Mycoplasma* spp. have demonstrated varying degrees of lung involvement. In one experiment, four calves inoculated with only *M. bovis* showed consolidation of 5 to 14% of the lung. In all four experimentally infected calves, catarrhal bronchiolitis with peribronchiolar cuffing was identified microscopically.[19]

Mixed infections are common in the field. Another experiment looked at infecting calves concurrently with BRSV and *Mycoplasma bovis*. Lung consolidation in calves infected with only *M. bovis* ranged from 4 to 10% in six of seven calves. In the seventh individual, lung consolidation was 37%. In most of the calves, interlobular septa were prominent. Histological lesions included varying degrees of coagulative necrosis, suppurative bronchiolitis, and peribronchiolar lymphoreticular hyperplasia.[51]

The same researchers infected another group of five calves with both *M. bovis* and BRSV. No significant differences in clinical signs or postmortem lesions were found between the two groups. However, mean duration of bacteremia was longer with the combined infections (9 days versus 2.7 days).[51]

Another experiment compared dual infections with *Mycoplasma bovis* and *Mannheimia haemolytica* in gnotobiotic and conventionally reared calves. More severe consolidation of lung tissue occurred when *M. bovis* was administered before *Mannheimia haemolytica*, especially in the group of gnotobiotic calves, where lung consolidation ranged from 16 to 64%. When calves received the *Mannheimia haemolytica* infection before the *M. bovis* infection, only 1% of the lung was consolidated. In the conventionally reared

calves, the percentage of lung consolidation was more variable. However, the order of infections produced similar results in the severity of lesions as with the gnotobiotic calves.[17]

In an Academy of Veterinary Consultants presentation, 21 of 99 cases of pneumonia were suspect for *M. bovis*. Of those, 16 were culture-positive for *M. bovis*, including six which had *M. bovis* as the only significant pathogen.[38] Mycoplasma organisms have been frequently isolated from normal cattle[8,9,41,52] and the organisms have been isolated from nasal swabs of normal calves that have nursed cows infected with mycoplasma mastitis.[8,14] These findings have fueled the debate as to mycoplasma's role in BRD.

Cattle with arthritis may exhibit stiffness, lameness, difficulty when rising, swollen joints and tendon sheaths, decreased appetite and weight loss. More than one joint may be affected, and the swelling may not be obvious until a few days after lameness is noted.[24,40,44,45] Cattle exhibiting mild clinical signs may recover within a few days,[24,40,44,45] but cattle exhibiting more severe signs and obvious joint or tendon sheath swelling usually do not recover, even with antimicrobial therapy.[2,22,24,38,42,45] There are, however, reports of cattle recovering after treatment for mycoplasma arthritis.[19,40] Synovial fluid is usually turbid and yellow, and may contain thick, purulent debris. Synovial fluid analysis reveals a poor mucin clot, elevated protein content and an increase in segmented neutrophils.[5,40,43,45,54] Necropsy findings of affected joints include thickened joint capsules, normal-appearing to purulent debris in the synovial fluid, and arthritic changes in the joints.[2,23,36,38]

Pathogenesis and Transmission

The exact role of *Mycoplasma* spp. in natural respiratory disease has been debated among professionals for several years. *Mycoplasma mycoides* subspecies *mycoides*, the causative agent of CBPP, can alone cause clinical disease. Mycoplasma organisms have been isolated from many diseased lungs. Other respiratory pathogens, such as *Mannheimia haemolytica*, *Pasteurella multocida*, *Haemophilus somnus*, BRSV, BVDV, PI_3 and IBRV are also frequently isolated.[2,3,10,11,17,38,49,55] Moreover, there are reports of naturally occurring or experimentally induced respiratory disease caused by *Mycoplasma* spp. with no other isolates identified.[3,19,38,50]

Researchers and clinicians have observed that the presence of mycoplasma increases the severity of respiratory disease.[2,17,21,26,38] Several possibilities exist regarding the role of mycoplasma in respiratory disease. An inflammatory toxin has been isolated from *Mycoplasma bovis,* which can activate the complement system and increase vascular permability.[16] Mycoplasma organisms can attach to the mucosal layer of the respiratory epithelium, such that the host's cells may absorb the organism or part of the organism and hence not reject it. The organism could reside in the respiratory tract as an opportunist.[18,29] There is additional evidence that mycoplasma organisms are immunosuppressive, which allows other organisms to multiply and create severe disease.[18,23] Synergism between other respiratory pathogens appears to play a role in the pathogenesis of mycoplasma infections.[11,17,21,26]

Some of the above-mentioned characteristics of mycoplasma, including damage to vascular membranes and ability to penetrate cells, allow the organism to enter systemic circulation. Because the organism has an affinity for membrane surfaces, it can readily colonize the synovia in one or several joints.[22,33,43] It is not uncommon that a *Mycoplasma* spp. is the only isolate from a septic joint.[2,7,19,24,31,40,43,44,45,48]

Diagnosis

History, clinical signs and gross postmortem findings aid the practitioner in clinically diagnosing mycoplasma pneumonia-arthritis. However, a positive culture of a known pathogenic species from affected tissues is required for a definitive diagnosis. A positive culture from cattle nasal passages may not be helpful, since the organism is found in normal calves.[9,16] To reiterate, because of the unique features and characteristics of the organism, it will not grow when using routine aerobic culture techniques. Practitioners may need to specifically request a mycoplasma culture from some diagnostic laboratories. When practitioners look for this etiologic agent, it is frequently found.

Other tests used by practitioners to support a diagnosis of mycoplasma include histopathological examination with immunohistochemistry (IHC) and cytology. When mycoplasma infection is suspected, a positive IHC test can support the diagnosis. Specific antibodies against *M. bovis* identify the antigen in affected tissue.[1,38] Immunohistochemistry may be useful in cases that have been treated with antimicrobials and are negative for culture, or if the cultures are overgrown by bacteria.[56] Polymerase chain reaction (PCR) has received attention lately as another possible diagnostic tool for mycoplasma, but most laboratories do not offer this test.[56]

Specimens from affected lung tissue should be collected for analysis. Tissue at least 5 inches (2 cm) in diameter should be collected from pneumonic areas, and 2 inches (1 cm) in diameter from non-pneumonic lung.[15] The microscopic finding of mononuclear cells (lymphocytes) accumulated around the bronchi and bronchioles, frequently described as a "cuffing pneumonia", supports the diagnosis. Other microscopic findings described include coagulative necrosis and microabscesses, espe-

cially in the peribronchiolar region.[1,10,17,18,37] Identifying the organism by IHC techniques in fixed tissue also supports the diagnosis. Cytological evaluation of synovial fluid generally reveals a typical septic exudate. An elevated protein and leukocyte count and poor mucin clot, although observed in many septic arthritides, confirms or strongly suggests a septic joint. The presence of antibodies to *Mycoplasma* spp. is indicative of exposure to mycoplasma. However, serologic tests for mycoplasma are usually performed only in research laboratories, and can be expensive.[46]

Therapy

There are no approved drugs in the United States labeled specifically for treating mycoplasma infections in cattle. In practice, animals suffering from severe infections frequently respond poorly to treatment. Several reported studies, both *in vitro* and *in vivo*, have investigated the efficacy of various drugs.

In a Northern Ireland study which compared the minimum inhibitory concentrations (MIC) of enrofloxacin, lincomycin, spectinomycin and tilmicosin for *Mycoplasma bovis,* enrofloxacin demonstrated greater mycoplasmacidal activity towards *M. bovis* than the other antibiotics.[6] No *in vivo* clinical studies were done, however, to evaluate response to treatment. However, since enrofloxacin is labeled for the treatment of BRD caused by *Mannheimia haemolytica*, *Pasteurella multocida* and *Hemophilus somnus* in the United States, treating cattle for mycoplasma pneumonia would be an extra-label use of the product and would violate federal law.

Other researchers have compared the *in vitro* activity of danofloxacin, florfenicol, oxytetracycline, spectinomycin and tilmicosin on 62 *Mycoplasma bovis* field isolates. While there was no evidence of danofloxacin resistance, nearly all the isolates were resistant to tilmicosin. No studies were done to determine clinical response to treatment.[4]

In another study, tilmicosin was administered to a group of calves six hours before experimental infection with *Mannheimia haemolytica* and *M. bovis*. The drug was given to a second group of calves at the onset of clinical signs following experimental infection. Colonization of the lung by *Mannheimia haemolytica* was prevented while colonization by *M. bovis* was greatly reduced, demonstrating that the drug had a beneficial effect.[20] Investigators in another trial treated calves with naturally occurring respiratory disease with either tilmicosin or a combination of lincomycin and spectinomycin. *Mycoplasma* spp. and respiratory pathogens were isolated from the calves. While improvement occurred in both treatment groups, calves treated with tilmicosin improved more rapidly.[34]

Other drugs, including tylosin and tetracyclines, have been used with varying results to treat mycoplasma infections. Despite periodic support from laboratory and clinical trials for a particular treatment, response to treatment is generally unrewarding and disappointing. Since results vary, it is difficult to recommend any particular treatment regimen with confidence.

There are possible explanations for disappointing treatment outcomes. Some of the common antimicrobials used to treat BRD have no activity against *Mycoplasma* spp. because the organism lacks a cell wall. Additionally, different strains of the organism vary in their susceptibility to specific drugs.[34,38,55] Many drugs fail to achieve therapeutic concentrations in certain tissues, such as in synovial fluid, and tissue damage is often so extensive that the disease process is irreversible.[23] In addition, the organism's unique ability to evade the host's immune system or cause immunosuppression may also contribute to treatment failure.[18,29]

Despite an often unfavorable prognosis, most clients want to attempt treatment of their animals. Results of culture (with speciation) and sensitivity testing can serve as a guide for selection of the antimicrobial. Supportive or symptomatic therapy is also indicated in some situations. In cases of septic arthritis, affected joints may need to be flushed several times. In commercial situations, however, individual care often is not an option.

Control

When dealing with outbreaks, a biocontainment program must be initiated for other animals in the herd. If an animal is suffering from severe chronic pneumonia or severe septic arthritis, it may be more humane to euthanize the animal. Practitioners and producers must make those decisions on an individual basis.

Sound biosecurity and biocontainment programs to guard against mycoplasma infections are not unique to those utilized for other infectious agents. Immunosuppressed animals are more susceptible to infections. Since stress plays a major role in many diseases of food-producing animals by causing immunosuppression, minimizing stress is beneficial. Specifically, minimizing noise from working chutes, people and dogs; length of transport; amount of commingling; time in holding pens; and avoiding drastic dietary changes should be recommended. By taking actions to minimize these stressors, the animal's immune system can have the best opportunity to function properly to prevent disease.

Minimizing or eliminating exposure to mycoplasma organisms is also important in developing a sound preventive program. If a dairy has mycoplasma mastitis, infected cows should be milked last to prevent contamination of equipment and infected milk

should not be fed to calves. Eliminate unnecessary traffic through the farm or ranch to prevent potential fomite transmission from vehicles and people. Isolate all new arrivals if possible and in the case of dairy cattle, culture these animals to identify any mycoplasma carriers. Additionally, ask the seller if they have a history of mycoplasma problems in their herd. This information will help determine the potential risk to the new herd.[18,37,46]

Since mycoplasma organisms can be secondary invaders, steps should be taken to eliminate this opportunity. Identification of sick cattle early in the disease process and prompt treatment to eliminate primary infections is a must. Also, preparing cattle for where they are going by stimulating a suitable degree of immunity against respiratory diseases should also decrease the likelihood of mycoplasma infections. Pre-conditioning programs that include vaccinating for respiratory diseases and parasite control are sound recommendations practitioners should make to their producers.

Vaccines have been used in challenge experiments and have demonstrated protection against both respiratory disease and arthritis.[12,13,27,28,49] A southern England field trial used a killed vaccine containing BRSV, PI_3, *M. bovis*, and *M. dispar*. Calves receiving this combination vaccine were compared to calves that received a monovalent killed BRSV vaccine, and to un-vaccinated control calves. Results demonstrated significant protection. Calves vaccinated with the combination vaccine were better protected against natural challenge than calves that received the BRSV vaccine or the controls.[28]

Another experiment investigated colonization of the lungs with *M. bovis* in calves that either received an *M. bovis* vaccine or served as non-vaccinated controls. There were two vaccinated groups of calves. Calves in group one were initially vaccinated with inactivated vaccine by the intramuscular route, followed by a booster administered intratracheally. The second group of calves were vaccinated with two doses of the vaccine by the intramuscular route. Calves vaccinated both intramuscularly and intratracheally were better protected, as evidenced by fewer mycoplasma organisms being isolated from their lungs than the other calves. This suggests that local immunity may be important in the protection of calves against *M. bovis*.[27]

In another trial, both live and inactivated *M. bovis* was administered intravenously to one group of calves, while a second group served as unvaccinated controls. Clinical arthritis occurred in all control calves after challenge, while most vaccinated calves were protected. Moreover, in the vaccinated calves that did develop arthritis, the lesions were less severe than in the unvaccinated calves. These results suggest that vaccination may help control mycoplasma arthritis in cattle.[13]

Researchers in Canada and Great Britian compared synovial fluid immunoglobulin levels in vaccinated and control calves and found the vaccinated calves had significantly fewer immunoglobulins than the non-vaccinated calves. Vaccinated calves developed arthritis less frequently than the control calves. Two out of 12 vaccinated calves developed arthritis, but it was less severe than that of the control calves.[12]

Vaccination has not always resulted in a favorable outcome. A study at Iowa State University showed that calves vaccinated with a mycoplasma vaccine had more severe lung lesions following challenge than controls.[38] Currently the U.S. Department of Agriculture has not fully licensed any mycoplasma vaccines in the United States.

Conclusions

The pneumonia-arthritis syndrome presents challenges to practitioners and producers. Other pathogens such as *Mannheimia haemolytica*, *Pasteurella multocida* and *Haemophilus somnus* are frequently isolated with *Mycoplasma* spp. from cattle suffering from pneumonia. Mycoplasma arthritis has been observed in cattle following respiratory infections, as well as being a single disease entity. Mycoplasma infections are frustrating because there are no treatments that consistently perform well. Sound biosecurity and biocontainment programs are important components in a control program to minimize disease caused by mycoplasma infections and to minimize losses to the producer. While experimental challenge in vaccinated cattle has at times looked promising, there are currently no fully licensed USDA vaccines available in the United States.

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