Disease risks to animal health from artificial insemination with bovine semen

M.D. Eaglesome & M.M. Garcia
Agriculture and Agri-Food Canada, Animal Diseases Research Institute, 3851 Fallowfield Road, F.O. Box 11300, Station H, Nepean, Ontario K2H 8P9, Canada

Summary
Two of the major goals of artificial insemination of domesticated animals are to achieve continuous genetic improvement and to prevent or eliminate venereal disease. In comparison with natural service, fewer males are needed to artificially inseminate the same number of females and to produce the same number of offspring. However, there are risks associated with artificial insemination, which has the potential to disseminate genetic defects and also to spread infectious disease nationally and internationally. This paper focuses on the risks of six specific diseases which are transmitted in bull semen and outlines the appropriate measures to prevent these risks.

Keywords

Introduction
The regular testing of semen donors under official veterinary supervision has been adopted by governments world-wide as a means of avoiding the spread of pathogens and reducing excessive contamination of semen by ubiquitous bacteria. National standards for semen production and distribution are usually based on regulatory programmes to ensure that diseases of importance are identified and appropriate tests are applied to all sires entering and residing in artificial insemination (AI) centres. These programmes take into account the national health status as well as the health status of the herds and flocks of the semen donors. In interpreting health status, prime considerations include the sensitivity and specificity of tests, particularly when they are applied to individual animals, and the risk of latent infections. Testing programmes need to be continually improved and updated as new information on the epidemiology, pathogenesis and control of traditional diseases becomes available. As ‘new’ infectious diseases emerge, these additional challenges and risks must also be met (92). At the international level, guidelines are published by the Office International des Epizooties (OIE) to enable the health of animals in AI centres to be maintained and to facilitate the global distribution of semen which is free of specific pathogenic organisms (62).

The aims of this paper are as follows:

a) to provide information on some infectious agents known to be transmitted in bull semen

b) to discuss risk management methods which will help to control or prevent disease transmission through semen.

Infectious bovine rhinotracheitis/infectious pustular vulvovaginitis

Bovine herpesvirus-1 (BHV-1), also called infectious bovine rhinotracheitis/infectious pustular vulvovaginitis virus, is a member of the subfamily Alphaherpesvirinae and is one of the most common viral pathogens found in bovine semen. Reproductive disorders caused by BHV-1 include infectious pustular vulvovaginitis, endometritis, salpingitis, shortened oestrus cycles and abortions in susceptible female cattle and balanoposthitis in susceptible bulls. In BHV-1 infection of the genital tract of the bull, the virus replicates in the mucosae of the prepuce, penis and distal part of the urethra, and semen is most likely to be contaminated during ejaculation by virus shedding from infected mucosae.

Disease risk
Infections with BHV-1 strains, including attenuated live vaccine strains, have the ability to remain latent in clinically normal animals (65). Following reactivation, the virus is excreted in respiratory and ocular secretions, or in semen, and...
in the latter case excretion can be with or without a serum antibody response (95). BHV-1 causes economically important genital, respiratory and neurological diseases in cattle populations world-wide. Infected animals may be immunosuppressed and thus be more susceptible to secondary bacterial infections. BHV-1 infection of the male genital tract can result in mild or severe clinical signs of balanoposthitis or can be clinically inapparent (1). Bulls play an important role in the dissemination of the disease because the virus is excreted in semen both during the acute phase of infection and also following the establishment of latent infection (94).

When assessing the risk of semen containing BHV-1, it is important to recognise that clinical signs of the disease may not always be observed in outbreaks of BHV-1 infection in bulls (95), and that neither the presence of serum neutralising (SN) antibodies nor vaccination may completely prevent shedding of virus in semen. BHV-1 has been detected in semen from infected AI bulls which showed no signs of balanoposthitis, rhinotraceitis or generalised disease (28). In some instances, semen may be contaminated by a primary local infection of the prepuce before production of neutralising antibodies has occurred (103). Moreover, animals latently infected with BHV-1 may have very low antibody titres or be seronegative, especially if they have not been stressed and virus reactivation has not taken place for a long period of time (29). In addition, primary genital tract infection may induce very low antibody responses or even none at all (94). Studies in North America have shown that semen from BHV-1 seropositive bulls can be free of virus for periods of several years when bulls are appropriately managed in a low-stress environment (57).

**Diagnosis and control**

Methods of BHV-1 detection currently used by diagnostic veterinary laboratories include virus isolation, examination of tissues by the fluorescent antibody (FA) technique and serological testing (SN test or enzyme-linked immunosorbent assay [ELISA]). Another method is the 'Cornell semen test', in which pooled samples of semen are inoculated into susceptible calves or sheep which are then monitored for neutralising antibodies to BHV-1 (76). The traditional method for detection of BHV-1 in bovine semen is virus isolation and identification in cultures of cells of bovine origin (86). Dilution of the semen (1:20 to 1:128), prior to its inoculation onto cell culture, decreases its cytotoxicity (17, 100, 104). Molecular-based techniques are also being developed and used to detect the virus (97, 103). For example, polymerase chain reaction (PCR) assays can identify BHV-1 contaminated semen within one day (103). However, PCR is not yet applied routinely, even in well-equipped laboratories.

It is preferable to use only seronegative bulls in AI centres and bulls should be bled for further serological testing 21 days after the semen has been collected, as recommended by the OIE (62). To limit the risks of disease transmission when semen is collected from bulls of unknown or positive serological status, at least two straws per semen batch should be assayed for virus (94), because semen is diluted before being frozen and not all straws will necessarily contain virus.

Assay of blood for gamma-interferon, a measure of cellular immunity, can be used to discriminate between BHV-1 non-infected (or vaccinated) and infected animals, as well as to distinguish serologically positive infected bulls from those with maternal antibodies (42). Vaccination can be used to control BHV-1 infection in bulls in AI centres, but is not generally used at present (95).

**Bovine virus diarrhoea**

Bovine virus diarrhoea (BVD) virus, a ribonucleic acid (RNA) virus, has two main types characterised by non-cytopathic (NCP) or cytopathic (CP) effects on cultured cells. They are indistinguishable serologically. The NCP biotype may infect the foetus and establish a persistent infection (PI) which continues into post-natal life. A high proportion of adult cattle world-wide have antibody to BVD virus (BVDV), although most infections in adults are subclinical.

**Disease risk**

Infection with NCP biotypes causes congenital and enteric diseases as well as predisposing infections with other pathogens (e.g. BHV-1, Pasteurella or Salmonella spp.). In the latter instance, there may be increased disease severity compared to the disease caused by either agent alone, and this has been attributed to the immunosuppressive effect of BVDV. Some NCP biotypes of BVDV have caused haemorrhagic disease in cattle with a high mortality rate (11) and, in North America, virulent NCP strains have caused severe diarrhoea and death in adult cattle and veal calves with clinical signs similar to those of mucosal disease (30). The CP biotypes cause mucosal disease, which occurs only in PI animals. The CP virus appears to arise by mutation from the NCP virus within PI animals (59).

BVDV is excreted in bull semen during acute, transient infection and is also present in the semen of PI bulls (51, 52, 66). The virus is transmitted in the semen of such bulls during natural or artificial breeding (56), and causes reproductive losses in females (55, 99).

**Diagnosis and control**

Antibodies to BVDV may be detected by complement fixation (CF), indirect FA and SN tests (71). In addition, a number of ELISAs of high serological sensitivity and group specificity have been described (1, 22). Tests to detect BVDV include virus isolation (1), antigen capture ELISAs (79), and reverse transcription-PCR assays (68).

It is important that PI bulls are prevented from entering AI centres. The best method for identifying PI bulls is by virological examination of two blood samples collected four
weeks apart. As homologous maternal antibody may interfere with detection of the virus (71), calves aged less than six months should be treated as if of unknown status and kept separate from others. It should be noted that PI bulls can seroconvert following superinfection or after vaccination with a virus antigenically dissimilar to the persistent virus (30). Although there is some concern that live attenuated vaccines may be immunosuppressive and potentiate the effect of other pathogens (1), the emergence of virulent NCP strains, and the severe losses that they can cause, make it a prudent strategy to vaccinate bulls (30).

Bovine brucellosis

Bovine brucellosis is a bacterial disease caused mainly by Brucella abortus. In cattle, the disease is characterised by abortion and is often associated with retained placenta, metritis and a subsequent period of infertility. Brucellosis affects approximately 5% of livestock world-wide and continues to increase. It is also an important zoonosis.

Disease risk

Brucella abortus infection in bulls may involve the testis and epididymis, and also the seminal vesicle and ampulla. Infected bulls may be serologically positive or negative (70). The shedding of B. abortus in the semen of bulls has been reported and this may pose a risk of disease transmission by AI (8). In a recent study, following the experimental inoculation of mature bulls, B. abortus strain 19 was constantly present in semen, and this was accompanied by a specific antibody response (20). However, there was no overt increase in seminal immunoglobulin (Ig) concentration and no definite conclusions could be made concerning the protective role of seminal antibodies in limiting spread of infection at service.

Diagnosis and control

Serological tests are applied routinely to monitor for brucellosis. A major breakthrough was the elucidation of the structure of the O-chain of the smooth lipopolysaccharide (LPS) of B. abortus (21). Indirect and competitive ELISA formats have been developed and evaluated in several countries. The ELISA based on use of the O-LPS has been shown to be capable of discriminating between vaccinated animals and non-vaccinated, infected animals (61).

Laboratory tests include isolation or demonstration of the organism in tissues or fluids, and serological tests and agglutination tests on milk or seminal plasma, as described in a World Health Organisation (WHO) monograph (4). A colony blot ELISA exploits the use of monoclonal antibodies to smooth Brucella O-chain to detect Brucella colonies on agar media even in the presence of contaminants. A specific and sensitive PCR assay has also been developed (37). Deoxyribonucleic acid (DNA) amplification using six B. abortus gene sequences was found to be highly specific and sensitive but did not differentiate between the different Brucella species (27).

Some authorities in Brucella-free countries consider that the serum agglutination test is sufficiently sensitive for health certification of AI bulls (69), although more sensitive tests are available (38, 93). Reports of bulls shedding B. abortus in semen while their serum agglutination titres were low or negative (6) indicate the benefits of testing semen for the presence of the organism, or testing seminal plasma for agglutinins, particularly in areas of high risk. Live strain 19 vaccine and the killed 45/20 vaccine have both played an important role in the control of brucellosis. However, strain 19 may produce permanent infections in bulls similar to those of natural disease (60). New vaccines such as RB51, which is an avirulent rough mutant lacking an O-chain, can induce a protective cell-mediated immune response without an accompanying seroconversion (77), but the value of these vaccines in the field remains to be tested.

Leptospirosis

Leptospirosis, an important zoonotic disease caused by parasitic spirochaetes, is endemic in animal populations world-wide (5). Genetic studies have revealed heterogeneity among leptospires, and L. interrogans (i.e. the parasitic form) is now subdivided into seven genospecies (72). There are also approximately 200 serovars of parasitic leptospires (102). Serovar hardjo, the predominant serovar in most cattle populations (10), has been divided into two genotypes: hardjo-prajitno and hardjo-bovis (89).

Disease risk

Clinically, bovine leptospirosis can be acute (septicaemia, hepatitis, nephritis), subacute (nephritis, agalactia), chronic (abortion, stillbirth, infertility) or, in its most common form, asymptomatic. Serovar hardjo has been recovered from the kidney, seminal vesicle, epididymis and testis of naturally infected bulls (36). Leptospira spp. have also been recovered from the semen of naturally (48) and experimentally (84) infected bulls, and seminal transmission has been reported (83).

Diagnosis and control

The reference laboratory test for serological diagnosis of leptospirosis in cattle is the microscopic agglutination (MA) test (25). There are also immunoenzyme assays for detection of leptospiral antibodies and antigens (88) but these, like the MA test, cannot distinguish between titres resulting from natural infection and those from vaccinal titres (91). Difficulties have been reported in isolating leptospires from experimentally infected semen, even when antibiotics were absent from the semen diluent (69). However, molecular
Leptospirae survive in extended unfrozen bovine semen, either with or without antibiotics (18), and also in frozen semen without antibiotics (74). Treatment of bulls with either with or without antibiotics (18), and also in frozen Leptospires survive in extended unfrozen bovine semen, probes for leptospira detection and identification have been described (31, 85) and one PCR used for L. serjoe in non-sterile urine detected as few as 5-10 leptospires per ml (41).

Bovine genital campylobacteriosis

Venereal campylobacteriosis, a widespread bacterial disease associated with both bovine infertility and abortion, is caused by *Campylobacter* (*Vibrio*) *fetus*, particularly the subspecies *venerealis*. *C. fetus* infection in cattle has decreased in regions where AI and vaccination are practised, yet the disease continues to be an important pathogen causing reproductive problems in many countries (2, 98).

Disease risk

In bulls, infection is not accompanied by either pathological lesions or modifications in the characteristics of the semen (23). The incidence of infection is higher among bulls over five years of age, and this may be attributed to the deeper epithelial crypts in the prepuce and penis of older bulls which allow the pathogen to survive and grow more readily. *C. fetus* is transmitted to female cattle at natural or artificial service of the infected bull, a symptomless carrier state occurs with persistence of the organisms. Special transport media have been developed to maintain these specific requirements during transit to the laboratory for subsequent culture (24, 39, 53, 54). PCR assays have also been developed (7, 9, 34) which can detect as few as three *C. fetus* subsp. *venerealis* cells per ml in experimentally infected raw and diluted bull semen (34). Since campylobacters have few unique biochemical features (63), (more discriminating) techniques such as lipopolysaccharide profiles and pulsed field gel electrophoresis can assist in differentiating the venereal subspecies of *C. fetus* from others (16, 73).

Bulls are usually tested in quarantine by culture of preputial samples on three occasions to ensure that they are free of *C. fetus* before entering AI centres. Thereafter, their disease-free status is confirmed by semi-annual testing. Infected bulls may be treated by simultaneous preputial infusion of an aqueous solution of DHS and subcutaneous injections of the same antibiotic (78). However, streptomycin-resistant strains of *C. fetus* have been reported (47), and as DHS has been withdrawn from some markets, alternative treatments will be required in the future. Vaccination is another possible approach which will not only prevent infection in bulls (15) but is also claimed to be curative, although failure to eliminate infection by vaccination alone has been reported (46, 96).

Various combinations of antibiotics have been used to control *C. fetus* in liquid or frozen bovine semen (33, 81). One of these, a combination of gentamycin, lincomycin and tylosin, has been recommended (80) and adopted for commercial application. However, it has been reported that *C. fetus* could be re-isolated after processing and freezing of experimentally inoculated semen in the presence of these three antibiotics (32).

Trichomonosis

Trichomonosis is a venereal disease of cattle caused by the protozoan parasite *Trichomonas foetus* in the female, it is characterised by infertility, early abortion and pyometra but in the infected bull, a symptomless carrier state occurs with *T. foetus* being found on the penis and preputial membranes. This does not interfere with spermatogenic function or the ability to copulate (31). Trichomonosis occurs world-wide, particularly among range cattle (44, 67). A high herd prevalence has been reported in areas of North America where natural breeding is practised (13, 73). Control can be achieved through a policy of testing breeding animals and the widespread use of AI (87).

Disease risk

Although the parasite can survive in diluted semen and through the freezing process, the probability of transmitting infection through AI is not known. If transmitted to cows or...
heifers at breeding, the infection invades the vagina, uterus and oviducts, causing embryonic death and infertility which may last for several months (12).

**Diagnosis and control**

The testing of bulls entering AI should be mandatory, and definitive diagnosis depends on the demonstration of the living motile organisms in preputial washings or scrapings (87). Since these organisms tend to be present only in small numbers, a vigorous scraping of the preputial epithelium is recommended. A diagnostic kit has been developed which consists of a clear plastic pouch with two chambers of selective medium. This is inoculated on-site with the sample and is then used for both transport and culture (90). This kit is an improvement compared to the traditional nutrient medium for recovering *T. foetus* (14). The inoculated culture media are examined microscopically for motile trichomonads for up to seven to ten days (49). The probability of obtaining a positive culture from a known positive bull has been calculated to be between 81.6% and 90% based on three successive weekly cultures (50, 82).

Studies with an ELISA have shown it was sufficiently sensitive to detect antibody in both seminal plasma and preputial washings of bulls after vaccination and challenge with *T. foetus* (19).

A specific DNA probe and PCR amplification system (45) have also been used to detect ten *T. foetus* parasites in samples containing bovine preputial smegma. Furthermore, a multiple target PCR technique enabled *T. foetus* to be distinguished from a variety of other protozoa. This might be a useful adjunct to culture in the primary diagnosis of *T. foetus* infection (73).

Bulls selected for entry into AI should preferably be from disease-free herds and be tested in quarantine by the direct microscopic and culture tests on three occasions to ensure freedom from infection with *T. foetus*. These health certification requirements are similar to those for genital campylobacteriosis. Continued freedom from infection should then be confirmed by semi-annual tests. The *T. foetus* protozoan is unaffected by antibiotics in semen extenders so if an AI bull is found to be infected, the entire stock of frozen semen or, at least, the semen collected from the date of the last negative test should be destroyed (64). Information of value in assessing the risk of *T. foetus* being present in imported semen includes the country of origin of the semen, the history and breed of the bull, and the testing programme applied by the AI centre, with particular reference to the number of pre-entry and annual tests for the organism.

**Conclusions**

In addition to the six examples considered in detail above, a wide variety of other disease agents may be excreted in bull semen (1, 31, 33, 43, 69). The authors propose a categorisation of diseases according to the likelihood of transmission through AI as shown in Table I. It should be noted that the suggestions of the authors in regard to Categories 1, 2 and 3 are based on current knowledge and may change as new information becomes available. For some diseases, there is ample evidence that transmission to the female can occur through AI (Category 1, Table I), whereas for others the available evidence suggests that the risk of transmission through AI is low (Category 2, Table I). A third category of disease agents includes those for which information on transmission is limited, but based on the reports which are available the authors propose that these agents be subdivided into those likely to be transmitted in semen (Category 3a, Table I) and those unlikely to be transmitted (Category 3b, Table I).

To illustrate the concept, bluetongue virus (BTV) is listed in Category 2 (Table I). This is because the presence of the virus in bull semen tends to be associated with virus-infected blood cells entering the male reproductive tract during the viraemic phase of infection (69). There is no evidence that bulls develop persistent congenital infection or immunotolerance to the virus, as is the case with BVDV. Thus, in areas free of BTV, semen from seronegative bulls should pose a very low risk, while the performance of tests to demonstrate the absence of BTV in the blood of any bulls with circulating BTV antibodies should provide a sufficient guarantee for the semen of those bulls to be approved for export. In areas where the disease is endemic, semen collected from bulls with or without circulating antibodies, could also qualify for export provided that blood tests confirmed that the bulls were free of BTV at the time of collection. The schedule and frequency of tests would be determined as part of any risk assessment procedure.

Several excellent models are available for assessing the risk of introducing disease into disease-free areas (58). Based on such models, practical risk assessment protocols can be developed. The quantitative assessment of risk of importation of disease by bull semen should be based on several factors, including the following:

- the country of origin and the incidence of the specific diseases of concern to the importing country
- knowledge of epidemiology of these specific diseases
- standards of health certification for AI bulls and integrity and technical competence with which certification is performed
- standards of hygiene applied to collecting, processing and storing semen
- antibiotic treatment of semen and extenders
- season of the year when semen is collected (relevant to vector-borne diseases).

Decisions on risk should be based on scientific knowledge of the diseases of concern and on whether international standards are applied for diagnosis and control.
Table I
Risk of transmission of infectious bovine diseases through artificial insemination

<table>
<thead>
<tr>
<th>Category</th>
<th>Diseases</th>
<th>Presence of disease agent</th>
<th>OIE Disease List</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diseases with evidence that risk of transmission is moderate to high</td>
<td>+</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Foot and mouth disease</td>
<td>+</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Vesicular stomatitis</td>
<td>NR</td>
<td>A</td>
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<tr>
<td></td>
<td>Rinderpest</td>
<td>+</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Infectious bovine rhinotracheitis</td>
<td>+</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Bovine virus diarrhea</td>
<td>+</td>
<td>-</td>
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<tr>
<td></td>
<td>Bovine tuberculosis</td>
<td>+</td>
<td>B</td>
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<tr>
<td></td>
<td>Bovine genital campylobacteriosis</td>
<td>+</td>
<td>B</td>
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<tr>
<td></td>
<td>Bovine brucellosis</td>
<td>+</td>
<td>B</td>
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<tr>
<td></td>
<td>Trichomonosis</td>
<td>+</td>
<td>-</td>
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<td></td>
<td>Mycoplasmosis</td>
<td>+</td>
<td>-</td>
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<tr>
<td></td>
<td>Haemophilus somnus</td>
<td>+</td>
<td>-</td>
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<tr>
<td></td>
<td>Ubiquitous bacteria (e.g. Pseudomonas aeruginosa, Escherichia coli)</td>
<td>+</td>
<td>-</td>
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<tr>
<td>2</td>
<td>Diseases with some evidence that risk of transmission is low</td>
<td>+</td>
<td>A</td>
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<tr>
<td></td>
<td>Bluetongue</td>
<td>+</td>
<td>B</td>
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<tr>
<td></td>
<td>Enzootic bovine leucosis</td>
<td>+</td>
<td>B</td>
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<tr>
<td></td>
<td>Bovine ephemeral fever</td>
<td>NR</td>
<td>-</td>
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<tr>
<td></td>
<td>Akabane virus</td>
<td>+</td>
<td>-</td>
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<tr>
<td></td>
<td>Leptospirosis</td>
<td>+</td>
<td>B</td>
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<tr>
<td>3</td>
<td>Diseases with little or no information on risk of transmission</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>a)</td>
<td>Transmission of Category 3 diseases through artificial insemination likely</td>
<td>+</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Epizootic haemorrhagic disease</td>
<td>+</td>
<td>-</td>
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<tr>
<td></td>
<td>Bovine immunodeficiency-like virus</td>
<td>+</td>
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<td>Bovine paratuberculosis</td>
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<td></td>
<td>Contagious bovine pleuropneumonia</td>
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<tr>
<td>b)</td>
<td>Transmission of Category 3 diseases through artificial insemination unlikely</td>
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<td>A</td>
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<td></td>
<td>Lumpy skin disease</td>
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<td>Rift Valley fever</td>
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<td></td>
<td>O fever</td>
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<td></td>
<td>Rabies</td>
<td>NR</td>
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<td></td>
<td>Haemorrhagic septicaemia</td>
<td>NR</td>
<td>B</td>
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<td></td>
<td>Bovine malignant ostearthritis fever</td>
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<td>B</td>
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<td></td>
<td>Bovine spongiform encephalopathy</td>
<td>NR</td>
<td>B</td>
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<tr>
<td></td>
<td>Listeriosis</td>
<td>+</td>
<td>-</td>
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<tr>
<td></td>
<td>Anaplasmosis</td>
<td>NR</td>
<td>B</td>
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<td></td>
<td>Babesiosis</td>
<td>NR</td>
<td>B</td>
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<tr>
<td></td>
<td>Chlamydia</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Fungi, yeasts</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

* Presence of disease agent in bull semen demonstrated

NR: Not reported

Consideration should also be given to the likely impact the disease would have on animal and human health in the event that the disease enters the country and becomes established. It should be realised that there is a risk of introducing new, more virulent, strains of indigenous disease agents, which may become established and cause major economic losses.
Risques pour la santé animale associés à l'insémination artificielle de bovins

M.D. Eaglesome & M.M. Garcia

Résumé
Deux des principaux objectifs de l'insémination artificielle des animaux domestiques sont l'amélioration génétique permanente des cheptels et la prévention ou l'élimination de maladies vénériennes. L'insémination artificielle offre l'avantage de féconder autant de femelles et de produire autant de descendants qu'en saillie, mais à partir d'un nombre limité de mâles. Toutefois, l'insémination artificielle n'est pas exempte de risques ; elle peut, en effet, être à l'origine de la dissémination de tares génétiques et propager des maladies infectieuses à l'échelle nationale et internationale. Les auteurs examinent les risques de transmission de six maladies spécifiques par la semence de taureau, et décrivent les mesures appropriées pour prévenir ces risques.

Mots-clés

Riesgos zoosanitarios asociados a la inseminación artificial de bovino

M.D. Eaglesome & M.M. Garcia

Resumen
Alcanzar una continua mejora genética y prevenir o eliminar las enfermedades venéreas son dos de los grandes objetivos de la inseminación artificial de animales de granja. Comparada con la monta natural, la inseminación artificial exige el concurso de menos machos para fecundar a un mismo número de hembras y producir un mismo número de descendientes. Sin embargo, la inseminación artificial no está exenta de riesgos, pues puede convertirse en vía de diseminación de tares genéticas o en fuente de propagación de enfermedades infecciosas a nivel tanto nacional como internacional. Los autores describen los riesgos asociados a seis enfermedades específicas que se transmiten a través del semen de toro, y presentan las medidas adecuadas para prevenir dichos riesgos.

Palabras clave
References


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