CHAPTER 3.8.5.

ENZOOTIC ABORTION OF EWES (OVINE CHLAMYDIOSIS) (INFECTION WITH *CHLAMYDIA ABORTUS*)

SUMMARY

***Description and importance of the disease**: Ovine chlamydiosis, also known as enzootic abortion of ewes* (*EAE*) *or ovine enzootic abortion* (*OEA*), *is caused by the bacterium* Chlamydia abortus. *Chlamydial abortion typically occurs in the last 2–3 weeks of pregnancy with the appearance of stillborn lambs and inflamed placentas. However, infection can also result in the delivery of full-term stillborn lambs or weak lambs that do not survive longer than 48 hours. Infected ewes can also give birth to healthy lambs. There are rarely any predictive signs that abortion is going to occur, although behavioural changes and a vulval discharge can be observed in the last 48 hours of pregnancy.*

Diagnosis of enzootic abortion depends on the detection of antigen or nucleic acid of the causative agent in the products of abortion or vaginal excretions of freshly aborted females. A humoral antibody response may be detected following abortion. Goats as well as sheep and, less commonly, cattle, pigs, horses and wild ruminants, can be affected. Chlamydiosis of small ruminants caused by C. abortus *is zoonotic and the organism must be handled with appropriate biosafety precautions. Pregnant women are particularly at risk.*

***Identification of the agent:** The basis for a positive diagnosis of infection with* C. abortus *depends on a history of abortion in sheep or goats* (*often in late pregnancy*), *evidence of purulent to necrotising placentitis with vasculitis, and the demonstration of large numbers of the organism in affected placentae by quantitative polymerase chain reaction* (*PCR*) *or antigen tests or in stained smears. The still moist fleece of fetuses or their abomasal content or vaginal swabs of females that have freshly aborted are also useful. It is important to distinguish cotyledonary damage caused by* Toxoplasma gondii *and, in stained smears, to be aware of the morphological similarities between* C. abortus *and* Coxiella burnetii, *the agent of Q fever.*

Chlamydial organisms in tissues and smears can be detected by staining, or antigen-detection methods (*immunohistochemistry or immunofluorescence*), *whereas chlamydial DNA can be detected by PCR-based methods including real-time PCR and DNA microarray. Some of these methods are available in commercial kit form.*

Chlamydia abortus *can be isolated only in living cells; thus facilities for growth in cell cultures or chicken embryos, with appropriate biohazard containment, are required.*

***Serological tests:** A rise in antibody titre to* C. abortus, *which can be detected by enzyme-linked immunosorbent assay* (*ELISA*), *is common after abortion or stillbirth, but this does not occur in every case.* Chlamydia abortus *shares common antigens with other* Chlamydia *species and some Gram-negative bacteria, so that the complement fixation* (*CF*) *test or crude ELISAs are not specific and no longer recommended. Serological screening during the period after parturition helps to identify infected flocks, to which control measures can then be applied. Serological tests to differentiate between vaccinated and naturally infected sheep or goats* (*DIVA tests*) *are not currently available.*

***Requirements for vaccines:** Inactivated and live vaccines are available that have been reported to prevent abortion and to reduce excretion. They assist in control of the disease but will not eradicate it.*

A. INTRODUCTION

1. Description and impact of the disease

Ovine chlamydiosis (enzootic abortion of ewes [EAE] or ovine enzootic abortion [OEA]) is caused by the bacterium *Chlamydia abortus.* Chlamydial abortion in late pregnancy causes serious economic loss in many sheep-rearing areas of the world, particularly where flocks are closely congregated during the parturient period (Aitken & Longbottom, 2007; Longbottom & Coulter, 2003). Abortion typically occurs in the last 2–3 weeks of pregnancy with the appearance of stillborn lambs and grossly inflamed placentas. Infection can also result in the delivery of full-term stillborn lambs and weak lambs that generally fail to survive beyond 48 hours. It is also not uncommon in multiple births for an infected ewe to produce one dead lamb and one or more weak or healthy lambs. Infection is generally established in a 'clean' (immunologically naïve) flock through the introduction of infected replacements and results in a small number of abortions in the first year, followed by an 'abortion storm' in the second year that can affect around 30% of ewes.

Infected animals show no clinical illness prior to abortion, although behavioural changes and a vulval discharge may be observed in ewes within the last 48 hours of pregnancy. Pathogenesis commences around day 90 of gestation coincident with a phase of rapid fetal growth when chlamydial invasion of placentomes produces a progressively diffuse inflammatory response, thrombotic vasculitis and tissue necrosis. Milder changes occur in the fetal liver and lung and, in cases with severe placental damage, there may be evidence of hypoxic brain damage (Buxton *et al*., 2002; Longbottom *et al.*, 2013). Abortion probably results from a combination of impairment of materno-fetal nutrient and gaseous exchange, disruption of hormonal regulation of pregnancy and induced cytokine aggression (Entrican, 2002).

Chlamydial abortion also occurs to a similar extent in goats and, less frequently, cattle, pigs, horses and wild ruminants may be affected. In sheep, abortion in late pregnancy with expulsion of necrotic fetal membranes are diagnostic indicators.

2. Nature and classification of the pathogen

Taxonomically, the family *Chlamydiaceae* comprises a group of Gram-negative, obligate intracellular bacteria within the single genus *Chlamydia,* which includes eleven species: *C. trachomatis* (humans), *C. suis* (swine), *C. muridarum* (mouse and hamster), *C. psittaci* (avian), *C. felis* (cat), *C. abortus* (sheep, goat and cattle), *C. caviae* (guinea-pig), *C. pecorum* (sheep, cattle and, koala), *C. pneumoniae* (humans), *C. avium* and *C. gallinaceae* (both in birds) (Sachse *et al*., 2015) as well as two candidate species named *Candidatus* Chlamydia ibidis and *Candidatus* Chlamydia sanzinia (Taylor-Brown *et al*., 2016; Vorimore *et al*., 2013).

Infected ewes shed vast numbers of infective *C. abortus* at the time of abortion or parturition, particularly in the placenta and uterine discharges, thus providing an infection source. Ewes having aborted do not usually abort again from *C. abortus* infection. Recent evidence suggests that the proportion of infected ewes is reduced at the subsequent breeding season and only low levels of chlamydial DNA are detected during the periovulation period and at lambing, so that this would not have significant impact on the epidemiology (Gutierrez *et al.,* 2011; Livingstone *et al.,* 2009).

3. Zoonotic risk and biosafety requirements

Human infection may be acquired from infected products of abortion or parturition or from carelessly handled laboratory cultures of the organism, with manifestations ranging from subclinical infection to acute influenza-like illness. Cultures and potentially infected tissues should be handled with appropriate biosafety and containment procedures as determined by biorisk analysis (see Chapter 1.1.4 *Biosafety and biosecurity: Standard for managing biological risk in the veterinary laboratory and animal facilities*). Authenticated cases of human placentitis and abortion caused by *C. abortus* of ovine/caprine origin indicate that pregnant women are at special risk and should not be exposed to sources of infection (Longbottom & Coulter, 2003; Sillis & Longbottom, 2011).

4. Differential diagnosis

Specific experience is needed to distinguish the diffuse pattern of necrosis and inflammation caused by *C. abortus* infection from necrosis caused by *Toxoplasma gondii,* which is limited to the cotyledons. Differentiation from other infectious causes of abortion, such as brucellosis (see Chapter 3.1.4), coxiellosis (see Chapter 3.1.16) or other bacterial pathogens (*Campylobacter* [see Chapter 3.10.4], *Listeria* [see Chapter 3.10.5], *Salmonella* [see Chapter 3.10.7]), can be achieved by conducting further agent-specific diagnostic tests. Recently, other chlamydial species, such as *C. pecorum* and *C. psittaci,* have been implicated as abortigenic agents in ruminants (Berri *et al*., 2009; Lenzko *et al.*, 2011).

B. DIAGNOSTIC TECHNIQUES

Table 1. *Test methods available for the diagnosis of enzootic abortion of ewes and their purpose*

Method	Purpose					
	Population freedom from infection	Individual animal freedom from infection prior to movement	Contribute to eradication policies	Confirmation of clinical cases	Prevalence of infection – surveillance	Immune status in individual animals or populations post-vaccination
Agent identification[1]						
Stained smears	–	–	–	+	–	n/a
Bacterial isolation	–	–	–	++	–	n/a
Antigen detection by IHC	–	–	–	++	+	n/a
Conventional PCR	–	–	–	+++	++	n/a
Real-time PCR	–	–	-	+++	++	n/a
Detection of immune response						
CFT	+	+	+	+	+	+
ELISA	+++	++	+++	++	+++	+++

Key: +++ = recommended for this purpose; ++ recommended but has limitations;
+ = suitable in very limited circumstances; – = not appropriate for this purpose.
IHC= immunohistochemisty; PCR=polymerase chain reaction; CFT=complement fixation test;
ELISA=enzyme-linked immunosorbent assay.

1. Identification of the agent

1.1. Smears

Where the clinical history of the flock and the character of lesions in aborted placentae suggest enzootic abortion, a diagnosis can be attempted by microscopic examination of smears made from affected chorionic villi or adjacent chorion. Smears are stained according to modified Machiavello, Giemsa, *Brucella* differential, or modified Ziehl–Neelsen (Stamp *et al*., 1950). In positive cases stained by the latter method and examined under a high-power microscope, large numbers of small (300 nm) coccoid elementary bodies are seen individually or in clumps stained red against the blue background of cellular debris. Under dark-ground illumination, the elementary bodies appear pale green. Fluorescent antibody tests (FATs) using a specific antiserum or monoclonal antibody may be used for identification of *C. abortus* in smears. However, polymerase chain reaction (PCR)-based tests are superior to stained or FAT smears regarding sensitivity and specificity and should therefore be applied if available. Stained smears might be useful as an initial screening test, but confirmation by molecular methods is highly recommended due to inferior sensitivity of staining and lack of species specificity.

If placental material is not available, smears may be prepared from vaginal swabs of ewes that have aborted within the previous 24 hours, or from the moist fleece of a freshly aborted or stillborn lamb that has not been cleaned by its mother, or from the abomasal content of the aborted or stillborn lamb. In general, such preparations contain fewer organisms than placental smears.

In terms of morphology and staining characteristics, *C. abortus* resembles *Coxiella burnetii* (see chapter 3.1.16 *Q fever*), which, in some circumstances, may provoke abortion and which causes Q fever in humans. Care must be taken to differentiate between these two organisms in cases lacking a good history or evidence of chlamydia-induced placental pathology.

1 A combination of agent identification methods applied on the same clinical sample is recommended.

1.2. Isolation of the agent – cell culture

Cell culture is the method of choice for isolation of the organism. The causative agent of ovine chlamydiosis is zoonotic and thus isolation and identification procedures must be carried out with appropriate biosafety and containment procedures as determined by biorisk analysis (see chapter 1.1.4).

Tissue samples, such as cotyledons, placental membranes, fetal lung or liver, or vaginal swabs, that may be subject to delay before laboratory isolation, should be maintained in a suitable transport medium in the interim period. For optimal recovery, such samples should be stored frozen, preferably at –80°C. The most satisfactory medium is sucrose/phosphate/glutamate or SPG medium (sucrose [74.6 g/litre], KH_2PO_4 [0.52 g/litre], K_2HPO_4 [1.25 g/litre], L-glutamic acid [0.92 g/litre]) supplemented with bovine serum albumin – fraction V (1 g/litre), antibiotics (streptomycin and gentamycin are suitable, but not penicillin), and a fungal inhibitor. A tissue-to-medium ratio of 1:10 is commonly employed. Alternatively, approximately 1 g of tissue can be ground with sterile sand in 8 ml of transport medium.

Chlamydia abortus of ovine origin can be isolated in a variety of cell types. McCoy, Buffalo Green Monkey (BGM) or baby hamster kidney (BHK) cells are most commonly used. For confirmatory diagnosis, cultured cell monolayers are suspended in growth medium at a concentration of 2×10^5 cells/ml. Aliquots of 2 ml of the suspension are dispensed into flat-bottomed vials, each containing a single 12 mm coverslip. Confluent coverslip monolayers are achieved after incubation at 37°C for 24 hours. The growth medium is removed and replaced with 2 ml of test inoculum, which is then centrifuged at 2500–3500 ***g*** for 30–60 minutes onto the coverslip monolayer and incubated at 37°C and 5% CO_2 for 2 hours. The inoculum is removed and replaced with serum-free or cycloheximide (0.5 µg/ml) containing tissue culture medium, and then incubated at 37°C for 2–3 days. The coverslip monolayers are fixed in methanol and stained using Giemsa or Gimenez procedures (Arens & Weingarten, 1981; Gimenez, 1964), or are detected by immunofluorescence using species- or genus-specific antibodies (Sachse *et al.,* 2009). After methanol fixation, infected cultures contain basophilic (Giemsa) or eosinophilic (Gimenez) fluorescent intracytoplasmic inclusions. Similar procedures are used in culturing *C. abortus* for antigen preparation.

1.3. Isolation of the agent – chicken embryos

Test samples are prepared as 10% suspensions in nutrient broth containing streptomycin (not penicillin) (200 µg/ml); 0.2 ml of suspension is inoculated into the yolk sac of 6- to 8-day old embryos, which are then further incubated at 37°C. Infected embryos die between 4 and 13 days after inoculation. Smears prepared from their vascularised yolk sac membranes reveal large numbers of elementary bodies.

1.4. Antigen detection in tissue sections

In histopathological sections, antigen detection can be performed using commercially available anti-*Chlamydiaceae* antibodies directed against lipopolysaccharide (LPS) or MOMP (major outer membrane protein) (Borel *et al*., 2006). Immunohistochemistry is an indispensable tool to show the association of chlamydial agent and pathological lesions in tissues. Genus- or species-specific antibodies in combination with streptavidin–biotin are used to detect the chlamydial antigen within histological lesions of the placenta or inner organs (mostly lung and liver) of aborted fetuses (Sachse *et al*., 2009).

Intracellular chlamydial inclusions can be demonstrated by Giemsa staining of thin (≤4 µm) sections taken from target tissues that have been suitably fixed in fluids such as Bouin or Carnoy. However, unambiguous immunological staining procedures as described above are more suitable.

1.5. Detection of DNA by conventional PCR, real-time PCR and DNA microarray

Amplification of chlamydial DNA by PCR for verifying the presence of chlamydiae in biological samples is the method of choice because of high sensitivity and specificity of PCR. Conventional PCR protocols for *C. abortus* DNA detection target the 16S–23S rRNA region (Everett & Andersen, 1999) or *pmp* genes (Laroucau *et al*., 2001) and can be combined with restriction fragment length polymorphism (RFLP) analysis for discriminating between amplified DNA sequences originating from *C. abortus, C. psittaci* and *C. pecorum*.

Real-time PCR has become the preferred method in diagnostic laboratories due to its high specificity, rapidity, high throughput and ease of standardisation (Sachse *et al.,* 2009). A hierarchical approach is recommended including a *Chlamydiaceae*-specific screening PCR based on the sequences of 23S rRNA (Ehricht *et al*., 2006), and, in positive cases, followed by a *C. abortus*-specific PCR assay based on sequences of the outer membrane protein (*omp*A) (Livingstone *et al.*, 2009; Pantchev *et al.*, 2009) or DNA microarray hybridisation assays (Sachse *et al*., 2005). Both real-time PCR and DNA microarray have been validated for the direct detection and identification of organisms from clinical samples (Borel *et al.,* 2008; Pantchev *et. al*., 2010).

PCR assays in combination with RFLP analysis or HRM (high resolution melting) analysis have been developed with the aim of differentiating naturally infected from vaccinated animals (DIVA) (Laroucau *et al.*, 2010; Vorimore *et al*., 2012; Wheelhouse *et al.,* 2010).

Table 1. *Real-time PCR assays for screening and specification of* C. abortus

Reference	Ehricht *et al.,* 2006	Livingstone *et al.,* 2009	Pantchev *et al.,* 2009
Specificity	*Chlamydiaceae*	*C. abortus*	*C. abortus*
Target	23S rRNA	*omp*A	*omp*A
Amplicon size	111 bp	86 bp	82 bp
Primer forward 5'–3'	CTG-AAA-CCA-GTA-GCT-TAT-AAG-CGG-T	GCG-GCA-TTC-AAC-CTC-GTT	GCA-ACT-GAC-ACT-AAG-TCG-GCT-ACA
Primer reverse 5'–3'	ACC-TCG-CCG-TTT-AAC-TTA-ACT-CC	CCT-TGA-GTG-ATG-CCT-ACA-TTG-G	ACA-AGC-ATG-TTC-AAT-CGA-TAA-GAG-A
Probe 5'–3'	FAM-CTC-ATC-ATG-CAA-AAG-GCA-CGC-CG-TAMRA	FAM-TGT-TAA-AGG-ATC-CTC-CAT-AGC-AGC-TGA-TCA-G-TAMRA	FAM-TAA-ATA-CCA-CGA-ATG-GCA-AGT-TGG-TTT-AGC-G-TAMRA
Cycling conditions	95°C/10 minutes 45 × (95°C/15 seconds, 60°C/60 seconds)	95°C/10 minutes 45 × (95°C/15 seconds, 60°C/60 seconds)	95°C/10 minutes 45 × (95°C/15 seconds, 60°C/60 seconds)

2. Serological tests

Sheep and goats are generally tested serologically within 3 months of abortion or parturition. Infection is evident through *C. abortus*-specific antibody response principally during active placental invasion by the pathogen in the last month of gestation and following the bacteraemia that often accompanies abortion. Consequently, serum collected after abortion will reveal an elevated antibody titre resulting from current or previous infection.

2.1. ELISA

Several ELISAs are commercially available for *Chlamydia* diagnosis in ewes (overview in Sachse *et al.,* 2009). Care must be taken to select an appropriate ELISA for each diagnostic problem considering different specificities and sensitivities. LPS or EB (elementary body) antigen-based ELISAs cannot differentiate between animals infected with *C. pecorum* and *C. abortus*, but were proven to be more sensitive primary screening tools for EAE compared with the CF test. Specific detection of anti-*C. abortus* antibodies can be accomplished by the use of ELISAs based on synthetic peptides of MOMP, recombinant MOMP (Salti-Montesanto *et al*., 1997), or POMP90 (polymorphic outer membrane protein) (Longbottom *et al*., 2002; Wilson *et al*., 2009). Most recently, a new indirect ELISA based on POMP90 has been commercialised and shown to be both sensitive and specific for *C. abortus,* in particular in differentiating animals infected with *C. pecorum* (Anon, 2015; Essig & Longbottom, 2015).

2.2. Complement fixation test

Complement fixation (CF) has traditionally been the most widely used procedure for detecting EAE. However, antigenic cross-reactivity between *C. abortus* and *C. pecorum*, which is endemic in small ruminants, as well as with some Gram-negative bacteria (e.g. *Acinetobacter*), can give rise to false-positive CF test results. This is because chlamydial antigen contains LPS as an immunodominant component, which is common to all *Chlamydiaceae* species. Furthermore, CF has been shown to be

less sensitive than alternative tests. Therefore, CF is no longer recommended as the method of choice for serological diagnosis of EAE, but might be used for herd diagnosis when no alternative tools are available and the limitations mentioned above are taken into consideration.

Antigen is prepared from heavily infected yolk sac membranes obtained from chicken embryos that have been inoculated in the same manner as for isolation of the organism from field material. The preparation of the antigen should be carried out in a biosafety cabinet with the appropriate biosecurity precautions to prevent human infection (see chapter 1.1.4). Chopped and ground membranes are suspended in phosphate buffer, pH 7.6, at the rate of 2 ml per g membrane. After removal of crude debris, the supernatant fluid is centrifuged at 10,000 ***g*** for 1 hour at 4°C, the deposit is resuspended in a small volume of saline, and a smear of this is examined to ensure a high yield of chlamydiae. The suspension is held in a boiling water bath for 20 minutes, or is autoclaved, and sodium azide (0.3%) is added as a preservative. Antigen may also be prepared from cell cultures infected with *C. abortus*. Infected monolayers are suspended in phosphate buffer, pH 7.6, and the cells are disrupted by homogenisation or ultrasonication. Gross debris is removed and subsequent procedures are as for the preparation of antigen from infected yolk sacs. In either case, CF tests with standardised complement and antisera will establish the optimal working dilution for each batch of antigen. Antigen for CF testing of ruminant sera is commercially available.

Samples are tested at twofold dilutions from 1/32 to 1/512. CF titres are expressed as the highest serum dilution giving 50% or less haemolysis: 50% haemolysis is graded 2+, and 0% haemolysis is graded 4+. A titre of 4+ at a dilution of 1/32 or greater is assumed to be positive, whereas a titre of 2+ at a dilution of 1/32 is assumed to be equivocal (Stamp *et al*., 1950).

None of the serological tests available to date can differentiate vaccination titres from those acquired as a result of natural infection (DIVA tests).

C. REQUIREMENTS FOR VACCINES

1. Background

1.1. Rationale and intended use of the product

Currently, two types of vaccine (inactivated and attenuated live vaccines) are available commercially, to be administered intramuscularly or subcutaneously at least 4 weeks before breeding to aid in the prevention of abortion. A multi-component recombinant vaccine against *C. abortus* remains a future goal of chlamydial vaccine research (Longbottom & Livingstone, 2006).

Inactivated vaccines can be prepared from infected yolk sacs or cell cultures (Jones *et al*., 1995) and incorporate whole organisms or fractions of them (Tan *et al*., 1990) using the appropriate biosecurity precautions to prevent human infection (see chapter 1.1.4). Operator care should be observed in handling commercial inactivated vaccines that incorporate mineral oil-based adjuvants, as self-injection can result in severe local inflammation and tissue necrosis. The commercial live attenuated vaccine is based on a chemically induced temperature-sensitive mutant strain of the organism that grows at 35°C but not at 39.5°C, the body temperature of sheep (Rodolakis, 1986). This vaccine is supplied lyophilised and must be reconstituted in diluent immediately before administration. Operator care should be observed in handling and administering this live vaccine, particularly by immunocompromised individuals and pregnant women. Importantly, the live vaccine must not be given to animals being treated with antibiotics, particularly tetracyclines. Inactivated vaccines are safe for administration during pregnancy, whereas live vaccines cannot be used in pregnant animals.

Both types of vaccine have a role to play in controlling disease, but neither confers absolute protection against challenge or completely reduces the shedding of infective organisms. However, vaccinates exposed to infection do experience significantly lower abortion rates and reduced excretion of chlamydiae for at least two to three lambings after vaccination. It has been claimed that the live vaccine could be an aid to eradication of disease (Nietfeld, 2001). In addition, the live vaccine strain 1B has been detected in the placentas of vaccinated animals that have aborted as a result of OEA, suggesting a possible role for the vaccine in causing disease (Wheelhouse *et al.,* 2010), but despite this the use of live vaccine remains the most effective method of protecting from the disease (Essig & Longbottom, 2015; Stuen & Longbottom, 2011).

Vaccine stored under refrigeration (5±3°C) should remain stable for at least 1 year. No firm data are available, but revaccination is recommended every 1–3 years, according to the exposure risk.

2. Outline of production and minimum requirements for conventional vaccines

2.1. Characteristics of the seed

2.1.1. Biological characteristics

One or more ovine abortion isolates that consistently grow productively in the chosen substrate are suitable, and an early passage of the seed stock can be established. Alternatively, an isolate that has been adapted to the chicken embryo by multiple passage (>100) can be used. Although adaptation to the embryo may diminish the isolate's virulence for sheep, there is no evidence that such change reduces its protective efficacy as an inactivated vaccine.

2.1.2. Quality criteria (sterility, purity, freedom from extraneous agents)

Before inoculation of large numbers of embryos or cell cultures, the viability and freedom from contamination (e.g. other pathogens, fungi, mycoplasma, toxins, etc.) of seed stock should be verified. It may be convenient to collect the total harvest in separate manageable lots. In this case, the infectivity of an aliquot of each lot should be separately titrated to ensure that each matches the requirements (see below). Store under refrigeration.

2.2. Method of manufacture

2.2.1. Procedure

For production, cell monolayers or chicken embryos are infected with *C. abortus*. Once the final harvest suspension is obtained, an aliquot is removed for titration of its infectivity. The bulk is treated with formalin to a final concentration of 4%, and stored until sterility tests confirm complete inactivation.

2.2.2. Requirements for substrates and media

The inactivated harvest is centrifuged and resuspended in phosphate buffered saline containing 0.2% formalin to a volume representing a preinactivation infectivity titre of approximately 10^8 infectious units/ml. Usually, the aqueous suspension is blended with an oil adjuvant, either directly or after precipitation by potassium alum ($AlK[SO_4]_2.12\ H_2O$). A preservative, such as 0.01% thiomersal, may also be added.

2.2.3. In-process controls

The main requirements are to ensure adequate growth of *C. abortus*, avoidance of extraneous infection of the culture substrate, completeness of inactivation and biohazard awareness by process workers.

2.2.4. Final product batch tests

Each separate batch of manufactured vaccine should be tested for sterility, safety and potency.

i) Sterility and purity

Tests for sterility and freedom from contamination of biological materials intended for veterinary use may be found in chapter 1.1.9.

ii) Safety

Subcutaneous inoculation into two or more seronegative sheep of twice the standard dose of manufactured vaccine should elicit no systemic reaction, but oil-adjuvant vaccines can cause a nonharmful swelling at the inoculation site.

iii) Batch potency

At present, potency is judged by the occurrence of a serological response in previously unvaccinated sheep given 1 ml of vaccine subcutaneously. Blood samples taken before and 28 days after vaccination are compared. Ultimately, potency has to be determined by a controlled vaccination-challenge study or field performance. No *in-vitro* correlation of protective efficacy has yet been established.

2.3. Requirements for authorisation

2.3.1. Safety requirements

See Chapter 1.1.8 *Principles of veterinary vaccine production*.

2.3.2. Efficacy requirements

See chapter 1.1.8.

2.3.3. Stability

See chapter 1.1.8.

3. Vaccines based on biotechnology

3.1. Vaccines available and their advantages

No biotechnology-based vaccines are currently in use for this disease.

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NB: There are OIE Reference Laboratories for enzootic abortion of ewes
(please consult the OIE Web site:
https://www.oie.int/en/what-we-offer/expertise-network/reference-laboratories/#ui-id-3).
Please contact the OIE Reference Laboratories for any further information on
diagnostic tests, reagents and vaccines for enzootic abortion of ewes

NB: FIRST ADOPTED IN 1990. MOST RECENT UPDATES ADOPTED IN 2018.