

Chapter 7

Foetal and Neonatal Diseases

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Introduction

This presentation focuses on diseases of pregnancy and congenital neonatal diseases of ruminants.

Normal Ruminant Conceptus

The **conceptus** is the whole product of conception, comprising the embryo or foetus plus foetal membranes.

The **placenta** is the structure of intimate contact between maternal and foetal tissue during gestation. It facilitates exchange of nutrients, oxygen, carbon dioxide and foetal waste products and produces various enzymes, cytokines and hormones necessary for implantation and maintenance of pregnancy.

The placenta has a **maternal endometrial part**, and a **foetal part** that may be:

- 1) Chorionic, non-vascularised (only transitional),
- 2) Choriovitelline (yolk sac placenta),
- 3) Chorioamnionic, or
- 4) **Chorioallantoic** (the predominant type in domestic animals).

In ruminants, the **maternal caruncles** (40 to 100 oval prominences on the endometrial surface) interdigitate with the **foetal cotyledons** (circular tufts of villi projecting from the chorionic surface of the chorioallantois) to form the **placentomes**, which are the units of placentation. The placentomes are the areas of closest proximity of the maternal and foetal circulations as the vessels of the foetal membranes are an extension of the embryonal or foetal circulation. Placentation in cattle is epitheliochorial, and in sheep is syndesmochorial due to the loss of endometrial epithelium within the placentomes. At birth separation is complete (ie the placenta is non-deciduate).

In cattle, the caruncles are dome-shaped and the villi of the foetal cotyledons project into them from the periphery.

In sheep and goats, the caruncles are cup-shaped and the cotyledonary villi project outwards from the centre of the caruncular cup. In sheep, haemorrhage within the placental arcade is a normal finding (ie from the tips of maternal caruncular septa between the bases of the chorionic villi).

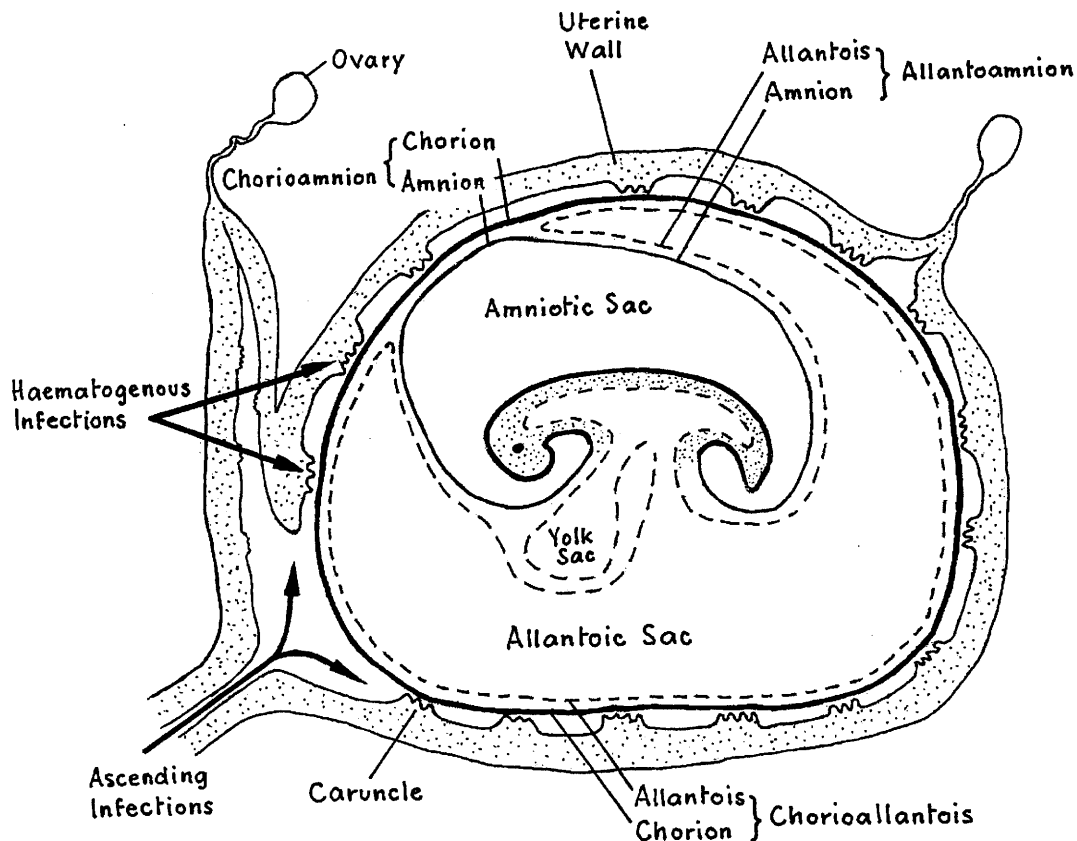


Figure 1. Diagram representing the relationships of the ruminant foetus, its membranes and the uterine wall, and routes of haematogenous and ascending infection.

At gross examination, two sets of foetal membranes can be identified surrounding the foetus (see **Figure 1**) and these contain a network of foetal blood vessels:

- The **chorioallantois** is the outer foetal membrane that results from fusion of the chorion and allantois. Its inner surface lines the allantoic sac, which in cattle contains up to 15 litres of watery allantoic fluid (hypertonic foetal urine received through the urachus). Its outer, chorionic surface comprises the cotyledons and the villus-free intercotyledonary areas. *In ruminants, the whole chorioallantois is usually referred to as the "placenta" although strictly speaking, placentation is limited to the maternal and foetal components of the cotyledonary placentomes.* The **chorioamnion** is that part of the outer foetal membrane formed by fusion of the chorion and amnion.
- The **allantoamnion** is a thin, translucent membrane resulting from fusion of the allantois and amnion. It envelops the amniotic sac, which contains the foetus and, in cattle, up to eight litres of amniotic fluid, a mucinous secretion consisting mainly of foetal saliva.

Routes of Infection of the Conceptus

Infectious agents can reach the conceptus via:

- **Maternal circulation to the uterus** (this occurs with most infections in ruminants),
- **Ascending uterine infection from the vagina through the cervix** (eg by *Campylobacter fetus venerealis*; also by pestivirus and *Ureaplasma diversum* contaminating semen or embryo transfer fluids), or
- **Infection within the ovum** (eg by transovarial transmission of viruses).

Once any part of the chorionic surface of the foetal membranes is exposed to an infectious agent, it has the potential to spread to the foetus and the rest of the chorioallantois by:

- **Foetal blood circulation**, and
- **Direct extension through foetal membranes and their contained fluids.**

These two routes of infection within the conceptus are intimately associated and can therefore occur concurrently. Chorioallantoitis ("placentitis") increases the risk of a pathogen invading of the conceptus.

Amniotic fluid, which bathes the foetus and is swallowed and aspirated *in utero*, can be a primary route of foetal infection, or be a medium for secondary proliferation of the pathogen following primary foetal infection via blood circulation. Lesions can develop in foetal skin, conjunctiva, lungs and stomach.

There is always the potential for rapid dissemination of an infectious agent within the conceptus via blood and foetal fluids. *Experimental inoculation of Listeria ivanovii into the amniotic sac of sheep results in infection of the foetus and dissemination of organisms to the chorionic surface of the placenta within 24 hours, via foetal blood circulation and direct invasion. Ascending human uterine infection by vaginal bacteria can result in amniotic fluid infection across intact foetal membranes and preterm delivery (in most cases without demonstrable foetal infection).*

Regardless of the route(s) of foetal infection, the essential sites for isolation of pathogens from cases of abortion are foetal stomach fluid and lung (see **Appendix 1. Necropsy procedure for conceptus and neonate**).

Reference:

Goldenberg RL, Hauth JC, Andrews WW. Intrauterine infection and preterm delivery. *N Engl J Med* 2000;342:1500-1507.

Pathogenesis of Conceptus Damage

The outcome of an infectious or toxic insult on the conceptus depends on:

- **Cytotoxicity of the infectious or toxic agent**
- **Age-dependant susceptibility of conceptus**, involving:
 - **Stage of development of immune and inflammatory responses.**
 - **Stage of differentiation or maturation of tissues and organs.**

Pathological responses of the ruminant foetus to various viral infections (eg pestivirus, Akabane virus, and vaccine strains of bluetongue virus) illustrate the above principles. The gestational age at the time of infection affects the **pathological pattern of disease**:

- In early gestation, before the foetus develops inflammatory or immune cells, foetal lesions are directly attributable to the cytotoxic effect of the agent on susceptible foetal cells. *Also, foetuses that survive **pestivirus** infection at this early gestational age may be immunotolerant and remain persistently infected by pestivirus after birth.*
- Following infection at a later stage of gestation, inflammatory and specific immune responses are elicited but are initially ineffective and contribute to the severity and pattern of the pathological changes.
- When infection occurs in late gestation, the foetal responses may neutralise the infection before tissue injury occurs.

Teratogenic effects of viruses and toxins are generally most marked in early to mid gestation during differentiation of organs and tissues:

- Cells of the external granular layer of the foetal bovine cerebellum are susceptible during their period of most rapid multiplication (at 107 to 150 days of gestation) to virus-induced necrosis (eg by pestivirus or bovine parvovirus), and **cerebellar hypoplasia** is the outcome.
- Foetal bovine cerebral hemispheres growing rapidly at 70 to 100 days of gestation are susceptible to lysis induced by Akabane virus, and **hydranencephaly** results.

Pathological Responses of the Conceptus to Infection

Once an infectious agent breaches the placental barrier and spreads within the conceptus via foetal blood circulation or direct extension, the outcome can be:

- **Foetal survival, with no placental or foetal lesions**, with or without foetal antibody response, or
- **Foetal death, with minimal placental or foetal lesions** (eg in leptospirosis), or
- **Foetal death** (or possible survival), **with lesions in one or more of:**
 - **Chorioallantois** (including cotyledons and intercotyledonary areas).
 - **Allantoamnion.**
 - **Foetus.**

*The type and extent of gross and microscopic lesions that develop in these three parts of the conceptus depend on **virulence of the agent** and **immunocompetence of the conceptus**.*

*Examination of the aborted conceptus (see **Appendix 1**) aims to detect the **pathological pattern of disease** in different organs and any **distinctive lesions** for diagnosis (see **Appendices 2 and 3**).*

Chorioallantoitis ("placentitis") involving cotyledonary and / or intercotyledonary areas is present to some degree in most cases of infectious abortion. The cut surface of cotyledons and caruncles may show evidence of infarction or suppuration.

Allantoamnionitis (amnionitis), usually with a concurrent chorioallantoitis, is a gross feature of *Ureaplasma diversum* and mycotic abortion in cattle, and can occur in *B ovis* infection in sheep.

Chronic chorioallantoitis and / or **allantoamnionitis (amnionitis) without** (or with only minimal) **foetal lesions**, despite spread of infection to the foetus, characterise(s) some bacterial and mycotic abortions. *Some of the agents that produce these **chronic lesions within foetal membranes** may multiply within the conceptus for long periods before abortion occurs (eg *U diversum* in amniotic fluid for 117 days; *B ovis* and *Aspergillus fumigatus* in the chorioallantois for 60 to 90 days and 25 days respectively).* Offspring born alive or aborted from cases with chronic lesions in foetal membranes (eg *T gondii* and *B ovis* in sheep) may be small for gestational age.

Foetal bronchopneumonia (usually a microscopic lesion only) is a feature of many bacterial and mycotic but not of protozoal or viral abortions. There may be minimal gross changes in foetal lungs, with or without fibrinous polyserositis (eg *Campylobacter* spp, *Y pseudotuberculosis*). In some cases, however, the lungs are swollen, firm

on palpation, and dark red, often with confluent, off-white foci of infiltration by inflammatory cells in a bronchiolar distribution (*eg Br abortus; A pyogenes*). *Inhalation of meconium-contaminated amniotic fluid may produce a microscopic giant cell alveolitis.*

Multifocal foetal hepatic necrosis may be seen grossly in abortions caused by various **bacteria** (*eg C fetus fetus, Listeria spp, Y pseudotuberculosis, Fusobacterium spp, and Flexispira rappini* in sheep) and by some **viruses** (*eg bovine herpesvirus 1 and Rift Valley fever virus*).

Hepatic enlargement, with **nodularity**, **mottling** and **ascites** indicates *in-utero*, right-sided, congestive heart failure.

Myocardial changes seen grossly include **mottling** and **discolouration** (due to myocarditis, myonecrosis, mineralisation or fibrosis), **fibrinous epicarditis**, and **congenital cardiac defects** (associated possibly with compensatory **cardiac dilation** or **hypertrophy**).

Teratogenic effects of viral infections include arthrogryposis and hydranencephaly (Akabane virus) and cerebellar hypoplasia (pestivirus).

Embryonic and Foetal Death, Abortion and Stillbirth

Zygote or early embryonic death is followed by **resorption** or **expulsion**. The incidence is high (15 to 30%) in all animal species. Causes include zygote chromosomal abnormalities (numerical or structural, with the latter caused by viruses, drugs and radiation), transport problems within uterine tubes, and attachment or implantation problems due to diseases of the blastocyst or endometrium. The dead, early embryo disintegrates and is resorbed or expelled, with a return to oestrus usually after a prolonged interoestral period.

Abortion is the expulsion of a live or dead foetus at any stage of gestation. **Stillbirth** is the expulsion of a dead foetus at term (ie within the period of expected viability). **Premature birth** is the birth of a viable foetus before expected parturition.

Foetal death may result in **abortion**, **stillbirth** or retention with **mummification** (requires absence of uterine bacterial infection) or **maceration** and **emphysema** (require uterine bacterial infection).

Non-specific autolytic changes are seen in the **foetus and foetal membranes** that have been retained *in utero* for 24 hours or longer after foetal death. Most obvious are **dark-red, haemoglobin-stained body fluids and tissues** from haemolysis of erythrocytes leaked from capillaries after death. **Bloody subcutaneous and perirenal oedema**, and **bloody fluid accumulated in body cavities** are also present. As autolysis advances, the tissues of the foetus develop a green-brown,

partially-cooked appearance, and solid visceral organs (especially kidneys, spleen and liver) and brain become soft, with the lungs and myocardium the last affected. The autolysing chorioallantois ("placenta") is oedematous and discoloured, initially dark-red and then progressively green-brown or tan. The cotyledons may be soft or pasty. Autolysis may mask antemortem lesions.

Meconium staining of the foetal skin and amnion follows *in-utero* defaecation (due to foetal diarrhoea, anoxia or stress) into the amniotic sac. The foetal skin and amnion have a prominent, yellow-stained appearance, and the amnion may be infarcted.

Non-inflammatory Changes in the Conceptus

Adventitial placentation in cattle is a response to inadequate development of placentomes when there are too few caruncles. This may be congenital or due to loss of caruncles following endometritis. Compensatory increase in size, with fusion of conventional placentomes is the first response. This is followed by formation of adventitial placental areas by simple villous interdigitation, initially adjacent to placentomes. It can extend along the floor of the uterus to involve much of the intercotyledonary areas; in such cases, pregnancy may not be maintained or **hydrallantois** may develop.

Amniotic plaques are foci of squamous metaplasia up 4 mm in diameter. They are frequently keratinised, and are a normal incidental finding on the internal surface of the amnion at the umbilical stump, particularly in cattle. They can infold to form spherical structures filled with keratinised material.

Placental mineralisation is a physiological process in ruminants. In **cattle**, it is visible between 60 and 120 days of gestation as milky, non-gritty foci and streaks along small vessels in the chorioallantois. In **sheep**, non-inflammatory **calcification of cotyledonary villi** is common and may involve a few or many cotyledons, which have several to many elongated white gritty structures amongst otherwise normal foetal villi. *These calcified villi may be mistaken for the cotyledonary lesions of ovine toxoplasmosis.*

Avascular chorion or "necrotic tips" are normal, white to brown, wrinkled, avascular and avillous structures at the ends of ruminant chorioallantoic membranes.

Amorphus globosus comprises a round, hard cystic structure next to the umbilical cord and considered to be an incomplete twin or "teratoma".

Hippomanes are amorphous rubbery masses that are frequently found in allantoic fluid of the horse but have been reported in cattle and pigs. They are allantoic calculi that result from deposition of material from

allantoic fluid on a central nidus of desquamated epithelial debris from the lining of the allantoic cavity.

Hydramnios in cattle and sheep is usually associated with foetal, musculoskeletal malformation particularly of the head, possibly affecting the foetal drinking reflex.

Hydrallantois in cattle results in a marked increase in allantoic fluid to up to 170 litres. Adventitial placentation and twin pregnancies predispose. Outcomes are abortion and dystocia associated with small dead calves with anasarca and ascites.

Prolonged Gestation

Foetal anomalies that disrupt the hypothalamic-pituitary-adrenal axis (an intact foetal axis appears necessary for initiation of parturition) can result in prolonged gestation. Sporadic cases occur in grossly deformed bovine foetuses with severe brain anomalies.

Akabane disease in sheep and cattle can prolong gestation. In sheep outbreaks in Israel (1971) and Japan (1975), gestation was prolonged (to 180 days) in association with severe foetal hydranencephaly, hydrocephalus and arthrogryposis (and a high incidence of abortion); in Australia, gestation was only marginally prolonged in sheep outbreaks (1974, 1976), in which micrencephaly was the most common foetal defect.

Two autosomal recessive defects in cattle, including one associated with adrenal hypoplasia in Holsteins and Ayrshires and one associated with cyclopean head anomalies or absence of the pituitary gland in Guernseys and Jerseys, prolong gestation.

Veratrum californicum ingestion by ewes on day 14 of gestation results in cyclopean giant lambs with displaced pituitaries, and prolonged gestation.

Salsola tuberculatisformis (a drought-resistant African shrub) ingestion by ewes during the last 50 days of gestation results in lambs with hypoplastic pituitaries and adrenals, and prolonged gestation.

Viral Causes of Foetal and Congenital Disease

Bovine pestivirus and Border disease virus infections

The outcome of *in-utero* infection of ruminants by pestivirus depends on the stage of gestation.

In **cattle**, exposure of the conceptus to **bovine pestivirus** at:

- 0 to 30 days of gestation causes either **embryonic death** or no infection.

- 30 to 100 days of gestation causes **abortion**, mummification, premature birth, stillbirth, **stunted, full-term calf** (due to **in-utero growth retardation**), normal but **immunotolerant, persistently-infected**, full-term, live calf and some **congenital malformation** (cerebellar hypoplasia and hydranencephaly).
- 100 to 180 days of gestation causes **congenital malformation** (cerebellar hypoplasia, hydranencephaly, micrencephaly, microphthalmia, chorioretinopathy, cataracts, hypotrichosis and rarely arthrogryposis).
- 180 days of gestation causes seroconversion only.

In **sheep** and **goats**, exposure of the conceptus to **Border disease virus** at:

- 30 to 55 days of gestation causes **abortion**, mummification, or normal but **immunotolerant, persistently-infected**, full-term, live lamb / kid.
- 55 to 70 days of gestation causes **hairy shaker** (with hairy fleece and hypomyelinogenesis), **immunotolerant, persistently-infected**, full-term, live lamb / kid, and **congenital abnormalities** (**HE, porencephaly, cerebral dysgenesis**).
- 70 to 90 days of gestation causes variable changes and seroconversion.
- 90 days of gestation causes seroconversion only.

Reference:

Taylor LF, Rodwell BJ. Outbreak of foetal infection with bovine pestivirus in a central Queensland beef herd. *Aust Vet J* 2001;79:682-685.

Akabane virus and other Bunyaviridae (Aino, Cache Valley and Rift Valley fever virus) infections

Akabane virus, a member of the Bunyaviridae, causes congenital malformations (Akabane disease) that depend on the stage of *in-utero* infection of the foetus.

Cattle are most commonly affected by Akabane disease. *In-utero* exposure to Akabane virus at:

- 76 to 104 days of gestation causes **hydranencephaly (HE)**, usually with a **normal-sized cerebellum**.
- 104 to 173 days of gestation causes **arthrogryposis (AG)**, after degeneration of lower motor neurons.
- > 173 days of gestation causes seroconversion only or **encephalomyelitis** in the newborn calf (or less frequently abortion or stillbirth).

Sheep and **goats** have a similar but not identical spectrum of congenital malformations associated with Akabane disease. *These malformations often develop concurrently (rather than sequentially as in cattle above) due to the shorter gestation and susceptibility periods in small ruminants.* Exposure of the conceptus at:

- 30 to 50 days of gestation causes **micrencephaly, porencephaly, AG, HE, scoliosis and kyphosis**.

Aino virus is reported to produce similar **congenital malformations** in ruminants as Akabane virus, but also **cerebellar hypoplasia** and **unilateral porencephaly**, which are not usual features of Akabane disease.

Cache Valley virus causes **AG** and **HE** in sheep in the USA, with foetal disease resulting from infections in a similar gestational age range as for Akabane virus. The main outcomes of foetal infections at 27 to 35 days of gestation are **foetal death** with **resorption** or **mummification**, and at 36 to 45 days are **AG** and **HE**.

Rift Valley fever virus, another member of the Bunyaviridae, is exotic to Australia but should be considered as a differential diagnosis of **abortions affecting multiple ruminant species** (cattle, sheep and goats) associated with outbreaks of **sickness** and **deaths** particularly in young animals, with necropsy findings of **hepatic necrosis** and generalised ecchymotic haemorrhages. Rift Valley fever is a zoonosis.

Reference:

Kirkland PD, Barry RD, Harper PAW, Zelski RZ. The development of Akabane virus-induced congenital abnormalities in cattle. *Vet Rec* 1988;122:582-586.

Orbivirus (Bluetongue, Epizootic Haemorrhagic Disease and Palyam virus) infections

Eight of 27 known serotypes of bluetongue virus occur in Australia, with infection occurring mainly in cattle, which do not develop clinical disease. Although all serotypes are potentially pathogenic for sheep and goats, clinical bluetongue in these species has not yet been reported in the main Australian sheep-raising areas.

Although **bluetongue virus** can cause foetal disease and congenital malformation (including **hydranencephaly** but not arthrogryposis) in ruminants (see **Appendices 1** and **2**), it is believed that only vaccine and not wild type viruses induce them, ie they are an artifact of laboratory manipulation.

Other members of the Orbivirus genus, including **six of eight known serotypes of epizootic haemorrhagic disease (EHD) virus**, and also **Palyam viruses**, cause subclinical infection in Australian cattle. One of these, a Palyam virus (**D'Aguilar virus**) is occasionally associated with **abortion, foetal mummification** and **congenital malformation** (**cerebellar hypoplasia** is reported).

In Japan, an EHD 2 virus (**Ibaraki virus**) causes outbreaks of severe disease in cattle with up to 10% mortality, and reported **abortion** and **congenital malformations**. Also in Japan, a Palyam virus (**Chuzan** or **Kasba virus**) causes **hydranencephaly** and **cerebellar hypoplasia** in cattle.

Bovine herpesvirus infections

Bovine herpesvirus 1 (BHV 1) causes infectious bovine rhinotracheitis and infectious pustular vulvovaginitis in Australia and New Zealand but not foetal infection with abortion.

Overseas, where **foetotropic strains of BHV 1** occur, abortions follow three to six weeks after clinical illness or IBR vaccination of non-immune pregnant animals, usually in the last trimester. Once the virus invades the foetus, death is rapid, but expulsion is delayed for at least for one to five days and the foetus and membranes are invariably markedly autolysed. **Abortion, mummification, stillbirth and birth of weak calves** are the outcomes. Gross lesions are usually absent or obscured by autolysis, but if present consist of multiple 1 to 3 mm diameter, off-white foci of necrosis in liver and less frequently lung and spleen. In live, affected newborn calves as well as **multifocal hepatic necrosis** there can be **necrosis and ulceration of the upper alimentary tract**, particularly in **forestomachs** where accumulated necrotic material on the mucosal surface resembles curdled milk.

Bovine parvovirus infections

In the USA, **bovine parvovirus** is described as a cause of diarrhoea in calves and of abortion and birth of weak calves. Infections in the first trimester cause **repeat breeding, early embryonic mortality and abortion**; in the second trimester **cerebellar hypoplasia**; and in the third trimester seroconversion only. Microscopically there are intranuclear inclusions in the cerebellar external granular layer cells, hepatocytes, adrenal cortical cells and intestinal cryptal epithelium.

Bacterial and Mycotic Causes of Foetal Disease

Many organisms of relatively low virulence and ubiquitous in the environment (eg *E coli*, *Bacillus* spp and fungi) can cause sporadic cases of abortion after invading the gravid uterus and conceptus. However, when isolated from the foetus and / or foetal membranes they should to be regarded as likely postmortem contaminants unless they are associated with lesions such as foetal bronchopneumonia or placentitis (often detectable only at histological examination).

The following infections of the ruminant conceptus have **pathological patterns of disease** that are an aid to differential diagnosis.

Brucellosis

Brucella abortus is now eradicated from cattle in Australia. The main lesion is a chronic placentitis with oedema, fibrosis and wrinkling of the intercotyledonary chorioallantois, which is covered by a custard-like exudate. Changes are most marked adjacent to cotyledons, all or portions of which are necrotic. The foetus is autolysed and oedematous

and may have gross evidence of foetal pneumonia (firm, red lungs, with fibrin strands on the pleural surfaces).

Brucella ovis is mainly a cause of epididymitis in rams, but can cause placental infection in late pregnancy resulting in abortion (the non-pregnant uterus is not susceptible to infection). As with *Br abortus*, *Br ovis* localises in the chorionic epithelium and produces a severe, chronic placentitis (vasculitis is a feature), with gross oedematous thickening, wrinkling and mineralisation of the intercotyledonary chorioallantois, and necrosis of cotyledons. The aborted foetus may be autolysed or mummified, but most are alive at the start of parturition (and may survive) and show no gross lesions other than calcified plaques on the hooves and the accessory digits (in about 50% of cases from grossly-diseased placentas).

Campylobacteriosis

Campylobacter fetus venerealis is a venereal infection transmitted by coitus, and causes infertility and abortion in cattle. *C fetus fetus* and *C jejuni* are intestinal organisms that are transmitted orally with bacteraemic spread to the pregnant uterus in sheep and cattle, causing abortion. *C lari* (also known as *C laridis*), which is common in seagulls and infrequently causes human enteric disease, is reported as causing ovine abortion in New Zealand.

In cattle, both *C fetus* subspecies can cause abortion from four months gestation onwards, with expulsion of the foetus and foetal membranes that may be fresh or show signs of *in-utero* autolysis. There is clear or bloodstained fluid within the subcutis, thorax and abdomen and the liver may be enlarged. Fibrinous polyserositis (sheets of fibrin covering the serosal surface of the lungs, liver and intestines) is a distinctive finding in some cases. Rarely there are multiple small necrotic foci in the liver. The gross placental changes resemble those of brucellosis but are milder. There may be intercotyledonary oedema and cotyledonary necrosis.

In sheep, *C fetus fetus* and *C lari* cause abortion outbreaks in late pregnancy to full term, with considerable variation in gross lesions. Gross changes are as for cattle. However, with *C fetus fetus* there is an additional distinctive liver lesion in a third of affected foetuses: multiple (few or many) circular, tan, necrotic areas 5 to 20 mm in diameter, often with a raised outer border to give a target appearance.

A microscopic foetal bronchopneumonia is present and the distinctive organisms can be demonstrated in and isolated from foetal stomach fluid.

Reference:

Van Donkersgoed J, Janzen ED, Chirino-Trejo M et al. *Campylobacter jejuni* abortions in two beef cattle herds in Saskatchewan. *Can Vet J* 1990;31:373-377.

***Flexispira rappini* infections**

Reported in the USA as a cause in sheep of sporadic cases of abortion, mummification and birth of weak lambs, *F rappini*, an anaerobic flagellated organism, can produce gross placental and hepatic lesions

identical to those of *C fetus fetus*, including the distinctive circumscribed hepatic foci.

Reference:

Kirkbride CA, Gates CE, Collins JE. Abortion in sheep caused by a nonclassified, anaerobic, flagellated bacterium. *Am J Vet Res* 1986;47:259-262.

***Fusobacterium* spp infections**

In New Zealand, a *Fusobacterium*-like organism causes abortion in sheep associated with similar gross and microscopic placental and foetal lesions to those of *C fetus fetus* and *F rappini*. The organism is demonstrable in Gram-stained smears of foetal stomach contents.

References:

Clark G, Gill JM A review of sheep abortions in Otago and Southland *VETscript* December 2002;:18-19.

Smart JA, Gill JM. *Fusobacterium*-like abortions – an overview. Proceedings of 29th Seminar, Society Sheep and Cattle Veterinarians NZVA 1999:35-38

Listeriosis

Listeria monocytogenes and *L ivanovii* cause sporadic abortions and occasionally small outbreaks of abortion in sheep and cattle, often associated with feeding silage. In early third trimester infections, there is rapid invasion of the placenta and foetus with foetal death and abortion within five days; minor gross lesions are masked by autolysis. In near term infections, abnormal parturition with dystocia and severe metritis can occur, and placental and foetal lesions are less likely to be obscured by autolysis.

Grossly there are multiple, circular, yellowish necrotic foci 1 to 3 mm in diameter in the liver (and occasionally in lungs). There is a microscopic foetal bronchopneumonia.

The gross placental changes are severe and include extensive thickening and necrosis of the intercotyledonary chorioallantois with adherent necrotic exudate and necrosis of cotyledons.

References:

Ladds PW, Dennis SM, Cooper RF. Sequential studies of experimentally induced ovine listerial abortion: Clinical and bacteriological examinations. *Am J Vet Res* 1974;35:155-160.

Ladds PW, Dennis SM. Sequential studies of experimentally induced ovine listerial abortion: Pathological changes. *Am J Vet Res* 1974;35:161-170.

Gill PA, Boulton JG, Fraser GC, Stevenson AE, Reddacliff LA (1997). Bovine abortion caused by *Listeria ivanovii*. *Aust Vet J* 75:214.

Leptospirosis

Abortion in cattle is caused worldwide by *Leptospira interrogans* serovar *pomona* (*L. pomona*), and in Northern Ireland by *L. interrogans* serovar genotype *hardjo-prajitno* (*L. hardjo-prajitno*). *L. borgpetersenii* serovar genotype *hardjo-ovis* (*L. hardjo-ovis*), which causes milk drop syndrome in Australia, is not associated with abortion in cattle. During systemic infection of the dam, *Leptospira* spp may localise in the placenta and in some animals produce foetal disease followed by abortion of an autolysed foetus.

The placenta may be grossly oedematous. Despite the presence of leptospires in the chorionic epithelium and in foetal tissues, inflammation is modest (there is occasionally microscopic, non-suppurative foetal nephritis and meningitis).

Mycoplasmosis

***Mycoplasma* sp bovine group 7** causes outbreaks of polyarthritis in calves, which may be associated with outbreaks of mastitis and abortion. Gross changes reported in aborted fetuses are excessive straw-coloured, turbid fluid in body cavities and hip joints. Microscopically there is a suppurative bronchopneumonia with an interstitial myocarditis and epicarditis. *Isolates from foetal stomach fluid, liver and lung appear as beta-haemolytic colonies after five days incubation, a period longer than that routinely used for bacteriological cultures (48 hours), so the diagnosis may be missed.*

Most post-natal-cases of polyarthritis are clinically affected between two to three weeks of age, a finding consistent with infection from consumption of milk contaminated with *Mycoplasma* sp bovine group 7.

Reference:

Hum S, Kessell A, Djordjevic S, Rheinberger et al. Mastitis, polyarthritis and abortion caused by *Mycoplasma* species bovine group 7 in dairy cattle. *Aust Vet J* 2000;78:744-750.

Ureaplasma diversum infections

***Ureaplasma diversum* (formerly T mycoplasma)** is frequently found in the nasal cavity, vagina and prepuce of cattle, and virulent strains can cause granular vulvitis, embryonic deaths, abortion and birth of weak calves. Abortion is in the last trimester, with retention of foetal membranes. Reports are mainly from North America, but in New Zealand vulvitis and an outbreak of abortion in embryo-transfer recipients associated with *U. diversum* have been reported.

Gross lesions are a chronic thickening of the amnion, with yellow, firm tissue running through white oedematous areas and multiple confluent red plaques, and hyperaemia of the chorioallantois, with intercotyledonary oedema. Microscopic changes are a chronic non-suppurative amnionitis and lymphocytic bronchiointerstitial pneumonia. Isolation of *U. diversum* from placenta, or foetus is necessary for diagnosis.

References:

- Johnstone AC, Voges H. *Ureaplasma diversum* as a cause of abortion in embryo-transfer recipient cattle in New Zealand. *Proc Annual Meeting Aust Soc Vet Pathol* Brisbane, May, 1997.
- Thornton R, Wake H. *Ureaplasma* in New Zealand dairy cattle. *Surveillance* 1997;24(3):15-16.

***Arcanobacterium* (formerly *Actinomyces*) *pyogenes* infections**

The pyogenic organism *A. pyogenes* is a common mucosal contaminant of tonsils and vagina and can localise in the placenta following a transient bacteraemia, causing sporadic cases of abortion in cattle and, less frequently, in sheep. Gross lesions are a suppurative placentitis (autolysed chorioallantois, with yellow to brown exudate covering swollen cotyledons), and in the foetus, a haemorrhagic tracheal cast and dark-red, swollen lungs containing multiple, off-white, suppurative foci with a bronchiolar distribution. Some cases with modest inflammation have massive microscopic *A. pyogenes* colonisation of placenta and foetal skin and lung.

***Bacillus* spp infections**

Bacillus spp cause abortion in cattle and sheep worldwide. *Bacillus licheniformis* abortion in cattle is reported mainly from Europe, but also from Australia and the USA. Gross lesions are a necrotising chorioallantoitis (yellow discolouration, thickening and oedema of cotyledons and intercotyledonary areas), with or without gross evidence of foetal bronchopneumonia, fibrinous polyserositis and mediastinal, bronchial and hepatic lymphadenopathy. Microscopically there is necrotising chorioallantoitis and suppurative bronchopneumonia.

References:

- Agerholm JS, Jensen NE, Dantzer HE et al. Experimental infection of pregnant cows with *Bacillus licheniformis* bacteria. *Vet Pathol* 1999;36:191-201.
- Mason RW, Munday BL. Abortion in Sheep and Cattle associated with *Bacillus* spp. *Aust Vet J* 1968;44:297-298.
- Mitchell G, Barton MG. Bovine abortion associated with *Bacillus licheniformis*. *Aust Vet J* 1986;63:160-161.

Salmonellosis

Salmonella spp abortion in ruminants can occur within a week of signs of systemic disease in the dam, or without such prior clinical signs. Sickness and death of the dam may occur after abortion occurs. Serotypes involved include *S*Typhimurium, *S*Dublin and *S*Brandenburg (abortion outbreaks caused by *S*Brandenburg in New Zealand sheep were first detected in 1997 and reached a peak incidence in 2001; it also caused bovine abortions). *Salmonella* spp infect the placentome, where they proliferate causing necrosis, mineralisation and suppuration within the foetal chorionic villi (with relative sparing of the maternal caruncular septa) and abortion, often with placental retention.

Grossly the chorioallantois is oedematous with a diffusely grey to red surface, and the cotyledons are tan to red and covered by a yellow exudate.

The aborted foetus is autolysed. There may or may not be detectable *Salmonella* spp invasion of the foetus, and when it occurs it produces only microscopic lesions (bronchopneumonia and multifocal hepatic necrosis).

Sheep fetuses from *Salmonella* Brandenburg abortions in New Zealand had haemorrhagic subcutaneous oedema and autolysed viscera; the skin of older fetuses with wool, had a "cooked" appearance. (*G Clark, pers comm 2003*).

Yersiniosis

Yersinia pseudotuberculosis is an intestinal inhabitant of sheep, cattle and goats, and following transient bacteraemia colonises the maternal caruncle before spreading to the chorioallantois and foetus. Grossly the cotyledons are red or tan and thickened, and the adjacent intercotyledonary areas may be thickened. The foetus is aborted fresh, with excessive amber-coloured thoracic and abdominal foetal fluid, and multiple pale tan foci 1 to 10 mm in the liver and possibly in the kidneys.

Microscopically there is a non-suppurative myocarditis and pneumonia and lymphoplasmacytic colitis.

References:

- Hannam DAR. Bovine abortion associated with *Yersinia pseudotuberculosis*. *Vet Rec* 1993;133:372.
Jerrett IV, Slee KJ. Bovine abortion associated with *Yersinia pseudotuberculosis* infection. *Vet Pathol* 1989;26:181-183.

Haemophilus somnus infections

Haemophilus somnus, usually a cause of respiratory and CNS disease, can cause abortion in cattle following bacteraemic spread to produce histological lesions of an acute nonsuppurative cotyledonary placentitis associated with severe fibrinoid necrosis and thrombosis of large and small chorionic arteries. The foetus becomes infected, dies rapidly, is aborted after undergoing marked autolysis, and shows few lesions other than a microscopic fibrinous bronchopneumonia.

Chlamydiosis

Chlamydophila abortus (formerly *Chlamydia psittaci* immunotype 1) causes enzootic abortion of sheep overseas, but is not reported as causing abortion in sheep, goats or cattle in Australia. Other strains of *C psittaci* may cause sporadic cases of abortion in ruminants.

Gross placental lesions are similar to those in brucellosis; there is a chorioallantoitis (with vasculitis). The foetus is usually fresh and without gross lesions. Microscopic changes include multifocal necrosis of liver and spleen, alveolitis and mild meningoencephalitis.

References:

- Cox HU, Hoyt PG, Poston RP et al. Isolation of an avian serovar of *Chlamydia psittaci* from a case of bovine abortion. *J Vet Diagn Invest* 1998;10:280-282.

Holliman A, Daniel RG, Parr JG et al. Chlamydiosis and abortion in a dairy herd. *Vet Rec* 1994;134:500-502.

***Coxiella burnetii* infections (Q fever)**

Coxiella burnetii is a widespread persistent intracellular infection of dairy cattle, goats and sheep. In Australia, it is rarely diagnosed as a cause of abortion. *C burnetii* is shed at parturition and in milk. Infection in people and animals is from inhalation of contaminated dust or fluid, or in animals from ingestion of massively contaminated pasture.

Gross lesions are confined to the placenta. There is a thickened, leathery chorioallantois with confluent areas of mineralisation and copious off-white exudate, most obvious in the intercotyledonary areas.

Microscopically there is colonisation by organisms, necrosis and neutrophilic infiltration of chorionic villi of cotyledons and of chorionic epithelium of the intercotyledonary areas. Within the underlying chorionic stroma there is a lymphoplasmacytosis (without the vasculitis of chlamydiosis).

Mycotic infections

Mycotic abortions in cattle are late-term, usually sporadic and caused by *Aspergillus* spp, *Absidia* spp, *Mucor* spp, *Rhizopus* spp and *Mortierella wolfii*. The placental lesions develop first within the placentomes (indicating haematogenous infection) which are enlarged and necrotic, and spread to the intercotyledonary chorioallantois which becomes leathery and ulcerated. The foetus is infected (fungal hyphae are demonstrable in foetal stomach) but is usually free of gross lesions. Some foetuses have a few or many ringworm-like, skin lesions and occasional necrotic foci in liver, lung, brain, and amnion.

M wolfii infection appears to be more acute and is often causes a fatal pneumonia in the dam following abortion.

Protozoal Causes of Foetal Disease

Babesiosis

Transplacental transmission of *Babesia* spp in cattle appears most likely to occur close to parturition, as most reports describe clinical disease in calves within a few days of birth. It is a rare cause of abortion. Gross lesions of *Babesia bovis* infection in an 8-month aborted foetus were anaemia ("thin, watery blood"), generalised icterus and a swollen, orange-coloured liver. Microscopically there was a concentration of parasitised erythrocytes in brain capillaries, hepatic canalicular cholestasis and Kupffer cell haemosiderosis, focal renal cortical haemorrhage, and depletion of erythrocytes from the splenic red pulp.

Reference:

Trueman KF, McLennan MW. Bovine abortion due to *Babesia bovis* infection. *Aust Vet J* 1987;64:63.

Neosporosis

Neospora caninum causes abortion in cattle during the second and third trimester. It can also cause ascending paralysis in neonatal calves.

Apart from non-specific autolytic changes in the foetus and foetal membranes, there are no gross lesions. Distinctive microscopic lesions of granulomatous myocarditis and necrogranulomatous encephalomyelitis are diagnostic. There is also microscopic necrosis of cotyledonary chorionic villi. As in toxoplasmosis in sheep and goats, the intercotyledonary chorioallantois is normal.

Toxoplasmosis

Toxoplasma gondii causes embryonic death, mummification, abortion, stillbirth and neonatal death in sheep and goats, with expulsion of most infected fetuses late in gestation.

Gross lesions are seen in about half of the placentas and are confined to the cotyledons. These are firm and usually contain distinctive multiple, white or pale-yellow, soft, 1 to 2 mm foci along the villi, with similar lesions in almost all cotyledons. The intercotyledonary chorioallantois is normal. The foetus tends to be undersized, but has no distinctive gross changes. Microscopically there is a necrogranulomatous encephalomyelitis and small to large necrotic areas within white matter of the forebrain (these latter areas may sometimes be detectable grossly).

Sarcocystosis

Sarcocystis spp are uncommon causes of abortion, stillbirth, and neonatal deaths in cattle, goats, and sheep. The different ruminant species are infected by ingestion of oocysts from the definitive hosts, and systemic spread results in an acute necrotising endometritis followed by abortion. There is autolysis but no other gross lesions of the foetus and foetal membranes.

Microscopic lesions of necrosis, with cysts containing zoites with a predilection for endothelium, may be confined to the endometrium and caruncles or also be disseminated through soft tissues of the foetus in association with a nonsuppurative meningoencephalomyelitis.

Trichomoniasis

Tritrichomonas foetus is a flagellated protozoal organism that spreads venereally in cattle and causes transient vaginitis and chronic cervicitis and endometritis that result in repeat breeding, abortion during the first half of pregnancy, and pyometra.

The chorioallantois has only mild gross changes of slight thickening, with small amounts of white or yellowish flocculent exudate, and cotyledonary haemorrhage with minimal necrosis. In the foetus there are no gross lesions but there is a microscopic bronchopneumonia. Trichomonads are detectable in the placenta, lungs and stomach contents.

Reference:

Rhyan JC, Stackhouse LL, Quinn WJ. Fetal and placental lesions in bovine abortion due to *Tritrichomonas foetus*. *Vet Pathol* 1988;25:350-355.

Congenital Developmental Abnormalities of Plant-associated Toxic Cause

Toxic, nutritional, genetic and other undefined diseases can cause reproductive failure, and some produce foetal disease resulting in abortion or congenital disease, including developmental malformation.

Arthrogryposis is reported in calves and lambs born to dams grazing *Sorghum* spp.

"**Bentleg**" ("bowie") of lambs is characterised by lateral curvature of the long bones of the forelegs and other deformities of limbs. It occurs as a congenital deformity in lambs born to ewes grazing **wild parsnips** (*Trachymene ochracea*, *T cyanantha* and *T glaucifolia*) during pregnancy and is reported in western Queensland and north-western New South Wales.

Overseas, the following plants have been associated with abortion or congenital disease:

- ***Veratrum californicum*** ingested by ewes on day 14 of gestation can cause **cyclopia** and **prolonged gestation** and, at other gestational ages, embryonic mortality and other anomalies in lambs (eg at 29 days, **shortening of metacarpals, metatarsals, tibiae** and sometimes **radii**). Ingestion by pregnant cows between 12 and 30 days of gestation can produce cleft palate, brachgnathia, hypermobility of hock joints, syndactylia, decreased length and diameter of all bones or shortening of metacarpals and metatarsals only, and reduction in number of coccygeal vertebrae; ingestion between 30 and 36 days produces shortening of metacarpals and metatarsals.
- ***Astragalus* spp** and ***Oxytropis* spp** (**locoweeds**) cause **abortions** and **bony abnormalities** (**brachgnathia, contractures or overextension of joints, limb rotations** and **osteoporosis**) in lambs.
- ***Lupinus* spp** (**lupins**) ingested by cows from days 40 to 70 of gestation cause **abnormalities of the limbs and axial skeleton** in calves (**crooked calves**).
- ***Nicotiana glauca*** (**wild tree tobacco**) ingested by cows from days 45 and 75 of gestation produces **arthrogryposis** and **spinal deformities** in calves. It also causes congenital **abnormalities of the limbs and axial skeleton** in lambs and kids.
- ***Pinus ponderosa*** and other ***Pinus* spp** cause **abortion** or **birth of weak calves** two to 20 days after ingestion of pine needles.

Congenital Developmental Abnormalities of Nutritional Cause

Selenium / vitamin E-responsive disease can cause **congenital cardiac lesions of nutritional myopathy (cardiac "white muscle disease")** in **lambs**, with gross, chalky-white lesions of necrosis and mineralisation in the **right ventricle**. In **calves**, **cardiac lesions of nutritional myopathy** are rarely congenital, and are usually **delayed** in onset until several weeks of age, with lesions mainly involving the **left ventricle**. In Australia, many cases of suspected bovine congenital cardiac "white muscle disease" have proved to be the inherited **cardiomyopathy and woolly haircoat syndrome (CWH)** in **Poll Hereford** calves. *In Saskatchewan, aborted bovine fetuses with cardiac dilation and hypertrophy, a nodular liver, ascites and often microscopic myocardial necrosis and mineralisation had a lower mean concentration of selenium in liver (but not kidney) than aborted fetuses without these lesions; the latter group had a lower mean liver selenium concentration than non-aborted fetuses.*

Iodine deficiency can cause **goitre**, with either cystic or solid enlargement of thyroids.

Copper deficiency can cause **congenital swayback** in sheep, with liquefactive necrosis of cerebrocortical white matter, resulting in cavitation and occasionally hydranencephaly. This condition is rare in Australasia.

Manganese deficiency in dams during pregnancy is reported to produce **congenital limb deformities** including reduced length and breaking strength of humeri, enlarged joints and twisted legs in calves, lambs and kids.

Reference:

Orr JF, Blakley BR. Investigation of the selenium status of aborted calves with cardiac failure and myocardial necrosis. *J Vet Diagn Invest* 1997;9:172-179.

Congenital Developmental Abnormalities of Genetic or Familial Cause

Chondrodysplasia in Dexter cattle, a type of disproportionate dwarfism, has an incompletely dominant, simple Mendelian mode of inheritance (the causative gene, which is required for normal cartilage development, has recently been identified). The heterozygotes are usually short-legged animals. The homozygotes, cases of **congenital lethal achondroplasia** (Dexter bulldogs), are usually aborted before the seventh month of gestation. Characteristics of these bulldog calves are disproportionate dwarfism, a short vertebral column, marked micromelia, a relatively large head with retruded muzzle, cleft palate, protruding tongue, and a large abdominal hernia. Lungs are ventrally multilobulated (presumably due to the ribs restricting lung development *in utero*) and represent those non-skeletal organs, including tongue and abdominal viscera, whose growth is not primarily affected by the growth retardation of the disease.

Cardiomyopathy and woolly haircoat syndrome (CWH) in **Poll Hereford** calves is an autosomal recessive congenital disease caused by a presumed defect of desmosomal intercellular junctions. Affected calves have a distinctive woolly haircoat and gross congenital cardiac lesions of fibrosis, necrosis and mineralisation in the ventricular myocardium. Death usually occurs within two months of birth and may be sudden or follow a period of congestive heart failure.

Other genetic or familial congenital diseases of **cattle** include **cerebellar hypoplasia, arthrogryposis and cleft palate in Charolais, proportionate and other types of disproportionate (chondrodysplastic) dwarfism, osteogenesis imperfecta, epitheliogenesis imperfecta, and polymicroglia.**

Genetic or familial congenital diseases of **sheep** and **goats** comprise an extensive list including **arthrogryposis, micrencephaly, congenital cystic kidney / bile ducts / pancreas, anasarca, spina bifida, skin fragility, photosensitisation and goitre.**

References:

- Harper PAW, Latter MR, Nicholas FW, Cook RW, Gill PA. Chondrodysplasia in Australian Dexter cattle. *Aust Vet J* 1998;76:199-202.
Morrow CJ, McOrist S. Cardiomyopathy associated with curly hair coat in Poll Hereford calves in Australia. *Vet Rec* 1985;117:312-313.
Whittington RJ, Cook RW. Cardiomyopathy and woolly haircoat syndrome of Poll Hereford cattle: electrocardiographic findings in affected and unaffected calves *Aust Vet J* 1988;65:341-344.

Congenital Developmental Abnormalities of Unknown Cause

Acorn calf syndrome occurs periodically in outbreak form or sporadically in the Riverina area of New South Wales. It affects all cattle breeds over a large area. Full term calves are born with shortened limb bones. Associated tendons and muscles seem unaffected and there is resulting hypermobility of joints. Most calves make a good recovery to normal bone growth if they are able to suck or are hand-reared. Some survivors have permanent bowing of limbs.

Hydrops foetalis is rare condition in ruminants. It has been reported in Australia in proportionate dwarf calves in pregnancies with multiple foetuses, and in lambs.

Congenital biliary atresia and icterus in lambs and calves was reported in outbreak form in 1964 and 1988 on two adjoining properties in the southern tablelands of New South Wales. During early pregnancy affected ewes and cows had grazed the exposed silt foreshores of Burrenjack Dam and a toxic insult to the foetus at this time was suspected.

Sporadic defects in any organ system represent *in-utero* arrest in development and are often combined with defects in other organs (ie **multiple congenital defects**).

For example, the following is a selection of gross **congenital CNS defects** that may be accompanied by defects in other organs:

- **Cerebral defects** include holoprosencephaly (cyclopia is its most severe form), arhinencephaly, agenesis of corpus callosum, anencephaly, exencephaly, hydranencephaly, hydrocephalus, meningoencephalocoele, micrencephaly and polymicroglia.
- **Cerebellar and brain stem defects** include Arnold-Chiari malformation (caudal displacement of cerebellar vermis and elongated medulla and fourth ventricle through foramen magnum, caudal displacement of occipital poles of the cerebral hemispheres, hydrocephalus, spina bifida and meningomyelocoele), Dandy Walker syndrome (hydrocephalus, aplasia or hypoplasia of cerebellar vermis, and cystic enlargement of fourth ventricle), and cerebellar aplasia, hypoplasia or degeneration.
- **Spinal cord defects** include spina bifida, spinal aplasia (amyelia), and spinal dysraphism.

References:

- Harper PAW, Latter MR, Wilkins JF. Hydrops foetalis in dwarf calves associated with twinning. *Aust Vet J* 1995;72:236-237.
- Harper PAW, Plant JW, Unger DR. Congenital biliary atresia and jaundice in lambs and calves. *Aust Vet J* 1990;67:18-22.

Neonatal Diseases

Dystocia and / or **prolonged birth** with anterior presentation produces moderate to marked, clear or blood-stained **localised oedema**, involving the head and tongue, and sometimes extending down the neck and to the extremities of the forelimbs. There may be extensive bruising of muscles over the thorax, and abdominal haemorrhage from liver rupture.

Trauma and / or **anoxia** within the central nervous system during birth can cause **meningeal congestion** and **haemorrhage**. It has been suggested that such lesions in neonatal animals are manifestations of injury that may lead to death during or immediately after birth, and that less severe injury may impair physical and behavioural activity and prejudice the survival of the neonate (Haughey 1973, 1975). These lesions are reported in lambs, calves (and foals).

In the **cranium**:

- **Subdural haemorrhages** (small to large clots in the space between the dura mater and leptomeninges).
- **Leptomeningeal haemorrhages (blood-stained cerebrospinal fluid** in the subarachnoid spaces over the cerebral sulci, **haemorrhages anywhere over the brain surface**, or large perivascular **extravasations along the course of the main leptomeningeal vessels**).
- **Leptomeningeal congestion** (marked engorgement of subarachnoid veins and capillaries).

In the **spinal canal**:

- **Epidural haemorrhages** extending over the length of several vertebrae (commonly at the level of the first two cervical vertebrae, at the thoracic inlet and the lumbar-pelvic junction).
- **Blood-stained cerebrospinal fluid** (in a subdural location, usually confined to the cervical region in an annular or banded distribution, and able to be freely moved along the cord by digital pressure).
- **Haemorrhages or congestion within the leptomeninges.**

Exposure lesions are difficult to define, describe or detect. Much depends on the age of the lamb or calf and whether it has sucked, and the severity and duration of exposure. Most affected animals will have breathed, walked and sucked. The essential lesion is a mild to moderate **generalised peripheral oedema**, cessation of milk absorption and relatively normal looking fat reserves and liver.

Starvation results in a slab-sided, dehydrated animal with dark musculature. It will have breathed and walked and there is usually no milk in the gastrointestinal tract. The liver is small and firm. All brown fat is replaced by shrunken, gelatinous, red tissue.

Neonatal navel infections can affect ruminants during the first two or three days of life (eg *Clostridium* spp, *E coli*, *Mannheimia haemolytica*, *Streptococcus* spp), while others are delayed for one to three weeks or longer. **Clostridial navel infections** cause oedema, congestion and perhaps necrosis of the abdominal wall extending around the round ligament of the bladder. The abdomen is distended with serosanguinous fluid and the serosa is markedly congested. *Mannheimia haemolytica* (formerly *Pasteurella haemolytica* type A) **navel infections** may also cause peritonitis, enlarged mesenteric lymph nodes and miliary necrotic small white foci throughout the liver.

References:

- Haughey KG. Vascular abnormalities in the central nervous system associated with perinatal lamb mortality. 1. Pathology. *Aust Vet J* 1973;49:1-8.
- Haughey KG. Meningeal haemorrhage and congestion associated with perinatal mortality of beef calves. *Aust Vet J* 1975;51:22-27.
- Wilsmore AJ. Birth injury and perinatal loss in lambs. *In Practice: J Vet Postgrad Clin Study* 1989;11:239-243.

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- Jamaluddin AA, Case JT, Hird DW, Blanchard PC, Peauroi JR, Anderson ML. Dairy cattle abortion in California; evaluation of diagnostic laboratory data. *J Vet Diagn Invest* 1996;8:210-218.
- Jerrett IV, McOrist S, Waddington J, Browning JW, Malecki JC, McCausland IP. Diagnostic studies of the fetus, placenta and maternal blood from 265 bovine abortions *Cornell Vet* 1984;74:8-20.
- Johnson CT, Lupson GR, Lawrence KE. The bovine placentome in bacterial and mycotic abortions. *Vet Rec* 1994;134:263-266.
- Kennedy PC, Miller RB. The Female Genital System: V. Diseases of the Pregnant Uterus. In: Jubb KVF, Kennedy PC, Palmer N, editors. *Pathology of Domestic Animals Volume 3* 4th edn. Academic Press Inc, San Diego, California, 1993:387-445.
- Larson RL. Diagnosing the cause of bovine abortions and other perinatal deaths. *Vet Med* 1996; 91(5):478-486.
- Roberts SJ. *Veterinary Obstetrics and Genital Diseases*. Edward Brothers Inc., Ann Arbor, 197:19.

Appendix 1. Necropsy procedure for ruminant conceptus and neonate (after Larson, 1996)

Examination	Comment
1. Establish age of gestation.	Estimate age using foetal size, crown / rump length (<i>see table below for bovine foetus data</i>).
2. Establish time of death as pre-natal, parturient, or post-natal.	Pre-natal: <i>In utero</i> autolysis; no thrombus in umbilical artery. Parturient: Clear, localised subcutaneous oedema. Post-natal: Thrombus in umbilical artery; lungs aerated; milk in abomasum; hooves worn.
3. Examine intact body for congenital defects and meconium staining (of foetal skin and also amnionic sac).	eg cleft palate, atresia ani, genito-urinary defect, skeletal defects or asymmetry.
4. Examine subcutis for evidence of oedema, autolysis, cyanosis, anaemia, or icterus.	Clear oedema fluid suggests dystocia. Red oedema fluid (haemolysis) suggests <i>in utero</i> autolysis (red fluid also in body cavities and around kidneys).
5. Examine thorax and then abdomen for presence of fluid or fibrin. Assess extent of autolysis of viscera. Assess extent of catabolism of fat reserves.	Collect pericardial or thoracic fluid (or heart blood if no fluid available) for serological examination and culture. Collect urine if required.
6. Examine and assess size of thymus, thyroids and lymph nodes.	Collect and formalin-fix samples of each.
7. Examine heart <i>in situ</i> for size, shape or position change, pericardial sac fat, pericardial fluid or fibrin, or epicardial haemorrhages.	eg ectopia cordis, cardiac dilation.
8. Remove heart and lungs with trachea, oesophagus and tongue attached. Examine lungs for evidence and extent of aeration, petechiae, oedema or bronchopneumonia.	Oedematous lungs are heavy.
9. Do not separate heart from lungs. Dissect heart and examine for congenital defects	eg transposition of large vessels, ventricular septal defect.
10. Examine liver for rupture, size, consistency, congestive nodularity or focal necrosis.	Compare relative involvement of right (dorsal) and left (ventral) liver lobes.
11. Examine kidneys for haemorrhage, infarction, focal necrosis, or perirenal oedema (due to autolysis).	
12. Examine stomach (abomasum) for presence of milk clot in neonates, or congestion.	
13. Examine and assess size of adrenals and pancreas.	Collect and formalin-fix samples of each.
14. Examine small intestine for haemorrhage, enteritis, or for presence of chyle in lymphatics of neonates.	Collect and formalin-fix samples of each.
15. Examine large intestine for atresia or colitis.	Collect and formalin-fix samples of each.
16. Examine limb joints for mobility, enlargement.	eg arthrogryposis, arthropathy.
17. Note skeletal muscle colour.	
18. Examine spinal column for congenital malformation.	eg spina bifida, torticollis, scoliosis, lordosis.
19. Remove brain. Examine for haemorrhage, abscess, meningitis, cerebellar hypoplasia, hydrocephalus, hydranencephaly, micrencephaly, or microphthalmia.	Collect and formalin-fix brain. <i>Note: Even markedly autolyzed brains should be poured into formalin solution, as such brains (at least their brain stems) are usually suitable for histological examination.</i>
20. Examine the foetal membranes for evidence of infection or infarction. <i>A fresh placentalome (maternal caruncle with attached foetal cotyledon tissue) can be removed from the postpartum uterus close to the cervix by gently twisting and pulling (Johnson et al. 1994).</i>	Cotyledons (and maternal caruncles): Size and colour, distribution of cotyledons with gross changes. Intercotyledonary areas: Consistency, colour, distribution of lesions. Amnion: Consistency, colour, distribution of lesions.
21. Microbiological sampling.	Collect fresh samples and hold at 4°C: Bacteriology: Stomach fluid and lung (liver optional). Virology: Lung and spleen.
22. Histological sampling.	Collect and formalin-fix samples: Lung* , myocardium* , brain* , placenta (also liver, kidney and any lesions seen). <i>*Essential even from markedly autolysed foetuses.</i>

Crown-rump lengths of bovine foetuses during pregnancy (after Roberts, 1971)

Gestational Age (days)	Crown-Rump Length (cm)	Gestational Age (days)	Crown-Rump Length (cm)	Gestational Age (days)	Crown-Rump Length (cm)
30 / 40	1.0 / 1.75 - 2.5	80	8 - 13	180	40 - 60
50	3.5 - 5.5	90	13 - 17	210	55 - 75
60	6 - 8	120	22 - 32	240	60 - 85
70	7 - 10	150	30 - 45	270	70 - 100

Appendix 2. Infectious causes of reproductive failure in cattle

Agent	Gestation age (days) infected	Syndrome	Lesions of conceptus Gross lesions Microscopic lesions
VIRUSES			
Flaviviridae			
Pestivirus (Bovine pestivirus)	-10-0	Conception failure (reduced ovulation rate due to pestiviral infection of ovaries)	-
	0-30	Infertility	Embryonic death. <i>Virus, no antibody</i>
	30-100	Abortion, mummification, premature birth, stillbirth Stunted full-term calf (Congenital malformation) Normal but immunotolerant, persistently-infected, full term, live calf that later succumbs to Mucosal Disease or pneumonia	Intrauterine growth retardation: • diffuse • brain, lung, thymus • bones: growth arrest lines long bones (Cerebellar hypoplasia, HE) <i>Virus, no antibody</i>
	100-180	Congenital malformation in stillborn, premature or full-term calf	Cerebellar hypoplasia HE, porencephaly, micrencephaly Dysmyelination Microphthalmia, chorioretinopathy, cataracts Hypotrichosis AG (rare) Intrauterine growth retardation <i>Antibody usually</i>
	> 180	Nil	Seroconversion only. <i>Antibody</i>
Bunyaviridae			
Akabane virus	76-104	Congenital malformation, (abortion, stillbirth)	Hydranencephaly (HE), normal cerebellum <i>Antibody</i>
	104-173	Congenital malformation, (abortion, stillbirth)	Arthrogryposis (AG). <i>Antibody</i>
	> 173	Nil Incoordination, recumbency, (abortion, stillbirth)	Seroconversion only. <i>Antibody</i> Encephalomyelitis
Aino virus		Abortion, congenital malformation	HE, cerebellar hypoplasia, AG
*Rift Valley fever		Abortion, congenital malformation	Multifocal necrosis of liver, AG, HE
Reoviridae			
Orbivirus genus			
*Bluetongue virus	0-85	Infertility, abortion	Embryonic death:(resorption), foetal death (abortion). <i>Virus, no antibody</i>
	85-105	Congenital malformation	HE, porencephaly. <i>Antibody</i>
	105-145	Congenital malformation	HE, porencephaly, necrohaemorrhagic encephalitis. <i>Antibody</i>
	> 145	Nil	Seroconversion only. <i>Antibody</i>
*EHD 2 (Ibaraki) virus		Abortion, congenital malformation	<i>As for Bluetongue virus</i>
Palyam (D'Aguilar) virus		Abortion, congenital malformation	Cerebellar hypoplasia, encephalitis
*Palyam (Chuzan / Kasba) virus		Congenital malformation	HE, cerebellar hypoplasia
Herpesviridae			
*Bovine herpesvirus 1		Abortion, stillbirth. Live weak calf (Abortion?)	Multifocal necrosis of liver, lung and adrenal, necrotising vasculitis of chorionic villi Necrosis forestomachs (oral cavity, oesophagus)
*Bovine herpesvirus 4 (cytomegalovirus)		(Abortion?)	-
*Bovine herpesvirus 5 (encephalitis virus)		(Abortion?)	-
Parvoviridae			
*Bovine parvovirus		Abortion, weak calves, congenital malformation	Cerebellar hypoplasia
Paramyxoviridae			
*Rinderpest virus		Abortion	-

Appendix 2. Infectious causes of reproductive failure in cattle (continued)

BACTERIA			
<i>*Brucella abortus</i>		Abortion	Placentitis, pneumonia
<i>Campylobacter fetus venerealis, C fetus fetus</i>		Abortion	Fibrinous polyserositis, hepatomegaly, pneumonia, (placentitis)
<i>Leptospira pomona, *L hardjo-prajitno</i>		Abortion (late) <i>Note: L hardjo-bovis causes milk drop syndrome in Australia, but is not associated with abortion</i>	Placental oedema, nephritis, meningitis
<i>Listeria monocytogenes L ivanovii</i>		Abortion, stillbirth	Placentitis, multifocal necrosis of liver, lung, myocardium, kidney, adrenal, spleen and brain, necrotising colitis, nonsuppurative meningitis.
<i>Yersinia pseudotuberculosis</i>		Abortion	Placentitis, multifocal necrosis of liver, lymphoplasmacytic colitis
<i>A pyogenes</i>		Abortion	Placentitis, pneumonia
<i>Salmonella spp</i>		Abortion	Placentitis
<i>Mycoplasma sp bovine group 7</i>		Mastitis, neonatal polyarthritis, abortion,	Mastitis, neonatal polyarthritis Foetal polyarthritis, polyserositis, pneumonia
<i>*Ureaplasma diversum (formerly T mycoplasma)</i>		Abortion, stillbirth, weak calves	Amnionitis, chorioallantoitis, non-suppurative pneumonia, erosive conjunctivitis
<i>Haemophilus somnus</i>		Abortion	Cotyledonary placentitis (with vasculitis)
<i>*Chlamydomphila abortus, C psittaci</i>		(Abortion)	Placentitis (with vasculitis)
<i>Coxiella burnetii (Q fever)</i>		Abortion	Placentitis (without vasculitis)
Other bacteria (eg <i>Bacillus licheniformis, Streptococcus spp, Pasteurella spp</i>)		Abortion, stillbirth	Variable (placentitis, pneumonia)
FUNGI			
<i>Aspergillus fumigatus, Mortierella wolfii,</i>		Abortion	Placentitis, dermatitis
PROTOZOA			
<i>Babesia spp</i>		Neonatal disease, (abortion)	Anaemia, icterus, erythroparasitaemia (sludging of <i>B bovis</i>-parasitised erythrocytes in cerebral capillaries)
<i>Neospora caninum</i>		Abortion (Neonatal ascending paralysis)	Non-suppurative necrotising encephalomyelitis, non-suppurative myocarditis and hepatitis
<i>Sarcocystis spp</i>		Abortion, stillbirth, neonatal deaths	Necrotising endometritis, non-suppurative encephalomyelitis, multifocal soft tissue necrosis, endothelial tropism
<i>Tritrichomonas foetus</i>		Abortion (early), pyometra	Placentitis, pneumonia (multinucleated giant cells), pyometra
<i>*Disease of conceptus not reported in Australia</i>			AG = arthrogryposis HE = hydranencephaly

Appendix 3. Infectious causes of reproductive failure in sheep and goats

Agent	Gestation age (days) infected	Syndrome	Lesions of conceptus Gross lesions Microscopic lesions
VIRUSES			
Flaviviridae			
Pestivirus (Border disease virus)	30-55	Abortion, mummification Normal but immunotolerant, persistently-infected full-term lamb / kid	<i>Virus, no antibody</i>
	55-70	Hairy shaker (also hairy, weak, non-shaker) immunotolerant, persistently-infected, full-term live lamb / kid Normal but immunotolerant, persistently-infected, full-term, live lamb / kid that later succumbs to Mucosal Disease-like syndrome Congenital malformation	Hairy fleece , hypomyelinogenesis <i>Virus, no antibody</i> HE, porencephaly, cerebral dysgenesis <i>Antibody</i>
	70-90	Variable	<i>Antibody</i>
	> 90	Nil	Disseminated nodular periarteritis <i>Antibody</i>
*Wesselsbron virus		Abortion, stillbirth, congenital malformation	Diffuse hepatic necrosis, AG, HE ,
Bunyaviridae			
Akabane virus	30-50	Congenital malformation, prolonged gestation, (abortion)	Micrencephaly, porencephaly, AG, HE, scoliosis, kyphosis <i>Antibody variable. Virus during gestation</i>
	> 80	Nil	Seroconversion only. <i>Antibody</i>
*Cache Valley virus	27-45	Infertility, abortion,, congenital malformation	Resorption, mummification, AG, HE
*Rift Valley fever		Abortion, congenital malformation	Multifocal hepatic necrosis, AG, HE
Reoviridae			
Orbivirus genus			
*Bluetongue virus	0-50	Infertility, abortion	Embryonic, foetal death
	40-60	Congenital malformation Stunted, full-term lamb	HE, cerebellar dysgenesis Intrauterine growth retardation <i>Antibody variable</i>
	60-80	Congenital malformation	HE, porencephaly. Antibody
	80-110	Variable	<i>Antibody</i>
	> 110	Nil	Seroconversion only. <i>Antibody</i>
Herpesviridae			
*Caprine herpesvirus		Abortion	-
BACTERIA			
<i>Brucella ovis</i>	21-90	Abortion	Placentitis
<i>Brucella mellitensis</i>		Abortion	Placentitis
<i>Campylobacter fetus fetus, C lari</i>		Abortion	Multifocal hepatic necrosis, fibrinous polyserositis, pneumonia, (placentitis)
* <i>Flexispira rappini</i>		Abortion, mummification, weak lambs (sporadic)	Multifocal hepatic necrosis, placentitis
* <i>Fusobacterium</i> spp (NZ)		Abortion	Multifocal, hepatic necrosis , fibrinous polyserositis, pneumonia, (placentitis)
<i>Leptospira hardjo</i> (<i>L pomona</i> , <i>L bratislava</i>)		Abortion (late), stillbirth	Placental oedema, nephritis, meningitis
<i>Listeria monocytogenes</i> <i>L ivanovii</i>		Abortion , stillbirth, weak lambs	Placentitis, multifocal necrosis of liver, lung, myocardium, kidney, adrenal, spleen and brain, necrotising colitis, nonsuppurative meningitis.
<i>Yersinia pseudotuberculosis</i>		Abortion	Placentitis, multifocal necrosis of liver, lymphoplasmacytic colitis
<i>A pyogenes</i>		Abortion	Placentitis, pneumonia
<i>Salmonella</i> spp		Abortion	Placentitis
* <i>Chlamydomphila abortus</i> (enzootic abortion), <i>C psittaci</i> (sporadic)		Abortion, stillbirth, weak lambs / kids	Placentitis (with vasculitis), multifocal necrosis of liver, spleen, alveolitis, meningoencephalitis

Appendix 3. Infectious causes of reproductive failure in sheep and goats (continued)

BACTERIA (cont'd)			
<i>Coxiella burnetii</i> (Q fever)		Abortion (late), stillbirth, weak lambs / kids	Placentitis (without vasculitis), mild nonsuppurative hepatitis, pneumonitis, nephritis
Other bacteria (eg <i>Bacillus</i> spp, <i>Streptococcus</i> spp, <i>Pasteurella</i> spp)		Abortion, stillbirth	Variable (placentitis, pneumonia)
PROTOZOA			
<i>Toxoplasma gondii</i>		Abortion	Placentitis (multifocal necrosis of cotyledons), non-suppurative necrotising encephalomyelitis, leukoencephalomalacia
<i>Sarcocystis</i> spp		Abortion, stillbirth, neonatal deaths	Necrotising endometritis, non-suppurative encephalomyelitis, multifocal soft tissue necrosis, endothelial tropism
<i>*Disease of conceptus not reported in Australia</i>			AG = arthrogryposis HE = hydranencephaly

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