Principles of Control and Eradication of Footrot of Sheep

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INTRODUCTION

Definitions: *Footrot* is a contagious disease of sheep and other ruminants. It results from an interaction of necessary environmental, bacterial and host factors. To be susceptible animals have to be exposed to an environment which predisposes the skin between the claws of the feet to bacterial invasion. This environment is normally provided by wet pasture. Mild ambient temperatures are also needed if new cases of footrot are to occur. Where ambient temperatures are consistently below 10° C transmission of the disease is not likely to occur. (Graham and Egerton, 1968) Where temperatures are high pasture dehydration is likely and again transmission is inhibited. A complex of bacteria causes the tissue damage which is characteristic of footrot. This complex includes *Fusobacterium necrophorum*. D*ichelobacter nodosus,* anaerobic spirochaetes and fusiform bacteria and many different aerobic organisms. Of these, *F.necrophorum,* an organism which normally occurs in the rumen, is believed to initiate bacterial invasion of hydrated predisposed interdigital skin. When *D.nodosus* is present in the same environment it invades with *F.necrophorum* and the other members of the flora of footrot (Egerton et al, 1969) *D.nodosus* is a parasite (Beveridge, 1941). Its only recognised habitat is the epidermal tissue of the feet of ruminants. It has no capacity to exist in the environment for more than seven days. *D.nodosus* is an essential component of the complex of factors which together cause footrot. It is the bacterium which results in transmission of the disease from one animal to another. Host factors, some of which are heritable, (Raadsma et al, 1994) determine whether or not animals are susceptible to footrot. The severity of footrot which is observed in individual animals and in flocks is thus the consequence of an interaction of the different environmental, bacterial and host factors which are involved in different outbreaks. In a flock of sheep in the same environment there will be animals which are highly susceptible, partially susceptible or resistant. Furthermore the persistence of the disease in individual animals and in the flock is determined by the interaction of all those factors which are responsible for its occurrence.

Control*:* In the context of this paper, control describes a system of disease management in which the objective is to limit the adverse effects of footrot on the flock in question. Such a system should lead to a reduction of prevalence of affected animals and a reduction of severity of infection in the low proportion of animals in which the disease will persist. Control does not have the objective of eliminating footrot from the flock although some individual animals may be cured temporarily. Control is achievable in all flocks but by definition incurs expense on a recurring basis.

Eradication*:* This is a process which has as its objective the complete elimination of a defined form of footrot or a particular strain of *D. nodosus* from a flock of sheep. If eradication is achieved there will be no further cases of that disease or strain in the flock unless it is re-introduced from another source. Eradication is achievable within individual flocks but is a more demanding task than control. It has the advantage of being permanent if suitable precautions are taken to prevent re-infection.

DIAGNOSIS OF FOOTROT

Diagnosis of cases of footrot: The diagnosis of footrot in an individual animal is based on the characteristic clinical signs and pathology of the disease (Egerton, 2000). The diagnosis may be confirmed by the demonstration of *D. nodosus* in Gram stained smears taken from lesion material. This form of diagnosis is not sufficient, however, to support a decision whether or not to commence a control or eradication program in the flock in which footrot is present. As indicated previously, footrot presents in a number of clearly defined ways. These have been described as virulent footrot (VFR) intermediate footrot (IFR) and benign footrot (BFR) although there may be a spectrum of disease which merges from one of these categories to another (Stewart, 1989). VFR is that form of the disease which causes the most serious lameness, weight loss and reduced wool production. In affected flocks, many animals have lesions which cause under-running of the sensitive laminae under the hard horn of the hoof. These severe infections persist in most affected animals irrespective of the environment. They are associated with infection by strains of *D. nodosus* which produce proteolytic enzymes which are distinguishable from those associated with BFR (Stewart 1989). The presence of these so-called virulent strains is not necessarily an accurate predictor of the presence of virulent disease. Quite often strains of this type are isolated from episodes where there is little evidence of severe disease. They are often found, for example, in out-breaks where only a low proportion of animals have severe infections. The recognition of these flocks led to the definition of IFR. In flocks with IFR many animals may have mild lesions of footrot (those confined to the skin between the claws and the heel region) but these are likely to regress without treatment as the environment becomes less favourable for the disease. By definition IFR is an outbreak where less than 10% of animals have severe infections. Although those animals with severe infections are adversely affected their impact over the whole flock is unlikely to be severe enough to warrant expensive programs. Recent research in Australia has indicated that IFR is not significantly affected by a change to a more favourable environment. Those animals with the most severe infections transmit a disease which, in a new flock, results again in a low proportion of severely affected animals (Abbott, 2000). BFR is the mildest form of footrot which has been described. The infections are predominately confined to the interdigital skin (IDS) although a few animals in a flock may have severe lesions. By convention this is about 1%. Again it is characteristic of BFR that most affected animals heal when the environment dries. The disease may cause lameness but this is temporary and unlikely to cause production loss. There are two important features of the strains of *D nodosus* associated with BFR. Their relatively heat labile proteolytic enzymes are an accurate predictor of the type of footrot in the flock so they are useful in confirming the nature of the disease present (Report, 2000). Of interest also is that these strains are frequently present in the feet of infected cattle which are on the same pastures as sheep. Cattle are therefore a reservoir of infection for sheep (Egerton, 1989). There is little or no evidence that strains of *D. nodosus* from VFR or IFR are able to infect cattle. The occurrence of benign strains of *D.nodosus* in cattle makes it unlikely that they can ever be eradicated from those farms which graze both sheep and cattle. Because footrot control and eradication programs are expensive and their cost is usually carried by owners it is essential that the form of footrot in a flock is diagnosed accurately.. The risks associated with incorrect diagnoses are summarised in Table 1.

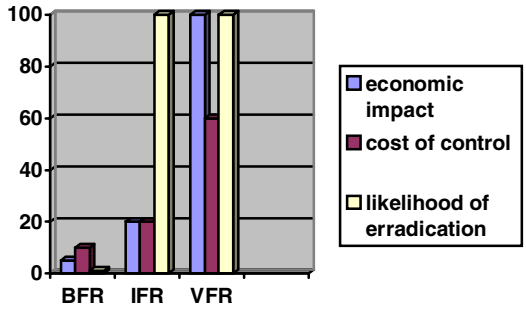
Table 1 Outcomes of incorrect diagnoses of footrot at flock level

DIAGNOSIS	VFR	IFR/BFR
False positive diagnosis	Unnecessary expense of program caused by disease.	Continuing damage caused by disease.
False negative diagnosis	Damage to flock; risk to neighbours and in market	Unnecessary expense

In principle a decision to undertake either eradication or control should be based on an analysis of the economic impact of the disease on the flock and the risk it represents for neighbouring flocks. The likely cost of the program and its likelihood of success should also be taken into account . The interaction of these components is illustrated diagrammatically in Figure 1

Figure 1

Decision factors in assessing management of footrot



Method for identifying type of footrot in flocks (Flock Diagnosis): The preferred method is to examine sufficient sheep to be confident that a representative sample of the disease has been observed. As each sheep is examined allocate a score to each of the feet. The simplest scoring system is one with a scale from 0 to 4. In this system score 4 is defined as one in which the necrotic process extends under the hard horn of the hoof, score 3 involves the soft horn of heel and sole, while score score 2 and score 1are restricted to the interdigital skin (IDS). Score 2 are those infections in which there is inflammation, exudation and necrosis of the IDS. Score 1 lesions of the IDS are less specific and may be the consequence of exposure of the feet to wet pastures and environmental bacteria. When the sample has been examined the record of scores which has been kept will help in making a diagnosis. When a high proportion of sheep examined have score 4 infections in at least one foot VFR is easily diagnosed. As the proportion of sheep with score 4 lesions is reduced to a low level it becomes essential to examine enough sheep to be confident that the estimate obtained from the sample is accurate enough for the flock in question. If there is doubt about inhibitory effects of environment or prior treatment on the expression of the disease it may be necessary to re-examine the flock after an interval of two or more weeks. Where there is a low prevalence of score 4 lesions there is difficulty in deciding whether or not VFR is present. The prevalence of score 4 infections which represents the threshold between VFR and IFR is a matter of debate and tends to be set at different levels by different authorities (Allworth and Egerton, 1999; Abbott, 2000). Clearly the objective should always be to target disease which is economically important and not to waste resources on disease which has a transient and trivial impact on sheep flocks. As a working model, the criteria for the different categories of footrot are summarised in Table 2.

Table 2 Distribution of foot scores in different clinical forms of footrot (Percent of sheep)

Clinical form	Score	VFR	IFR	BFR
	Score 4	10- 70 +	1-10	0-1
	Score 3	10- 50	10-30	1-15
	Score 2	5-50	20-70	10-80 +
	Score 1	5-10	5-10	5-10
	Score 0	30-50	30-60	20-80

In the most severe types of footrot the majority of animals have advanced lesions. Accompanying these will be varying proportions of the lesser scores. By contrast in the mildest disease there are few if any advanced lesions. In IFR there are sufficient advanced lesions to create some difficulty in arriving at a diagnosis.

CONTROL OF FOOTROT

There are a number of circumstances where control rather than eradication may be a preferable objective after a diagnosis of VFR has been made. This would be the case in a flock which regularly introduces sheep from flocks of unknown footrot status. It may be desirable also where the flock is located where it is surrounded by other affected flocks and where straying sheep cannot be excluded with confidence. Investigations in Australia have shown that the most likely sources of infection are sheep from neighbouring flocks. It is obvious also, that where sheep are traded in public markets which do not exclude footrot, there is a continuing potential for introduction and transfer of disease. Where risk factors like these can be identified control is a better option than eradication.

Principles of control: Control programs should be designed to give the maximum benefit from the least possible outlay in time and money. For this reason they should be directed at the flock as a unit rather than at individual affected sheep. There are two principal objectives of a control program for footrot. These are to limit the spread of the disease and to reduce the impact of the disease in those animals which do become affected Such a control program should be based on an understanding of the seasonal behaviour of footrot in the district in which the flock is located. There are periods of the annual cycle in which effort should be intensified; at others less input will be required. For example if it is known when transmission is most likely to occur preventive measures should be applied intensively just before and during this period.

Preventive measures: Frequent footbathing in solutions of formalin, zinc sulphate or copper salts have been shown to limit the spread of footrot in flocks. The key to success of a footbathing program is its frequency. For optimum effect the whole of the flock at risk should be walked through the footbath solution at least once weekly during the high risk period. Topical solutions used in this way prevent the invasion of bacteria beyond the interdigital skin and thus limit the severity of disease in many animals. It is emphasised that, during transmission footbathing should be done without preparation of the feet of individual sheep. Those animals with severe infections will benefit from the footbathing but are not expected to be cured. Time and effort should not be wasted attempting to cure animals at times when re-infection is likely to occur. Each of the chemicals listed is equally effective for this purpose but zinc sulphate and copper salts are less painful for the sheep and more pleasant for the operators.

Vaccination: Vaccines which are formulated to contain the major known serogroups of *D. nodosus* can be successful in the control of footrot. They have two effects; they prevent infection in a proportion of the flock and they also accelerate cure in those animals which are already affected. Ideally the first course of vaccination should be complete before transmission is likely to occur. However where prevalence is high it may be desirable to vaccinate to derive early benefit from their therapeutic effect. Commercial vaccines are limited in their usefulness by the short period of immunity which follows their use. Again, increased value can be obtained from vaccine if it is applied prior to known transmission periods. Annual revaccination needs to be timed according to what is known of the epidemiology of the disease.

Treatment: Depending on the resources available some detailed attention may be given to badly affected animals at the conclusion of intensive footbathing or after a vaccination program. If these animals are to be treated topically their feet should be prepared by careful paring. This preparation should not cause

bleeding nor should it make the animals more lame than footrot does. An alternative to topical treatment is the use of parenteral antibiotics if these are permitted under food hygiene regulations (Egerton 2000) Table 3. If parenteral antibiotics are used there is no requirement for the degree of paring necessary for topical treatment. It is essential to the success of parenteral treatment that animals be kept in a dry environment for the 24 hours following treatment. Under no circumstance should animals with footrot be treated with parenteral drugs when the environment is wet.

Table 3.Recommended single doses for parenteral antibiotic treatment of virulent footrot

Antibiotic	Dose	Withholding period (days)
Procaine penicillin/ Dihydrostreptomycin sulfate	70 000 U/kg+ 70 mg/kg	28
Oxytetracycline LA 200 mg/ml	1 ml/10 kg	42
Lincomycin HCL Monohydrate/spectinomycin SO_4 tetrahydrate (Lincomycin base 50mg/ml Spectinomycin base 100mg/ml)	1 ml/10 kg	28 days
Erythromycin base 200 mg/ml	0.2 ml/10kg	3

Intensive and frequent footbathing during the transmission phase with or without vaccination can reduce the prevalence of VFR to acceptable levels. Combined with treatment or culling of residual cases after transmission has ceased it should reduce the economic impact of footrot to an acceptable level. The process needs to be repeated in each successive year.

ERADICATION OF FOOTROT

Principles of eradication of footrot The transmitting agent of footrot, *D.nodosus,* persists only in the feet of affected animals. It does not persist in the environment for more than seven days. Eradication of footrot requires the elimination, within a flock, of all cases of infection with *D. nodosus* .Normally only VFR and IFR are targets for eradication. In his section of the paper footrot will be used to refer only to these forms of the disease. There are a number of prerequisites for successful eradication of footrot from a flock. These are:

- Correct diagnosis of the form of footrot in the flock
- Knowledge of the transmission patterns in the flock‘s environment
- Application of knowledge of seasonal patterns of disease in planning the program for a flock
- Ability of the operator of the program to recognise all cases of footrot
- Acceptance that while footrot is present, all cases irrespective of severity, are cases of VFR/IFR.
- Acceptance that eradication of footrot is time consuming and costly
- Understanding that, especially in flocks with a high prevalence at the start of the program, eradication may take 2 or more years to achieve.
- Acceptance that eradication should only be attempted where the flock can be protected against re-infection from neighbours or sheep purchased from elsewhere

Methods of eradication

1. ***Whole flock disposal***. The simplest and most effective method for the eradication of footrot is to dispose of the whole flock as soon as it is convenient after the diagnosis has been made and to replace it two or more weeks later with animals free of the disease. This method presupposes that there is a market for the affected sheep, that disease free sheep are available and that the cost of the *disposal-replacement* program is acceptable taking into account the time and cost which is involved in alternative methods. Many of the prerequisites listed above do not apply to the *disposal – replacement* approach.
2. ***Disposal of affected animals***. The next simplest approach is to dispose of the infected animals in the flock. If the prevalence of infected animals is so high that their disposal would severely affect production, a season or more of control by footbathing or vaccination may be used to reduce prevalence to a level where disposal is acceptable. Success in eradication by disposal of affected animals depends on identifying every single case of footrot and removing it from the flock. This can be achieved by inspecting all feet of all sheep in the flock at least three times at intervals of approximately three weeks. These inspections should only be done at a time when transmission is unlikely to be occurring. There should not be any treatment applied to the sheep for at least three weeks before and during these inspections . Animals identified as affected should be marked and segregated in a separate flock and disposed of, preferably by sale for slaughter. The objective of eradication by disposal of cases is to ensure that no source if reinfection remains in the flock when environmental conditions again favour transmission.
3. ***Identification and treatment of affected animals***. Eradication using this method is possible but the probability of success is lower than in either of the two preceding methods. The procedure for identifying affected animals i.e. repeated whole flock inspections is again used as in 2 above. Again it is essential that there is no possibility of transmission and thus the presence of cases in incubation during this identification process. When cases have been identified they may be treated either topically or by the injection of parenteral antibiotics as described under **Principles of Control** above. Whichever method of treatment is adopted it is necessary to inspect treated animals three weeks later to identify those animals which have not responded to treatment. Even under optimally dry environmental conditions some animals will not be cured. These animals should be removed from the flock. It is unlikely that re-treatment will be effective.

The key to successful eradication of VFR/IFR from flocks is examination and re-examination of animals considered to be free of disease. Concentration of effort on this component of the flock is more productive than work with affected animals. Eradication cannot be claimed until the flock has passed through at least one season known to be suitable for footrot transmission. It is important to recognise also that after the eradication of VFRIFR there is a high probability that BFR will persist in the flock. The methods based on identification and disposal and identification and treatment do not usually eliminate the strains of *D. nodosus* associated with the benign disease. The normal sequence and the principal features of each stage of the footrot management process are summarised in Table 4.

Table 4 Sequence and principal features of footrot management in flocks

PHASE	OBJECTIVES	METHODS	TIME IN CYCLE
Diagnosis	Identify disease Determine if VFR Is present	Clinical Examination Scoring of sample of sheep	When disease is fully expressed
Control	Limit economic impact; reduce prevalence if goal is eradication	Frequent whole flock footbathing; vaccination	Transmission period mainly Any time for quick effect.
Eradication	Eliminate all cases of footrot from flock	**a.** Flock disposal *or* **b.** identify and remove all affected sheep *or* **c**. identify and treat all affected sheep. **b** and **c** require repeat inspections of disease free sheep **c** requires finding and removing sheep not cured	**a** ; anytime **b** and **c**; non transmission period
Surveillance after eradication	Maintain freedom from VFR	Immediate investigation of lameness; annual whole flock inspection; ensure; precautions with new sheep.	Vigilance in whole cycle; annual inspect ion following transmission

SURVEILLANCE

Flocks free of VFR/IFR whether following an eradication program or not, should be subjected to a clearly defined surveillance program. This program will include immediate investigation of lameness or other signs of VFR/IFR in the flock, annual foot by foot inspection of all sheep, and inspection of sheep before they are introduced from other flocks. If there is any evidence of footrot in any sheep being considered for purchase or evidence of treatment for footrot the whole group should be rejected. Maintenance of freedom from VFR is highly dependent also on the status of neighbouring flocks and the integrity of fences or other barriers between farms. There should not be any requirement for any form of footrot treatment in a flock which has successfully eradicated VFR/IFR. Surveillance and early recognition of recurrence will be inhibited by routine or even spasmodic footbathing. In the event that VFR/IFR recurs it is important to identify it early and limit it to restricted groups on the farm.

ERADICATION AT REGIONAL OR REGIONAL LEVELS

While the principles of eradication of VFR have been known and applied for half a century the disease persists in most sheep producing countries. Even in Australia where a substantial amount of money has been invested in research and the extension of research results there are many regions where there is a continuing high prevalence of the disease. In three states, South Australia, Western Australia and New South Wales, there has been considerable progress towards eradication. The success in New South Wales in particular has resulted from a number of factors separate from scientific understanding of the disease. The most important of these has been the enthusiastic support of the majority of sheep owners for a program of eradication. The cost of this program has been borne principally by the sheep owners themselves. While the program has been voluntary from the outset in 1988 it is backed by state laws which restrict owners of affected flocks from sale of diseased sheep in markets and from their using public roads to move sheep. The state‘s eradication program was given impetus by the early formation of groups of farmers who owned neighbouring properties.(Walker,1997) These groups were an ideal focus for extension of information about the development and application of programs for individual flocks. At the time the official program commenced there was an extensive veterinary and para-veterinary infrastructure in the state which supported these farmer groups in diagnosis and in the investigation of problems which arose. The program was supported through the establishment and implementation of a flock accreditation scheme. The stud sheep industry was a strong supporter of this and similar schemes. There was also a process whereby people selling sheep signed a formal declaration about the footrot status of those sheep and their flock of origin. These declarations were instrumental in reducing the transfer of infected animals through markets.

The program in NSW has made substantial progress. At the beginning of the program the flock prevalence in some districts was as high as 50%. There are now many areas which qualify for Protected Status i.e a flock prevalence of less than 1%. There are many other flocks in areas designated as Control areas i.e. a flock prevalence of between 1 and 10%. At the outset it was estimated that there were approximately 10.000 affected flocks in the state. Now there are less than 1000. As the program continues it is apparent that benign footrot persists and that IFR is being diagnosed more frequently. This presents a challenge. In some of these flocks the severity of the disease is low but organisms which are sometimes identified as virulent in *in vitro* tests have been isolated from them. There is considerable argument about the capacity of the environment to prevent full expression of disease in such flocks. Recent research however suggests that the level of expression observed in these IFR flocks is independent of the environment (Abbott, 2000). On the other hand there is also evidence that some of the strains of *D.nodosus* present in these episodes can be eradicated using conventional approaches with one important exception regarding treatment. The use of parenteral antibiotics seems to be contra-indicated. (Abbott, 2000).

In Western Australia the program is based on using stability of proteases from *D. nodosus* as the single criterion for the diagnosis of VFR. IFR is not recognised as a clinical entity. As a consequence eradication is pursued wherever a positive isolate is identified irrespective of the severity of the disease which is present. Eradication of all such strains is justified on the basis of some evidence suggesting that environment does materially affect the expression of footrot of marginal severity. In South Australia the presence of “stable “ strains of D.nodosus has been shown not to be an accurate predictor of the type of disease present in flocks with a low prevalence of score 4 infections. It is true however that fully virulent disease has essentially eliminated from South and Western Australia.

BENIGN FOOTROT AS A PRECURSOR OF OTHER DISEASE

In the Australian environment BFR is considered not to be of sufficient clinical or economic importance to justify intervention. This is not to say that BFR has no effect on the flocks in which it occurs. When lambs are born at times which predispose to infection, they are often lame as a result of BFR. So too are the ewes in these flocks. This lameness is usually transitory and where necessary is readily controlled by walk- through footbathing. In other environments, and especially where either old world or new world screw worm flies are prevalent, BFR lesions in the IDS are attractive sites for oviposition. The myiasis which results is serious and serves as a generator of further populations of these flies. Of greater importance is the tissue invasion by fly larvae . This leads to severe cases of foot abscess. These are sufficiently bad to cause the death of some animals. In sheep producing environments like those in Uruguay BFR assumes a much greater importance because of the screw worm flies and their adverse effects. The challenge is to determine whether better control can be achieved through footbathing in anti bacterial chemicals or in insecticides or repellants. Other options which have not been fully exploited for any of the manifestations of footrot are selective breeding and the use of specific vaccination.

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