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Understanding Veterinary Decision-making for Antimicrobial Use in Sheep and Cattle

Bakgrunn for veterinærers valg av antimikrobiell behandling til sau og storfe – en kvalitativ studie

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Table of Contents

Summary	4
Abbreviations	5
Introduction	6
Antimicrobial resistance: a threat to humans, livestock and the environment.....	6
Livestock production in Norway.....	7
Literature review	8
Quantitative vs. qualitative research	9
Global research on AMU in livestock.....	10
AMU in pigs.....	11
AMU in dairy cattle.....	12
AMU in beef cattle and sheep	13
Identified knowledge gap	14
Aim of study.....	14
Materials and methods	15
Selection of participants	15
Data collection.....	15
Vignettes.....	16
1. <i>E. coli</i> associated enterotoxaemia of neonatal lambs.....	17
2. Ovine mastitis.....	17
3. Septic arthritis in young lambs and calves	18
4. Pneumonia in calves.....	19
Data analysis	19
Results	21
Treatment and medicines protocol for selected bacterial diseases.....	21

Watery Mouth Disease	22
Ovine Mastitis	23
Arthritis in lambs and calves	23
Pneumonia in calves	23
Factors influencing treatment decisions	24
The relationship to the farmer	26
Farming factors	28
Veterinary knowledge and experience	30
Clinical disease and animal welfare	33
Professional ethics and selection for AMR	34
Politics and consumer awareness of AMU	36
Discussion	37
Limitations of the study.....	44
Conclusion.....	46
Acknowledgements	47
Sammendrag	48
References	49
Attachments.....	53
Appendix 1. Kasus	54
Appendix 2. The Norwegian prudent use guidelines for antibacterial treatment of food-producing animals.	55

Summary

Title: Understanding Veterinary Decision-Making for Antimicrobial Use in Sheep and Cattle

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The aim of this study was to understand veterinary decision-making regarding antimicrobial usage (AMU) for the treatment of some common bovine and ovine bacterial infections in Norway. A literature review was firstly performed to (i) identify the current state of knowledge on veterinary decision-making for AMU in livestock, and (ii) identify knowledge gaps for AMU in sheep and cattle in Norway and (iii) inform the design of a qualitative research study in order to capture novel data on prescribing decisions for AMU in sheep and beef cattle by veterinarians in Norway. A qualitative study based on semi-structured, face-to-face individual interviews with four practising veterinarians in Norway was conducted. Four case-based vignettes described common clinical signs associated with 1. *Escherichia coli* associated enterotoxaemia in lambs, 2. ovine mastitis, 3. septic arthritis in lambs and calves and 4. calf pneumonia. These diseases were selected as they are commonly reported in the Norwegian cattle and sheep health registers. Interviews were recorded, transcribed and thematically analysed. The main themes identified regarding veterinary decision-making on AMU in the sheep and cattle cases included; the relationship to the farmer, agricultural factors

including management and economics, knowledge-based factors, animal welfare, professional ethics and antimicrobial resistance, politics and consumer awareness of AMU.

The sample size was small and a saturation of veterinary beliefs on AMU in Norway was not captured. However, to our knowledge it is the first qualitative study in Norway into this field and presents novel, preliminary insights into some veterinary perceptions and beliefs that influence decisions for and warrants further research.

Abbreviations

AMU	Antimicrobial usage
ABU	Antibiotic usage
AS	Antibiotic stewardship
AMR	Antimicrobial resistance
CIAAs	Critically important antimicrobials
NSAIDs	Non-steroid anti-inflammatory drugs
AST	Antimicrobial susceptibility testing

Introduction

Antimicrobial resistance: a threat to humans, livestock and the environment

The increased occurrence of multi-drug resistant bacteria constitutes a severe global threat to both human and animal health. Globally an increase in the emergence of antibiotic-resistant bacteria has been reported both in animals and in humans. This development can be seen in Norway as well, but so far, the problem appears less widespread than in other countries (1). The association between antimicrobial usage (AMU) and the occurrence of antimicrobial resistance (AMR) is well established (2). This has given rise to an amplified focus on AMU in livestock.

As part of the national action plan regarding AMR in Norway (3) the occurrence of AMR and AMU across human and animals, food and plants is monitored and reported annually by two surveillance programs, known as NORM and NORM-VET respectively (4, 5). Norway is currently the global leader in terms of the lowest recorded sales of antimicrobials (1, 6), but further reductions have been suggested (3, 7). The target for food-producing terrestrial animals is a ten percent (%) reduction in AMU by 2020, as compared to recorded AMU in 2013. The current figures indicate that during the period 2013 to 2018 the sales of antibacterial drugs for cattle, pigs, poultry, sheep and goats has declined by 17 % (5).

Overall AMU in farm animals in Norway is remarkably low compared to many other countries (6). There are also different patterns in the antibiotics prescribed for livestock. For example, in 2018 penicillins were by far the most selling antibacterial class for therapeutic use in farm animals and contributed to 85.8 % of all antibiotic sales in Norway (5). They were followed by trimethoprim sulfonamides (5.7 %), aminoglycosides (4.2 %), tetracyclines (1.4

%) and other classes (2.9 %). The amount of antibiotics for group treatment accounts for only 4% of all antibiotics sold for use in terrestrial farm animals (5). Furthermore, the use of critically important antimicrobials (CIAs) (8) in livestock is very low in Norway (5).

Livestock production in Norway

Cattle and sheep are major livestock species in Norway - in 2018, 1 006 000 breeding ewes and 77 800 suckling beef cows were registered, as compared to 182 000 dairy cows and 49 500 breeding pigs (5). Despite their contribution to livestock production, the quantity of antibiotics reportedly used in beef cattle and sheep is low compared to other farm animal sectors (5). This might reflect a higher health status among the sheep flocks and beef herds in Norway. Although, both species are managed in relatively less intensive production systems for parts of the year, and national animal health register data indicated that sheep are also less treated by veterinarians compared to other livestock species (9).

It is important both for both human health and animal health and welfare, i.e. One Health, to better understand the way antimicrobials are used and to understand the perceptions of the decision-makers who are responsible for selecting, prescribing and administering antimicrobial drugs in Norway. Antimicrobial stewardship (AS) concerns the systematic effort to reduce AMU to the minimum. The goal is not to stop using antibiotics all together, but to follow evidence-based prescribing following the tenant “as little as needed, as much as necessary”. By prescribing the appropriate type of antibiotics early in the course of the disease, by the appropriate administration route and of sufficient duration, the AMU can be refined and the selection for AMR may be minimised.

Previous studies outside of Norway have shown that veterinarians are the most influential and trusted source of information for the farmer regarding AMU in livestock (2). Recent work comparing AMU in broilers, pigs, dairy cattle and fattening calves between Denmark, Portugal and Switzerland revealed significant cross-country variations in the antimicrobials selected and highlighted the use of several critically important antimicrobials (CIAs) in farm animals, which is a cause for great concern for human health (10). This inspired the need to review the scientific evidence regarding decision-making on AMU in Norwegian livestock. Sheep and beef cattle were selected as the species of focus here as they make a large contribution to the national livestock statistics, appear to be relatively “green” industries but are relatively neglected in terms of disease research funding, and the understanding of veterinary and producer interactions in less intensive production systems.

Literature review

The main aims of the review of the scientific literature and clinical texts presented in this chapter was to:

- (i) identify the current state of knowledge on veterinary decision-making for AMU in livestock;
- (ii) identify knowledge gaps surrounding AMU in sheep and cattle in Norway;
- (iii) inform the design of research study to capture novel data on decisions-making of veterinarians in Norway towards AMU in sheep and cattle.

A literature search was conducted in PubMed and Google Search to include English, Scandinavian and Finnish languages from 2005 to 2019 to identify global scientific literature regarding veterinary prescribing and treatment decisions for AMU in livestock, with a

specific focus on qualitative research methods. Abstracts were screened for keywords (antibiotics, antimicrobials, AMU, AMR, AS, veterinary decision-making) with a particular focus on literature relevant to bovine, porcine and ovine treatment. Following an appraisal of the relevance of the methods and findings to the study aims, a summary of the main findings is presented below.

Quantitative vs. qualitative research

Qualitative research is occupied with understanding the circumstances behind the statistics. In comparison to quantitative research methods, a qualitative methodology focuses on contextual language instead of numbers. Qualitative research generally generates narrow, but rich data from fewer participants and typically has smaller sample sizes than familiar to epidemiological studies.

Qualitative research aims to explore, interpret and make sense of the subject matter and understand the meanings of participants in their natural settings (11). In other healthcare sectors, interviews and focus groups are common methods of qualitative data capture (12). Interviews allow participants to provide deeper insights and are more appropriate when addressing sensitive topics as compared to focus groups. A semi-structured interview approach using face-to-face interviews also gives flexibility to allow participants to discuss areas that the researchers might not have addressed (12).

So far, most of this work has been concentrated on antimicrobial stewardship (AS) amongst the human medical, pharmacological and nursing sectors. More recently, interest in AS within the veterinary sector has led to a number of studies that have attempted to understand the decision-making process regarding veterinary prescribing of antibiotics for farm animals.

Global research on AMU in livestock

In 2013 a survey was undertaken amongst veterinarians from most European countries in order to gain better insight into their decision-making for prescribing antibiotics (13). Using a questionnaire, respondents were asked to score the importance of several listed factors, which might influence prescribing behaviour. The factors that most strongly affected the prescribing behaviour were antibiotic sensitivity tests, prior experience of the drug, the perceived risk for development of AMR, and the ease of drug administration (13).

One of the first qualitative studies to identify the underlying factors influencing the decision to prescribe antimicrobials to farm animals was conducted in the Netherlands and the results were published in 2014 (14). This qualitative study used semi-structured individual interviews with farm animal veterinarians working with poultry, swine, veal calves and dairy animals and revealed three levels for promoting prudent use of antimicrobials in farm animals; prevention of animal disease, making the correct diagnosis and antimicrobial selection. Veterinarians were considered to play important advisory roles and regular farm visits to be important for the early detection of health and herd problems (14).

Economic considerations were recognized as an important cause to the need for antimicrobial use as poor financial status could result in low-quality feeding, suboptimal housing conditions and low staffing conditions (14). Farmer skills and behaviour were identified as important factors influencing veterinary decisions regarding AMU (14). Improved disease diagnosis could reduce unnecessary antimicrobial treatment and whilst diagnostic tests were considered important by all interviewees, they were not often used. Instead, antimicrobials were generally chosen in accordance with the existing national veterinary guidelines, but sensitivity testing, pharmacological properties, administration routes and intervals and withdrawal times

also played a part in the decision. The views differed regarding the importance of the veterinary use of antimicrobials for the evolution of AMR in humans (14).

AMU in pigs

To-date, the pig sector has received the most qualitative research attention regarding AMU. For example, in the UK the motivations behind the use of antimicrobials and veterinary prescribing patterns in the pig industry have been explored (15, 16). The researchers used a combination of different qualitative research methods including focus groups of farmers and qualitative face-to-face interviews with veterinarians. Exploration of data by thematic analysis identified eight major themes considered to influence AMU and prescribing patterns in the UK pig industry. These included disease epidemiology and outcomes, agricultural factors, external pressures, vet-client relationship, drug-related factors, responsibility, economic factors and knowledge base. Disease epidemiology and expected outcomes were also drivers for antimicrobial prescription. The nature of the disease (agent, chronic/acute, severity), antimicrobial susceptibility testing, and alternative preventive treatment options (vaccination, health status, management) influenced of veterinary decision-making (15, 16).

Agricultural factors included farming system, geography, weather conditions, genetics as well as management features as housing, surroundings and personnel were also identified as aspects influencing veterinary decisions regarding AMU (15, 16). The quality of the pig unit management was considered to be the most significant factor in avoiding excessive AMU. External pressures from the media and the public opinion, pressure from colleagues, surrounding practices and the pig industry in other countries, as well as the relationships to the clients and customer compliance (15, 16).

When considering the drug-related factors that influenced veterinary prescribing decisions, the UK-based study found that the type and accessibility of the antibiotics, type of

formulation, withdrawal periods and the prophylactic use of antibiotics (15, 16). The experience of the prescribing veterinarian and that of the colleagues were important factors behind the decision to prescribe antibiotics. Whilst guidelines on responsible AMU existed, veterinarians reported that these guidelines were seldom applied, and identified a lack of disease-specific protocols for pigs (15, 16).

Qualitative research findings informed the development of a questionnaire which was used to further quantify the factors influencing veterinary decision-making towards AMU (17).

Questionnaire research confirmed that the decision to prescribe antimicrobials was influenced by numerous factors such as the veterinarian's experience, the clinical situation and the vet's confidence in their own diagnosis (17).

AMU in dairy cattle

The decision-making process must be seen in a context with the local and national premises taken into account. There are cross-country differences in AMU, even between countries that appear geographically and culturally close. This was highlighted in a study into treatment of mild clinical mastitis in dairy cows (18). The main objective of this study was to find out veterinarians' treatment decisions regarding clinical mastitis in dairy cows across the four Nordic countries of Norway, Sweden, Finland and Denmark. This was done by first a qualitative study followed by a quantitative questionnaire. The results showed that the treatment decision behaviour varied significantly between the countries, with the exception of Norway and Sweden which share similar approaches in the treatment of mastitis (18).

Since 2012 Norwegian veterinarians are by law obliged to report all use of veterinary medicines in food-producing animals (19). In 2017 the AMU with regards to treating mastitis

in dairy cows was further investigated with the reported data as background material (20).

The study revealed weaknesses in the registration system, but nevertheless the amounts and types of antibiotics most commonly used for the indication were identified (20)

AMU in beef cattle and sheep

A quantitative analysis of antibiotic usage in British sheep flocks showed significant variations in antibiotic usage between farms and between veterinary practices (21). In the UK Doidge and co-workers investigated veterinarians' decision making when prescribing antimicrobials for sheep and beef farms without a preceding clinical consultation (22). They used a factorial survey method to measure the influence of different factors important to the decision-making process. Participating veterinarians were given eight different real-life case scenarios, known as vignettes, with seven factors that varied; farm type, farmer relationship, other veterinarians in practice, time pressure, habit, willingness to pay and confidence in the farmer. Data on the age, gender, year and university of graduation of participating veterinarians were also captured (22). At the end of each vignette the vet was asked to quantify the likelihood of them prescribing antibiotics in that particular scenario and to consider the percentage of other vets i.e. their peers who would do so too. The vets' confidence in the farmer was found to be the factor with the highest influence - they were more likely to prescribe to familiar farmers with whom they had an existing good working relationship. This study also revealed that prescribing of antimicrobials for the prevention of *Escherichia coli* associated enterotoxaemia – colloquially referred to as 'watery mouth', still appears to be common amongst UK farm animal veterinarians (22).

Identified knowledge gap

Following a review of the scientific literature, we identified a lack of research regarding veterinary medicines use in cattle and sheep in Norway. There are quantitative data on the amount of overall medicines use in Norwegian livestock farms. However, we lack knowledge on the rationale for selecting and using antimicrobial drugs, specifically antibiotics. To-date there is no existing knowledge of the perceptions of Norwegian veterinarians who are responsible for treating these animals in the field, nor the drivers or beliefs behind their reasoning for the selection of particular antimicrobials, including antibiotics and anti-inflammatory drugs.

Aim of study

The aim of this study was to understand veterinary decision-making regarding the prescription and treatment of some common bacterial infections of sheep and beef cattle in Norway using antimicrobial drugs. For the purposes of this study, we defined antimicrobials to include antibiotics and anti-inflammatories (including NSAIDs). By listening to the vets narrative, we aimed to gauge their perceptions and beliefs behind their decisions and reasons to prescribe antibiotics (the ‘if’, and ‘why’), and specifically to understand how they selected the drug(s) used, routes of administration and duration of therapy (the ‘what’, ‘how’, ‘when’ and ‘where’). We also aimed to explore current veterinary perceptions regarding AMR in these species. Following a review of the scientific literature, we selected semi-structured face-to-face interviews with a small number of practising livestock veterinarians in Norway as an appropriate qualitative research method. This aim of the qualitative study, described below, was to capture the depth in their beliefs and perceptions around the clinical reasoning and decision-making on AMU for five common ovine and bovine bacterial infections.

Materials and methods

Selection of participants

A purposeful sampling approach was taken to identify veterinarians that were willing to participate and gave informed verbal consent to participate in the qualitative research study. Accordingly, interviews were carried out with four veterinarians; one in Nordland and three in Rogaland. The participants worked full-time with production animals and were in regular contact with beef cattle and sheep farming clients. Sample size was based on the acquiring the depth of understanding of a small number of veterinarians, rather than a saturation of views.

Data collection

We used semi-structured interviews to better understand the potential factors influencing decision-making processes for veterinarians treating common bacterial infections of sheep and beef cattle in Norway. Qualitative in-depth interviews of a semi-structured nature were conducted in Norwegian during 1 July and 31 August 2019 in Oslo and in Rogaland at a familiar place and at a time selected by the participant.

The interview schedules and vignettes were pilot tested on one practising veterinarian from Nordland (Table 1; Vet A) before the study was extended to check the questions, and to maintain the interview duration to approximately one hour for each interview. Data captured during pilot interview testing were considered valid and were analysed together with data from the three veterinarians inform Rogaland.

During the individual face-to-face interviews with the two researchers and one participant, the four different fictive case scenarios were presented (Appendix 1). Interview data were

recorded using a digital voice recorder (Olympus Digital Voice Recorder VN-2100).

Interviews were conducted in a quiet, comfortable place at a time and place best suited to the participant. The voice recorder was switched on and a brief introduction to the project was given by the main researcher (interviewer). The research clarified that participation was voluntary, participants were free to leave at any point, and could request the recording to be stopped at any point. Before proceeding, informed verbal consent of the veterinarian (participant) was captured. At the start of the interview, background data were collected on participant demographics, their place of undergraduate training, estimated annual working time (percentage of time) spent working with beef cattle and sheep and their earlier work experience.

Thereafter, each of the vignettes was read aloud by one researcher and a set of semi-structured, open questions were asked in order to capture the depth in the views regarding the on-farm approach and decisions for each of the fictive cases. The interview was led by one researcher, supported by a second researcher who took responsibility for recording and acted as a prompt for the main interviewee. During the interviews, veterinarians were also asked some open questions to capture qualitative data on their perceptions and recollections of their experiences of working with farmers and the perceived risk of AMR. The main focus of the interviews was to allow the participants to describe their practices and perceptions surrounding AMU decision-making.

Vignettes

A collection of four case scenarios or 'vignettes' were developed as a basis for allowing veterinarians to discuss their clinical approach and treatment decisions for common bacterial infections in sheep and cattle in Norway. The cases were based on fictive information, following review of clinical texts and anecdotal reports from NMBU diagnostic and

pathological service records. The cases were designed to provide the veterinarian with familiar clinical details and encourage open discussion and sharing of their experiences and practices. The vignettes included four infectious conditions (Appendix 1) described below. The recommended treatment according to the Medicines Agency veterinary medicines guidelines for the selected diseases is freely translated in appendix 2.

1. *E. coli* associated enterotoxaemia of neonatal lambs

In the first scenario *E. coli* infection in neonatal lambs (first week of life) was described. This infectious disease is commonly known as “watery mouth disease” or “rattle belly” and is closely associated with poor administration of colostrum (23) and poor hygiene. Clinical signs typically appear within 1-3 days after lambing and include profuse salivation, depression, ceased suckling and abdominal tympany. Severely affected lambs can be challenging to treat, and untreated lambs will often die (24). Early intervention is of the essence. The Norwegian Medicines Agency veterinary medicines guidelines recommend glucose and/or electrolytes *per os* and antibiotics, trimethoprim-sulfa for 2-3 days *per os* for treatment of *E. coli* infection in neonatal lambs (25). This particular scenario was chosen because *E. coli* infection is a common neonatal disease for which antibiotics are known to be prescribed both prophylactically and for treatment of clinical disease (26).

2. Ovine mastitis

Mastitis is another common bacterial disease of sheep. Recent data confirms that the most common bacterial agent associated with clinical mastitis in sheep is *Staphylococcus aureus* (27). Surveys in Norway has showed that more than 90% of *S. aureus*-isolates are sensitive to penicillin (1, 27). According to the national veterinary medicine guidelines, the first choice of treatment of acute clinical ovine mastitis is penicillin (25). The penicillin can be administered with intramuscular injection once a day for 2-3 days or alternatively with an initial

intramuscular injection in combination with intramammary treatment, followed by 3 days of intramammary treatment of the affected gland. An important part of the treatment is frequent emptying of the udder, with the administration of oxytocin if necessary. Non-steroid anti-inflammatory drugs (NSAIDs) are also proven to be effective and are important for the general well-being of the sheep (25).

3. Septic arthritis in young lambs and calves

Infected joints can be caused by trauma or hematogenous spread from infectious foci. Septic arthritis in young lambs (aged two weeks or under) in Norway is most frequently associated with the culture of *Streptococcus dysgalactiae* (28). However, a range of pathogens have been cultured including *Staphylococcus aureus*, *E.coli* and *Trueperella pyogenes* (29). In some cases, no bacterial pathogens are identified from clinically affected lambs, which may represent sampling under post-antibiotic treatment, poor sampling technique or arthritis arising from systemic inflammation or another cause (29). For the treatment of arthritis in neonatal and young lambs, the national guidelines recommend benzylpenicillin as first choice of antibiotics for at least 5 days (25).

Joint infections in calves are also often associated with penicillin sensitive bacteria. National guidelines recommend benzylpenicillin for at least 5 days, and an extended course of 10-14 days in severe cases (25). The guidelines advise for infections associated with penicillin-resistant strains of bacteria to be treated systemic with trimethoprim-sulfa or gentamycin. As arthritis is a very painful condition, NSAIDs are indicated for both calves and lambs (25). If several joints are affected or the lameness is of a chronic nature, the prognosis is poor, and euthanasia is warranted on animal welfare grounds (25).

4. Pneumonia in calves

Most respiratory infections in calves have a viral origin and the disease typically affects multiple animals in the herd (30). Primary viral infection is often followed by a secondary bacterial infection. Commonly isolated bacteria (*Pasteurella multocida*, *Mannheimia haemolytica*, *Histophilus somni*, *Trueperella pyogenes*) are all sensitive to penicillin in AST (25). Although, anecdotally the clinical response to penicillin may differ somewhat from AST results. National guidelines for calf pneumonia include systemic treatment with benzylpenicillin for 5-7 days, in some cases for 10 days (25). Supportive treatments include NSAIDs, and fluids for dehydrated animals. There is a lack of data on treatment efficacy, but chronically affected animals with multiple pneumonic episodes carry a poor prognosis (25).

At the end of the interview, the main interviewer clarified the purposes of the study, thanked the participants, and ended the recording.

Data analysis

The interviews were captured as four individual digital voice clips. Interviews were manually transcribed verbatim by the researchers. The identifying details of participants were anonymized. Transcribed scripts were then analysed using thematic analysis approach, as described by Braun and Clarke (31). The flexibility of the method lies within the interpretation the researchers do, and means they have to be active and take conscious choices about the approaches used. Essentially, Braun and Clarke divide the process of thematic analysis into six phases, briefly summarised below:

1. Familiarize yourself with the data and note the items of interest
2. Generate codes – these are essentially “labels” that catches what is interesting within the data and together they form a theme.

3. Clustering of the codes together so that they are organized into potential themes. The process of generating codes is redone several times.
4. By using thematic maps, the relationships between the themes are further explored.
5. The major themes identified by the researchers are reviewed, defined, discussed and named.
6. Finally, a report is produced where the analysis is related to the research question and literature.

Accordingly, veterinarian responses were firstly examined and manually coded by one researcher to identify the broad themes. Coding was later checked by the second researcher. Where any discrepancy was identified, the descriptions were reviewed, and a consensus reached between the two authors. The interviews and transcripts were carried out in Norwegian. A thematic map was assembled, using the software Simple Mind. Individual quotes were selected to illustrate the broad themes identified and were then translated for this report into English by the researchers and cross-checked by reverse transcription to check the meaning by a third assessor.

Results

Four semi-structured interviews were completed with practising veterinarians actively working with sheep and beef farmers. The veterinarians included two male and two female participants, one from Nordland and three from Rogaland. A brief summary of the participants is provided in Table 1. To maintain anonymity, participant details, sex and location are not presented together.

Table 1. Details of Veterinary Participants details.

Participant Identity	Age category (years)	Place of training	Years since qualified	District of practice
A	25-35	Norway	1 year	Nordland
B	25-35	Germany	10 years	Rogaland
C	36-45	Budapest	13 years	Rogaland
D	36-45	Norway	8 years	Rogaland

The main themes we identified are presented, and where appropriate, specific quotes have been selected to illustrate the diverging perceptions and beliefs of the four veterinarians.

Treatment and medicines protocol for selected bacterial diseases

The first thing that all participants suggested when presented with each of these scenarios were the likely bacterial or other pathogens implicated in disease, and the prophylactic measures that could be taken in order to avoid similar problems in the future. The participants were all focused on the importance of appropriate neonatal care, with sufficient colostrum at the correct time, good housing conditions, and optimal hygiene around navel dipping and ear marking practices. None of the interviewed vets used diagnostic testing routinely as part of

their clinical investigation, but the veterinarians close to NMBU Sandnes reported delivering animals for free-of-charge necropsy during the lambing period, when possible for the farmer.

Watery Mouth Disease

Whilst they were interviewed separately, all the interviewed veterinarians were in agreement on their perceptions regarding the underlying risk factors for developing an *E. coli* infection in neonatal lambs. Vets focused on neonatal lamb/calf care, hygiene, housing conditions, management and the whole flock/herd health perspective. Three vets discussed the benefits with giving probiotic agents (in the form of Zoolac or Biola) immediately after the first feed with colostrum to all of the lambs and reported having positive experience with that practice.

There were clear personal preferences over the treatment of individual lambs. Participant A mentioned dihydrostreptomycin per os. Participant D orally administered neomycin (Colivet, VetPharma A/S, a broad-spectrum antibiotics, an aminoglycoside) if lambs presented early in the course of the disease. At a later stage when the lambs had developed systemic illness, the same veterinarian perceived tetracyclines to be more effective. Participant D reported that their practice in the past had received varying test results when they had sent cadavers for necropsy and sensitivity testing. Sometimes the bacteria were resistant to tetracycline and sometimes to trimethoprim-sulfa.

Only one of the veterinarians (participant C) proposed supportive treatment with fluids and was also the only one veterinarian that reported administering NSAIDs to watery mouth cases. This veterinarian also reported that tetracyclines were often a more convenient treatment because of the long-lasting nature of the formulation available (Terramycin prolongatum; Pfizer), as compared to trimethoprim-sulfa that required daily dosing.

Ovine Mastitis

When treating ovine mastitis cases, these veterinarians shared a consensus on the treatment and administered penicillin intramuscularly for a range of 3-5 days and 1-3 days of NSAIDs. One of them (participant D) said that they felt that they almost never used tetracyclines any longer. In addition to medical treatment, they all emphasised the importance of emptying the udder and administered oxytocin to ease the process. None of them sent samples of milk for bacterial testing mainly because of the expense of the analysis, and the farmers' reluctance to spend more money than necessary.

Arthritis in lambs and calves

The preferential treatment for treating lambs with arthritis was intramuscular benzylpenicillin for a range of 4-7 days in combination with one dose of meloxicam for three of the veterinarians. Two participants (vet C and vet D) stated tetracyclines were their second treatment choice. Whereas, participant B identified that penicillin has a poor penetration into the joints and based on that knowledge and the formulation of procaine benzylpenicillin available in Norway, purported that this drug should be administered 2-3 times a day to achieve an optimal effect. Tetracycline was their preferred first choice. All vets reported treating calf arthritis as described for lambs.

Pneumonia in calves

Three of the four veterinarians would treat calf pneumonia cases with intramuscular penicillin for 7-10 days and NSAIDs 1-3 days. Other treatment options mentioned included trimethoprim-sulfa, tetracyclines and florfenicol (Resflor, MSD). One veterinarian (participant B) experienced that penicillin often does not have a clinical effect and, in those cases, would then administer tetracyclines for 5-6 days with a reportedly improved clinical effect.

Factors influencing treatment decisions

The thematic analysis identified six major themes to be influencing the choice of treatment; the relationship to the farmer, agricultural factors, knowledge and experience, clinical disease and animal welfare, ethics and antimicrobial resistance and finally politics and consumer satisfaction. The main themes were interlinked and to illustrate their mutual relationships, the main themes and sub-themes were mapped out in figure 1.

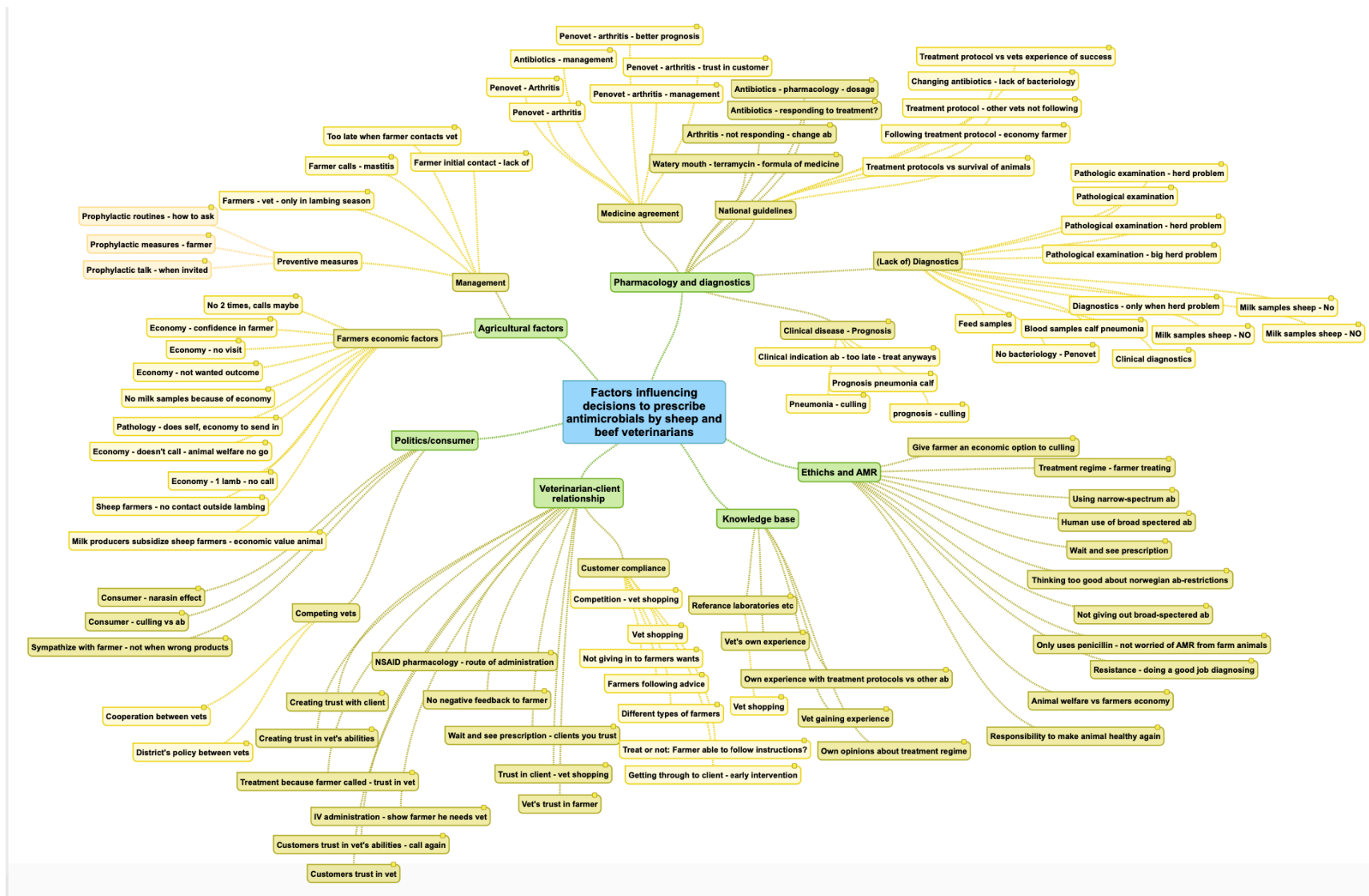


Figure 1. Thematic Analysis Map (green boxes represent main themes; yellow boxes represent sub-themes and codes)

The relationship to the farmer

Trust and medicine agreements

All participating veterinarians considered the relationship between themselves and the clients to be of great importance when choosing treatment. The trust in the farmer influences the behaviour of the veterinarian, as they have to trust that their clients follow their advice, in particular when it comes to the widespread use of medicine agreements. For example:

“You must make sure you feel safe that this (penicillin) is used in the correct manner, so you must have trust (...) I have had one client I had to tell he could no longer have a medicine agreement because he misused it for other diagnoses time after time (...) so he stopped using me.” (Vet D)

Medisinavtale: "du må sørge for å ha den nødvendige tryggheten i at dette brukes på rett måte, så du må ha tillit ... det er en kunde som jeg har sagt at han ikke får ha medisinavtale lengre fordi han gang etter gang brukte det på andre diagnoser enn avtalen sier ... så han sluttet å bruke meg ...

All three interviewees from Rogaland are used to providing veterinary medicines agreements with their sheep clients, to allow the dispensing of antibiotics (primarily for benzylpenicillin) before any veterinary visit for the treatment of septic arthritis in lambs. This was considered a useful way to encourage the farmers to start treatment early, and when there exists a good veterinarian-client relationship most participants feel comfortable with this arrangement. Good management and prophylactic routines were considered to be important criteria for signing a veterinary medicines agreement, and it was recognised that farmers do everything “correctly”, but still can have sick animals.

“They can get a prescription for antibiotics (...) and a form where they fill in which animals they treat (...) and then a thorough review of their prophylactic routines.”

(Vet D)

"da får de eventuelt ab på resept ... og et skjema der de må fylle ut hvilke dyr de behandler ... og så en grundig gjennomgang av hvilken forebygging de gjør."

One participant (vet C) was more reluctant, only giving out some penicillin for arthritis if the client specifically asked for this antibiotic.

Customer compliance and practice profits

Customer compliance also appeared to play a major role in the decision-making. Interestingly, all interviewees from Rogaland discussed the threat of competition between colleagues as leverage that the clients use to their benefit. Veterinarians were aware of this practice of farmers “shopping” around for a lenient vet and the threat of losing a good client, e.g.:

“At the same time there is a lot of competition (...) with so many vets in the area you can pick whomever you want, and if you aren't happy with the job done, you just say “too bad” and then call someone else.” (Vet D)

“... men samtidig så er det jo veldig konkurranse ... med så mange dyrleger i området at du kan velge hvem du vil og hvis du ikke er fornøyd med jobben som er gjort, så sier du bare synd for deg og så ringer du til en annen”

Making the clients see the need for veterinarian services, creating a trusting relationship, and being able to communicate with clients was also considered important for their services to be requested again in the future. E.g.

“Customer contact is in many ways a much bigger part of the job than treating animals (...) if you can't handle that part, you'll not get the chance to treat the animals, because they won't call you again” (Vet D)

“Kundekontakt - på mange måter er jo det en mye større del av jobben enn behandling av dyr (...) hvis du ikke klarer den biten, så får du heller ikke sjansen til å behandle dyra for da ringer de ikke deg igjen.”

One participant talks warmly about the farmers' general trust in the veterinary profession, and another says the opposite:

"Because there isn't a culture for telling the farmers off. For this (misuse of medicine agreement/ab). Then you loose ... (your customers)" (Vet C).

"Fordi det er ikke kultur for oss å kunne kjefte her. På sånt. Da mister man..."

All of the participants mentioned the administration of NSAIDs intravenously as an important skill to show the clients in order to enhance the farmer's trust in the veterinarian.

"... But I think it is kind of a cool thing to do, because then you show the farmer that you can do something which he cannot. Right in the blood. So that is kind of cheating..." (Vet C).

"Men jeg synes det er litt kjekt å gjøre det (meloxicam iv), for da viser du bonden at du kan gjøre noe som bonden ikke kan gjøre selv. Rett i blodet. Så det er litt sånn joks. "

Farming factors

Farm management

One of the first conditions all of the participating veterinarians immediately asked about when presented with the vignettes were the management of the farmer. Good prophylactic routines are by all interviewees considered highly important both in finding the cause of disease, but also in preventing further disease this season and next. For some of the interviewees, in some scenarios, management and prophylactic routines is said to be the only treatment of choice. Walking through management practices and all routines connected to periparturient sheep, as assistance during birth, disinfections of navels, colostrum and environment are mentioned as focus areas by all. An invitation given by a farmer that seeks help with a flock health problem, opens doors and makes it easier for the veterinarian to give prophylactic advice.

"Prophylactic measures are important. You are really too late if you rely on firefighting. This I also try to communicate (to the farmers)" (Vet C).

"Det er jo viktig med forebygging. Du er egentlig alltid for sent ute om du skal bruke brannslukking. Det prøver jeg og å si."

Farmer's economic situation

Especially as far as treating sheep is concerned, the economy of the farmer widely influences the veterinarians' treatment options. Even when the relationship between the farmers and veterinarians is described as very good, the economy plays the most important role when deciding to call upon the veterinarian.

"Most people have a good relationship to the vets here. It is mostly the economy that plays in, more than anything else. It is not will or lack of understanding, it is economy." (Vet A)

"De fleste har et godt forhold til dyrlegene her. Det er mer det økonomiske som spiller inn synes jeg, enn noe annet. Det går ikke på vilje eller forståelse, det går på økonomi."

When presented with the vignette describing the ewe with mastitis, the economic aspect of the sheep production was highlighted of all of the participants. If the outcome of a treatment of mastitis meant that an ewe lives, but cannot feed her lambs, the cost of the veterinarian treating the ewe surpassed the economic value of the ewe. Other examples of the importance of economy was the that vets suggested that one sick lamb alone was not a sufficient threshold nor financially valuable enough for the farmer to request more than free-of-charge telephone advice. A second treatment of a sick ewe often was not considered to even by an option – vets suggested that culling was preferred by the farmer over a veterinary visit.

How far along the disease has progressed before the client contacts the veterinarian was also mentioned, and two interviewees feel that some farmers have a tendency to contact the veterinarian when the disease has developed too far. This appears to be strongly associated to the perceived financial situation of the farmer of by these interviewees. Some suggested that

the farmer will try to solve a situation themselves, or have a “wait and see” approach, and often only call the veterinarian when they are unsuccessful, or the animal doesn’t get well.

“There are some that time after time are too late and responds too late and these you have to get to understand the value of early intervention.” (Vet D)

Ringe i rett tid: Stort sett ja, men ikke alltid. ... det er noen som går igjen at de oftere enn andre er seine og reagerer for seint og de må man jo prøve ... å få til å forstå verdien av å begynne tidlig".

In terms of the use of diagnostics, the economic cost is considered too high to bear for the client. This influences the treatment in several ways; sometimes the participants will prescribe antibiotics based upon the client’s clinical description on the phone, they will keep from collecting milk samples, or decide to do post-mortem autopsies themselves for free. One interviewee describes it like this:

“It is only fair that the milk producers should subsidize the sheep farmers because of their bad economy, it is merely an adjustment to the fact that the less economic value in each animal, the harder it is to observe each case yourself before starting treatment.”
(Vet D)

“... det er jo rettferdig at storfebøndene skal være med å subsidiere sauebøndene fordi de har så dårlig økonomi, det er rett og slett en tilpasning til at dess mindre økonomisk verdi dyrene har dess vanskeligere er det å klare å se hvert tilfelle selv før man starter behandling.”

Veterinary knowledge and experience

Personal experience and use of colleagues

Prior personal experience appeared to be important for several interviewees. The most recently qualified veterinarian in the sample population underlines the importance of seeking advice from more experienced colleagues, both because of their experience with the clients, knowing who has the ability to follow treatment instructions, and in assessment of prognosis and length of treatment. One more experienced interviewee had mentors he called when in

doubt at the start of his career, both for professional advice, and for peer support towards more restrictive antimicrobial usage practices.

The national veterinary medicine guidelines

The national guidelines are an influential tool in Norwegian veterinary medicine, and all interviewees described having respect for these recommendations and there was an apparently high awareness of the recommended medicines protocols. The most experienced of the interviewees recognised that they often used prior clinical experience when choosing treatment regimens and were not always in accordance with the guidelines.

“If I were to follow what the treatment protocols say 100% of the time, then a lot of animals, that could get well by switching antibiotic, would be culled” (Vet D)

"Hvis jeg skulle stått hundre prosent på det som står i terapianbefalingene så er det jo en del dyr som hadde blitt avlivet som helt fint kan bli friske av å endre behandling".

Of the participants from Rogaland, there is a broad spectrum of opinions about the clinical efficiency of following the treatment protocols. When treating mastitis there is little variation between protocol and actual chosen treatment. Several participants underline the fact that benzylpenicillin is supposed to be the first choice for most diagnosis' in sheep and beef, but also say that they at times need to switch to other antibiotics. Two participants are frustrated by the fact that not all colleagues follow the treatment protocol.

“Some vets don't give a shit about it (treatment protocols) and doesn't use first choice antibiotics for almost anything (...) That's something that has frustrated me in my practice when I've tried to reduce the use of medicine.”(Vet D)

"Det er enkelte dyrleger som driter fullstendig i det (terapianbefalingene) og som ikke bruker førstevalget nesten til noe ... det er jo noe som jeg har følt har vært litt frustrerende i min praksis når jeg har prøvd å skjerpe inn igjen medisinbruken."

Pharmacology

One interviewee explains their choice of antibiotic for treating pneumonia in calves with their own knowledge of pharmacology.

“with some of these I will go straight for either tetracycline or resflor (...) (Penovet) has less penetrance into some tissues that for example tetracycline, and in addition tetracycline has an immune-modulating effect.” (Vet D)

Lungebetennelse kalv: " det kan hende på enkelte sånne så har jeg gått rett på enten tetrasyklin eller resflor umiddelbart rett og slett av den grunn at jeg opplever at Penovet virker veldig godt på akutte luftveisinfeksjoner, trenger dårligere inn i en del vev enn for eksempel tetrasyklin gjør i tillegg til at tetrasyklin ... har en sånn immunmodulerende effekt".

“(Penovet) should theoretically be administered 2-3 times a day because of short time of half life. (...) I would probably switch to something called Terramycin (...) From my theoretical knowledge, this should give a better effect.” (Vet B)

"Hadde han ringt meg igjen og sagt at det ikke har fungert i det hele tatt, så hadde jeg prøvd en annen type ab. En annen type ab som har litt bedre fordelingskoeffisient i de forskjellige vevsstrukturer. Penicillin er ikke akkurat den beste typen av ab som trenger inn veldig godt i vev. (..) det som i Norge heter Penovet, burde teoretisk sprøytes 2-3 ganger om dagen fordi det har så kort halveringstid. Så jeg hadde nok prøvd en annen type ab, som går litt bedre inn i ledd. Men i Norge har vi Terapiabefalingene (...) jeg hadde antakelig bytta til noe som heter Terramycin (...) Men ut i fra den teoretisk kunnskap jeg har, burde det ha en bedre effekt".

Diagnostics

Treatment of the diseases presented to the participants is mainly based upon clinical examination and diagnosis. If there is a flock health problem, all participants would like to perform a pathological examination in the field. Because of the lack of financial leverage, some find it hard to suggest bacteriological diagnostics, or recommend necropsy examination at a veterinary diagnostic centre.

“It has to be quite a big flock problem before I recommend to euthanise a lamb for necropsy examination” (Vet D)

"Det skal være nok så stort besetningsproblem før jeg anbefaler å slå i hjel et lam for å levere inn for obduksjon."

All participants feel the client's interest in performing diagnostics becomes larger if there is a substantial loss of animals. The one participant from northern Norway still says that the client will choose to perform diagnostics if it is recommended by the veterinarian.

Milk samples are usually not collected from ewes with mastitis. All participants are used to this from milk production but identified that it was a struggle to motivate their sheep clients to pay for these services.

"Yes, you should do that, but there are few far between sheep farmers that will"

(Vet A)

Speneprøver: "ja, det burde man gjøre, men det er langt mellom sauebøndene som vil.

Still, three participants mention different cases where more elaborate diagnostics have been performed, as blood samples from calves with pneumonia, feed samples, bacterial growth and one also collected some milk samples at the start of the career.

Clinical disease and animal welfare

The presence of clinical disease was the only consistent criterium for starting veterinary treatment. Prognosis was also considered important, but in some cases where the participants have come to examine an animal, treatment will be given in spite of a poor prognosis.

"You don't give penicillin only because they called, it's not like that, but often it is like that really... it has been an indication for penicillin in the beginning, but it's really too late. (...) but you try anyways even though you might think it is too late." (Vet A)

"Man gir ikke penicillin bare fordi de har ringt, det er ikke sånn, men ofte så er det sånn at det er egentlig ... det har vært en indikasjon for penicillin i utgangspunktet, men det er på en måte egentlig for sent. Kanskje, det er ofte det som er tilfellet, men så prøver man likevel selv om man kanskje tenker at det her er for sent".

The medicine agreements and animal welfare are closely related in the minds of the veterinarians.

“In Norway, it’s really a bit in the grey zone that the veterinarian has to set the diagnosis and start treatment. I am fully aware of that (...) but I think a little bit about animal welfare, what is best? Is it better that the farmer doesn’t have any medicine himself, and then the lamb is in pain, and he won’t call us because of the economy, or is it better that a farmer we find trustworthy, that is motivated and listens to us (has medicines).” (Vet B)

"I grunnen er det sånn i Norge at det er litt sånn i gråsonen at veterinæren må stille diagnosen og sette behandling i gang. Jeg er helt klar over det (...). Men jeg tenker littegranne på dyrevelferden, hva er best? Altså er det best at bonden ikke har noe medisin stående og så har lammet det vondt og han ringer ikke inn til oss pga økonomiske årsaker, eller er det best at en bonde som vi synes er veldig troverdig, som er veldig motivert og hører på oss..."

The perceived impact of these bacterial infections on animal welfare perspective explained divergence in the treatment of choice away from national guidelines. On several occasions, these veterinarians choose a more broad-spectrum antibiotics in order to improve the health and well-being of the animal. At the same time one veterinarian also suggested that sometimes the “big picture” and the “greater good” of restrictive AMU should be prioritised over the survival of individual animals.

“But it is hard to make them (the farmers) understand that since we always use penicillin, they have to stand losing an animal every now and then (...) but that is how it has to be in order for us to have the good status that we have.” (Vet C)

“Men det er litt vanskelig at få dem at forstå at da vi faktisk alltid bruker penicillin så må de kunne tåle at miste et eller annet dyr, fordi vi vil jo kunne velge feil noen ganger. Men det er sånn det må være for at vi skal kunne ha den gode statusen vi har da.»

Professional ethics and selection for AMR

Anecdotally, different parts of Norway appear to have different cultures of using broad-spectrum antibiotics. For the participant from northern Norway, they seem their use as very restrictive, and the farmers are used to this. When antibiotics are selected and used for sheep and beef, it was reported to only be benzyl penicillin, and they did not perceive a very high risks for AMR as a threat to cattle or sheep health:

“We nearly don’t treat sheep (...) and we never treat with anything else than penicillin on sheep. And beef is really the same. (...) So I don’t think sheep and beef is where we will get problems with resistance.” (Vet A)

"Vi behandler jo nesten ikke på sau, så det er ikke så mye og vi behandler jo aldri med noe annet enn penicillin på sau. Og på kjøttfe er det egentlig det samme. På kalver så kan vi bruke Borgal av og til, men det er ikke ofte... Så jeg tror ikke det er der vi får problemer med resistens på sau og ammeku rett og slett".

By contrast the three participants in Rogaland reported that they had concerns for AMR in sheep and beef farms. Specifically, they highlighted concerns for the use of broad-spectrum antibiotics in the area and made reference to colleagues that do not adhere to national veterinary medicine guidelines protocols nor use penicillin as a first-choice antibiotic.

“Many people pat themselves on the shoulder and say that we use so little (ab) in Norway anyway. But we can’t think like that because then we easily use a lot more. We are in a good spot because of the choices we have made, and it’s been restrictive. And we are not restrictive here anymore, it is quite open.”(Vet C).

"Det er mange som slår seg på skulderen og sier at vi bruker så lite i Norge uansett. Men vi kan jo ikke tenke sånn for da bruker vi lett mye mer. Vi har det jo bra fordi vi har gjort de valgene vi har og vært restriktive. Vi er ikke restriktive på (...) lengre, det er ganske åpent.

Two participants from Rogaland (vet C and D) reported trying to maintain prudent AMU but have several times experienced the loss of customers if they are too restrictive in their treatment and prescribing decisions. This causes a conflict between the veterinarian’s professional ethical conduct and the need to maintain good working relationships with farming clients. The perceived financial situation of the individual farmer also influences the way the veterinarian treats sick animals. Veterinary medicines signed agreements between vets and farmers were thought to be an important element for safeguarding the on-farm welfare of sheep, as this is was seen as the only way to convince farmers to start medical treatment of sick animals early in the course of disease.

“It’s an honest case if the farmer sees it economically more profitable to cull an animal, but it is kind of meaningless if this is done too much just because of vet’s prices. It’s the reason why we have these medicine agreements because I don’t feel it is necessary that I come out to diagnose arthritis every time.” (Vet D)

"Det er jo en ærlig sak at bonden ser lønnsomhet i å slå ihjel et dyr men det er jo litt meningsløst om en skal gjøre det alt for mye bare fordi dyrlegen er for dyr. Det er jo en grunn til at vi har disse medisinavtalene for jeg føler ikke at det er nødvendig at jeg skal komme og stille diagnosen leddbetennelse hver gang ..."

Politics and consumer awareness of AMU

Consumers are becoming increasingly aware and interested in the source of food production lately. One participant mentioned the removal of narasin from chicken production (an antibiotic previously sold as coccidiostat feed additive in Norway), and all of the participants discussed a controversial pig documentary released earlier in 2019. If the consumers discover that more antibiotics than necessary was to be used in production of food, this can have a negative effect on the consumer’s view on farm animal production.

“One factor that has to be taken into account is what we are doing in relation to the consumer. Like narasin in chicken, how fast this had effect when the consumer in Norway was made aware of something in the chicken feed that actually was antibiotics”. (Vet D)

"en faktor som må være med i alt dette her det er jo at hva vi driver med i forhold til forbruker. Sånn som narasin på kylling hvor raskt det fikk effekt når det kom ut til forbrukere at i Norge at det noe i kyllingfôret som egentlig er antibiotika"

Somewhat in contradiction, the same veterinarian identified that culling animals that could be treated with antibiotics also contributes to a negative image of production animals by consumers.

Discussion

The main themes identified around decision-making by veterinarians were knowledge-based, and the national guidelines perceived to be a trusted source of advice for vets, as well as personal experience and the advice from colleagues. In veterinarian-dense Rogaland farmer compliance was identified as an important factor. However, we did not interview sufficient veterinarians from other areas of Norway to identify if this represents variation from other regions from Nordland. Within the theme of farming factors, sub-themes of farm management and the economy of sheep production were identified as common challenges.

The qualitative methodology identified individual beliefs and perceptions of veterinarians that were the key decision-makers in prescribing antibiotics in sheep and beef cattle, but found that the perceptions, and reported practices were complex and the main themes identified were often interconnected.

The relationship to the farmer was emphasized as a key element influencing decision-making for AMU by all veterinary participants. The relationship to the farmer as a paying customer played an important role in the decision-making process for the veterinarians practising in Rogaland. This region of the counties in Norway with the highest density of farm animals and at the same time a high density of practising veterinarians. According to the three vets interviewed, it appears that farmers can very easily choose to switch from one vet to another if not happy with the veterinary treatment or services provided. Norway is a vast country with demanding landscape and climate and in parts of the country veterinarian coverage is low. It is not unusual for the response times to acute illnesses to be several hours. At the same time, in other parts of the country, the farm animal and the veterinarian coverage are dense. In Rogaland the importance of customer compliance was assumed to be greater

than in other parts of the country. This was interpreted to imply that districts in Norway with less competition between veterinarians, and thus more cooperation, might be positively linked with less need for customer compliance and thus less use of antibiotic treatment. Our findings concur with those from earlier studies from UK and the Netherlands with larger number of participants and also found this to be a factor influencing prescribing of antibiotics. Both British pig veterinarians (15-17) and farm animal veterinarians in the Netherlands (14) experienced pressure from customers to prescribe antibiotics not to lose customers. This perceived client demand, real or not, was also found amongst UK veterinarians working with beef and sheep, where a long lasting client-veterinarian relationship increased the likelihood of antibiotic prescribing compared to a shorter client relationship (22).

The relationship to the farmer as a partner in treating sick animals was considered a fundamental part in the written veterinary medicine agreements. In Norway there is an window in the legislation for the veterinarian to enter into an agreement with a farmer that allows specific medicines to be left on the farm and permits the farmer to administer these drugs for specific disease syndromes (32, 33). The trust in the farmer to fulfil initiated treatments and to contact the veterinarian again if the treatment was not working was a crucial part of all of the treatment protocols. Coyne and co-authors have shown the choice of formulation of antibiotics amongst pig veterinarians was influenced by the veterinarians' trust in the farmers' ability to administer drugs. As such, those vets were inclined to choose a formula with more long-lasting effect (16). The participating interviewees in Norway all expressed full trust in the farmer's ability to administer drugs via the intramuscular route, but we did not identify whether all veterinarians had provided training or observed farmers performing intramuscular injections before prescribing antibiotics in the event of no veterinary visit.

The trust in the farmer was also considered important for the veterinarian in their role as a flock/herd health advisor. The farmer has to implement proposed changes and the relationship between farmer and veterinarian appeared to be as strongly interconnected with perceptions on herd/flock health management when deciding upon a suitable antibiotic treatment plan.

For all vignettes, all veterinarians mentioned the importance of prophylactic routines, and good management to prevent these common bacterial diseases. Even though they were likely to treat the sick animals described in the cases, they reflected that they would also suggest measures on which to advise the farmer for improved management and routines to prevent a future reoccurrence. All interviewees showed awareness of their role as advisors for the farmers. This is in contrast to what other studies have showed, as vets in Netherlands and UK wanted more knowledge on how to advise about preventive measures for the farmer (14-17). This difference might have connection with the national action plan against AMR, which promotes prudent use of antimicrobials and bans prophylactic use of antimicrobials.

Sheep production in Norway is very varied and ranges from extremely extensive systems with grazing of animals in mountain pastures and forests compared to a very intensive winter-housing period. Most sheep flocks have lambing in springtime, after which they are released to pastures around the farm. The lambing season is the period of the production cycle where most deaths and disease in ewes and lambs occur, and the time of year when vets are most likely to be contacted by sheep producers. Beef production in Norway is increasing and concentrated calving is not uncommon with the subsequent seasonal need of veterinary services.

All of the interviewees pointed out that the current low economic value of the sheep production was the reason to why they more rarely are called out to sick sheep and that all treatment of sheep had to be performed with the economic value of the animal in mind. By contrast, this did not appear to be considered to be as important a factor when treating calves. Taking the farmers' economy into account when advising the farmer and starting treatment was reported by all interviewees.

At the basis for all treatment decisions was personal knowledge and experience. The national guidelines were given great importance, and in Norway penicillin is almost always the first choice of antibiotics because of the privileged situation with a low antimicrobial resistance (1, 5). National AST performed in 2018 on *Staphylococcus aureus* and *E. coli* isolated from milk and feces sheep showed that the occurrence of resistance is low, and findings of Methicillin-resistant *S. aureus* (MRSA) in the Norwegian animal population are rare (5). Nevertheless, the interviews revealed that their personal confidence in the efficacy of some of their recommended antibiotic appeared to vary. The biggest differences were encountered when the vets were asked about how they would treat neonatal lambs with an assumed *E. coli* infection. They were all in agreement that an *E. coli*-infection was primarily a flock health problem and as such, preventive measures were of utter most importance. They described identifying any underlying primary causes, discuss management with the farmer, routines around lambing and the neonatal care with an extra interest in the administration of colostrum. None of these vets suggested prophylactic use of antibiotics to all lambs as a possibility, but they mentioned that they have heard about this being the practice in the past.

Treatment of suspected *E. coli* associated enterotoxaemia in lambs was the case that stood out as having most variations in the reported prescribing practices of these individual

veterinarians. The recommended antibiotic treatment described in the national guidelines is trimethoprim-sulphonamide orally for 2-3 days (25). In Norway there is no for sheep approved trimethoprim-sulfa formulation for oral administration. Only one vet mentioned injectable trimethoprim-sulfa, as a treatment option. None of the participants suggested oral administration of trimethoprim-sulfa – although this is the recommended treatment according to the national guidelines. Instead, they reportedly preferred to give a longer-duration formulation which is approved in Norway against infections in sheep (Oxytetracycline; Terramycin prolongatum, Pfizer). However, the effect of this formulation is 48 hours rather than the daily administration of trimethoprim-sulfa. Another mentioned dihydrostreptomycin tablets, which is the treatment that allegedly was widespread in the past, and a third veterinarian prescribed neomycin sulphate (Colivet, VetPharma). Both of these are types of aminoglycosides and as such broad-spectrum antibiotics effective against a large number of gram-positive and gram-negative bacteria. Vets also discussed prophylactic non-antibiotic treatments including the use of probiotics sold through vets themselves or use of probiotic-supplemented milk products for human consumption. Whilst this practice is anecdotally widely reported in Norway and appears to be advocated by several practising veterinarians, there is a lack of evidence for the benefits of the probiotics in prevention of *E.coli* enterotoxaemia.

Tetracycline resistance occurs most often as a result of the acquisition of new genes (a total of 45 different genes have been identified) and the resistance genes are often linked to other known resistance genes and the animal may become multi-drug resistant (34). Resistance against aminoglycosides are reported to be rapidly spreading mainly through conjugation of plasmids and a strong association with cross-resistance with extended spectrum β -lactamases (ESBLs) (35). Both tetracyclines and aminoglycosides are reported to be resistance-driving

and for those types of antibiotics to be in use when treating a typical flock health problem are particularly concerning given the current guidelines in Norway (34, 35). Although the amounts given to each individual are low, the total amount when potentially treating great numbers of lambs could be relatively high. The national guidelines do not recommend tetracyclines as first or second choice for treatment of any disease and clearly states that tetracyclines never should be prescribed without preceding susceptibility testing (25). However, there are considerable differences in international perspectives on tetracycline use in the veterinary sector (36).

Interestingly none of these veterinarians mentioned the human formulation that could be given orally (Trimethoprim sulfamethoxazole; Bactrim, Roche), which was recommended by the Norwegian Veterinary Medicines authorised board Vetlis (Marit Bangen, personal communication, 2019). Only one of these vets mentioned knowledge of the recommended choice of antibiotics (trimethoprim and sulfonamide). This may indicate a lack of knowledge of the guidelines, a lack of knowledge of available medicines, or a choice to not adhere based on prior clinical experience. For the other common bacterial diseases, the awareness of the guidelines and adherence to the recommendations was noteworthy, and these guidelines appeared to be an important factor in the decision-making process when prescribing antibiotics. Furthermore, the legislation and the prescribing cascade (37, 38) could potentially be confusing when the treatment *E. coli* infections in neonatal lambs is concerned as there is no approved antibiotics for this indication in lambs in Norway, and it may not be widespread knowledge that, contrary to usual restrictive AMU, a human antibiotic preparation could be used.

Veterinarians in Norway are, by law, forbidden to make profits from selling medicinal products (39) and the economical motivation to prescribe antibiotics in Norway should be almost non-existent. Compared to other European countries where profit from drugs, and thus the loss of income if the right to sell drugs is taken away from vets, is as strong motivator to keep prescribing drugs (14).

Routine AST nor other forms of diagnostic testing were not routine applied by these veterinarians, and most cited the cost of testing as a reason for this. Although, all vets recognized that they could make more use of diagnostic testing. This coincides with what has been reported in other studies; where vets would prefer to use more diagnostic testing, but perceive it as expensive, slow, and not always clinically informative (15-17). Vets in Rogaland reported that when AST was performed, the AST results would occasionally detect AMR resistance for the first-line antibiotic of choice.

Participants expressed some concerns about the increasing levels of AMR. Vets in Rogaland expressed concerns about the generous and wrongful use of broad-spectrum antibiotics of non-compliant colleagues in their area. They claimed the situation in Rogaland had deteriorated and reported that a lot of broad-spectrum antibiotics been used without clear indication. Interestingly, the improved situation was used as the excuse to defer from the national guidelines. This coincides with what Speksnijder et al have reported in their study, in which veterinarians felt responsible to reduce the use of antimicrobials, but did not believe that AMU in farm animals was a key driver for the development of AMR (14). Coyne et al described similar findings, where there was a difference between the desired behaviour and the actual reality of prescribing of antimicrobials (16).

Limitations of the study

Qualitative research methods are excellent for mapping complex problem with multi-factorial solutions, but awareness of the limitations when interpreting the results is imperative. It is important to avoid unacknowledged assumptions during the data collection, during the transcriptions and when analysing the data.

A qualitative study typically has few participants and the researchers have to be careful not to make generalisations about study conclusions. Whilst qualitative study uses participant numbers that are typically much smaller than quantitative studies, the sample size used here was small even by qualitative standards. However, this was limited by resources and timing. Transcription required a considerable amount of time to perform by hand. The study was focused on a specific geographical region, and participants were selected on their willingness and consent to participate. We do not suggest that the participants recruited here are representative for the entire veterinary population in Norway. Personal details as age, gender, background and practicing area are factors which are likely to affect the prescribing patterns but were not fully explored here. In this study three out of four participating veterinarians are practising in the same county, Rogaland, and animal and veterinary density are higher in this part of the country. It would be interesting to repeat the study using the same vignettes and interview a larger number of vets including more diverse experience and covering a wider geographical area across Norway.

The manner of the interviewers will naturally influence the interviewees and their answers. We used open-ended questions and visited veterinarians at their preferred location in order to provide a comfortable environment. Clearly, interview responses can be influenced by the relationship between the interviewer and participant. The choice of open-ended questions will

also influence the type and depth of data collected. Evidently, when presenting case scenarios, the selected diseases and the manner in which they are described in the given vignettes will influence the assumed treatment protocols and the underlying decision-making processes.

Transcription was a crucial part of processing of this data. Orthographic, i.e. verbatim, transcription should transcribe spoken words and other sounds captured in the data recordings. This requires that researchers should write exactly what the interviewees say and not “fix” the language. Common errors that occur are sentence structure errors (i.e. avoiding full stops and commas), quotation mark errors, omission errors (words that are not included) and mistaken word/phrase errors (31). For the sake of the ease when analysing the transcripts, commas and points were added to the transcripts to support their meaning. During the process of thematic analysis, the processes of identifying and discussing codes, grouping them together into themes and mapping the relationships between the themes are all subjective. The personal experience of the researchers reflects the assumptions and the choices they do. A qualitative study will always be subject to these limitations.

Finally, whilst we captured some diversity in bacterial conditions across sheep and cattle, we did were not able to tease out veterinary behaviours and beliefs that were specific to beef cattle. The cases on septic arthritis and pneumonia related to calves. However, this is an issue familiar to quantitative researchers analysing national health and veterinary medicines data since beef and dairy cattle are registered under the same cattle code.

Conclusion

To our knowledge, this is the first study to explore veterinary decision-making around AMU for common infections of sheep and cattle in Norway. This study has identified several themes regarding veterinary decision-making of relevance to AMU, AMR and AS including diagnostic, prognostic and treatment approaches for some common bacterial infections using antimicrobial drugs, including antibiotics and NSAIDs in ewes, lambs and calves. These included the relationship to the farmer, agricultural factors, knowledge and experience, clinical disease and animal welfare and politics and consumer satisfaction. AMR was not perceived to be major issue, but there were concerns expressed about the global situation and One Health threat.

This study indicated that prescribing decisions on AMU for common infectious diseases in sheep and calves can widely vary between practitioners. Whilst all four vets were aware of the national guidelines – not all always choose to follow them. We identified that the use of tetracyclines is still common in Rogaland and highlights a need for more evidence-based veterinary medicine regarding the most appropriate treatment for *E. coli* infections in lambs.

This study is part of a first step towards identifying models for good antimicrobial stewardship, as well as identifying practices where further training and knowledge exchange strategies could be focused to support change away from unnecessary and/or inappropriate antibiotic use in sheep and cattle. The work presented here represents preliminary data in this field, which deserved further attention and investigation.

Further studies are not within the scope of this thesis but are highly recommended.

Qualitative interviews with farmers could bring forward other aspects of the antimicrobial use. More in-depth interviews with veterinarians in focus groups from geographical regions across Norway could explore whether there are major differences between prescribing decisions and reported practices across different regions. With the incorporation of quantitative research methods, so-called “mixed methods approaches”, the relationship between specific factors such as personality traits of the veterinarian, gender, age and training background, influence decision-making towards AMU.

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Sammendrag

Tittel: Bakgrunn for veterinærers valg av antimikrobiell behandling til sau og storfe – en kvalitativ studie

Forfattere: Martina Elisabeth Sjöblom og Sofie Paulsen Sletvold

Veileder: Clare Phythian and Adam Martin

Formålet med denne studien har vært å undersøke behandlingsprotokoller og bakgrunnen for de valg veterinærer gjør ved behandling av utvalgte, normalt utbredte sykdommer i ammeku- og saueproduksjon.

En kvalitativ undersøkelse ble gjennomført, der fire veterinærer ble intervjuet og presentert for fire vignetter som omhandlet infeksjose sykdommer hos sau og kalv; slevelam, mastitt hos søyer, leddbetennelse hos lam og kalv, og lungebetennelse hos kalv. Disse sykdommene ble valgt fordi de er vanlig forekommende, ofte relatert til management, og antibiotika kan brukes både som behandling og forebygging.

Semistrukturerte intervjuer ble gjennomført, og intervjuene ble tatt opp på bånd, transkribert og deretter analysert ved hjelp av tematisk analyse som beskrevet av Braun og Clarke. Temaer identifisert som faktorer som påvirket beslutningsprosessen ved valg av behandling og behandlings-protokoll; forhold mellom veterinær og kunde, kunde-tilfredshet, kundens økonomi, hold, veterinærens kunnskapsbase, etikk og antimikrobiell resistens, og politikk/forbruker.

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Attachments

Appendix 1: Vignettes

Appendix 2: The Norwegian prudent use guidelines for antibacterial treatment of food-producing animals.

Appendix 1. Kasus

Kasus 1. Slappe spelam

Du blir tilkalt til en sauebonde med 180 vfs mitt i lammingssesong. Dyrene står inne i binger på spaltegulv. Nå opplever bonden at han har mistet et par lam, som bare vart et par dager gamle. Han beskriver at lammene har vart tvillinger og trillinger og at lammene ikke har hatt lyst å suge, legat mye, vart kalle om nosen, siklet og til sist blitt slappe og dødt samme dag. I fjor opplevde han lignende problemer og mistet flere lam, så i år ønsker nå bonden hjelp innen problemet forverres.

Kasus 2. Mastitt hos sau

En bonde ringer om ei søye med mistenkt mastitt. Han har 100 vinterfôra sau, NKS, og er nå godt i gang med lamminga. Sauene står på talle, og ingen er sluppet ut enda. Den aktuelle søya har fått trillinger for en uke siden, og fødselen gikk normalt. Dette er hennes 2. lamming. Du drar ut og finner ei nedstemt søye, hun spiser ikke, står for det meste og sturer, og slipper ikke lamma til juret. Ved undersøkelse finner du en hard, varm venstre jurkjertel, med sparsomt med vannaktig slintrete sekret. Den høyre kjertelen er tom. Temperaturen er 40,1, respirasjonsrate 40/min og hjertefrekvens 100/min.

Kasus 3. Leddbetennelse hos lam

Etter å ha behandlet mastitten ber bonden deg se på et par halte lam. Disse lammene er 4 og 5 dager gamle, begge tvillinger, men fra forskjellige søyer. Begge lammene går med mor. Når du kommer bort finner du at det ene lammet er hoven og varm over høyre framkne. Den er palpasjonsømt, og 4 grader halt. Temperaturen er 40,4, respirasjon er rask og overfladisk, og lammet virker nedstemt. Det andre lammet har litt stiv gange, og er litt hoven over koden på venstre bakbein.

Begge søyene er i normalt hold, og disse lammingene har gått helt uten fødselshjelp. Bonden sprayer navlene rutinemessig, og øremerker, begge deler ila første levedøgn. Bonden forteller deg at han har noen slike halte lam hvert år, i fjor var det omtrent 8 stk. Lammene har ikke mottatt noen form for behandling ennå.

Kasus 4. Kalv med hovne ledd

Hva om det var en kalv med leddbetennelse? (Lese og bruke 'kalv' for kasus 3)

Kasus 5. Lungebetennelse hos kalv

Du er ringt ut til en melkekubesetning med 40 årskyr, NRF.

Du kommer til en kalv på 10 uker. Den står med utstrakt nakke, litt åpen munn, og puster anstreng og abdominalt. Respirasjonen er 100/min, temperatur 41,0. Kalven har nedsatt matlyst, og er i dårlig hold. Den går i bås med 3 andre kalver på samme alder. Denne kalven er litt liten sammenlignet med de andre.

Fjøset er et gammelt båsfjøs omgjort til løsdrift. Kalvene står i enkeltbinger den første uken, og settes deretter sammen i alderslike grupper. Han har ingen andre syke dyr nå, men flere av kalvene hadde hoste for to uker siden. Han kjøper ikke inn noen dyr.

Appendix 2. The Norwegian prudent use guidelines for antibacterial treatment of food-producing animals.

Selected parts freely translated from Norwegian to English.

The udder: mastitis (page 22)

Cause

Mastitis in sheep is usually caused by *Staphylococcus aureus*. In some cases, infections can also be caused by *Escherichia coli*, coagulase negative staphylococci, streptococci (in particular *Streptococcus dysgalactiae*), *Mannheimia haemolytica* and *Trueperella pyogenes*. Surveys in Norway have showed that more than 90% of *S. aureus*-isolates are sensitive to penicillin G.

Diagnostics

The diagnosis is usually based solely on clinical signs, but can be verified through milk sample bacteriology.

Flock follow-up

If there is a flock problem, milk samples for bacteriological verification and antibiotic sensitivity testing should be performed.

Treatment

Treatment is only recommended for acute mastitis in sheep.

The first choice of antibiotics is penicillin, 45 mg/kg intramuscularly, SID for 3-5 days. Another option is initially 45 mg/kg intramuscularly together with intramammary treatment, followed by 3 days of intramammary treatment of the affected gland. The lambs must be kept away from the udder the first two hours after intramammary treatment.

An important part of treatment besides antibiotics is frequent emptying of the udder, with oxytocin if necessary. Treating inflammation and pain with NSAIDs is also effective.

In cases with gangrenous mastitis, surgery or drainage of affected gland should be considered, or massage and frequent emptying of the udder. NSAIDs are important for the general well-being of the sheep.

Comments

Other types of antibiotics should be avoided unless the diagnostic tests indicate that penicillin is an inappropriate choice.

Neonatal and young lambs - Coli-infection (page24)

Diagnostics

There are several types of coli-infections:

1. Septicemia in day-old lambs. Treatment must often be prophylactic
2. Septicemia in lambs aged 3-4 weeks, often with different forms of gastritis/enteritis. Coli-infections can also be seen as polyarthritis and encephalitis, usually in lambs in the age of 3-8 weeks.
3. "Watery mouth" seems to be closely associated with poor uptake of colostrum. The symptoms appear within 1-3 days after delivery. Symptoms are profuse salivation, depression with ceased suckling and tympani of the abomasum. Rattle belly when handling can be heard. Untreated lambs will die within 24 hours.

Treatment

Generous and early supply of colostrum is of key importance to prevent *E. coli* infections. Probiotics also seems to be effective. Lambs with septicemia are often found dead. If the infection has spread throughout the body, antibiotics rarely gives a satisfactory result.

Lambs with severe clinical signs of “watery mouth” are hard to treat. Early intervention is of the essence. Initial treatment should be glucose and/or electrolytes per os (at least 10% glucose), and antibiotics. Per os treatment with trimethoprim/sulfa, 25 mg sulfa and 5 mg trimethoprim per kg SID for 2-3 days.

Neonatal and young lambs - Polyarthritits and pyemia (page 24)

Cause

1. Pyemia most often occurs before lambs are released to pasture, but can also be seen in lambs on pastures rich in ticks and *Anaplasma phagocytophilum*. The condition is most often caused by infections with *S. aureus* or *T. pyogenes*.
2. Polyarthritits is usually caused by streptococci, but also *S. aureus*, especially with pyemia.
3. Arthritits can also be caused by *Erysipelothrix rhusiopathiae*, but is relatively rare. These infections usually become clinically visible after some time.

Treatment

Prevention is the most important factor. Successful treatment is dependent upon early intervention. First choice of antibiotics is penicillin (45 mg/kg im) for at least 5 days. This should be combined with NSAIDs. The prognosis is poor if the lamb does not respond to treatment within 5 days. In flocks with diagnosed *E. rhusiopathiae* ewes could be vaccinated before lambing.

Infections in calves - Airway infections (page 40)

Most airway infections are viral, and an outbreak can affect many individuals in a herd. If there is a persistent problem in a herd, diagnostics should include laboratory work.

If a calf has impaired general condition and a primary or secondary bacterial infection is suspected, treatment should include systemic treatment with benzyl penicillin. The common bacteria (*Pasteurella multocida*, *Mannheimia haemolytica*, *Histophilus somni*, *Trueperella pyogenes*) are sensitive to penicillin. Treatment should last for 5-7 days, in some cases as much as 10 days.

Supplementation with NSAIDs can be appropriate when breathing is clearly constrained. Dehydrated animals should be treated with fluids, but NSAIDs administered to dehydrated animals is associated with increased risk of kidney failure.

Poor prognosis for animals with multiple episodes or suffering from chronic disease.

Infections in calves - Infectious arthritits (page 41)

Infected joints can be caused by trauma or hematogenous spread from infectious foci.

The condition is often caused by penicillin sensitive bacteria, and should be treated with systemic benzyl penicillin. Duration of treatment at least 5 days, 10-14 days in serious cases.

Infections caused by penicillin resistant bacteria should be treated systemically with trimethoprim sulfa or gentamycin.

As arthritis is very painful, NSAIDs can be supplied.

If there is considerable effusion in one joint, local treatment can be considered in addition to systemic treatment. Intraarticular flushing with Ringer-Acetate or isotone NaCl-solution and injection of benzyl penicillin in the joint. If bacteriological testing shows the infectious agent is penicillin resistant bacteria, gentamycin can be provided intraarticularly.

When more joints are affected or there is consistent lameness and/or reduced range of motion, the prognosis is poor, and the calf should be culled.



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