Importance of selective antibiotic use: Drying off and clinical mastitis treatments

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Take Home Messages

- The majority of antimicrobial use on dairy farms is for mastitis treatment or dry cow therapy.
- Changing from blanket to selective dry cow therapy can decrease on-farm antimicrobial use without negative effects on udder health or milk production.
- Teat sealants prevent new dry period intramammary infections and must be part of a selective dry cow therapy protocol.
- Using a selective clinical mastitis protocol based on rapid diagnostic tests will not negatively affect cure rates, somatic cell counts, or recurrence of clinical mastitis.

Introduction

Antimicrobial Use and Resistance

Antimicrobial use (AMU) increases emergence of antimicrobial resistance (AMR). Although evidence regarding the scope of the contribution of AMU on dairy farms towards AMR in human health care settings is lacking, the World Health Organization and other international agencies are pressuring livestock industries to reduce AMU. Fortunately, reducing AMU in livestock can decrease prevalence of AMR in livestock and humans. Furthermore, effects of reducing AMU in livestock on AMR in human pathogens potentially acquired from livestock are more prominent in people with direct contact with animals compared with the general public. Therefore, AMR in livestock is particularly important for farmers and their families, and for farm workers.

The majority of AMU on dairy farms is for mastitis treatment and prevention, with dry cow therapy (DCT) using high concentrations of long-acting antimicrobials. Due to pressure to reduce overall AMU in food animals and eliminate preventive antimicrobial treatments, selective DCT (SDCT; treatment of selected cows at drying off) is being considered instead of blanket DCT (BDCT; treatment of all cows at drying off), and selective treatment of clinical mastitis (CM) instead of treating all cases of CM. By reducing livestock-associated AMU there is potential to reduce prevalence of AMR, with expected benefits for both animal and public health. In addition to reducing overall AMU, the dairy industry signals it is making more prudent use of antimicrobials and promoting sustainability.

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Dry Cow Therapy

Blanket DCT is a key component of the National Mastitis Council (NMC) Mastitis 10-point Control Program and the previous 5-point mastitis control plan to prevent and treat contagious udder infections. Consequently, it is done in many countries. In contrast, SDCT involves selecting only cows or mammary quarters with existing udder infections or at increased risk of developing new infections to be given antimicrobials at drying off.

Although SDCT has been done in Scandinavia for decades, it has only recently been considered in national policies in many other countries. This is possible due to changes in mastitis epidemiology, including considerable decreases in percentage of cows with an udder infection at drying off, lower prevalence of contagious mastitis bacteria such as *Streptococcus agalactia*e and *Staphylococcus aureus*, and reductions in bulk milk somatic cell count (SCC). In addition, there are now reliable and affordable diagnostics and teat sealants (TS). With these improvements, there is an opportunity, or arguably an obligation, to reduce or perhaps eliminate preventive AMU in the dry period.

Treatment of Clinical Mastitis

As non-selective or blanket antimicrobial treatment of CM is common worldwide, interventions such as selective antimicrobial treatment of CM are an opportunity to refine AMU. The main principle of selective antimicrobial treatment of CM is to only treat Gram-positive (most frequently *Staphylococcus* and *Streptococcus*) cases that will respond to antimicrobials. Not treating all CM cases with antimicrobials is possible due to improvements in udder health management practices and diagnostics. In many countries, a large percentage of CM cases are caused by Gram-negative bacteria (most frequently *Escherichia coli* and *Klebsiella*). There are now on-farm diagnostic tests to identify the bacteria or group of bacteria (Gram-positive and Gram-negative), or to determine that no bacteria are present.

Aims and Objectives

In this review, we will first summarize core principles and elements of SDCT and selective treatment of CM protocols. In addition, a summary of positive and negative consequences associated with SDCT and CM treatment protocols will be presented. Finally, we discuss challenges in promoting antimicrobial stewardship strategies and highlight future steps.

▪ Principles of Selective DCT and Treatment of CM

Dry cow therapy

Herd selection

There are general indications, but no definitive guidelines, to make herd-level selections for farms to adopt SDCT. Herd and udder health characteristics are important to consider and should be optimized before SDCT implementation. Herd considerations can include bulk milk SCC (BMSCC) thresholds (e.g., < 250,000 cells/mL), CM incidence, and factors that influence these, e.g., hygienic drying off practices and mastitis bacteria profiles. Major pathogen udder infections at drying off and incidence of new major pathogen udder infections in the dry period must be minimized. Additional considerations include good record keeping (i.e., CM cases, antimicrobial treatments, etc.), to know whether cows had CM during lactation or had other health consequences (i.e., CM recurrence, culling, etc.), and to determine if a SDCT protocol was successful.

Cow selection

The main challenge to implementing SDCT is deciding which cows or quarters should be treated with antimicrobials. The objective is to accurately identify cattle likely to have a major pathogen udder infection and likely to benefit from antimicrobial treatment. If antimicrobials are applied preventively, cows or quarters at high risk of acquiring a new major pathogen udder infection during the dry period need to be identified. Identification of udder infections can be done with various methods: SCC at cow- or quarter-levels, identification of bacteria, California Mastitis Test (CMT), milk leukocyte differential, conductivity testing, lactate dehydrogenase, or N-acetyl-β-D-glucosaminidase. Further, Lactanet can identify cows that are good candidates to be dried off without DCT. Figure 1 provides a suggested protocol.

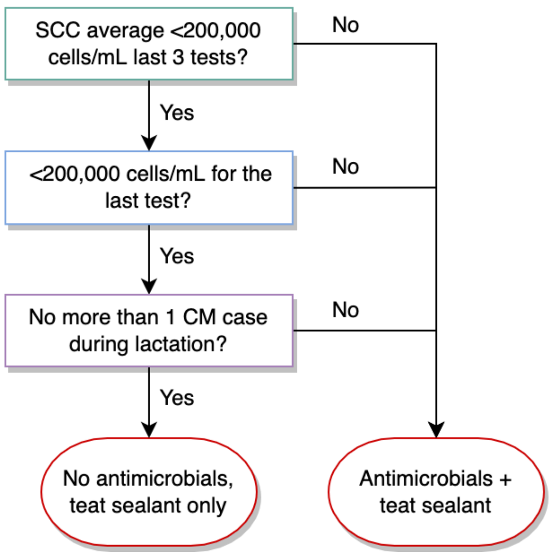

Figure 1: Example of a selective dry cow therapy protocol.

Teat sealants

To prevent new udder infections in the dry period, it is important to reduce the likelihood that bacteria enter the teat canal and proliferate in the udder. Up to 50% of teats remain open ten days after drying off, and 23% are open for six weeks. Teat sealants were developed to reduce new udder infections by creating a physical barrier with more reliability than keratin plug formation. Although TS help to reduce preventive AMU, they do not replace other measures to prevent udder infections in the dry period such as bedding hygiene.

There are external and internal TS. External TS are external coatings on the teat end, usually applied with a dipping cup. However, they can be difficult to apply correctly, are ineffective long-term, and require frequent reapplication. Internal TS is an inert product infused into the teat canal, ideally forming a physical barrier that remains in the distal teat cistern throughout the dry period but stripped out the first milking after calving. An internal TS plug will still be present at first milking in 83% of treated quarters. The National Mastitis Council currently recommends TS application as part of DCT. Teat sealant material must be removed from the udder before milk is put into the bulk tank.

Internal TS use without concurrent AMU in cows identified as not infected at drying off has been successful, with no difference compared with BDCT for CM incidence in the dry period and during the first 120 days in milk, dry period new infection risk and at calving, SCC, and milk production in the subsequent lactation. Internal TS reduced new udder infections in the dry period by 52% compared with no treatment and by 23% compared with antimicrobials in the udder in cows entering the dry period without an infection.

In a meta-analysis (1974-2020), if internal TS was administered to untreated, healthy quarters or cows at drying off, there was no difference between BDCT and SDCT for the risk of new udder infections during the dry period and at calving, and early lactation CM risk, milk yield, and SCC (Kabera et al., 2021). However, without an internal TS, the risk of new udder infections in the dry period and harboring an udder infection at calving was higher with SDCT than with BDCT (Kabera et al., 2021), emphasizing the importance of TS.

Clinical Mastitis

Decisions regarding antimicrobial administration for CM aim to achieve bacteriological cure and clinical cure, and to avoid negative health and economic consequences. The objective of selective treatment of CM is to reduce and refine AMU by treating only CM cases with the highest odds of clinical cure, and to withhold antimicrobial treatment from CM cases unlikely to benefit. This can be achieved by considering signs associated with the current CM case, (potential) causal bacteria, and cow-related factors such as SCC and CM history (Figure 2). Combining these factors can be used to identify CM cases less likely to benefit from antimicrobial treatment. Other cow factors such as parity and lactation stage also impact clinical cure but are not important for choosing antimicrobial administration for CM cases. Antimicrobial susceptibility is important, but usually not available in time and will not influence the decision to treat.

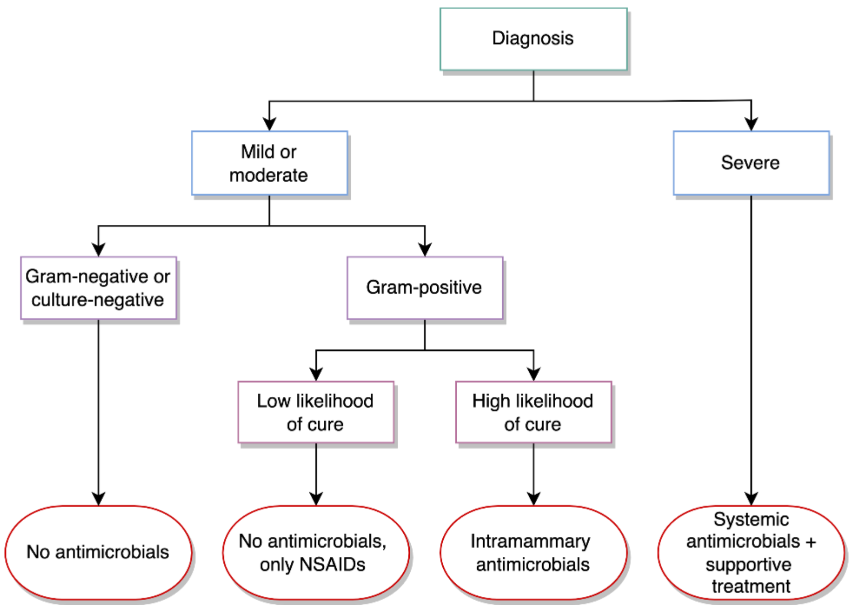

Figure 2: Selective clinical mastitis treatment protocol.

Severity

Severity of CM is generally classified as mild (changes in milk only), moderate (infected quarter has signs of inflammation), or severe (including signs of general illness). Typically, mild and moderate CM cases are treated only with intramammary antimicrobials. For those cases, bacteriological and clinical cure rates are not affected when treatment in the udder is delayed for a maximum of 24 hours after onset compared to immediate initiation, allowing time to get diagnostic test results.

With automated milking systems, systemic (in muscle, intravenous or under the skin) AMU may be more practical. Systemic antimicrobials for mild and moderate CM, in addition to intramammary AMU or alone, is common in Scandinavia, Estonia, and Spain. There is little evidence that systemic antimicrobials are better than treatments in the udder. Severe CM cases typically receive systemic antimicrobials in addition to supportive treatments (i.e., anti-inflammatories and fluid therapy), although there is limited evidence that systemic antimicrobials are necessary.

Identifying causal agent

Because CM typically occurs after an inflammatory response to an udder infection, many CM cases are detected after successful bacteriological clearance. If viable bacteria are no longer present in the udder, and bacteriological culture of a milk sample is negative, antimicrobial treatment should not be considered. Additionally, when a mild or moderate case is caused by an infection with *Escherichia coli* (Gram-negative), antimicrobial treatment is not indicated because there is a high spontaneous cure rate that is not improved by antimicrobials. However, when the Gram-negative agent is *Klebsiella*, antimicrobial treatment increases bacteriological cure rates. In addition, udder infections caused by non-bacterial pathogens such as yeast and algae do not respond to antimicrobials and should not be treated with them. These non-bacterial pathogens also produce negative bacteriological cultures. Various on-farm testing methods are available to identify the cause of CM and can be used on-farm or in a laboratory. Getting results within 24 hours is key for timely treatment of Gram-positive CM cases.

Expected chance of cure

In combination with bacterial identification, cow-level SCC and CM history can be used to identify CM cases with a high probability of cure and should be combined with rapid diagnostic tests to decide whether antimicrobial treatment is appropriate. Cattle with a persistent high SCC (i.e., chronic subclinical mastitis; typically defined as composite SCC > 200,000 cells/mL on at least two of three consecutive SCC records) have a lower likelihood of cure. Similarly, cases preceded by CM in the same lactation also have a lower likelihood of cure. For both situations, nonsteroidal anti-inflammatory drugs (NSAID) only (and no antimicrobial treatments) are favored.

Other considerations: anti-inflammatory treatment

Regardless of antimicrobial treatment, giving an NSAID to reduce pain and inflammation is recommended for all severe CM cases. Providing NSAID to mild and moderate cases in addition to antimicrobials lowers SCC and reduces the risk of culling compared to providing only antimicrobials (if most cases are caused by Gram-positive bacteria, e.g., *Streptococcus uberis* or *Staphylococcus aureus*). Therefore, NSAID are strongly indicated for severe CM cases, and also benefit mild and moderate cases. However, milk withdrawals for NSAID products may reduce farm profits. Thus, consideration of NSAID for mild and moderate CM cases should be discussed with the herd veterinarian.

Other types of supportive treatments (i.e., fluids, frequent milk-out, oxytocin, calcium, hypertonic saline, and corticosteroids) are sometimes considered for CM treatment, although limited research is available regarding their effects on clinical signs and clinical cure.

▪ Impact of selective treatment practices

Dry cow therapy

Udder Health

If SDCT programs are successful, udder infection dynamics (i.e., new udder infections, bacteriological cures) during the dry period will be similar to BDCT, resulting in a similar percentage of udders infected at calving. If this is achieved, udder health and performance in the subsequent lactation should be equivalent to BDCT. The majority of recent clinical trials concluded SDCT can be implemented in commercial dairy herds without negative consequences for udder health. Similarly, recent meta-analyses concluded udder health was similar for BDCT and SDCT, provided SDCT protocols used on-farm culture systems or SCC-based selection, and internal TS was used in untreated healthy quarters.

The recent BDCT ban in the Netherlands resulted in a 36% reduction in AMU for DCT without major negative udder health impacts. However, there was a small increase (+0.41%) in high test-day SCC (heifers: > 150,000 cells/mL; older cows: > 250,000 cells/mL) and a new high test-day SCC (either at first test after calving, or a high SCC report after low SCC at previous test day during lactation) (+0.06%). Therefore, most herds can enact SDCT with minimal or no negative effects on udder health. Impacts of TS use are unknown, but from 2013 to 2015, TS sales in the Netherlands increased by 73%.

To summarize, considering udder health, SDCT is a viable option, with consistent reports of no negative effects on SCC after calving, elimination of udder infection, new udder infection risk, and presence of infection at calving. With appropriate selection criteria and other mastitis control procedures (i.e., TS and good overall hygiene) to reduce udder infection, SDCT can be used without negatively affecting udder health.

Milk Production

Although selection criteria and specific udder health impacts differed among studies considering SDCT impacts, most studies reported no difference between BDCT and SDCT for milk production in the next lactation. Although most studies reporting no effect on milk production included internal TS in their SDCT protocols, one study without TS also had no negative effects on milk production.

In an Irish study, low SCC cows (< 200,000 cells/mL throughout lactation) that received only internal TS had higher mean daily milk yield (0.67 kg) over the entire lactation, compared to low SCC cows getting both internal TS and antimicrobials in the udder. However, there are no other reports of similar findings for milk production.

Based on available literature, with selection criteria sensitive enough to identify most infected cows at drying off and use of TS to prevent new udder infections, negative milk production consequences can be avoided. However, further research is needed to better define relationships among SDCT, TS, and milk production.

Economics

Economic evaluations are country- or region-specific, due to variations in costs or milk prices (the latter differ between countries with or without supply management), the availability of low-SCC incentives, and other regional differences. In a U.S. study, SDCT was more economically beneficial than BDCT, and SCC-based SDCT was more economically beneficial than SDCT based on culture (mean costs savings/cow of US$7.85 versus US$2.14, respectively). However, DHIA SCC testing was assumed to be available, and no additional testing costs were included. Furthermore, economic impacts varied considerably. In a sensitivity analysis, economic advantages of SDCT were substantially lower if its implementation increased clinical and subclinical mastitis after calving. Although economic benefits of SDCT were highest in herds with lower CM incidence and BMSCC, all herd types can have reduced AMU at drying off without greater economic losses.

Economic impacts of SDCT likely differ among herds and management systems because of bacterial profiles, selection criteria, costs for antimicrobial treatments, and level of AMU reduction. Therefore, it would be useful to have general agreement on economic model development and coefficient inclusion, the ability to adapt economic analysis to farm-specific scenarios, and assumptions about ‘routine’ mastitis management strategies (i.e., pre- and post-dipping, culling of recurrent high SCC cows, bedding management, etc.). Therefore, economic models need to consider costs associated with evaluating current mastitis management practices and implementation of new management practices as required, rather than application of SDCT. Models must also be updated with real-world data supported by literature and be contextually specific while minimizing structural limitations of model development.

A partial budgeting tool can be adapted to a variety of herd contexts for individual producers to compare economic impacts of various DCT approaches. Here is an example of an interactive partial budgeting tool: https://dairyknow.umn.edu/research/udder-health/selective-dry-cow-therapy-cost-calculator/. Economic evaluations specific to various industry contexts are needed.

Additional considerations

Various factors impact drying off decision making and dry cow management, including social determinants of AMU, product availability, and cows’ physical environment. Administration of antimicrobials in the udder has some risk due to potential for contaminating the udder. Therefore, hygienic drying off practices and other management decisions are also important for overall dry cow wellbeing and for limiting udder infections. These include, but are not limited to, milk production at drying off (abrupt versus gradual reduction), nutrition, housing, culling chronically infected cows, dry period duration, and limiting udder infections during lactation to reduce udder infections at drying off.

Clinical Mastitis

Cattle health

Thirteen studies in North America, Europe, and New Zealand evaluated effects of selective and blanket CM treatment protocols. Short-term outcome measures included bacteriological cure and clinical cure, whereas long-term outcome measures included SCC, CM recurrence, and culling rate. Clinical cure is defined as absence of clinical signs; it is easy to observe and often used by farmers and veterinarians for treatment evaluation. In contrast, bacteriological cure is achieved when the causative agent is eliminated, providing a more reliable measure of antimicrobial treatment efficacy. No difference in bacteriological cure was reported between CM cases treated in a selective versus a blanket antimicrobial treatment protocol. Regarding clinical cure, a slightly higher proportion of cases that reached clinical cure within 14–21 days was observed in the selective treatment group, as well as 0.4 day longer time to clinical cure. These results were, however, influenced by co-administration of NSAID in selectively treated cows.

Regarding long-term outcomes, there was no difference in SCC after CM between selectively treated and blanket treated CM cases. Similarly, there was no difference in risk for recurrent CM cases in the selective versus blanket treatment groups, and no significant difference in culling rate and milk production.

Economics

Similar or lower costs have been consistently reported fora selective treatment protocol based on rapid diagnostic tests compared with a blanket treatment protocol. Direct costs associated with selective treatment protocols include costs for analyzing milk samples (i.e., labor and testing plates). Potential benefits to selectively treating CM cases compared with blanket treating are reduced treatment costs and reduced days of discarding milk. Indirect costs include production losses due to CM and potential culling and replacement costs. Farms with a higher proportion of Gram-positive CM cases will have similar costs compared with farms with a blanket CM treatment approach.

Reduction of antimicrobials

Reductions in AMU achieved through bacterial identification-based selective CM treatment is determined by two factors: the initial distribution of bacteria of CM cases and CM incidence. If the majority of CM is Gram-negative or culture-negative, a selective CM treatment protocol will substantially reduce AMU. Reducing CM incidence also contributes to lower AMU. Therefore, udder health management needs to be optimized to reduce infection pressure by Gram-positive bacteria. There is also a lower risk of receiving a follow-up treatment for cases that are treated according to a selective CM treatment protocol. With knowledge of the presence of bacteria and the specific kind of bacteria, farmers may be less prone to initiate another antimicrobial treatment when there is no resolution of clinical signs.

▪ Antimicrobial Use Motivations

Despite literature supporting SDCT and selective CM adoption, it can be difficult to convince some producers and veterinarians to follow these approaches. To increase uptake, drivers and barriers to adoption of selective treatment strategies must be considered. For example, regulations and fines for ‘overuse’ can be introduced, but unintended consequences must be considered; for example, illegal AMU requiring constant enforcement, and animal welfare concerns. Furthermore, concerns of producers toward regulations are associated with increased AMU, and veterinary consultation for antimicrobial decision-making and treatment for antimicrobials routinely available to producers may be limited.

Producers

Although cattle health and welfare influence on-farm AMU, other factors for choosing antimicrobial treatments include producer practices and perceptions, previous experience, economic considerations including lack of time and resources, atmospheric climate, farm ‘uniqueness’, farm biosecurity, societal pressure, risk aversion, difficulty of implementing management changes, and a ‘moral’ duty to treat a sick animal. Concern for financial consequences and uncertainty regarding mastitis recovery without AMU were among the most important factors for producers choosing BDCT over SDCT. For CM treatment, concerns about reduced welfare when withholding treatment were often mentioned.

Existence and awareness of prudent AMU guidelines vary worldwide, with greater producer AMR knowledge and awareness in high-income countries. Skepticism has been identified regarding the degree to which agricultural AMU contributes to AMR, especially human health impacts, where awareness of the relationship between AMR in humans and agriculture was low. In a South Carolina study (2007), 86% of producers were not concerned that livestock antimicrobial overuse could cause AMR infections in farm workers. Minimal concerns regarding consequences of AMU may contribute to a lack of desire to reduce AMU. In contrast, in 2013, 70% of producers in the UK thought reducing AMU was a good idea.

Recent research conducted by our group in Alberta, Canada, identified that although producers were skeptical of a link between AMU in dairy cattle and AMR in humans, producers sought to act in the best interest of animals, humans, and the environment, and were committed to maintaining the integrity of their food product. While some producers identified as stewards of the land, they also valued their independence in AMU decision-making and hoped future AMU regulation would reflect their desire for on-farm autonomy. Further, Alberta producers believed their knowledge and experience are undervalued by consumers and policymakers and expressed concern that AMU policy will be based on misguided consumer concerns rather than being evidence based. Familiar with implementation of AMU policies in other contexts (e.g., the Netherlands), producers were knowledgeable about regulations that would not be well-suited for the community and instead were interested in initiatives tailored to farms in Alberta. Understanding the context of on-farm AMU decision-making is important to consider when striving for improved antimicrobial stewardship and critical in establishing long-term uptake by producers.

Selective DCT and selective CM education, training, and campaigns are important in changing producer perspectives and practices regarding mastitis management. However, successful communication of farm management improvement opportunities must acknowledge various producer perspectives, capabilities, opportunities, and learning styles. Producers motivated to improve udder health are most impacted by a ‘central route’ of information, including providing instruction cards, treatment plans, checklists, and software with rational arguments for change. In contrast, producers without initial behavioural change motivation were most impacted by a ‘peripheral route’ using a subconscious or indirect method without reasoning or rational arguments that focused on a single message (e.g., wearing gloves while milking). Both methods should be combined to optimize effectiveness of AMU reduction campaigns.

Crucial components of successful communication are a proactive approach, message personalization, provision to producers of practice-based examples, and use of social environment. Integration of science and producers’ knowledge and experience increases recommendation credibility and practicality, leading to measurable and lasting reductions in AMU.

Veterinarians

It is important to consider the perspective of veterinarians because they substantially influence producer AMU. Until recently, BDCT was endorsed by veterinarians in many countries, and some remain adamant in their support. Literature regarding attitudes and perceptions of veterinarians towards AMU and AMR generally indicates agreement on the importance of reducing AMU in livestock production. Antimicrobial prescribing behaviour of livestock veterinarians is dependent on multiple factors, including obligations to ease animal suffering, financial dependency on clients, risk avoidance, advisory skill limitations, producer economic limitations, lack of producer compliance, public health safety, and beliefs regarding degree of veterinary AMU contributions to AMR. Veterinarians consider economic drivers to be strongly correlated with producer compliance with veterinary recommendations.

In the Netherlands, views regarding SDCT differed among veterinarians. National policy was introduced in 2013 that determined that only SDCT could be used; many veterinarians agreed, but some felt they were endorsing a decision not aligned with their own beliefs of dry period risks. Most UK veterinarians interviewed preferred SDCT because it aligned with prudent AMU strategies. Regarding veterinary SDCT perspectives, there were three themes: 1) prioritizing prudent AMU and attempting to maintain producer engagement; 2) veterinary experience level and ability to influence producer decisions; and 3) veterinary perceptions about SDCT risks and implementation difficulties, which varied greatly. With increasing experience, veterinarians were less likely to consider veterinary contributions to AMR as a concern, whereas junior veterinarians were less likely to take a primary prescribing role or make suggestions contradicting senior colleagues, despite an expressed desire to assume more prescribing responsibility. Because senior veterinarians have greater influence on producer AMU, they should facilitate the transition from BDCT to SDCT, where prudent to implement, and increase producer trust of their junior colleagues to further optimize AMU decisions. Furthermore, initiatives to mitigate negative veterinary perceptions of SDCT risks and improve producer perceptions of the veterinary community as a 'united front' of SDCT support, will likely promote industry changes.

Changing veterinary perceptions and access to new information does not always progress logically. For example, although new data supporting TS use were accepted by most veterinarians, research conclusions close to their own beliefs were more readily accepted. Consequently, new data on SDCT and TS may cause uncertainty and doubt in decision making. Advocating SDCT instead of BDCT, the longstanding industry norm, is a considerable change from an udder health perspective. Therefore, it may take substantial evidence to convince more change-averse veterinarians to adopt SDCT.

Some UK producers and veterinarians felt their personal stewardship efforts were undermined by the actions of others, including other countries' agricultural sectors, with specific blame on the human medical community. Previous research suggests increasing One Health stewardship efforts that are focused on individual knowledge and motivations may increase personal responsibility and reduce blame placed on others. The relationship between producers and veterinarians can either be a barrier or a facilitator of antimicrobial stewardship, depending on the dynamic, with producer-veterinary partnerships fostering shared responsibility and improved stewardship efforts. Promoting desired behavior change requires end users (i.e., producers and farm workers) to perceive that their actions regarding AMR are effective and important.

▪ Further Steps

With increasing scrutiny of preventive AMU and calls to decrease agricultural AMU worldwide, adoption of SDCT and selective treatment of CM can be expected to increase. Specifically, an industry 'paradigm shift' is required to transition from indiscriminate AMU to justified AMU based on presence or risk of an udder infection (DCT) or odds of cure (CM). As this shift occurs, it is worth considering how to facilitate sustained behaviour change using a holistic approach. It is important to integrate priorities of all relevant stakeholders in development of any public health initiative that will be both impactful and practical. Providing benchmarks of antimicrobial prescribing to veterinarians and producers may allow them to contextualize their antimicrobial prescribing and use compared to their peers, encouraging conversations regarding AMU practices. Overall, national SDCT and selective treatment of CM guideline development that consider country-specific industry differences, along with supportive veterinarians, and effective communications, would provide producers with tools to successfully implement SDCT and selective treatment of CM with limited negative consequences on udder health and productivity. This should be coupled with ongoing evaluation of AMU and impacts on AMR in the dairy industry.

▪ Conclusions

Although described selection protocols and results differed, common themes emerged that support SDCT and selective treatment of CM. To improve chances of SDCT success, producers should be provided with various protocols (i.e., SCC or identification of bacteria), based on their access to data or willingness to choose one method over another, with TS considered an important part of the protocol. If SDCT recommendations are practical and based on producer situations, uptake will likely increase.

Not all CM cases benefit from antimicrobial treatment. Therefore, correctly identifying CM cases that do and do not benefit from antimicrobial treatment is key to support further judicious AMU in dairy farming. Herd characteristics and history as well as the individual cow should be considered in CM treatment, accompanied with a relatively fast crude identification of the organism causing CM. Various rapid field tests are available to provide presumptive identification of the causative organism and support treatment decisions. Most reports did not indicate negative economic or udder health consequences (e.g., clinical cure, bacteriological cure, SCC, culling rate, milk production, milk withdrawal time, or number of follow-up treatments) after initiating selective CM protocols using on-farm testing.

Using selective treatment protocols depends on legislation, management systems, and adoption of udder health control programs. The level of AMU reduction following selective protocol initiation depends on the distribution of bacteria responsible for the CM cases and percentage of quarters infected at drying off. Furthermore, ongoing producer and veterinary education is essential to increase antimicrobial stewardship in the dairy industry and increase personal responsibility in AMR mitigation. Proper evaluation mechanisms are needed to evaluate impacts of introduced SDCT and selective treatment of CM protocols. In summary, SDCT and selective CM treatment protocols can be used without affecting udder health and milk production, but reducing AMU and potentially reducing AMR.

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Many studies were indirectly cited in the text, but there were too many to list. This manuscript is a shortened version of two invited reviews on DCT (McCubbin et al., 2022) and another on selective treatment of CM (De Jong et al., accepted). Because Journal of Dairy Science is an open access journal since January 2022, these manuscripts will be freely accessible once published. An additional manuscript on the effects of selective treatment of CM on cure, SCC, recurrence, and culling is in press in Journal of Dairy Science (De Jong et al., in press). Finally, a manuscript on the perspectives of Alberta dairy farmers on AMU is also in press (Ida et al., in press).

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