TREATING MASTITIS: BALANCING CURE, MONEY, WELFARE AND RESISTANCE

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Mastitis is an animal welfare problem. Also, mastitis might be a food safety problem, but surely mastitis is an economic problem. Being an endemic disease on dairy farms all over the world, mastitis is an important cause of a less efficient milk production. Moreover, mastitis affects milk quality directly through a change in technical and hygienic milk quality and indirectly through the intrinsic milk quality. This makes mastitis a concern for the dairy industry. Mastitis management, therefore, should have the goal of improving milk quality and the efficiency of milk production and thus make the production of milk more sustainable.

Given the multi-factorial nature of mastitis, management consists of a wide range of activities. For the dairy farmer, many of the daily decisions taken on mastitis are associated with treatment: treatment of diseased cows (clinical or subclinical) and dry cow therapy. The following factors are important when evaluating the optimal treatment: welfare of the cow, use of antibiotics, economics, and performance of the treatment (cure rate). The relative importance of these factors differs between dairy production systems. Choosing the correct treatment approach is therefore an act of balancing.

This paper describes the current knowledge on the balance between economics, welfare and use of antibiotics with regard to mastitis treatment decisions. It will first describe the factors that are involved with treatment decisions and will then give available knowledge on treatment decisions for clinical mastitis, subclinical mastitis, dry cow therapy and finally on treatment decisions in automatic milking.

Factors in Treatment Decisions

Economics has, for a long time been one of the factors that has been taken into account in treatment discussions. Dairy farmers do have a business and control of disease should be a weighing of the costs of control versus the reduced losses because of that control. The decisions farmers take are, therefore, aimed at economic optimization rather than maximization of animal health.

Mastitis is associated with pain (e.g., Kemp et al., 2008) and can therefore be seen as an animal welfare problem. In a recent, study where changes in behavior in relation to occurrence of clinical mastitis were studied, it was found that cows with mild clinical mastitis did have a reduced lying time, increased activity and restless behaviors during milking (Medrano-Galarza et al., 2012). However, there are no good assessments yet to assess the pain associated with mastitis more directly. As a proxy for the effect of mastitis on animal welfare, up to now, we can only use the number of cases with clinical mastitis.

Resistance to antimicrobials among mastitis pathogens has been documented for a long time. Although there is some resistance, there has been no evidence presented that there is a change in the resistance patterns of mastitis pathogens (e.g., Erskine et al., 2004). There is also discussion in the relation between the use of antibiotics in animal husbandry and the development of antimicrobial resistance in public health (e.g., Acar et al., 2012). In a review, Oliver et al (2011) indicated that on the basis of published scientific work, there was no support of emerging resistance in human pathogens because of the use of antibiotics in adult dairy cattle. However, they also concluded that antimicrobial resistance does occur and that the use of antibiotics in adult dairy cows does contribute (although in a very minor way) to increased antimicrobial resistance. That means that prudent use of antibiotics should be advocated. The debate on this issue in the Netherlands lead to an agreement that the use of antibiotics in animal husbandry should be reduced (van Werven, 2013).

The most important factor in treatment decisions is, of course, the cure rate. The cure rate influences all of the factors mentioned above. There is a large amount of studies on the treatment of clinical mastitis (see for some recent papers Barkema et al., 2006, Roberson, 2013, Roy and Keefe, 2012; Suojala et al., 2013, Swinkels et al., 2013). A review of cure rates of antimicrobial therapy is, however, beyond the scope of this paper.

<u>Treatment of Clinical Mastitis</u>

In many countries, cases of clinical mastitis cases in cows on dairy farms are treated with a standard intramammary antimicrobial treatment. Several antimicrobial treatments are available, differing in antimicrobial compound, route of application, duration and costs. Scandinavian countries are used to strict rules with regard to the treatment of clinical mastitis, including a protocol for which antibiotics to be used for pre-defined cases of mastitis (Espetvedt et al., 2013). Many other countries have much more liberal regulations with regard to the application of

Most of the cows with clinical mastitis are treated with antibiotics. In the US, approximately 90 % of the clinical mastitis cases are treated with antibiotics (Hill et al., 2009). The type of treatment might differ from case to case. Cow factors (e.g., parity, stage of lactation and somatic cell count history) and the causal pathogen influence the probability of cure after treatment with antibiotics. Therefore, cow-specific treatment of clinical mastitis is often recommended. Steeneveld et al. (2011) determined if cow-specific treatment of clinical mastitis is economically beneficial. For each simulated case of clinical mastitis, the consequences of using different antimicrobial treatment regimes (standard three day intramammary, extended five day intramammary, a combination of three day intramammary plus systemic, a combination of three day intramammary plus systemic plus one day non-steroid anti-inflammatory drugs, and a combination of extended five day intramammary plus systemic) were simulated simultaneously. Bacteriological cure for each individual cow depended on the antimicrobial treatment regime, the causal pathogen and the cow factors parity, stage of lactation, somatic cell count history, history of clinical mastitis and whether the cow was systemically ill or not. Finally, total costs of the 5 antimicrobial treatment regimes were compared. Total costs for each case depended on treatment costs for the initial case of clinical mastitis (including costs for antibiotics, milk withdrawal and labor), treatment costs for follow-up cases of clinical mastitis, costs for milk production losses and costs for culling.

Table 1. Average total costs (€;on dec. 1 2013 € 1 ≈ $US 1.37) for the five treatment regimes for all cow characteristics (source: Steeneveld et al., 2011).

	Treatment regime[1]				
	IMM3	IMM5	IMM3_S	IMM3_S_ NSAID	IMM5_S
Overall	177	191	198	201	212
Causal pathogen					
Streptococcus dysgalactiae or *uberis*	154	170	175	186	195
Staphylococcus aureus	199	202	210	215	226
Escherichia coli	188	205	212	217	227
Daily milk production (kg)					
<20	115	120	131	142	147
20-25	129	141	158	157	168
25-30	138	153	168	169	184
30-35	153	169	179	180	190
35-40	183	195	200	202	218
>40	222	238	241	244	255

[1]IMM3 = standard 3 d intramammary treatment with antimicrobials, IMM5 = extended 5 d intramammary treatment with antimicrobials, IMM3_S = 3 d standard intramammary + systemic treatment with antimicrobials, IMM3_S_NSAID = standard 3d intramammary + systemic with antimicrobials + 1d NSAID, and IMM5_S = extended 5 d intramammary + systemic with antimicrobials.

The average total costs for clinical mastitis using the 5 treatments were $US 242, $US 272, $US 271, $US 275 and $US 295, respectively (Table 1). Average probabilities of bacteriological cure for the 5 treatments were 0.53, 0.67, 0.67, 0.72 and 0.81, respectively. The causal pathogen and several cow characteristics influenced the total costs of clinical mastitis treated with different treatment regimes (Table 1). On average, the total costs of a case of clinical mastitis caused by streptococci and treated with a standard 3 d intramammary antimicrobial was $US 211, while the total costs of a case of clinical mastitis caused by *Staphylococcus aureus* and treated with a standard three day intramammary antimicrobial was $US 274. The costs of clinical mastitis increased with increasing daily milk production at the onset of clinical mastitis (Table 1). The costs of clinical mastitis increased as well with increasing relative production value, increasing parity number and decreasing month in milk. Also, for repeated cases clinical mastitis and cases of clinical mastitis in systemically ill cows, the costs were higher than for non-repeated cases and cases of clinical mastitis in not systemically ill cows, respectively. For all different simulated cases of clinical mastitis, the standard three day intramammary antimicrobial treatment had the lowest total costs (Steeneveld et al., 2011). This can also be seen in Figure 1, which represents the association between total average costs and the probability of bacteriological cure. Treatment of all simulated cases of clinical mastitis with a standard three day intramammary antimicrobial resulted in the lowest average costs but also in the lowest probability of bacteriological cure. The figure also presents the treatment regimes which are most cost effective, which are the treatments included on the least-cost frontier. Also from Figure 1 it can be seen that treatment with a standard three day intramammary antimicrobial resulted in the lowest total average costs for all the specific cows.

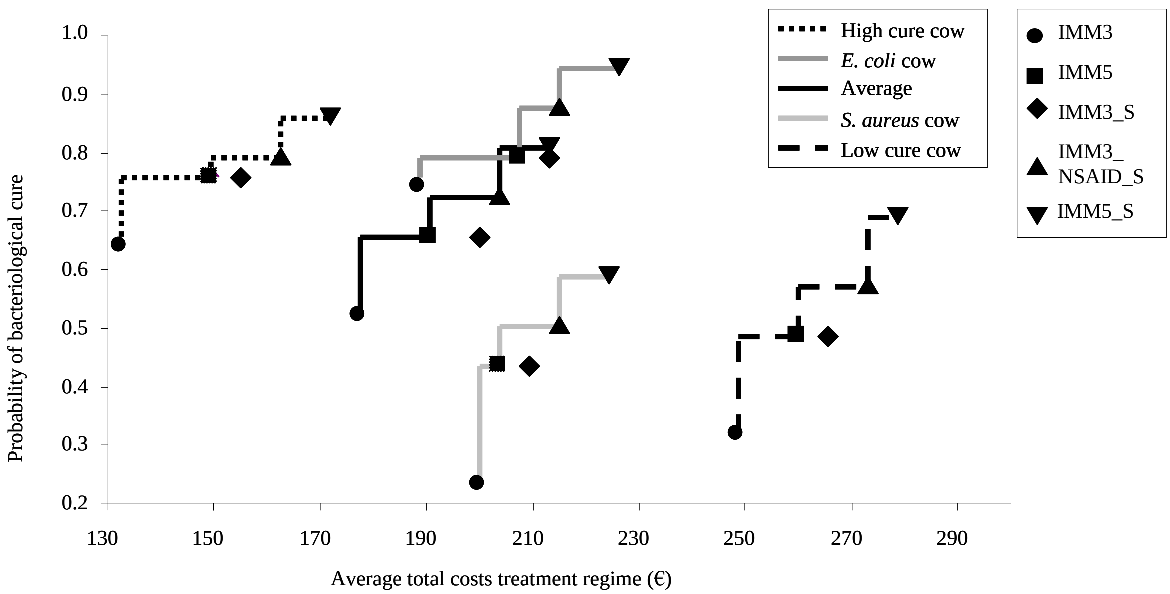

Figure 1. Average total costs (€ per case; on dec. 1 2013 € 1 ≈ $US 1.37) for each antimicrobial treatment regime with their associated average probability of bacteriological cure for different cows (IMM3 = standard 3 d intramammary treatment with antimicrobials, IMM5 = extended 5 d intramammary treatment with antimicrobials, IMM3_S = 3 d standard intramammary + systemic treatment with antimicrobials, IMM3_S_NSAID = standard 3d intramammary + systemic with antimicrobials + 1d NSAID, and IMM5_S = extended 5 d intramammary + systemic with antimicrobials). The lines resemble the least-cost frontier of treatment for the different clinical mastitis cases (source: Steeneveld et al., 2011).

As a follow-up study, Halasa (2012) has used the same treatment possibilities but included transmission of pathogens. The inclusion of transmission dynamics, did alter the order of optimal treatment options. The total costs ($US per 100 cows per year) for mastitis were $US 10,885 per 100 cows per year[1] when clinical mastitis was treated intramammary for three days. Extended treatments had lower total costs; $US 8,621 and $US 8,441 respectively for a standard treatment of 5 days intramammary and five days intramammary plus three days systemic.

In a similar study of Down et al. (2013), the important role of transmission of mastitis was confirmed. Approximately one third of total costs of a case of clinical mastitis ($US 547 per case

[1] In the original publication the economic figures were given in Euro's. A conversion rate of € 1 ≈ $US 1.37 as of Dec 1, 2013 was used.

when treated for three days intramammary) was due to transmission of mastitis. In this study, the most straightforward treatment regime (three days intramammary) was the most cost-effective.

There seems to be a general consensus among scientists that mild clinical mastitis caused by gram-negative pathogens does not need to be treated Using a severity level and culture to determine the choice of treatment allows for a justified and judicious use of antibiotics. According to Roberson (2012), antibiotic therapy is not warranted for mild-to moderate gram-negative clinical mastitis. Therefore, using an on-farm culturing system (e.g., Cameron et al., 2013) in combination with a delay of the decision for treatment, systems have been developed to carry out culture based treatments. Such a system has been able to reduce the use of antibiotics with half without differences in cure, nw intramammary infections and treatment failure risk (Lago et al., 2011a) nor in recurrence of clinical mastitis, somatic cell count, milk production and survival (Lago et al., 2011b).

Using a decision tree, the economic consequences of treatment decisions, including culturing, for mild and moderate clinical mastitis in early lactation have been studied (Pinzón-Sánchez et al., 2011). Two sequential decisions were modelled: the first one being culturing or not and the second one the administration of antibiotics for zero, two, five, or eight days. For most scenarios, the optimal economic strategy was to treat clinical mastitis caused by gram-positive pathogens for two days and to avoid antimicrobials for clinical mastitis cases caused by gram-negative pathogens or when no pathogen was recovered. Extended intramammary antimicrobial therapy (five or eight days) resulted in the least expected monetary values (Pinzón-Sánchez et al., 2011). From this study, unfortunately, the additional value of doing on-farm culturing could not be concluded.

Treatment Subclinical Mastitis

Chronic subclinical mastitis is usually not treated the lactation. However, sometimes, especially in the case of chronic subclinical mastitis, lactation therapy is seen as a solution. Following a presentation at the NMC in 2005 (Hogeveen et al., 2005) a number of studies on the economics treatment of subclinical mastitis (both caused by *Streptococcus uberis* and *S. aureus*) have been carried out with an increasing level of modelling complexity (Swinkels et al., 2005a; Swinkels et al., 2005b; Steeneveld et al., 2007). These three studies did take, in a rather pragmatic way, the effect of lactational therapy of subclinical mastitis on transmission dynamics into account. These effects are shown in practice (Barlow et al., 2013). The general outcomes of these studies were that lactational treatment of subclinical mastitis was, on average, not cost-effective. The average costs of a chronic *S. uberis* case was $US 149 and $US 164 for respectively non-treated and treated chronic *S. uberis* mastitis cases. (Table 2). There was a substantial variation in costs of cases, depending on milk production level, lactation stage and transmission probability. The variation was larger for the non-treated cases (Steeneveld et al., 2007).

For *S. aureus* subclinical mastitis treatment of chronic subclinical cases gave an expected negative effect of $US 21 when treated for 3 days with antibiotics. With a high transmission rate, there was an expected benefit of $US 131 of treatment (Swinkels et al., 2005b).

Table 2. Average economic consequences (€/case; on dec. 1 2013 € 1 ≈ $US 1.37) of chronic subclinical mastitis caused by *S. uberis* after the day of diagnosis for Dutch circumstances. Str. uberis after the day of diagnosis. Between brackets the 5 and 95 percentiles are given. Data published earlier in Steeneveld et al. (2007).

	No treatment	Treatment
Drugs	0	27
Discarded milk	0	21 (9-38)
Milk losses during IMI	7 (1-19)	3 (0-14)
Milk losses after IMI	21 (0-53)	27 (0-61)
Clinical flare-ups	9 (0-58)	5 (0-49)
Culling	38 (0-373)	0 (219)
Newly infected cows	34 (0-221)	17 (0-82)
Total	109 (4-489)	120 (40-374)

More recently, an experiment was conducted where lactational treatment was given to subclinical mastitis cases that were not (yet) chronic (van den Borne et al., 2010a). In this study, cows with a first elevated (for primiparous and multiparous cows > 150,000 and 250,000 cells/ml respectively) composite SCC after 2 consecutive low composite SCC measurements during milk production recording were eligible for enrollment. Cows with one or more culture-positive quarters and with a quarter SCC >= 100,000 cells/ml were randomly assigned to treatment or control (no treatment). Farmers used their own treatment protocols to treat infected quarters. Treated quarters had a higher bacteriological cure rate than control quarters for all pathogens. Treatment resulted in lower quarter and composite SCC, but milk yield was not affected by treatment.

The results of the study above were used in an existing bio-economic model to calculate the costs of mastitis. An interesting element of that bio-economic simulation model is that it also models transmission of IMI in a detailed manner (Halasa et al., 2010). So, if, by treatment, a case of contagious mastitis is earlier cured, transmission ends and less cows will be infected. The total failure costs of mastitis (including subclinical mastitis) were calculated for a default situation (where all clinical mastitis cases were treated with antibiotics) and two scenario's where subclinical mastitis, caused by contagious pathogens, were treated. The total costs for mastitis in the default situation were $US 12,412 per year for 37 clinical cases and 78 subclinical cases (Table 3). The largest proportion of the costs was for clinical mastitis (production losses, antibiotics, costs for the veterinarian, labor and culling). For both subclinical treatment scenario's the total costs were lower. For the treatment after two weeks scenario, the total costs were $US 5,447 and for the four weeks scenario, the total costs were $US 8,331. The total use of antibiotics (and thus also the costs of antibiotics) was lower in the situations where subclinical mastitis caused by contagious pathogens was treated during the lactation.

This knowledge opens interesting opportunities. It seems, based on modelling results, that lactational treatment of subclinical mastitis increases animal welfare (less cases of clinical mastitis), reduces the use of antibiotics and saves money. The most important cause of these very positive results is the expected effect of a reduction in transmission of IMI. Therefore, we have to be careful. The estimates are based on a limited number of transmission studies and these results can be too optimistic. Before advising this broadly in practice, a clinical trial should confirm these modelling results.

Table 3. Average (between brackets 5 and 95 percentiles) mastitis cases and costs (€/year; on dec. 1 2013 € 1 ≈ $US 1.37) of mastitis for a default situation (no treatment of subclinical mastitis), a situation where subclinical mastitis cases were treated after 2 weeks and a situation where subclinical mastitis cases were treated after 4 weeks, simulated on a 100 cow herd. (Source: Van den Borne et al., 2010).

	Default	Treatment (2wk)	Treatment (4wk)
Total cases	78 (9-168)	27 (6-69)	45 (8-114)
Clinical cases	37 (7-77)	15 (4-33)	23 (5-52)
Subclinical cases	41 (2-93)	12 (1-37)	22 (1-64)
Costs of mastitis			
Subclinical IMI	3,899	918	1,911
Subclinical intervention	0	1,006	988
Clinical IMI	5,056	2,008	3,115
Clinical IMI during dry period	105	44	66
Total costs mastitis	9,060	3,976	6,081

A specific type of subclinical mastitis cases are those related to coagulase-negative staphylococci (CNS). CNS are the most frequently isolated bacteria from milk samples in several studies worldwide. Recently a study was published that calculated the economic efficiency of lactational treatment of subclinical mastitis caused by CNS (Bexiga et al., 2013). The calculations included the transmission of IMI and average result per antimicrobial treated quarter was a net loss of $US 53[2]. Even when input parameters of the model were changed in a sensitivity analysis, the result was almost always a negative economic effect of treatment. It was therefore concluded that for most situations, lactational treatment of CNS subclinical mastitis was not financially justifiable.

Dry Cow Therapy

A specific case of treatment of subclinical mastitis is treatment at dry-off. For many cases of subclinical mastitis this is a delayed treatment. However, treatment with antibiotics at dry-off can also serve as prevention. For that reason, in some countries, treatment at dry-off with antibiotics is not allowed and thus in those countries dry-off treatment is done selectively instead of blanket. In the past this was especially the case in Scandinavian countries. This lead to heavy debates in the international mastitis community and in 2003 a symposium on dry cow therapy was organized at the NMC Annual Meeting. During that symposium, also some economic figures were provided. Interestingly, the economics differed when different farming systems were looked at (Table 4). In a UK study (Berry and Hillerton 2002), where blanket and dry cow therapy were compared, blanket dry cow therapy was much cheaper ($US 27 per cow) than selective dry cow therapy ($US 47 per cow). Moreover, there was less clinical mastitis associated with the dry period, leading to less welfare losses. However, in the blanket dry cow

[2] In the original publication the economic figures were given in Euro's. A conversion rate of € 1 ≈ $US 1.37 as of Dec 1, 2013 was used.

therapy situation more antibiotics were used (even when the higher incidence of clinical mastitis was taken into account). Under Norwegian circumstances as studied by Østerås et al. (1991; 1994), there was still a little higher incidence of clinical mastitis when selective dry cow therapy was used. This difference, however, was small and the associated costs were almost equal between the two approaches.

More detailed calculations for the Netherlands (Huijps and Hogeveen, 2007) showed that, also for the Dutch situation, there was a little economic advantage for selective dry cow therapy over blanket dry cow therapy. The costs associated with the dry period were respectively $US 21 and $US 19 for blanket and selective dry cow therapy. But also here, in the selective dry cow therapy scenario, more cases of clinical mastitis were associated with the dry period than in the blanket dry cow therapy scenario. In a different study (Halasa et al., 2010) for the Dutch circumstances, blanket dry cow therapy had a little economic advantage over selective dry cow therapy, indicating that differences are small and that, from an economic point of view, there is not much difference between blanket dry cow therapy and selective dry cow therapy.

Table 4. Simulated dynamics of infections and total costs (€/cow; on dec. 1 2013 € 1 ≈ $US 1.37) for two specific situation as described in literature (Source Hogeveen, 2003).

	Berry and Hillerton (2002) • New IMI dry period: 0.29 • New IMI dry period with treatment: 0.06		Østerås et al (1991, 1994) • Spontaneous cure of IMI: 0.37 • Cure IMI after treatment: 0.65 • New IMI dry period: 0.2 • New IMI dry period with treatment: 0.15	
	Dry cow therapy		Dry cow therapy	
	Blanket	Selective	Blanket	Selective
Probabilities				
IMI at dry off (%)	15	16	15	15
Treatment at dry off (%)	100	48	100	49
Non cured IMI (%)	4	5	5	6
New IMI in dry period (%)	6	18	15	17
IMI at calving	9	22	19	22
Mastitis after calving (%)	30	20	9	10
Costs				
Total costs (€)	20	34	34	35

<u>Treatment in automatic milking</u>

In the early nineties of the last century, robotic milking systems were introduced on commercial Dutch dairy farms. The technology gained worldwide acceptance with >10,000 farms milking robotically globally today (Rodenburg, 2013). It also signposted a revolution in the dairy industry as cows were milked fully automatically and humans were, for the first time ever, no longer an essential element of the milking process. As a consequence, it was essential to develop a new method to detect cows with clinical mastitis. This new method involves two diagnostic tests. The first involves a mastitis detection model on the robotic milking system that uses sensor data (e.g., electrical conductivity, milk yield) as input to generate mastitis alert lists as output. These attention lists report cows likely to have clinical mastitis and, therefore, warn farmers which cows require attention. The second test involves visual confirmation of these mastitis alerts. To find all cows with CM, farmers are advised to visually check all mastitis alerts. However, a review on the performance of these detection model showed that these system still generate a relatively large number of false positive alerts (Hogeveen et al., 2010; Rutten et al., 2013). As a consequence, checking all mastitis alerts is a time-consuming and frustrating task as in most cases the alerted cow will not show any signs of clinical mastitis.

Farmers milking robotically have indicated to prefer detection models that focus on finding cows with severe clinical mastitis and that generate very few false alerts at the same time (Mollenhorst et al., 2010). In other words, farmers are eager to minimize the additional time and nuisance of checking large numbers of false alerts even on the expense of missing cows with (mild or moderate) clinical mastitis (Claycomb et al., 2009). This is in line with results from a small though practical experiment demonstrating that the majority of mastitis alerts are not associated with mastitis and that farmers use their own rules to decide which mastitis alerts to check visually (Hogeveen et al., 2013). Main reasons for farmers to check a mastitis alert visually included a spike in electrical conductivity, a drop in milk production, presence of clots on the filter sock, when the robot failed to milk a cow or a combination of these reasons. Main reasons for farmers not to visually check a mastitis alert included the absence of flakes or clots on the milk filter (28%), the decline in milk yield was not sufficient or alarming (19%), the cow has a high electrical conductivity but keeps re-appearing on the mastitis alert list (10%), and a lack of time (10%) (Table 5). The decision-making process of farmers to check or not to check mastitis alerts resulted in <3% of all mastitis alerts that were confirmed visually and, as a consequence, it was estimated that ~75% of cows with clinical mastitis that had been correctly identified by the detection model were missed. It can, therefore, be concluded that on farms that milk robotically, a large proportion of cows with clinical mastitis do not receive antimicrobial treatment.

Table 5. Main reasons for farmers not to visually confirm mastitis alerts (n = 421). Reasons that were used for less than 1% of the alerts are not presented (Source: Hogeveen et al., 2013)

No flakes/clots on the filter sock	28%
Milk production deviation not alarming	12%
Combination repeatedly on the list and high conductivity	10%
No time	10%
Combination conductivity alert en milk production deviation not alarming	7%
Temporarily physical problems	6%
Conductivity alert not alarming	5%
AMS disorders	4%
Already more cows in mastitis treatment	4%
Green alert	2%
Checked before, not clinical at that moment	2%
Not clinical at the last check, repeatedly on the list	2%
Will be culled	1%
In heat	1%

The presented data demonstrate that not all cows with clinical mastitis are diagnosed and treated immediately on farms that milk robotically. The question arises whether this is a problem since farmers that milk robotically are still able to produce milk of such quality sufficient for human consumption. Moreover, results suggest that the cow's own immune system is capable to clear (mild) cases of mastitis (Erskine, 1992). This observation, in addition to the presence of mastitis causal pathogens that are resistant to antimicrobials, are a strong incentive to develop alternative mastitis treatment protocols for farms that milk robotically. Such an alternative treatment paradigm does not exist (yet) and may address today's increasing public concern regarding animal welfare and the development of (multi)resistant pathogens in human health and in the animal production sector (Van Werven, 2013).

Final Remarks

Treatment decisions are important decisions with regard to the control of mastitis. The most important factor in a treatment decision is the expected cure rate of the chosen treatment for the mastitis case at hand. This paper did not look at cure rates of different treatments but merely at optimizing treatment. Traditionally this optimization is on economics: do we accept the economic losses of a lower cure rate versus the savings of a more expensive (extended) cure. Because of the changes in our societies, for clinical mastitis we do not only have to look at economic losses (and the labor burden associated with it) but also at the welfare losses connected to clinical mastitis. Finally the de facto use of antibiotics is becoming an item of concern, putting a constraint on the use of antibiotics. Also we did not describe prepartum treatment decisions of end-term heifers (e.g., Passchyn et al., 2013).

From the studies on clinical mastitis that we described above, it becomes clear that most of them provide an economic balance. The trend that can be found is that extended treatments do not provide better economic results (although they do provide better cure rates and thus a better animal welfare). When taking the use of antibiotics into account, the balance tips towards short duration treatments with antibiotics. However, the negative consequences of shorter treatment periods become larger when transmission dynamics are taken into account. In that case extended treatments have more advantages, because of the prevention of new cases of clinical mastitis (and thus saving some antibiotics as well). Especially when the use of antibiotics is limited, there is a large potential in the on-farm culturing to reduce the use of antibiotics without reducing the level of mastitis. Economics are, however, not known yet.

For subclinical mastitis, most studies indicate that lactational treatment of subclinical mastitis is not cost-effective. However, with a farm-level simulation model that takes transmission into account, it seems that the reduction of spread of mastitis does outweigh the additional use of antibiotics, not only in terms of money but also in terms of reduced incidence of clinical mastitis (and thus improved animal welfare) and reduced use of antibiotics. However, there not too much quantitative knowledge on the between-cow dynamics of mastitis infections. Therefore, herd level clinical trials should be conducted to validate these model outcomes before we can make recommendations.

With regard to dry cow therapy, for most countries there is not much difference in economic efficiency between blanket and selective dry cow therapy. Therefore, until recently in the

Netherlands the balance for dry cow therapy was held in favor of the blanket dry cow therapy. In that balance, there was a little higher use of antibiotics, approximately equal costs and better animal welfare through a reduction of the level of clinical mastitis. Due to discussions on antimicrobial resistance in humans in the Netherlands in relation to the use of antibiotics in animal husbandry, a substantial reduction in the use of antibiotics is agreed upon (van Werven, 2013). The weighing of animal welfare versus use of antibiotics shifted and, therefore, the recommendations for blanket dry cow therapy have been changed towards a recommendation for selective dry cow therapy (see the paper of Lam et al. in this proceedings).

With automatic milking treatment of mastitis is based on checking of cows identified by on-line mastitis detection systems. The performance of those systems is such, that farmers do miss cases of clinical mastitis. The consequences of this and possible solutions with regard to a change in view of treatment decisions in the situation of automatic milking requires attention in the future.

Finally, the decision to treat animals is an important one, but at the same time it is a routine decision. Farmers should, together with the experts (their veterinarian) think about a farm-specific treatment plan that can be routinely used for each mastitis case. In the definition of such a plan the use of on-farm or off-farm culturing should be considered as well as the type of treatment and duration of treatment. The plan should balance the welfare of the animals, the economics of treatment and disease and the use of antibiotics into account. A final weighing is dependent on the preferences of the farmer and the constraints of the society.

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