Understanding the economic impact of mastitis therapy – the role of duration and drug selection

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Abstract

Mastitis occurs on all dairy farms, and veterinarians can help producers reduce losses and promote more judicious antimicrobial usage. In the US, 7 intramammary (IMM) antibiotics are approved for treatment of mastitis, but no antibiotics are approved for systemic treatment of mastitis. Most cases of clinical mastitis present with mild or moderate clinical signs and there is no evidence that use of systemic antimicrobials is of benefit. Farmers typically underestimate costs associated with treatment of clinical mastitis, and about 75% of costs are associated with milk discard. Selection of drugs and duration of treatment are both areas that can have significant impact on economic losses associated with mastitis therapy. The distribution of etiologies is associated with the value of antimicrobial therapy, and use of intramammary antibiotics should be determined based on knowledge of etiology. Clinical outcomes of most mastitis cases that are culture-negative or caused by *E. coli* are not improved by use of antimicrobials, and considerable losses can be incurred when longer-duration therapy is used as the standard protocol. When etiology of non-severe clinical mastitis is unknown, use of narrow-spectrum IMM antimicrobials for short duration results in optimal economic outcomes.

Key words: dairy, mastitis, treatment, economics

Résumé

La mammite est présente dans toutes les fermes laitières et les vétérinaires peuvent aider les producteurs à réduire leurs pertes et à promouvoir une utilisation plus judicieuse des antimicrobiens. Aux États-Unis, il existe sept antibiotiques intramammaires approuvés pour le traitement de la mammite bien qu'aucun antibiotique ne soit approuvé pour le traitement systémique de la mammite. La plupart des cas de mammite se présente avec des signes cliniques de légers à modérés et il n'y a pas d'évidence que l'utilisation d'antimicrobiens systémiques soit bénéfique. Les producteurs sous-estiment habituellement les coûts associés au traitement de la mammite clinique et près de 75% des coûts sont associés au lait jeté. Le choix des drogues et la durée du traitement sont deux éléments qui peuvent avoir un impact significatif sur les pertes économiques associées à la thérapie de la mammite clinique. La distribution des étiologies est associée à la valeur de la thérapie antimicrobienne et l'utilisation des antibiotiques intramammaires devrait être basée sur la connaissance de l'étiologie. Le résultat clinique de la plupart des cas de mammite négatifs à la culture ou causés par *E. coli* ne s'améliore pas avec l'utilisation d'antimicrobiens et des pertes considérables peuvent s'ensuivre si la thérapie à long-terme est utilisée comme protocole de routine. Lorsque l'étiologie de la mammite clinique non-sévère n'est pas connue, l'utilisation d'antimicrobiens intramammaires à spectre d'activité étroit pour une courte durée produit des résultats économiques optimaux.

Introduction

Mastitis treatment protocols were initially developed when the majority of cows were affected with *Streptococcus agalactiae* and/or *Staphylococcus aureus*, and the principles developed during that era continue to influence current treatments.[22] Spontaneous cure of *Str agalactiae* and *Sta aureus* is rare, and without effective antimicrobial therapy many cows develop chronic subclinical infections which may infect other animals. Widespread adoption of effective preventive management practices have essentially eradicated *Str. agalactiae* and greatly reduced the prevalence of mastitis caused by *Sta. aureus*,[22] and principles of treatment need to be aligned with the distribution of current pathogens. Treatment protocols should be designed to use antimicrobials responsibly, maintain well-being of cows, and limit economic losses. On most modern farms, the majority of clinical mastitis cases are non-severe and caused by opportunistic environmental pathogens, many of which are effectively cleared by the cow's immune response.[7,15,26] While prevalent etiologies may vary among farms, microbiological results of milk samples obtained from cases of clinical mastitis are usually distributed as no growth (25-30%), gram-negative (25-30%), gram-positive (25%), and 10-15% other non-responsive etiologies (such *as Staph aureus*, *Prototheca* spp, *Serratia* spp, yeasts, etc.). Most cases of clinical mastitis are treated using antibiotics[30] but many cases do not benefit and unnecessary use of antimicrobials is not cost effective. The purpose of this paper is to review the economic impact of antimicrobial usage for treatment of non-severe clinical mastitis with emphasis on drug selection and duration of treatment.

Antimicrobial Usage for Treatment of Clinical Mastitis

Recommendations for mastitis therapy should promote responsible antimicrobial usage, and veterinarians can refer to AABP guidelines for judicious antimicrobial usage

(www.AABP.org/Resources). Those guidelines include the following statements (italics added for emphasis):

"The veterinarian should select an antimicrobial drug, product and regimen that is likely to be effective *given strong clinical evidence of the identity of the pathogen causing disease* and based on clinical signs, history, necropsy examination, laboratory data and clinical experience."

"Regimens for antimicrobial use should be optimized using current pharmacological and microbiological information and principles. This includes *using antimicrobials at an appropriate dosage, for the shortest appropriate period,* and in the smallest number of animals reasonable."

"Whenever possible, label instructions should be followed to include using antimicrobials labeled for the condition diagnosed *following the labeled, dose, route, frequency, duration and withholding period.*"

There is considerable opportunity for veterinarians to help producers use antimicrobials more responsibly. Many mastitis treatments are given solely based on observation of clinical signs, and lack evidence of active bacterial infection. The duration of treatment often exceeds label recommendations, and broader-spectrum compounds are often used when narrower-spectrum drugs would be effective. In the US, dairy farmers have access to 7 intramammary (IMM) products that are approved for treatment of bovine mastitis and in most states, 5 require a veterinary prescription (Table 1). Approved IMM antibiotics have been tested to ensure that the parent compound (or active metabolite) reaches a sufficient concentration in milk during the approved dosing interval to kill or inhibit growth of organisms listed on the product label. Several approved IMM antibiotics are in classes that have been ranked by the World Health Organization based on their importance in treating human disease (Table 1).[1] Aminopenicillins and 3rd generation cephalosporins are considered to be critically important to human health and when efficacy is expected to be equivalent, veterinarians should recommend use of less critically important products.

In a nationally representative study,[30] all farmers reported occurrence of mastitis, with 25% of cows affected and 90% of farmers reported using antibiotics for treatment. Almost all treated cows (88%) received IMM antibiotics. Approved IMM products containing ceftiofur and cephapirin were most common and were used on 34% and 32% of farms, respectively.[30] While no antibiotics are approved for systemic treatment of mastitis, extralabel systemic usage of antibiotics for treatment of clinical mastitis was reported by 48% of farmers. While there is some evidence that systemic therapy is beneficial for cows experiencing severe clinical mastitis,[4,32] one researcher demonstrated that systemic therapy using ceftiofur did not improve outcomes of cows with non-severe mastitis,[33] and this route cannot be recommended for routine treatment of non-severe clinical mastitis.

We previously reported detailed treatment data for 589 cases of clinical mastitis occurring on 51 Wisconsin dairy farms.[16] In our study, 66% of cases received only IMM antibiotics, 1% received a single systemic antibiotic, 2% received 2 concurrent systemic antibiotics, 16% received both IMM & systemic antibiotics, 14% were given a second antibiotic treatment (due to perceived treatment failure), and 18% received non-antibiotic supportive therapies. Of enrolled cases, milk samples collected at case detection were later cultured from 558 cases (Figure 1). Of total IMM treatments, 32% were given to cases that were bacteriologically negative when detected and 19% were given to cases caused by *E. coli*. Researchers have shown that clinical outcomes of non-severe mastitis that are culture-negative or caused by *E. coli* are not improved by use of 5-d of IMM ceftiofur.[8,9] While severe cases may benefit from antimicrobial therapy, this data illustrates the importance of determining etiology of non-severe cases of mastitis before administering antibiot-

Table 1. All antibiotics approved for intramammary use in the US. All products are classified as beta-lactams except pirlimycin (lincosamide).

Product name active compound	Label dosing no. & interval	Label claims for efficacy	WHO classification[6]	Prescription status*
Amoxi-Mast™ 62.5 mg amoxicillin	3 tubes @ 12 h	*Str. agalactiae, Sta. aureus*	Critically important	Prescription
DariClox™ 200 mg cloxacillin	3 tubes @ 12 h	*Str. agalactiae, Sta. aureus*	Highly important	Prescription
Masti-Clear™ 100,000 IU PenicillinG	3 tubes @ 12 h	*Str. agalactiae, Str. Dysgalactiae, Str. uberis*	Highly important	OTC
Pirsue™ 50 mg pirlimycin	2-8 tubes @ 24 h	*Sta. aureus, Str. Dysgalactiae, Str. uberis*	Highly important	Prescription
Polymast™ 62.5 mg ampicillin	3 tubes @ 24 h	*Str. agalactiae, Str. Dysgalactiae, Sta. aureus, E. coli*	Critically important	Prescription
SpectramastLC™ 125 mg ceftiofur	2-8 tubes @ 24 h	*CNS, Str. dysgalactiae E. coli*	Critically important	Prescription
Today™ 200 mg cephapirin	2 tubes @ 12 h	*Str. agalactiae, Sta. aureus*	Highly important	OTC

*All antimicrobials require a prescription in California

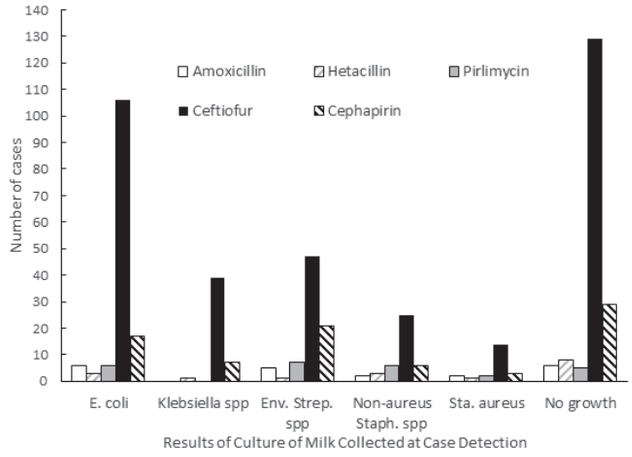

Figure 1. Treatments administered to 558 cases of clinical mastitis occurring on 51 Wisconsin dairy farms in 2010. Etiology was determined after treatment was completed using milk samples collected at detection of the case. From Oliveira and Ruegg, 2014.

ics, as almost 50% of IMM usage could have been eliminated if etiology had been known.

In 2017, as part of a broader study, we collected extensive animal health and treatment data on 40 large dairy farms in Wisconsin.[12] The overall incidence of clinical mastitis was 34% and the incidence and use of antimicrobials varied among farms (Figure 2). Of 26,007 cases of clinical mastitis, 31% received no IMM antimicrobial, 53% received commercial products containing IMM ceftiofur, 10% received IMM cephapirin, 3% each were treated with IMM hetacillin or pirlimycin, and about 1% received IMM amoxicillin. Systemic antibiotics were given to 14% of cases on 29 farms (11 farms did not report use of systemic treatments for mastitis). The wide variation in antimicrobial usage for treatment of mastitis is related to the lack of evidence-based guidelines for mastitis treatment and indicates an opportunity to improve therapy and reduce costs.

Selection and Evaluation of Antimicrobials for treating non-severe clinical mastitis

Clinical mastitis is detected based on observation of non-specific signs of inflammation and is usually treated empirically without knowledge of etiology.[11,16] Producers often evaluate efficacy based on time until milk returns to a normal appearance, but this outcome has almost no variation and is not a good indicator of longer-term outcomes.[21] There is very little evidence that drug selection has a significant impact on clinical outcomes. Of 7 recent studies evaluating IMM mastitis treatments, days to normal milk varied little among protocols (Table 2).[8,9,14,26,28,29,31] In 5 studies, cases were enrolled based on observation of inflammation without regard of pathogen and included cases that would not be expected to benefit from IMM therapy (no growth, *E. coli* and *Sta aureus* and other intrinsically resistant pathogens).[14,26,28,29,31]

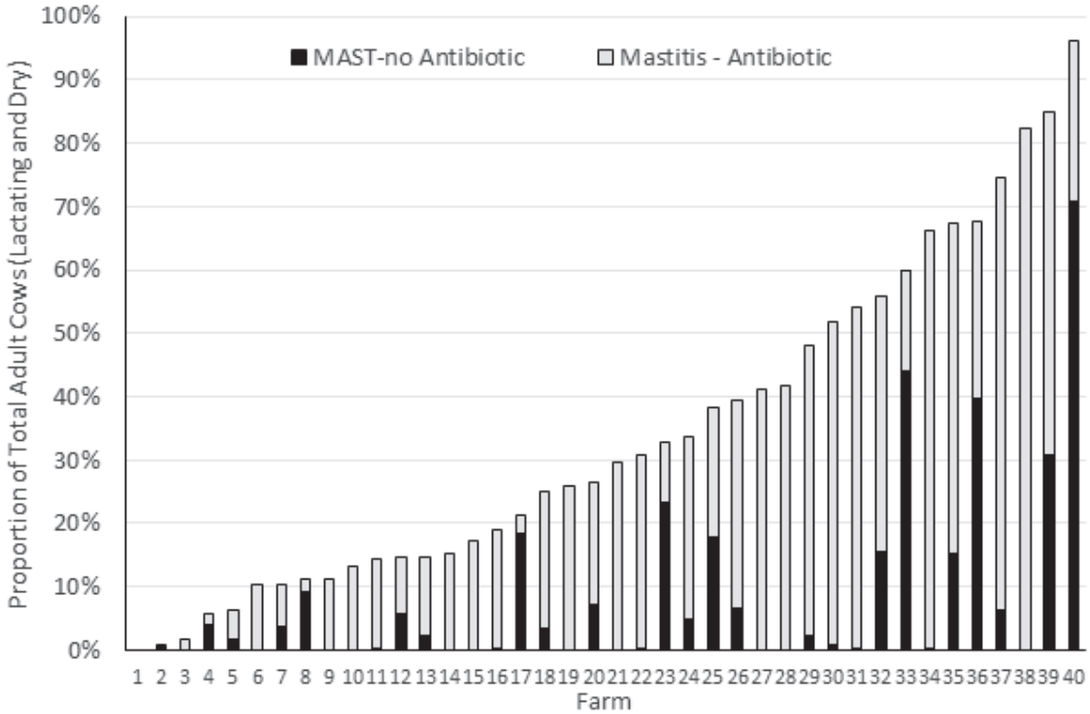

Figure 2. Use of antimicrobials to treat 26,007 cases of clinical mastitis occurring on 40 large Wisconsin dairy farms in 2017. The herds contained about 52,000 cows. From unpublished data, Leite de Campos and Ruegg.

Table 2. Clinical outcomes of recent studies evaluating treatment of non-severe clinical mastitis.

		Criteria to enroll	Comparison – all IMM treatments		Days to normal milk		Bacteriological cure		Other outcomes	
Study	Cases		Rx1	Rx2/Rx3	Rx1	Rx2	Rx1	Rx	Rx1	Rx2
Truchetti 2014	197	Clinical signs	2 @ 24 h Ceftiofur	8 @24 h Ceftiofur	2.8*	3.7**	32%[1*]	61%**	NIMI 13%	NIMI 8%
McDougall 2019[2]	304	Clinical signs	3 @ 12 h Combo[3]	5 @ 12 h Combo[3]	--	--	73%	72%	Recur21 28%[a]	Recur21 13%[b]
Tomazi 2018	236	Clinical signs	4 @ 12 h combo1[4]	4 @ 12 h combo2[5]	@4d 36%	@4d 36%	68%	73%	SCC 29%	SCC 28%
Schukken 2013	296	Clinical signs	2 @ 12 h cephapirin	5 @ 24 h ceftiofur	62%[6]	62%	61%	73%	Culling 21%	Culling 12%
Vasquez[7] 2016	596	Clinical signs	3 @ 24 h hetacillin	5 @ 24 h ceftiofur	@4d 70%	4@d 59%	68%	73%	Culling 7.8%	Culling 10.0%
Fuenzalida[8] 2019	121	No growth	No treat	5 @ 24 h ceftiofur	4.0	4.2	--	--	Recur 5%	Recur 8%
Fuenzalida[9] 2019	168	*E. coli* & *Klebsiella*	No treat	2 @ 24 h 5 @ 24 h ceftiofur	4.2	4.8 4.5	[10]67%*	84%** 89%**	Recur 32%	Recur 34% 32%

*signifies statistically significant differences; [1]calculated only for *Strep.* spp and *S. aureus*; [2]reported no difference in NIMI (15%; 14%), postRX SCC at 21(6.8,6.6) or 28 d (6.4,6.3); [3]Amoxicillin-clavulanic acid and prednisolone; [4]cephapirin and prednisolone; [5]tetracycline, neomycin, bacitracin and prednisolone; [6]determined at 10 and 17 days post-enrollment; [7]no difference in post-treatment milk yield (37, 38.2 kg) or SCC (3.4, 3.1); [8]no difference in IMI @ 14 or 28 d (25%, 13%); post-treatment culling (<5% both groups), ¼ SCC (5.4 and 5.5), or milk yield (43 kg for both groups); [10]signficant interaction with pathogen, BC was (no treatment – 97% for *E. coli,* 18% for *Klebsiella* spp; Combined IMM Rx – 99% for *E. coli,* 74% *Klebsiella* spp); [9]no difference in post-treatment probability of voluntary quarter dry-off, culling, quarter SCC, daily milk yield (37.1, 36.3, 37.6 kg)

Regardless of enrollment criteria, IMM antibiotic or duration of treatment, few important differences were noted in clinical outcomes (Table 2). Thus, choice of IMM product should be based on other characteristics, such as dosing schedule, price, and social responsibility.

Of approved IMM products, all except pirlimycin (lincosamide) are classified as beta-lactams and all are expected to have some efficacy against gram-positive pathogens (Table 1). Almost all approved IMM antibiotics are labeled for treatment of *Streptococci* and *Staphylococci,* and 2 include label claims for efficacy against *E. coli* (Table 1). No products have explicit label claims for treatment of mastitis caused by *Klebsiella* spp and this organism is considered intrinsically resistant to aminopenicillins (ampicillin, amoxicillin, and hetacillin). Little to no research exists to support efficacy claims of any IMM product for other organisms, and the lack of efficacy data makes it very difficult to justify use of antibiotics for treatment of mastitis caused by many opportunistic pathogens.

Except for mastitis caused by *Staph aureus*, there is little evidence that mastitis pathogens in North American dairy herds have acquired resistance to most commonly used IMM antimicrobials.[5,13,24,25] However, intrinsic resistance should be considered when selecting appropriate therapies. Use of sensitivity results to select antimicrobials is not cost effective nor predictive of clinical outcomes.[2,3,10] Knowledge of etiology is strongly associated with results of *in vitro* sensitivity tests and culture is a critical aspect for selection of appropriate antimicrobials (Table 3). Except for pirlimycin and cloxacillin, few streptococci demonstrate *in vitro* resistance to most IMM products, and very little *in vitro* resistance is demonstrated by gram-positive organisms for 1st or 3rd generation cephalosporins nor by *E. coli* for ceftiofur.

In general, selection of antimicrobials should be based on knowledge of the etiology and producers should be encouraged to culture milk samples to determine the need for use of IMM antibiotics. Infections caused by gram-positive organisms should be treated using a relatively narrow-spectrum IMM antimicrobial, while broad-spectrum products should be reserved for cases that will not respond to narrow-spectrum compounds. In immunologically healthy cows, the spontaneous cure rate is very high for non-severe mastitis caused by *E. coli* and most cases will not benefit from IMM antimicrobials.[8] However, when veterinarians prescribe antimicrobials for cases caused by gram-negative pathogens, they should use a broader-spectrum compound. When cases are treated empirically, without knowledge of etiology, a narrow-spectrum drug should be used for the shortest labeled duration, because only a small proportion of cases will benefit.

Costs of Clinical Mastitis Treatment

Producers typically underestimate costs of clinical mastitis and it was estimated that direct costs (without milk

Table 3. Prevalence of reported in-vitro resistance of antibiotics approved for IMM treatment of mastitis.

Pathogen	Study year	Ampicillin	Cloxacillin	Procaine Penicillin	Pirlimycin	Ceftiofur	Cephapirin
Staph aureus	2002[21]	50%	1%	50%	2%	--	<1%
	2003[20]	35%	2%	35%	5%	--	<1%
	2015[32]	23%	0%	20%	23%	0%	0%
Staph spp	2003[20]	30%	7%	33%	14%	--	<1%
	2015[32]	8%	2%	10%	25%	0%	0%
Strep spp	2002[21]	2%	42%	5%	20%	--	<1%
	2003[20]	2%	42%	5%	21%	--	3%
	2015[32]	3%	0%	8%	19%	0%	0%
E. coli	2002[21]	15%	NT[a]	NT	NT	5%	26%
	2003[20]	22%	99%	NT	NT	--	28%
	2018[33]	4%	100%	98%	100%	2%	13%
Klebsiella	2002[21]	16%	NT[c]	NT[c]	NT	14%	4%
	2003[20]	NT	99%	100%	NT	--	12%
	2018[33]	98%	100%	100%	100%	32%	32%

*not tested due to expected intrinsic resistance

discard) were about $43 per case, which were distributed as $14 (IMM antibiotics), $9 (systemic antibiotics), $5 (supportive drugs), $8 (farm labor), and $7 (veterinary services).[30] In our recent 40-herd study, the average cost (not including labor) of treating a case of mastitis was $147 (95% CI = $130-165) which was distributed as $15 for systemic antibiotics ($1-$29), $24 for IMM products ($21-$26), and $109 for milk discard ($100-$117) (Figure 3). Across all 40 herds, the distribution of direct expenses was 10% (ranging from 0 – 65%) for cost of systemic treatments, 74% (58-100%) for cost of milk discard, and 16% (0-22%) for cost of IMM products. The cost of clinical mastitis varied widely among farms, indicating that treatment decisions can have strong economic consequences (Figure 3).

In a previous study, we used decision tree analysis to model losses (negative expected monetary values, EMV) attributable to treatment of a first case of mastitis occurring in a single quarter of a cow that was 30 DIM.[20] Expected monetary values are calculated as the sum of the products of the probabilities of each outcome multiplied by the estimated cost of each outcome. We included costs of diagnosis, initial treatment, recurrence, labor, discarded milk, post-treatment milk loss due to clinical and subclinical mastitis, culling, and transmission of infection to other cows (only for CM caused by *S. aureus*). Overall, losses due to treatment of mastitis ranged from -$262 (high prevalence of coliforms) to -$363 (high prevalence of *Staph aureus*). Duration of antimicrobial treatment had a strong impact on overall costs because milk discard comprises the greatest proportion of overall economic losses.

Determining Duration of Treatment

Dutch researchers have demonstrated that farmers are insecure about appropriateness of mastitis treatments and will often extend antibiotic therapy simply based on meeting perceived social norms of being a "good farmer."[27] Mastitis is detected based on observation of abnormal milk, and it seems logical to evaluate treatments based on improved appearance of milk, but this outcome is misleading. With or without treatment, return to normal milk is expected to occur within 4 to 6 days because immunologically competent cows will often successfully reduce the number of bacteria infecting the gland, allowing inflammation to subside.[8,9,15,16,21] With the exception of pirlimycin and ceftiofur, the label for approved IMM treatments ranges from 1 to 3 days (Table 1). However, farmers typically extend therapy and regardless of product, average durations of treatment used by WI farmers ranged from 3.3 to 5.7 days (Table 4). These durations correspond with the expected duration of inflammation, suggesting that farmers are extending therapy based on appearance of abnormal milk. While some studies have indicated that extended treatment of mastitis caused by some gram-positive pathogens results in faster bacteriological clearance,[17,18,19] there is no evidence that extended therapy improves important clinical outcomes (Table 2). Costs of treatment are strongly associated with duration of milk discard, and the use of extended durations increased costs from $14 to $87 per case as compared to label usage (Table 4).

For routine treatment protocols, duration of IMM treatment should be as short as possible to reduce unnecessary

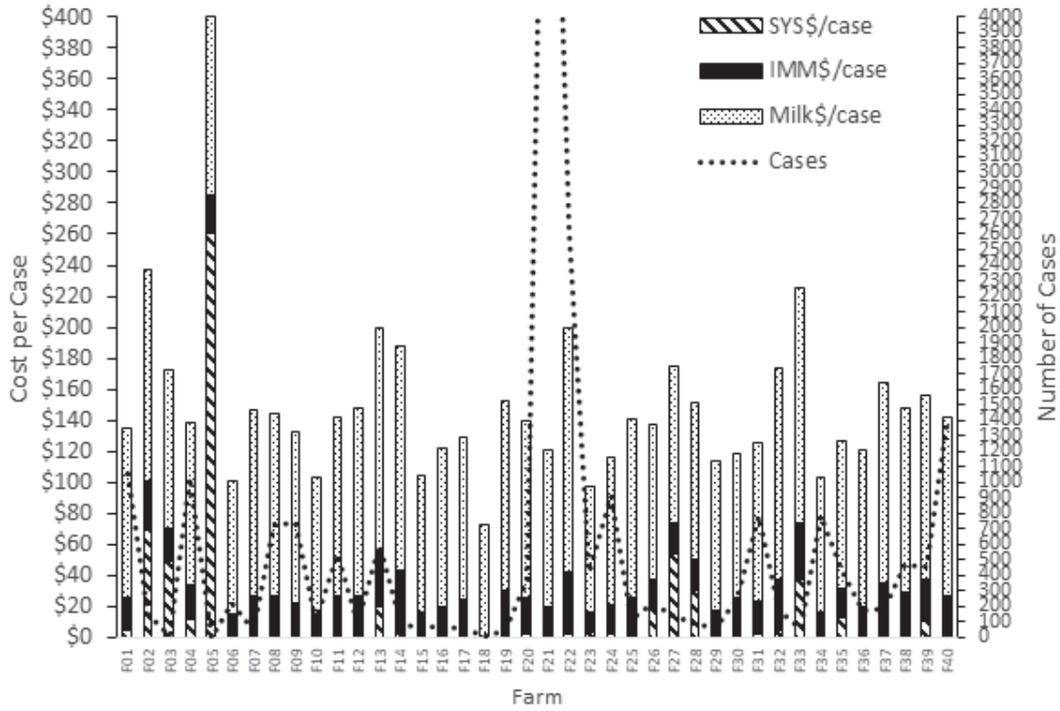

Figure 3. Cost of clinical mastitis treatment per case on 40 Wisconsin dairy farms in 2017. From unpublished data, Leite de Campos and Ruegg.

Table 4. Estimated cost of antimicrobial therapy and milk discard based on products used in 40 large Wisconsin dairy herds in 2017 (Leite de Campos and Ruegg, unpublished)

	Today™	Amoximast™	Polymast™	Pirsue™	SpectramastLC™
WI 2017 herds using (maximum = 40)	14	6	10	16	36
Tubes given per day	2	2	1	1	1
Cost per tube	$3.50	$3.08	$4.20	$5.00	$5.00
Milk discard after Rx (days)	4.0	2.5	3.0	1.5	3.0
Label duration of Rx (days)	1.0	1.5	3.0	2-8[a]	2-8[a]
Total milk discard when used on label (days)	5.0	4.0	6.0	6.5	8.0
WI 2017 herds duration of Rx (days)	3.3	5.7	3.9	4.8	5.7
Total milk discard as used by WI 2017 herds (days)	7.3	8.2	6.9	6.3	8.7
Cost of drug used on label	$7.00	$9.24	$12.60	$25.00	$25.00
Cost of drug WI 2017 herds	$23.10	$35.11	$16.38	$24.00	$28.50
Cost of discard – label use	$72.00	$57.60	$86.40	$93.60	$115.20
Cost of discard – WI 2017	$105.12	$118.08	$99.36	$118.60	$140.20
Total cost Rx label use	$79.00	$66.84	$99.00	$118.60	$140.20
Total cost Rx – WI 2017	$128.22	$153.19	$115.74	$114.72	$153.78
Difference in cost per case (Label vs WI 2017)	$49.22	$86.35	$16.74	-$3.88	$13.58
Annual projected herd difference in cost: label vs WI 2017 usage[c]	$11,075	$19,429	$3,767	----	$3,056

[a]5-day duration was used for economic calculations;
[c]$18/cwt milk, 80 lb per cow, 1000-cow herd with 30% IR; 75% cases treated 25% not treated

use of antimicrobials and minimize economic losses associated with milk discard.[20] Routine use of extended duration IMM treatment increases costs without improving economic outcomes.[20] An additional consideration is the ability of farm personnel to adequately perform IMM treatments without inducing new infections. When longer-duration therapy is recommended, veterinarians should assess the ability of farm workers to perform aseptic infusions, as extended intramammary treatment is associated with an increased risk of infection from opportunistic pathogens and herds

with poor infusion techniques are not good candidates for multiple doses of intramammary tubes.

Our decision tree analysis demonstrated that the optimal economic outcome occurred when mastitis caused by gram-positive pathogens was treated for 2 days and antimicrobials were not used when CM was caused by gram-negative pathogens or when no pathogen was recovered.[20] When mastitis is treated without knowing the etiology, duration of therapy had a considerable impact on differences in economic losses. In a herd with a typical distribution of etiologies (35% gram-positive, 30% gram-negative, 35% no growth) EMV were -$266 (no treatment and 2-d IMM), -$317 (5-d IMM) and -$371 (8-d IMM).

We also evaluated economic consequences of using on-farm culture (OFC) to guide therapy. When short-duration therapy (or no treatment) was primary treatment strategy, our model indicated that use of on-farm culture (OFC) did not reduce costs. In contrast, herds routinely using extended-duration therapy (without knowledge of etiology) could incur considerable savings by adopting OFC. For example, a 1000-cow dairy with a 40% incidence of CM and a typical distribution of pathogens would experience 400 first cases of mastitis per year. If standard treatment was 5 d of IMM antimicrobial, the EMV (loss) for each case in primiparous cows would be approximately $369, or $147,600 per year (for 400 cases). In contrast, the overall EMV for each case treated using a strategy of OFC would be $325, or $130,000 per year. In this instance, the use of OFC would result in approximately $18,000 in annual savings.

Conclusions

Mastitis is caused by a diverse group of bacterial pathogens with differing distributions among farms. Costs of treatment are strongly associated with duration of milk discard. Most cases of clinical mastitis are currently treated using IMM antibiotics, but many cases that are culture-negative at detection or caused by *E. coli* will not benefit from use of antimicrobials. To use antibiotics responsibly and minimize losses associated with treatment, veterinarians should encourage use of narrow-spectrum, short-duration IMM products when appropriate. Based on antibiotics that are approved for systemic use in US dairy cows, there is no evidence to support routine use of systemic antibiotics for treatment of non-severe clinical mastitis. Survey data demonstrate variation in mastitis treatments among farms, and there is considerable opportunity for veterinary involvement in reducing losses associated with treatment and encouraging improved antimicrobial stewardship.

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