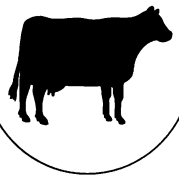

The effect of vaccines and antimicrobials on the formation of injection site lesions in subprimals of experimentally injected beef calves

Joyce Van Donkersgoed, Paula L. Dubeski, Jennifer L. Aalhus, Mary VanderKop, Sue Dixon, William N. Starr

Abstract — Two hundred and thirty-nine beef calves were used to determine the occurrence of injection site lesions at slaughter (16 to 17 mo of age) following the use of 3 different 8-way clostridial bacterins, a 4-way viral respiratory vaccine, various long-acting oxytetracycline preparations, florfenicol, ceftiofur, and trimethoprim-sulfa when injected in the top hip (top butt), thigh (round), or neck (blade) of calves at 2 to 3 or 5 to 7 mo of age. The occurrence of lesions varied by product, route of administration, and location of injection. The number of steaks affected with lesions, the trim weight of lesions, the histological class of lesions, and the economic losses from trim are described.

Résumé — L'effet des vaccins et des antimicrobiens sur la formation de lésions de site d'injection dans des coupes spécifiques de bouvillons injectés expérimentalement. Deux cent trente-neuf bouvillons furent utilisés afin de déterminer à l'abattoir (16 à 17 mois d'âge) l'incidence des lésions de site d'injection suite à l'utilisation de différents agents biologiques et chimiques tels que : bactérines de clostridium, vaccin respiratoire viral, diverses préparations d'oxytétracycline à longue action, florfénicol, ceftiofur et triméthoprime-sulfa. Ces veaux (2 à 3 ou 5 à 7 mois d'âge) ont été injectés au niveau de la hanche (haut de surlonge désossé), de la cuisse (ronde), ou le cou (haut de palette). L'incidence des lésions varient selon le produit utilisé, la voie d'administration, et le site d'injection. Le nombres de bifteks affectés par des lésions, la classification histologique des lésions, et les pertes économiques du parage (viande rejetée) sont décrits.

(Traduit par docteur Daniel Perron)

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Introduction

Three recent injection site surveys in fed cattle in Canada have found injection site lesions in 13% to 22% of top butts, 1% to 8% of rounds, and 22% to 23% of blades (1–3). Similar results have been found in surveys conducted in the United States (4–7). Injection site lesions cost the beef industry millions of dollars annually from losses in trim, devaluation of cuts, and consumer dissatisfaction from eating tough beef (1–7).

A few studies have been conducted in the United States and Europe to evaluate the effect of various animal health products on tissue reactivity in livestock (8–16). Clostridial bacterins, when administered IM to calves, have been shown to cause injection site lesions frequently, with the extent of injury appearing to depend on the volume of the dose (2 mL vs 5 mL), the calf's age at injection, and the anatomical location of the injection (8,10–12). Even when administered SC, some clostridial bacterins have been shown to cause damage to the underlying musculature (11,12). One long-acting oxytetracycline preparation has been tested in beef calves, and lesions were found in 51% to 100% of the animals when injected IM (8,10). The local tissue reactivity and the persistence of oxytetracycline in calves and pigs has been shown to vary with different formulations of the antibiotic (14–16) and by injection site (8–10).

As well, the type of antibiotic appears to affect the severity of injection site lesions. In one study (10), ceftiofur caused fewer lesions in the butt and round of calves at weaning than tylosin. In pigs, scar tissue

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Table 1. Description of animal health products administered to beef calves and the treatment sites

Calf age (mo)	Injection site	Animal health product	Number of calves injected	Route	Dose (mL)
150 spring-born calves					
2–3	right thigh	Blacklegol 8[a]	49	IM	5
		Covexin 8[b]	48	IM	4
		Ultrabac 8[c]	49	IM	5
	left thigh	saline[d]	146	IM	5
6–7	left neck	Blacklegol 8	25	IM	5
		Covexin 8	25	IM	4
		Ultrabac 8	24	IM	5
		Blacklegol 8	24	SC	5
		Covexin 8	24	SC	4
		Ultrabac 8	24	SC	5
	right neck	Bio-mycin 200[e]	73	IM	10
		Bio-mycin 200	73	SC	10
	right top hip	Bio-mycin 200	73	IM	10
		saline	73	IM	10
94 fall-born calves					
2–3	left top hip	Cattlemaster 4[f]	53	IM	2
	left neck	Cattlemaster 4	41	IM	2
6–7	left top hip	Cattlemaster 4	41	IM	2
	left neck	Cattlemaster 4	53	IM	2
5–6	right thigh	Nuflor[g]	32	IM	10
		Trivetrin[h]	31	IM	10
		Excenel[i]	31	IM	5.5
	left thigh	no product	94		
6–7	right top hip	Liquamycin LA-200[j]	32	IM	10
		Tetroxy-LA[k]	29	IM	10
		no product	33		
	right neck	Liquamycin LA-200	23	IM	10
		Tetroxy-LA	21	IM	10
		Micotil[l]	25	SC	10

[a]8-way clostridial bacterin (Bayer, Etobicoke, Ontario)
[b]8-way clostridial bacterin (Mallinckrodt Veterinary, Ajax, Ontario)
[c]8-way clostridial bacterin (Pfizer Canada, London, Ontario)
[d]Physiologic saline (MTC Pharmaceuticals, Cambridge, Ontario)
[e]Long-acting oxytetracycline (Boehringer Ingelheim Vetmedica, Burlington, Ontario)
[f]Chemically altered IBR and PI_3 viruses, modified-live BRSV, and killed BVD virus vaccine (Pfizer Canada)
[g]Florfenicol (Schering-Plough Animal Health, Pointe Claire, Quebec)
[h]Trimethoprim-sulphadoxine (Mallinckrodt Veterinary)
[i]Ceftiofur (Pharmacia & Upjohn Animal Health, Orangeville, Ontario)
[j]Long-acting oxytetracycline (Pfizer Canada)
[k]Long-acting oxytetracycline (Mallinckrodt Veterinary)
[l]Tilmicosin (Provel, Guelph, Ontario)

formation and muscular necrosis were found 6 d and 30 d after injection with sulfa drugs, including those with trimethoprim (13). Vitamin ADE products administered to calves at branding or at weaning have been shown to produce lesions in 5% to 65% of the calves at slaughter (8,10). Saline can also produce lesions in a small percentage of calves (10).

The impact of respiratory vaccines on muscle damage has been examined in a single study (10). Lesions in the top butt and outside round were more frequent in beef calves injected at weaning with the killed viral vaccine than in those injected with the modified-live virus vaccine.

This paper reports the results of a study to determine the occurrence of injection site lesions and the severity of carcass damage, as measured by the number of steaks with lesions, the trim loss, and the reduced tenderness of beef associated with injections of vaccines and antimicrobials that are commonly used in Canada. The shear test results from this study will be published elsewhere.

Materials and methods

Herd

This study was conducted at the Lacombe Research Centre by using 150 calves born in the spring of 1996 at 2 locations (Bowden — 55 calves, Lacombe Research Centre — 95 calves), and 94 calves born in the fall of 1996 at the same 2 locations (Bowden — 25 calves, Lacombe — 69 calves). The calves were between 2 and 3 mo of age when the initial trial injections were given. They were between 5 to 6 mo of age at preweaning and 6 to 7 mo of age at weaning, when the other trial injections were given. These injection times were chosen because they represent the times in the life of a calf when most vaccines and antimicrobials are administered.

At birth, all calves were identified with a unique ear-tag. Treatment records, including the anatomical location of injections, were kept on all calves from birth to slaughter. Herdsmen were instructed to avoid giving any treatments for disease in the subprimals to be

used in the study. The calves were housed on pasture with their dams until weaning, then fattened at the Lacombe Research Centre feedlot on a barley-based diet, until slaughter at 16 to 17 mo of age.

Treatment protocol

The treatment protocols for the spring 1996 and fall 1996 calves are shown in Table 1. The working group for the study, which consisted of producers, veterinarians, and research scientists chose the products and protocols based on common treatment regimes used by producers (1–3).

Calves were randomized into treatment groups on a systematic basis as they passed through the chute. Each calf born in the spring of 1996 and each calf born in the fall of 1996 received an injection in each of the treatment sites as indicated in Table 1. New, sterile needles (16-gauge × 3/4″ needle for SC; 16-gauge × 1″ needle for IM) were used for each injection. The tented method was used to administer animal health products SC, and IM injections were given perpendicular to the skin. The animal hides were not prepared by clipping and regional disinfection with alcohol before injection, because this treatment practice is not representative of normal techniques used by producers or practitioners. Obvious areas of manure on the animal's surface were avoided when giving injections to prevent abscess development from contamination. Calves were well restrained prior to injections, by hand when very young or in a chute when older. Injections were given in the top hip (top butt), the thigh (round), and the neck (blade) in the triangular area in front of the shoulder. Doses were based on manufacturer's recommendations for the average body weight of the group of calves, similar to producers' and veterinarians' practices. The maximum volume of an animal health product administered in any one site was 10 mL, based on manufacturer's and beef quality assurance recommendations. Only one product was administered per site. All products were administered by the same person to reduce variability in injection site technique.

Processing

Calves were slaughtered at the Lacombe Research Centre by using simulated commercial procedures. The spring 1996 calves were processed from June 17 to August 21, 1997, and the fall 1996 calves were processed from February 10 to April 16, 1998. Slaughter dates were based on back fat thickness and live weight, as well as the availability and slaughter capacity of the research abattoir. One hundred and forty-six spring 1996 calves and 93 fall 1996 calves were processed. Four of the spring 1996 calves died, and one of the fall 1996 calves was culled because of poor growth. An outbreak of scours occurred in the calves from Bowden. Some of these calves received therapeutic injections in sites reserved for experimental treatments; thus, subprimals from these sites were deleted from the study.

Subprimals were obtained from chilled carcasses 6 d after slaughter. Prior to harvesting, whole carcasses were examined for SC lesions. Top butts, rounds, and blades were cut manually by the processing staff into 3/4 in. (1.9 cm) steaks from the blade and top butt, and into 1 in. (2.5 cm) steaks from the round, in order to detect lesions. The rounds were cut into 1 in. (2.5 cm) rather than 3/4 in. (1.9 cm) steaks, because this additional thickness was needed for the shearing tests in the rounds (shearing test results to be published elsewhere).

Injection site lesions were identified by trained personnel (1–3); the number of steaks affected were counted, the total trim was weighed, and then samples were placed in formalin. Subsequently, the samples were examined microscopically to classify lesions according to the Colorado system (6,15) and as previously described (1–3). To reduce bias and diagnostic variability, samples for microscopy were not identified by treatment and were evaluated by the same pathologist (1–3).

Statistical analysis

All data were entered into a database (Reflex 2.0, Borland International, Scotts Valley, California, USA) and analyzed by an analytical software package (STATISTIX for Windows, Analytical Software, Tallahassee, Florida, USA). The proportion of injection site lesions, the median number of steaks with lesions, the median weight of trim, and the type of histological lesions were calculated by experimental treatment.

For the economic estimate of dollars lost from trim and devaluation of subprimals, calculations similar to those in previous injection site surveys (1–3) were made by using the average International Surveys Limited retail prices for September 1997, the proportion of injection site lesions, the median number of steaks affected, and the median trim weight. For example, when Blacklegol (Tables 2 and 3) was injected into the round of calves at 2 to 3 mo of age, lesions occurred in 82% of the calves, 4 steaks were damaged (median over all animals within the treatment group), and 228 grams of meat were trimmed (median over all animals within the treatment group). According to processors, the average round produces 16 one-inch steaks, each with a weight of approximately 0.67 kg, and the retail price of rounds for September 1997 was $6.42/kg. Four steaks were damaged; therefore, 4 × 0.67 kg = 2.68 kg were damaged. We assumed that 20% of the purveyors did not salvage anything, and the estimated loss was 2.68 kg × $6.42/kg = $17.21. We assumed that 80% of the purveyors cut out the lesion and discarded it (median weight of trim) and salvaged the rest as ground beef. The price of ground beef was $3.02/kg. The average cost of the salvage operation was $0.84 [2 min at $0.42/min (wage $25/h)]. Therefore, they recovered 2.68 kg–0.228 kg (trim) = 2.45 kg. This was sold at 2.45 kg × $3.02/kg = $7.41. The calculated net recovery was $7.41–$0.84 (labor) = $6.57; therefore, $17.21–$6.57 (salvaged) = $10.64 was lost. The loss from injection site lesions was estimated to be [82% lesioned rounds (proportion of lesions) × 20% discarded × $17.21] + [82% lesioned rounds × 80% salvaged × $10.64] = $9.80 average loss per injected subprimal.

Results

At slaughter, the spring 1996 calves had an average live weight of 495 kg (s = 61), a hot carcass weight of 296 kg (s = 39), a yield of 57% (s = 3%), a grade fat of

Table 2. Injection site lesions in beef calves administered vaccines and antimicrobials at various ages

Calf age (mo)	Product	Route	Volume (mL)	Injected subprimal	Number of subprimals	Lesions %	$ trim loss per injected subprimal[a]
Spring 1996							
2–3	Blacklegol 8[b]	IM	5	round	39	82	9.80
2–3	Covexin 8[c]	IM	4	round	32	78	9.32
2–3	Ultrabac 8[d]	IM	5	round	33	100	14.87
2–3	saline[e]	IM	5	round	139	2	0.85
6–7	Blacklegol 8	IM	5	blade	16	25	0.64
6–7	Covexin 8	IM	4	blade	16	25	0.63
6–7	Ultrabac 8	IM	5	blade	16	69	2.33
6–7	Blacklegol 8	SC	5	blade	9	0	0
6–7	Covexin 8	SC	4	blade	16	12	0.20
6–7	Ultrabac 8	SC	5	blade	16	50	1.23
6–7	Bio-mycin 200[f]	IM	10	blade	31	6	0.15
6–7	Bio-mycin 200	SC	10	blade	39	2	0.05
6–7	Bio-mycin 200	IM	10	top butt	70	19	1.06
6–7	saline	IM	10	top butt	69	3	0.17
Fall 1996							
2–3	Cattlemaster 4[g]	IM	2	top butt	53	11	0.59
2–3	Cattlemaster 4	IM	2	blade	39	8	0.12
6–7	Cattlemaster 4	IM	2	top butt	39	21	1.14
6–7	Cattlemaster 4	IM	2	blade	53	13	0.31
5–6	Nuflor[h]	IM	10	round	32	69	6.44
5–6	Trivetrin[i]	IM	10	round	30	77	9.30
5–6	Excenel[j]	IM	5.5	round	31	16	1.02
6–7	Liquamycin LA-200[k]	IM	10	top butt	32	41	2.27
6–7	Tetroxy-LA[l]	IM	10	top butt	29	42	2.34
6–7	no product			top butt	32	9	0.50
6–7	Liquamycin LA-200	IM	10	blade	23	13	0.30
6–7	Tetroxy-LA	IM	10	blade	21	5	0.12
6–7	Micotil[m]	SC	10	blade	24	0	0

[a]Average $ loss from trim and devaluation of product across all injected subprimals
[b]8-way clostridial bacterin (Bayer)
[c]8-way clostridial bacterin (Mallinckrodt Veterinary)
[d]8-way clostridial bacterin (Pfizer Canada)
[e]Physiologic saline (MTC Pharmaceuticals)
[f]Long-acting oxytetracycline (Boehringer Ingelheim Vetmedica)
[g]Chemically altered IBR and PI_3 viruses, modified-live BRSV, and killed BVD virus vaccine (Pfizer Canada)
[h]Florfenicol (Schering-Plough Animal Health)
[i]Trimethoprim-sulphadoxine (Mallinckrodt Veterinary)
[j]Ceftiofur (Pharmacia & Upjohn Animal Health)
[k]Long-acting oxytetracycline (Pfizer Canada)
[l]Long-acting oxytetracycline (Mallinckrodt Veterinary)
[m]Tilmicosin (Provel)

11 mm (s = 3), and a median marbling score equivalent to a Canada AAA. For the fall 1996 calves, the average live weight was 541 kg (s = 52), the carcass weight was 335 kg (s = 32), the yield was 61% (s = 2%), the grade fat was 7 mm (s = 2), and the median marbling score was equivalent to a Canada AA.

The occurrence of IM and SC lesions found in the experimental population is shown in Table 2 and described below. Lesions in the top butt were usually observed in the cap (biceps femoris muscle), whereas, in the round, the lesions were usually observed in the inside round (semimembranosus muscle).

Although the majority of lesions caused by IM administration of clostridial bacterins were found in the muscle (Table 2), some of these clostridial bacterins injected IM or SC in the neck caused lesions in the subcutaneous tissue. Blacklegol 8 (Bayer, Etobicoke, Ontario) given IM caused 2 (12%) SC lesions; when administered SC, 4 (44%) lesions were observed in the subcutaneous fat. In contrast, when Covexin 8 (Mallinckrodt, Ajax, Ontario) was administered IM, it caused one (6%) SC lesion, and when given SC, it did not cause any SC lesions. Ultrabac 8 (SmithKline Beecham, London, Ontario) caused one (6%) combined IM and SC lesion when given IM and 7 (44%) SC lesions when given SC in the neck, 4 of which were associated with IM lesions. Two (6%) SC lesions were observed when Bio-mycin 200 was administered IM in the neck. When Liquamycin LA-200 (rogar/STB, London, Ontario) was administered IM in the neck, one (4%) combined IM and SC lesion was observed. Cattlemaster 4 (SmithKline Beecham) caused one (3%) combined lesion IM and SC, when administered IM in the neck at 2 to 3 mo of age.

The histological class of lesions by treatment is shown in Table 3, along with the median number of steaks with lesions, and the median weight of trim. Most products caused a variety of microscopic lesions. "Woody calluses" were the most common class of lesion; whereas, "mineralized scars" were observed in only a few subprimals injected with Trivetrin. Lesions previously classed as "normal fat" (1–3) were now called "fatty infiltration." These were discrete, often large, areas within muscle where muscle was replaced primarily by fat.

Economic losses from trim ranged from $0 to $14.87 per injected subprimal (Table 2). The dollar losses

Table 3. The histological class of lesion, the number of steaks damaged, and the trim weight of injection site lesions in beef calves administered vaccines and antimicrobials at various ages

Calf age (mo)	Product	Route	Injected subprimal	Woody callus %	Clear scar %	Mineralized scar %	Scar with nodules %	Fatty infiltration %	median *n* steaks affected (range)	median trim weight in grams (range)
2–3	Blacklegol 8[a]	IM	round	64	14	0	0	23	4 (2–7)	228 (53–861)
2–3	Covexin 8[b]	IM	round	78	7	0	7	7	4 (2–6)	225 (109–496)
2–3	Ultrabac 8[c]	IM	round	18	0	0	82	0	5 (3–8)	325 (107–407)
2–3	saline[d]	IM	round	100	0	0	0	0	4 (3–4)	117 (95–139)
6–7	Blacklegol 8	IM	blade	75	0	0	0	25	2 (1–2)	110 (44–231)
6–7	Covexin 8	IM	blade	75	0	0	25	0	2 (2–3)	102 (42–118)
6–7	Ultrabac 8	IM	blade	27	0	0	73	0	3 (1–4)	123 (39–270)
6–7	Blacklegol 8	SC	blade	0	0	0	0	0	0 (0–0)	0 (0–0)
6–7	Covexin 8	SC	blade	100	0	0	0	0	1 (1–2)	64 (34–95)
6–7	Ultrabac 8	SC	blade	12	0	0	75	12	2 (1–4)	70 (36–122)
6–7	Bio-mycin 200[e]	IM	blade	100	0	0	0	0	2 (1–3)	70 (57–123)
6–7	Bio-mycin 200	SC	blade	0	0	0	0	100	2 (2–2)	23 (23–23)
6–7	Bio-mycin 200	IM	top butt	58	33	0	0	8	2 (1–3)	86 (26–214)
6–7	saline	IM	top butt	50	50	0	0	0	2 (2–2)	69 (56–82)
2–3	Cattlemaster 4[f]	IM	top butt	50	17	0	33	0	2 (1–3)	42 (38–136)
2–3	Cattlemaster 4	IM	blade	100	0	0	0	0	1 (1–2)	33 (22–62)
6–7	Cattlemaster 4	IM	top butt	25	0	0	75	0	2 (1–3)	54 (31–103)
6–7	Cattlemaster 4	IM	blade	43	0	0	43	14	2 (1–4)	34 (10–97)
5–6	Nuflor[g]	IM	round	62	38	0	0	0	3 (2–6)	259 (22–321)
5–6	Trivetrin[h]	IM	round	38	54	8	0	0	4 (2–11)	279 (72–456)
5–6	Excenel[i]	IM	round	33	67	0	0	0	2 (2–3)	114 (38–131)
6–7	Liquamycin LA-200[j]	IM	top butt	54	38	0	8	0	2 (1–4)	74 (15–176)
6–7	Tetroxy-LA[k]	IM	top butt	58	42	0	0	0	2 (1–4)	66 (13–188)
6–7	no product		top butt	100	0	0	0	0	2 (0–2)	71 (61–125)
6–7	Liquamycin LA-200	IM	blade	100	0	0	0	0	2 (1–2)	23 (23–35)
6–7	Tetroxy-LA	IM	blade	100	0	0	0	0	2 (2–2)	24 (24–24)
6–7	Micotil[l]	SC	blade	0	0	0	0	0	0 (0–0)	0 (0–0)

[a]8-way clostridial bacterin (Bayer)
[b]8-way clostridial bacterin (Mallinckrodt Veterinary)
[c]8-way clostridial bacterin (Pfizer Canada)
[d]Physiologic saline (MTC Pharmaceuticals, Cambridge, Ontario)
[e]Long-acting oxytetracycline (Boehringer Ingelheim Vetmedica)
[f]Chemically altered IBR and PI_3 viruses, modified-live BRSV, and killed BVD virus vaccine (Pfizer Canada)
[g]Florfenicol (Schering-Plough Animal Health)
[h]Trimethoprim sulphadoxine (Mallinckrodt Veterinary)
[i]Ceftiofur (Pharmacia & Upjohn Animal Health)
[j]Long-acting oxytetracycline (Pfizer Canada)
[k]Long-acting oxytetracycline (Mallinckrodt Veterinary)
[l]Tilmicosin (Provel)

depended on the retail price of the subprimal when cut into steaks, the proportion of lesions, the median number of steaks affected with lesions, and the median weight of trim.

Discussion

Vaccines and antimicrobials that were injected into calves at 2 to 3 or 5 to 7 mo of age caused scars that persisted until slaughter. Clostridial bacterins that are given IM to calves at spring branding or at weaning have been reported to cause injection site lesions frequently (8,10–12), and the results of the present study confirm that finding. More frequent and severe lesions have been found in calves immunized at spring branding than at weaning (8), suggesting growth of the lesions with age. This explanation appears contrary to the theory proposed by McFarlane et al (12) that lesions are due partly from repeated exposure to the bacterin. Larger lesions would be expected at weaning than at spring branding, because of booster vaccinations at weaning. In the current study, the proportion of lesions, the median number of steaks damaged, and the median weight of trim appeared to be higher in calves immunized at 2 to 3 mo of age than at 6 to 7 mo of age. The association between age and severity of lesions in the present study and the study by George et al (8) were completely confounded by the site of injection, because different subprimals were injected with clostridial bacterins at different ages. The occurrence and severity of lesions may vary with location of injection (9,10). Glock et al (9) suggested that lesions are less severe in the blade than in the butt or round because the products are introduced intermuscularly (between muscles) in the neck due to the presence of numerous fascial planes. The intermuscular location and the excellent lymphatic supply in the neck may result in accelerated absorption of products and rapid healing (9).

Clostridial bacterins have been reported to cause damage to the underlying musculature when administered SC (12), similar to what was observed in the present study with Ultrabac 8 (Table 2). This damage may have been due to the inflammatory response to the product or to improper vaccination technique. Although the tented method was used to give SC injections, some of the dose may have been injected into the muscle. The

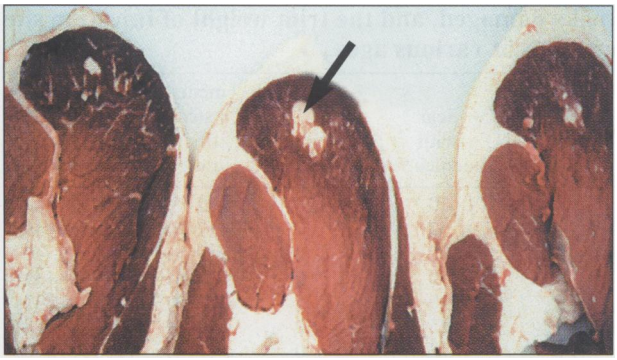

Figure 1. A visible injection site lesion in the inside round following administration of an 8-way clostridial bacterin.

histological class of lesion caused by clostridial bacterins varied slightly amongst products. "Woody calluses" were the predominant lesion observed with Blacklegol 8 and Covexin 8 (Table 3); whereas, "scars with nodules" were more commonly observed with Ultrabac 8 (Table 3). George et al (4) said that clostridial bacterins give a distinct subtype of "woody callus," with mature adipose cells and a few trapped muscle fibers and bands of dense connective tissue. However, the present study indicates that the lesions produced by clostridial bacterins are not distinctive microscopically. George et al (4) and Dextor et al (5) have also suggested that "clear scars" and "woody calluses" represent lesions originating in the cow/calf or stocker (backgrounding) phase and "scars with nodules" occur in mid- to late feedlot stages. In the current study, all 3 classes of lesions were observed in calves injected at either 2 to 3 or 5 to 7 mo of age.

The high occurrence of lesions associated with IM injections of clostridial bacterins in the present study supports past research (8–12) and current beef quality recommendations in Canada and the United States to give clostridial bacterins SC in the neck (Canadian Cattlemen's Association and National Beef Cattlemen's Association, personal communication). In the United States, labels have already been changed, so that clostridial bacterins may only be administered SC. It is hoped that, in the near future, clostridial bacterin labels in Canada will be similarly changed in order to reduce carcass damage. The development of low dose, multivalent clostridial bacterins should also help to reduce the risk of injection site lesions (Figure 1).

Long-acting oxytetracyclines have their prolonged activity because of their high dosage and tissue irritation, which appears to vary among different products, due, in part, to the different carriers (14–16). The most extensive research on tissue reactivity in beef calves has been conducted on Liquamycin LA-200, which is a long-acting oxytetracycline in a carrier of 2-pyrrolidone. In 2 independent studies (8,10), Liquamycin LA-200 caused 51% lesions in the inside round when injected at spring branding, and 92% to 100% lesions in the butt and outside round when injected at weaning. In a drug company sponsored study (9), the prevalence of scars from Liquamycin LA-200 was influenced by the length of time between injection and slaughter. At 120 d from injection to slaughter, light scars were observed in 35% of the necks, 85% of the rounds, and 90% of the butts (9). In other studies (8–10), the occurrence of lesions was lower. The reason is unknown, because the product, the 10-mL dose, the injection site locations, the age at slaughter, and size of steak cuts were similar. The slightly lower occurrence of lesions in the blade than those in the butt reported in the current study was similar to the findings of Glock et al (9). Lesions caused by Liquamycin LA-200 in the present study were predominantly "woody calluses" and "clear scars," similar to previous reports (8,10). However, Glock et al (9) originally reported that Liquamycin LA-200 caused lesions consisting mainly of adipose tissue, concluding that the quality of the meat was minimally affected, which was not confirmed by this and other studies (8,10).

The occurrence of lesions, the histological class of lesions, the median number of steaks affected, and the median trim weight were similar among Liquamycin LA-200, Tetroxy-LA (Mallinckrodt), and Bio-mycin 200 (Boehringer) in the present study, even though the 3 long-acting oxytetracyclines are reported by manufacturers to be in different carriers. Tissue reactivity has been shown to vary, in part, from differences in the formulation of the oxytetracycline products (14–16). Similar to Liquamycin LA-200 and Tetroxy-LA, Biomycin 200 appeared to produce fewer lesions in the blade than in the butt. Only one lesion was observed in the calves injected SC with Bio-mycin 200 in the neck, and it was classed as "fatty infiltration." The findings from the present study and previous reports (8–10,14–16) suggest that long-acting oxytetracyclines should be administered in the neck and not in the rump. Manufacturers' label recommendations indicate that no more than 10 mL should be injected per site. When the product has a label claim for SC and IM use, then we recommend that the product be injected SC rather than IM, to reduce the risk of muscle damage.

Four other antibiotics were assessed. Micotil injected SC in the neck caused no lesions, making it an excellent product from a beef quality perspective. Nuflor (Schering-Plough Animal Health, Pointe-Claire, Quebec), Trivetrin (Mallinckrodt), and Excenel (Pharmacia & Upjohn Animal Health, Orangeville, Ontario) did cause injection site lesions. The occurrence of injection site lesions was higher in rounds injected with Nuflor and Trivetrin than in those injected with Excenel. The occurrence of lesions, median number of steaks affected, median trim weight, and economic losses following injections with Nuflor and Trivetrin have not been reported previously in cattle. In swine, Trivetrin has been shown to cause necrosis of muscle and subcutaneous tissue shortly after injection (13). Glycerol formol, the vehicle in Trivetrin, may contribute to the tissue damage. Species differences in tissue reactions with injectables have been reported (14); therefore, we recommend that the results from one species should not be extrapolated to another. In a previous study (10), Naxcel, which is the US counterpart to Excenel, caused 7% lesions in the butt and outside round when injected at weaning, which was similar to the level observed in the current study. Nuflor, Trivetrin, and Excenel produced mainly "woody calluses" and "clear scars," and they damaged a few steaks and caused large amounts of trim. Economic

losses from trim were high. Trivetrin can be injected IV, and this may be one solution to reduce tissue damage. Manufacturer's label directions suggest that Nuflor should be injected in the neck. Although neck and rump locations were not assessed in this study, we recommend that Excenel be administered in the neck rather than in the rump, because of the differences in the cost per kg of retail cuts from these differing anatomical sites.

The final product evaluated in the present study was a chemically altered and modified-live combination vaccine called Cattlemaster 4 (Table 2). The vaccine caused lesions in 8% to 21% of the calves when injected at 6 to 7 or 2 to 3 mo of age in the neck and top hip. In a previous study (10), a killed virus vaccine caused 62% to 75% lesions when injected in the round and top butt at weaning, whereas, the modified-live virus vaccine caused lesions in 7% and 15% of the subprimals. Killed vaccines and a few modified-live virus vaccines contain an adjuvant, and some of the adjuvants are oil-based. Differences in adjuvants may contribute to the variability observed in lesions between killed and modified-live virus vaccines (12).

There did not appear to be any clear differences in the histological class of lesions produced by products, injection locations, and ages at the time of administration. Thus, it is difficult to identify the sources of lesions observed in injection site surveys (1–3), and thus be in a position to help direct beef quality assurance extension and education efforts. Calves injected with Ultrabac 8 and Cattlemaster 4 appeared to have a high occurrence of "scars with nodules." This lesion is very distinctive in that it is highly active with granulomatous inflammation, suggesting a persistent antigenic stimulus or a more recent exposure to the antigen. It is interesting to note that this class of lesion was rarely seen with the antimicrobials tested in the present study, indicating that "scars with nodules" may be due to the type of adjuvant used in the vaccine. The class of lesion called "fatty infiltration" was observed in calves injected with clostridial bacterins, Cattlemaster 4, and Bio-mycin 200. "Fatty infiltration" may represent fat that was present in the muscle prior to injection (normal IM deposit) or it may be a response to tissue damage. However, in many cases, these lesions were large and did not appear to be "normal" IM fat. In cases where the "fatty infiltration" lesions were relatively small and more likely to be "normal IM fat," the occurrence of injection site lesions in the present study may be overinflated. In this study, if the lesions were small, they may have been missed by visual observation. Three woody calluses were observed in the top butt of muscles that were not injected with any products (Tables 1–3), suggesting an error in treating calves or in recording treatments. Alternatively, the lesions could have developed from some other type of muscle injury, such as blunt trauma, although they were deep in the muscle, so this is not as likely. Estimated economic losses from trim and devaluation of product varied from $0 to $14.87 per injected subprimal. The losses did not take into account reduced beef sales from consumer eating dissatisfaction due to tough beef from injection site lesions (4,6,7,10). These losses are very hard to estimate, but the findings to date help to explain why the beef industry is demanding pharmaceutical and biological products that can be administered by routes other than IM.

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