The effect of animal health products on the formation of injection site lesions in subprimals of experimentally injected beef calves

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Abstract — Two hundred and twenty beef calves were used in an experimental study to determine the occurrence of injection site lesions at slaughter (15 to 18 months of age) following subcutaneous and intramuscular injection of various products into the top hip (top butt), thigh (round), and neck or rib of calves at birth, branding, or weaning. Products tested were: 2 different preparations of selenium; a 2-way, a 7-way, and an 8-way clostridial bacterin; 2 combination 7-way clostridial and *Haemophilus somnus* bacterins; 2 *H. somnus* bacterins; 2 different 4-way modified-live viral respiratory vaccines; a 4-way killed viral and *H. somnus* vaccine; and penicillin, florfenicol, ceftiofur, trimethoprim-sulfa, and tilmicosin. The occurrence of lesions, number of steaks affected with lesions, the trim weight of lesions, the histological class of lesions, and the estimated economic losses are described. Generally, products administered subcutaneously in the neck produced minimal tissue damage and economic losses.

Résumé — L'effet de diverse substances médicatrices sur la formation de lésions de sites traditionnels d'injection de bouvillons injectés expérimentalement. Une étude expérimentale sur 220 bouvillons présentés à l'abattoir (âgés de 15 à 18 mois) a eu lieu afin de déterminer l'incidence de lésions de sites d'injection suivant la voie utilisée (intramusculaire ou sous-cutanée) de diverses substances au niveau de la croupe, de la cuisse, du cou ou des côtes de veaux à la naissance, au marquage ou au sevrage. Ces substances testées furent : 2 préparations différentes de sélénium; bactérine clostridiale; 2 combinaisons de bactérines clostridiales/*Haemophilus somnus;* 2 bactérines d'*H. somnus;* et pénicilline, florfénicol, ceftiofur, triméthoprime-sulfa, et tilmicosin. L'incidence de telles lésions, le nombre de pièces de viande affectées avec ces lésions, le poids des trimures des lésions, la classification histologique des lésions et les pertes économiques estimées sont décrites. En général, les substances médicatrices administrées par voie sous-cutanée dans le cou ont produit un dommage tissulaire et des pertes économiques minimes.

(Traduit par docteur Daniel Perron)

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Introduction

A few studies have been conducted in Canada, the United States, and Europe to evaluate the effect of various animal health products on muscle damage in cattle (1–5). Vaccines, antimicrobials, and vitamins injected into the muscle have been shown to cause injection site lesions and create tough beef, with the extent of damage depending on the calf's age at injection, the volume of the product injected per site, the anatomical site of the injection, the route of injection, and the product.

In response to these quality concerns, pharmaceutical companies have been licensing existing products for SC use and developing new products that do not have to be administered by IM injection. Even when injected SC, some clostridial bacterins have been shown to create damage to the underlying musculature (1,5). Despite some of these changes and extension efforts by industry to educate producers and veterinarians on proper injection techniques, injection site lesions in cattle continue to be a significant beef quality concern (6–7).

Current beef quality assurance guidelines (1,6,7) recommend that the parenteral animal health products to be used should be "tissue friendly" and low volume; they should be injected in the neck only and never in the top hip or thigh, and they should be administered SC when label directions permit. To determine if these recommendations could be verified and generalized across different animal health products, various commonly used selenium products, bacterins, killed and modified-live viral vaccines, and short- and long-acting

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Table 1. Intramuscular injection site lesions in beef calves administered animal health products at various ages

Calf age (mo)	*n* calves injected	Product	Route	Volume (mL)	Injected subprimal	*n* Subprimals	IM lesions % (n)	Trim loss per injected subprimal[a] ($)
128 spring-born calves								
birth	63	Dystosel[b]	IM	1	top butt	51	4 (2)	0.30
birth	61	Selon-E[c]	IM	1	top butt	46	0 (0)	0
2–3	59	Vision 7[d]	SC	2	neck	49	0 (0)	0
2–3	27	Somnugen[e]	IM	2	neck	20	5 (1)	0.07
2–3	29	Somnugen	IM	2	top butt	26	15 (4)	0.71
2–3	24	Somubac[f]	IM	2	neck	19	5 (1)	0.12
2–3	31	Somubac	IM	2	top butt	24	29 (7)	1.42
5–6	19	Fermicon 7-Somnugen[g]	IM	5	neck	16	19 (3)	0.43
5–6	18	Fermicon 7-Somnugen	SC	5	neck	13	8 (1)	0.37
5–6	17	Ultrabac 7/Somubac[h]	IM	5	neck	15	80 (12)	1.91
5–6	17	Ultrabac 7/Somubac	SC	5	neck	13	0 (0)	0
5–6	63	Bovishield 4[i]	IM	2	round	52	48 (25)	3.85
5–6	62	Pyramid MLV 4[j]	IM	2	round	52	6 (3)	0.48
157 fall-born calves								
2–3	75	Tasvax 2[k]	SC	2	neck	58	2 (1)	0.14
2–3	75	Triangle 4 + HS[l]	IM	5	neck	58	22 (13)	1.70
2–3	75	Triangle 4 + HS	IM	5	top butt	58	67 (39)	5.00
2–3	76	Ethacilin[m]	IM	3	top butt	58	2 (1)	0.15
5–6	152	Triangle 4 + HS	IM	5	top butt	116	89 (103)	6.75
5–6	51	Trivetrin[n]	IM	10	round	41	98 (40)	14.53
5–6	50	Nuflor[o]	IM	10	round	40	92 (37)	13.45
5–6	51	Excenel[p]	IM	5	round	35	3 (1)	0.44
6–7	76	Fortress 8[q]	SC	5	neck	58	5 (3)	0.35
6–7	76	Micotil[r]	SC	7.5	neck	58	3 (2)	0.21

[a]Average $ loss from trim and devaluation of product across all injected subprimals
[b]Vitamin E-Selenium (Pfizer Canada, Animal Health Group, London, Ontario)
[c]Vitamin E-Selenium (Vetoquinol N.-A., Lavaltrie, Quebec)
[d]7-way clostridial bacterin-toxoid (Bayer, Agriculture Division — Animal Health, Toronto, Ontario)
[e]*Haemophilus* bacterin (Boehringer Ingelheim Vetmedica, Burlington, Ontario)
[f]*Haemophilus* bacterin (Pfizer Canada)
[g]7-way clostridial-*Haemophilus* bacterin-toxid (Boehringer Ingelheim Vetmedica)
[h]7-way clostridial-*Haemophilus* bacterin-toxoid (Pfizer Canada)
[i]Modified-live BRSV-BVD-IBR-PI[3] vaccine (Pfizer Canada)
[j]Modified-live BRSV-BVD-IBR-PI[3] vaccine (Ayerst Veterinary Laboratories, Guelph, Ontario)
[k]2-way clostridial bacterin-toxoid (Schering-Plough Animal Health, Pointe-Claire, Quebec)
[l]Killed BRSV-BVD-IBR-PI[3] vaccine-*Haemophilus* bacterin (Ayerst Veterinary Laboratories)
[m]Penicillin injection (Pfizer Canada)
[n]Trimethoprim-sulfa (Schering-Plough Animal Health)
[o]Florfenicol (Schering-Plough Animal Health)
[p]Ceftiofur (Pharmacia & Upjohn Animal Health, Orangeville, Ontario)
[q]8-way clostridial bacterin-toxoid (Pfizer Canada)
[r]Tilmicosin (Provel, Guelph, Ontario)

antimicrobials were injected into calves at birth, branding, preweaning, and weaning by various routes and sites to see whether they caused muscle damage that persisted until slaughter. This paper reports the results from the continuation of an experimental study (1) to determine the occurrence of injection site lesions and the severity of carcass damage by product, route, and location, as measured by the number of steaks with lesions, and the trim loss associated with injections of commonly used animal health products 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 128 British and continental calves born from February 15 to May 13, 1997 (spring 1997 calves), and 157 British and continental calves born from August 16 to November 10, 1997 (fall 1997 calves). At birth, all calves were identified with a unique ear tag. Treatment records, including the anatomical locations 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, backgrounded on grass, and fattened at the Lacombe Research Centre feedlot on a barley-based diet until slaughter.

Treatment protocol

The treatment protocols for the spring 1997 and fall 1997 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. Calves were randomly assigned to treatment groups on a systematic basis, as they were born (for the selenium injections) or as they passed through the chute at calfhood round-up, preweaning, and weaning. The calves received 1 injection in each of the treated subprimals, as indicated in Table 1. In the spring 1997 calves, all right rounds and half of the right butts were not injected, so that they could

serve as controls for shearing tests (data not presented). Half of the left necks were not injected, so that a concurrent *Haemophilus somnus* antibody study could be conducted (data not presented).

The injection technique was similar to that reported previously (1). Injections that were administered over the rib were given SC behind the top of the shoulder blade by using the tented method.

Processing

Fattened cattle were processed at the Lacombe Research Centre abattoir by using simulated commercial procedures. The spring 1997 calves were processed from June 23 to July 16, 1998, and the fall 1997 calves were processed from January 25 to April 21, 1999. Slaughter dates were based on back fat thickness and live weight, as well as the availability and slaughter capacity of the abattoir. One hundred and four spring 1997 calves and 116 fall 1997 calves were processed. Of the spring 1997 calves, 6 died before weaning, 2 died after weaning, and 16 were removed as replacement heifers. Of the fall 1997 calves, 8 died before weaning, 1 died after weaning, 1 was culled because of an injury, and 31 were removed as replacement heifers.

During hide removal at processing and on the morning prior to harvesting subprimals, whole carcasses were examined for lesions in the SC fat in the neck and rib area. Subprimals from the neck and hip were obtained from chilled carcasses 6 d after slaughter. They were cut manually by the processing staff into 1.9-cm steaks from the neck and top butt, and into 2.5-cm steaks from the round, in order to detect lesions. The rounds were cut into 2.5-cm steaks, because the extra thickness was needed for objective measures of tenderness using shearing tests.

Injection site lesions were identified by trained personnel (1,6,7). The number of steaks affected by each lesion was recorded. For each product injected into the round, lesions (n = 10) were randomly allocated for objective measurements of tenderness. All remaining lesions in the round, and all lesions in the neck and top butt were trimmed out of the muscle, weighed, placed in formalin, and stored for microscopic examination. These lesions were classified according to the Colorado system (2,3) and as previously described (1,6,7). To reduce bias and diagnostic variability, samples for microscopy were not identified by treatment and were evaluated by the same pathologist who evaluated lesions in previous studies (1,6,7).

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 proportion of histological lesions were calculated by experimental treatment. The chi-squared test and Fisher's exact test were used to test for differences in the proportion of lesions between products and by routes and injection sites. For the cost estimate of trim and devaluation of subprimals, calculations similar to those in previous studies (1,6,7) were made by using the current average International Surveys Limited retail prices (Beef Information Center, personal communication), the proportion of injection site lesions, the median number of steaks affected, and the median trim weight.

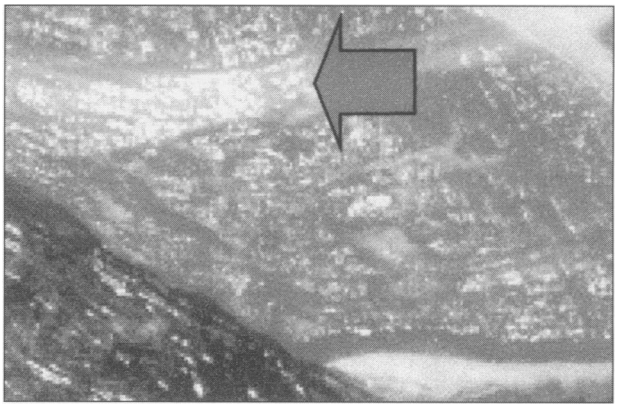

Figure 1. A visible injection site lesion in the top sirloin butt following the IM administration of a 4-way killed viral and *Haemophilus somnus* respiratory vaccine (Triangle 4 + HS) in the top hip at weaning.

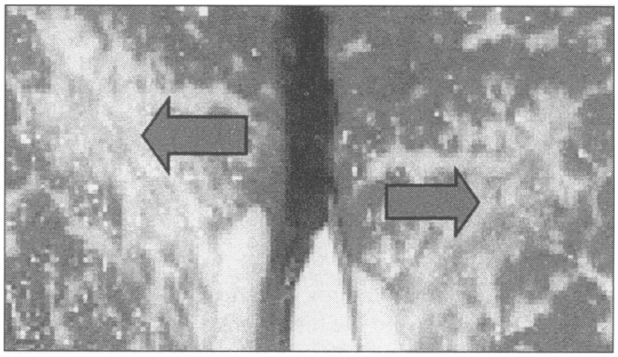

Figure 2. A visual injection site lesion in the inside round following IM administration of trimethoprim-sulfa (Trivetrin) in the thigh at weaning.

Results

At slaughter, the spring 1997 calves had an average live weight of 523 kg (standard deviation (s) = 46), a hot carcass weight of 320 kg (s = 43), a grade fat of 12 mm (s = 5), a marbling score of 469 (s = 78), and a median lean meat yield of Canada 2 (54% to 58%). The fall 1997 calves had an average live weight of 549 kg (s = 66), a hot carcass weight of 334 kg (s = 42), a grade fat of 9 mm (s = 9), a marbling score of 515 (s = 91), and a median lean meat yield of Canada 2.

The occurrence of IM lesions in the experimental calves is shown in Table 1 and visual examples of some of the observed lesions are shown in Figures 1 to 3. The majority of lesions in the top butt were found in the cap (biceps femoris muscle), whereas, in the round, the lesions were usually observed in the inside round (semimembranosus muscle).

Subcutaneous lesions were not observed on the carcasses after SC injection over the rib area behind the top of the shoulder blade with Vision 7, Fortress 8, Tasvax 2,

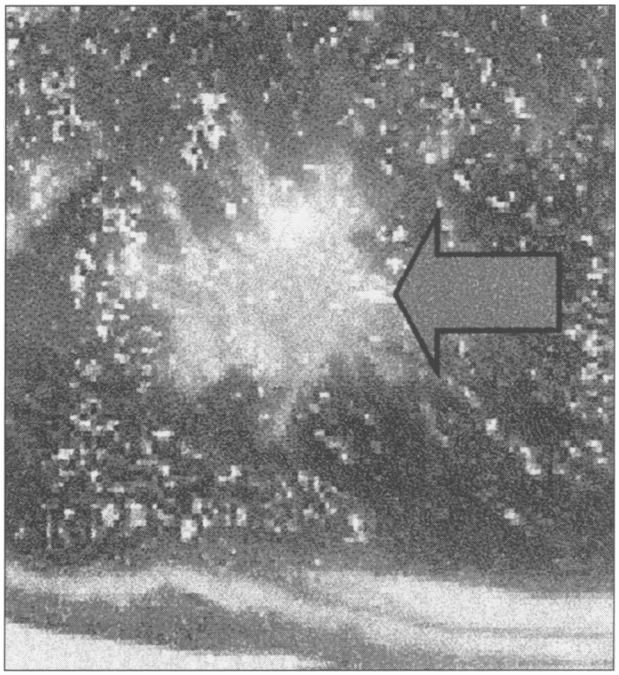

Figure 3. A visible injection site lesion in the inside round following IM administration of florfenicol (Nuflor) in the thigh at weaning.

and Fermicon7-Somnugen (Table 1). Subcutaneous scars and adhesions to the hide were observed in the left neck of 3 (18%) spring 1997 calves that were injected SC with Ultrabac 7/Somubac. In the fall 1997 calves, SC scars and adhesions to the hide were observed in 4 (7%) calves injected SC in the neck with Micotil and in 2 (3%) calves injected IM in the neck with Triangle 4 + HS.

The histological class of lesion by treatment is shown in Table 2, along with the median number of steaks with lesions and the median weight of trimmed muscle. No single microscopic lesion was associated with any one product.

Economic losses estimated from trim and devaluation of product ranged from $0 to $14.53 per injected subprimal (Table 1). This variability was a reflection of the retail price of the subprimal, the proportion of lesions, the number of steaks affected with lesions, and the trim weight.

Discussion

Injecting calves at birth with selenium is a common preventive practice. Both Selon-E and Dystosel caused minimal tissue damage when administered IM in the top butt at birth. It is unknown whether these products caused any changes in muscle tenderness due to the injection and whether the SC use of Dystosel as per the label claim would result in fewer lesions. In previous studies (2,3), a vitamin ADE preparation, injected at branding and weaning caused observable injection site lesions in 5% to 69% of rounds and butts, and it increased muscle toughness.

Multivalent clostridial bacterins given IM or SC to calves at branding or weaning have been reported to cause injection site lesions (1–3,5). In this study, we studied 2 new generation 7- and 8-way clostridial bacterins; 2 7-way clostridal and *H. somnus* combination bacterins; and a 2-way clostridial bacterin. Vision 7 and Fortress 8 are new generation clostridial bacterins that have been developed with claims that they are less damaging to tissue. When used SC in the neck in our study, IM lesions were not observed, except in 3 (5%) calves injected in the neck with Fortress 8. Fortress 8 appears to produce fewer lesions (5%) than the older generation product Ultrabac 8 (Pfizer Canada) (50%), when administered SC in the neck to calves at weaning (1), which supports the company's claim. However, there does not appear to be a difference in lesions observed between Fortress 8 (5%) and the older generation vaccines Blacklegol 8 (Bayer) (0%) or Covexin 8 (Schering-Plough Animal Health, Pointe Claire, Quebec) (12%) (1).

Among the clostridial bacterins combined with *H. somnus* bacterins, Fermicon 7-Somnugen caused a few lesions when administered SC or IM in the neck. The proportion of lesions from Fermicon 7-Somnugen was significantly ($P = 0.001$) less than those produced by Ultrabac 7/Somubac, when injected IM in the neck at weaning. Ultrabac 7/Somubac produced significantly ($P < 0.001$) more lesions when administered IM in the neck than when given SC. In a previous study (1), Ultrabac 8 caused a very high proportion of lesions, when injected in the neck or thigh. The results here and from the past study (1) confirm that clostridial bacterins vary in their ability to cause muscle damage, and whether used singly or in combination with other antigens, such as *H. somnus,* they should be administered SC and not IM, when label directions permit.

Currently, only information on muscle damage caused by SC injections in the neck is available, because rib muscles were not dissected to see whether the SC use of clostridial bacterins caused IM lesions in the absence of overlying SC lesions. While the SC administration of Vision 7, Fortress 8, Fermicon 7-Somnugen, and Ultrabac 7/Somubac over the ribs did not cause SC lesions, they may have caused some muscle damage, which was not adequately evaluated in this study. Our results from SC injection in the neck indicate that IM lesions may occur in the absence of visible overlying SC lesions. Furthermore, some small SC lesions may be obscured by the SC fat layer, as cattle put on fat while they are on feed.

Haemophilus somnus bacterins are commonly used in calves in Canada, and their effect on tissue damage has not been reported previously. When administered IM at 2 to 3 mo of age in the neck and top butt, Somugen and Somubac caused a similar low level of injection site lesions. The occurrence of lesions was higher in the top butt than in the neck for Somnugen ($P = 0.37$) and Somubac ($P = 0.06$), although the difference was not statistically significant ($P > 0.05$), probably due to the small sample size. The trend was consistent and supports the results from previous studies (1–3), where products generally caused a higher proportion of lesions when administered in the top butt and round than in the neck. This may be due to the intermuscular introduction of the products and the excellent lymphatic supply in the neck, which may promote faster absorption of products and rapid healing (1); alternatively, it may be due

Table 2. The histological class of intramuscular lesions, the number of steaks damaged, and the trim weight of injection site lesions in beef calves administered animal health products at various ages

Calf age (mo)	Product	Route	Injected sub-primal	% Woody callus	% Clear scar	% Mineralized scar	% Scar with nodules	% Fatty infiltration	Median number of steaks affected (range)	Median trim weight (g) (range)
Spring 1997										
birth	Dystocel[a]	IM	top butt	0	50	0	0	50	3 (3–3)	223 (207–238)
birth	Selon-E[b]	IM	top butt	0	0	0	0	0	0 (0–0)	0 (0–0)
2–3	Vision 7[c]	SC	neck	0	0	0	0	0	0 (0–0)	0 (0–0)
2–3	Somnugen[d]	IM	neck	0	0	0	100	0	1 (1–1)	18 (18–18)
2–3	Somnugen	IM	top butt	50	0	0	25	25	2 (2–2)	56 (37–237)
2–3	Somubac[e]	IM	neck	0	0	0	100	0	2 (2–2)	65 (65–65)
2–3	Somubac	IM	top butt	29	0	0	57	14	2 (1–3)	94 (40–250)
5–6	Fermicon 7-Somnugen[f]	IM	neck	67	33	0	0	0	2 (2–2)	48 (42–151)
5–6	Fermicon 7-Somnugen	SC	neck	0	0	0	100	0	2 (2–2)	140 (140–140)
5–6	Ultrabac7/ Somubac[g]	IM	neck	17	0	0	75	8	2 (1–3)	94 (18–213)
5–6	Ultrabac 7/ Somubac	SC	neck	0	0	0	0	0	0 (0–0)	0 (0–0)
5–6	Bovishield 4[h]	IM	round	83	17	0	0	0	3 (2–4)	167 (69–356)
5–6	Pyramid MLV 4[i]	IM	round	0	100	0	0	0	3 (3–3)	165 (165–165)
Fall 1997										
2–3	Tasvax 2[j]	SC	neck	100	0	0	0	0	1 (1–1)	18 (18–18)
2–3	Triangle 4 + HS[k]	IM	neck	0	0	0	100	0	2 (2–3)	36 (14–126)
2–3	Triangle 4 + HS	IM	top butt	15	0	0	85	0	2 (1–4)	65 (20–334)
2–3	Ethacilin[l]	IM	top butt	0	0	0	100	0	1 (1–1)	31 (31–31)
5–6	Triangle 4 + HS	IM	top butt	20	0	0	80	0	2 (2–4)	88 (39–226)
5–6	Trivetrin[m]	IM	round	88	12	0	0	0	4 (1–7)	262 (8–1293)
5–6	Nuflor[n]	IM	round	92	8	0	0	0	3 (2–5)	177 (60–920)
5–6	Excenel[o]	IM	round	100	0	0	0	0	2 (2–2)	130 (130–130)
6–7	Fortress 8[p]	SC	neck	100	0	0	0	0	2 (1–2)	39 (8–62)
6–7	Micotil[q]	SC	neck	0	0	0	100	0	2 (2–2)	32 (17–37)

[a]Vitamin E-Selenium (Pfizer Canada)
[b]Vitamin E-Selenium (Vetoquinol Canada)
[c]7-way clostridial bacterin-toxoid (Bayer)
[d]*Haemophilus* bacterin (Boehringer Ingelheim Vetmedica)
[e]*Haemophilus* bacterin (Pfizer Canada)
[f]7-way clostridial-*Haemophilus* bacterin-toxoid (Boehringer Ingelheim Vetmedica)
[g]7-way clostridial-*Haemophilus* bacterin-toxoid (Pfizer Canada)
[h]Modified-live BRSV-BVD-IBR-PI_3 vaccine (Pfizer Canada)
[i]Modified-live BRSV-BVD-IBR-PI_3 vaccine (Ayerst Veterinary Laboratories)
[j]2-way clostridial bacterin-toxoid (Schering-Plough Animal Health)
[k]Killed BRSV-BVD-IBR-PI_3 vaccine-*Haemophilus* bacterin (Ayerst Veterinary Laboratories)
[l]Penicillin injection (Pfizer Canada)
[m]Trimethoprim sulpha (Schering-Plough Animal Health)
[n]Florfenicol (Schering-Plough Animal Health)
[o]Ceftiofur (Pharmacia & Upjohn Animal Health)
[p]8-way clostridial bacterin-toxoid (Pfizer Canada)
[q]Tilmicosin (Provel)

to a classification error, because lesions are more difficult to see in the neck muscles than in the top butt or round on account of the additional connective tissue present in the neck.

In 2 previous reports, viral respiratory vaccines were evaluated for tissue damage when given to calves (1,3). In the present study, Bovishield 4 caused 48% lesions when given IM in the thigh at weaning, similar to that previously reported (3). Pyramid MLV 4, a modified-live viral vaccine containing adjuvant, caused 6% lesions when given IM in the thigh at weaning, which is significantly ($P < 0.001$) fewer lesions than those caused by Bovishield 4. Previously (1,5), it has been suggested that differences in adjuvants may contribute to the variability observed in lesions between killed and modified-live virus vaccines. However, Pyramid MLV 4 contains adjuvant and Bovishield 4 does not; therefore, this does not explain the observed difference. Triangle 4 + HS injected IM in the neck or top hip caused a high occurrence of lesions, similar to another killed viral vaccine

(3). The occurrence of lesions with Triangle 4 + HS was higher in the top hip than neck ($P < 0.001$) and higher in the top hip when given at weaning than at branding ($P = 0.001$). It has been postulated that lesions grow with age (2,3), but this was not supported by the findings in this study. The results here suggest that killed and live viral vaccines may cause muscle damage, that the damage may vary by product, and that products should be administered in the neck rather than in the top hip, to reduce the amount of tissue damage.

In this study, earlier antimicrobial treatments (1) were repeated in order to increase the sample size and, thus, the reliability of the findings. The prevalence of lesions was higher in this study than previously observed (1) for Nuflor ($P = 0.01$) and Trivetrin ($P = 0.008$), but similar for Excenel ($P = 0.09$). This difference in lesions by year may be due to changes in injection technique, animal restraint or hide cleanliness. Excenel resulted in significantly ($P < 0.001$) fewer injection site lesions than did Nuflor or Trivetrin when injected IM in the thigh at weaning, which is in agreement with an earlier work (1).

As previously observed (1), Micotil, like Bio-mycin 200 (Boehringer Ingelheim Vetmedica) (1), appeared to cause minimal tissue damage when given SC in the neck at weaning. A new antimicrobial was evaluated here, which has not been reported previously. Ethacilin, a procaine penicillin, caused few lesions when injected in the top hip at 2 to 3 mo of age, at label dosages. Procaine penicillin is rarely used at label dosage levels in cattle, because of its perceived limited effectiveness in practice; therefore, its tissue effects may vary from those reported here, if used at off-label dosages. Off-label use is not recommended because of potential drug residue concerns.

The results of this and past studies (1–5) indicate that animal health products, including vitamins, antimicrobials, vaccines, and bacterins, may cause muscle damage and affect meat quality. The findings here support current "Quality Starts Here Program" recommendations (1,6,7) to use products that cause minimal tissue damage and to use products SC when label directions permit. When IM products must be used, it is recommended that products that cause minimal tissue damage be used, that no more than 10 mL be administered per site, and that products be administered in the neck rather than in the top butt or round. However, neck injections are not without problems if they produce lesions that must be trimmed and create tough beef. Scars in the neck are more difficult to observe at fabrication due to the connective tissue present and the different types of processing, which may not allow as close a scrutiny as for the round and top butt. If lesions in the neck are not trimmed before they reach the consumers' plate, they may cause an unpleasant eating experience. Veterinarians and/or livestock managers should try to avoid all IM injections if possible.

The results of this study underscore the need for the pharmaceutical industry to continue to reevaluate existing products to determine their effect on carcass quality; to establish SC label claims on existing products, where possible; and to develop new, low volume, nonirritating animal health products that do not have to be administered by IM injection.

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