Effects of parenteral or intranasal modified-live virus respiratory vaccination and revaccination on day 14 in auction-derived feedlot heifers

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Abstract

Auction-derived beef heifers (n = 3,517; initial body weight [BW ± SD] = 607 ± 2 lb; 275 ± 0.9 kg) were received in 12 arrival blocks and randomized to 4 treatment groups: **1)** parenteral MLV vaccination on d 0 (INJ), **2)** intranasal MLV vaccination on d 0 (INT), **3)** parenteral MLV vaccination on d 0 and revaccination with intranasal on d 14 (INJ-R), **4)** intranasal MLV vaccination on d 0 and revaccination with intranasal on d 14 (INT-R). Pen was experimental unit, with 12 pens/treatment and 65 to 76 heifers/pen in a randomized complete block design. Performance, health, carcass traits and BRSV and *H. somni* frequency of carriage in the nasopharynx of revaccinated groups on d 0 and 60 was determined. All data were analyzed in SAS using the MIXED or GLIMMIX procedure. Morbidity ($P = 0.95$), mortality ($P = 0.80$), and other health variables ($P > 0.74$) did not differ. However, an improvement in gain-to-feed (G:F) ($P = 0.04$), increased ribeye area (REA) ($P \leq 0.01$) and percentage of edible livers ($P \leq 0.01$) was observed for INJ and INJ-R. The BRSV ($P = 0.09$) and *H. somni* ($P < 0.01$) frequency of carriage in the nasopharynx increased with time but no treatment effect ($P \geq 0.23$) nor treatment x day interaction ($P \geq 0.29$) existed. Revaccination with an intranasal MLV did not impact health or growth, and arrival intranasal vaccination (INT and INT-R) resulted in less G:F and REA concomitant with increased liver abscessation, compared to parenteral (INJ and INJ-R). Detection of *H. somni* in the nasopharynx was frequent on d 60, suggesting important prevalence of this bacterial pathogen in the southern U.S. cattle population.

Key words: intranasal, parenteral, vaccination, bovine respiratory disease

Introduction

More than 90% of U.S. feedlots vaccinate against causative viral agents of bovine respiratory disease[1] (BRD) and it is the most common and costly disease syndrome in beef cattle in North America.[2] The use of intranasal vaccines is increasingly popular as their commercial availability increases. Intranasal respiratory vaccines may contain modified-live virus (MLV) antigens, or attenuated versions of infectious bovine rhinotracheitis (IBRV), bovine respiratory syncytial virus (BRSV), and parainfluenza-3 virus (PI-3V). Because bovine viral diarrhea virus (BVDV) antigens are currently excluded in intranasal respiratory vaccines, a bivalent parenteral vaccine containing BVDV type I and II is required for prevention. Current literature evaluating respiratory vaccination is largely comprised of controlled pathogen challenge models designed to evaluate vaccine efficacy, but vaccine safety and efficiency should be determined from randomized, well-replicated field trials under conditions in which they are used in the industry.[3]

In a survey conducted by Terrell et al. (2011),[4] 69.6% of consulting feedlot veterinarians recommended revaccination. However, few revaccination studies have been published and they typically do not report differences in performance and health outcomes.[5,6]

It has been demonstrated that BRSV's immunomodulatory effects can foster an environment that promotes *H. somni* colonization in the host.[9] A Th1 response with bacteria-specific IgG2 is required for disease resolution and protection from *H. somni*. Bovine respiratory syncytial virus stimulates an IgE and histamine response during infection that can modulate immunity in favor of a Th2 immune status.[16] Thus, a Th2 response could impact vaccine safety and efficacy, or secondary bacterial infections. Cattle vaccinated with BRSV and *H. somni* had enhanced IgE production, increased bronchoconstriction, edema formation, chemotaxis and introduction of histamine that contributed to IgE production.[7] Gershwin et al.,[8] reported calves dually infected with BRSV and *H. somni* had significant gross lesions and large areas of pulmonary consolidation along with increased IgE but was not observed in calves challenged with BRSV or *H. somni* alone. Powledge et al.[9] reported increased *H. somni* in nasal swabs for intranasal, but not parenteral vaccination against BRSV and other antigens. The results from these studies support the hypothesis BRSV can shift the immune system towards a Th2 response, potentiating increased *H. somni* colonization.

The objectives of the current research were to evaluate the effect of route of MLV respiratory vaccine administration and revaccination on d 14 on health, performance, and carcass traits in auction-derived feedlot heifers and to determine the frequency of carriage of BRSV and *H. somni* and if their prevalence is influenced by vaccination strategy.

Materials and methods

The study was conducted from June 2021 to February 2022 at a commercial feedlot in central Oklahoma. Animal procedures were reviewed by the research sponsor and closely followed standards in the Guide for Care and Use of Farm Animals.

Experimental design

This experiment was a randomized complete block design with 4 different treatment groups. Treatment groups were: **1)** cattle administered a parenteral, pentavalent modified-live virus (MLV) respiratory vaccine with a bacterin[a] on d 0 (INJ),

2) cattle administered an intranasal trivalent with a bacterin MLV respiratory vaccine[b] with a parenteral BVDV type I and II vaccine[c] on d 0 (INT), 3) cattle administered a parenteral, pentavalent MLV respiratory vaccine with a bacterin component[a] on d 0 and revaccinated with an intranasal trivalent MLV respiratory vaccine[d] on d 14 (INJ-R), 4) cattle administered an intranasal trivalent with a bacterin MLV respiratory vaccine[b] with a parenteral BVDV type I and II vaccine[c] on d 0 and revaccinated with an intranasal trivalent MLV respiratory vaccine[d] on d 14 (INT-R). Pen was the experimental unit and replicated for a total of 12 pens per vaccine treatment with 65 to 76 heifers per pen. The number of pen replicates per treatment group and heifers per pen was determined and justified by previous studies with similar independent and dependent variables. An a priori power calculation was not performed.

Arrival processing

A total of 3,517 crossbred beef heifers (607 ± 2 lb; 275 ± 0.9 kg), were acquired from auction market locations in Texas, Oklahoma and Missouri. Upon arrival, heifers were unloaded into receiving pens based on truckload and gate-sorted into 4 different pens until the truckload was evenly distributed across all 4 pens. To achieve appropriate randomization via gate sorting, each truckload of cattle was kept in a separate pen based on location and arrival time. The truckload was evenly distributed across all treatments using a randomly generated number (1 to 10) that indicated the number of heifers for each gate cut added to each treatment sort pen until the entire truckload was assigned. This process was repeated until each pen contained 65 to 76 heifers, depending on the arrival block and the total number of heifers in each. After treatment pen assignments were complete, each pen was weighed on a pen scale. Heifers were then processed which included individual body weight, electronic identification tag, visual ear tag, an injectable clostridial vaccine,[e] a growth promoting implant containing 80 mg of trenbolone acetate, 8 mg estradiol USP, and 29 mg tylosin tartrate,[f] and an injectable[g] and oral[h] antiparasitic. Additionally, an ear tissue sample was collected to test for BVDV persistent infection via antigen-capture ELISA,[i] heifers received an injection of cloprostenol[j] on arrival, metaphylaxis with tildipirosin,[k] and were administered the appropriate MLV vaccine treatment. A post metaphylactic interval (PMI) of 7 d was implemented after metaphylaxis. All animals were reimplanted (approximately d 60) with a growth promoting implant that contained 200 mg of trenbolone acetate and 20 mg of estradiol.[l] Handling and administration of vaccines and other products followed Beef Quality Assurance guidelines.

Cattle management

Cattle were housed in soil-surfaced pens with approximately 11 inches of linear bunk space per animal and fed a common starting ration before being transitioned to a common finishing ration. Cattle were fed 3 times a day with first feeding starting at 0600. During the final 36 d of the feeding period, heifers were supplemented with ractopamine hydrochloride.[m] Feed samples were collected daily and composited weekly for nutrient and dry matter analysis at a commercial laboratory.[n]

Seven heifers tested positive for BVD-PI and were removed from their study pen on d 1 and excluded from all analyses. For field diagnostic purposes, clinical illness score (CIS, 0 to 3 scale) was assigned daily by trained investigators that were blinded to pen treatments. A CIS of 0 described a "normal" animal with no signs of clinical illness and the animal is alert and responsive. A CIS of 1 describes a "mildly depressed" animal. Symptoms of a CIS of 1 include nasal/ocular discharge, cough, head down and falling behind pen mates. A CIS of 2 describes a "moderately depressed" animal. These symptoms include depression, gaunt, labored breathing, nasal/ocular discharge and isolation from pen mates. A CIS of 3 describes a "severely depressed/moribund" animal. These animals were unresponsive to human approach or near death. Heifers assigned a CIS of at least 1 were removed from their home pen and brought to a hospital facility for treatment. The animals were restrained in a hydraulic restraining chute[o] and a rectal temperature was recorded using a digital thermometer.[p] If rectal temperature was ≥ 104° F (40° C), that animal was considered a BRD case and treated according to protocol and returned to their home pen. Heifers with a CIS of 2 or 3 were treated regardless of rectal temperature and returned to their home pen, while those with a CIS of 3 were treated regardless of rectal temperature unless it was determined they should be euthanized. The absence of a rectal temperature requirement to determine a BRD case for heifers with CIS of 2 or 3 in this study could result in a greater number of false BRD positives, but rectal temperature is not always required for BRD treatment in the commercial setting, and this was applied only to heifers observed to display "moderate" or "severe" clinical signs.

Heifers initially diagnosed with BRD (BRD1) were treated with florfenicol and flunixin meglumine[q] at 6 mL/100 lb (40 mg florfenicol/kg and 2.2 mg flunixin meglumine/kg) of body weight (BW) with a 3-d post-treatment interval (PTI). Once the PTI expired, heifers were evaluated using the same BRD case definition. Heifers qualifying for a second BRD treatment (BRD2) received 5 mL/100 lb (11 mg/kg) of BW of enrofloxacin[r] and were assigned a 3-d PTI. After expiration of the PTI, heifers eligible for a third treatment (BRD3) were administered oxytetracycline[s] at 4.5 mL/100 lb (9 mg/0.45kg) of BW with a 3-d PTI. The short duration of PTI (3 days) used in this study could result in a greater rate of treatment failure, as some veterinarians may recommend a longer PTI that would allow additional time for convalescence before being eligible for a subsequent BRD diagnosis and treatment. If a fourth treatment was required, heifers were deemed chronically ill and removed from study and placed into a hospital pen. Heifers that calved, were lame, bloated or had other various anomalies were removed from the study and placed into a hospital pen after their body weight was recorded. Necropsies were performed by trained feedlot personnel on all dead and euthanized heifers and diagnosis was confirmed by a licensed veterinarian utilizing digital photos of the major organs of interest.

Performance and carcass data

Initial and interim (reimplant, approximately d 60) BW was recorded individually upon restraint in a hydraulic chute, and final pen BW was recorded using a platform scale. Dry matter intake was recorded and feed efficiency (gain-to-feed: G:F) was calculated for the entire feeding period. When heifers within block were deemed to be of suitable finish based on visual appraisal and use of an historic projection system for cattle of similar type and expected marketing month, they were harvested at a commercial abattoir. Carcass data collection[t] included backfat, ribeye area (REA), KPH, USDA yield grade, marbling, USDA quality grade and dressing percentage. Liver score data was collected using the Elanco liver scoring system[10] and is reported herein as edible liver, minor liver abscess (A$^-$ and A), or major liver abscess (A+, A+ Adhesion, A+ Open, and A+ Open Adhesion).

Nasal swab collection

A random number generator was used to select 12 animals/pen from treatment groups INJ-R and INT-R to be sampled for rtPCR analysis. Deep nasopharyngeal swabs[u] were collected on d 0, 14, and 60 (reimplant). The swabs were stored in additive-free polystyrene tubes[v] at -80 °C until submission to a diagnostic laboratory[w] for rtPCR testing to determine the frequency of carriage and cycle time of BRSV[11] and *H. somni*.[12] Cycle times were reported up to 40; however, 36 cycles were considered the positive threshold for binomial data analysis.

Statistical analysis

This study was a randomized complete block design with pen (experimental unit) replication across blocks. Continuous data were analyzed using the MIXED procedure of SAS.[x] Categorical data were analyzed using the GLIMMIX procedure of SAS. The fixed effect of treatment and random effect of block was used in the model. Data derived from nasal swab collections was analyzed using the MIXED procedure with repeated measures and treatment, day and their interaction were included as fixed effects. Statistical significance was considered using an alpha-level of 0.05. If an F-test was statistically significant, mean separation was performed using the least significant differences test (pdiff in SAS) and treatment means were separated statistically using an alpha-level of 0.05 with a tendency considered for a *P*-value of $0.05 < P \leq 0.10$.

Results

Feedlot performance

Initial BW did not differ ($P = 0.38$) on d 0 (Table 1). There was no difference in final BW ($P = 0.14$), dry matter intake (DMI; $P = 0.66$) or average daily gain (ADG; $P = 0.29$) between vaccination treatments. However, a difference was observed in gain:feed (G:F; $P = 0.04$) such that INJ (0.177) and INJ-R (0.177) had improved G:F compared to the INT (0.173) and INT-R (0.174) treatments.

Clinical health outcomes

Cumulative BRD morbidity is displayed in Figure 1. There were no differences ($P = 0.95$) in the percentage of heifers treated for BRD at least once (BRD1; Table 2), nor were differences observed for those requiring a second (BRD2; $P = 0.91$) or third (BRD3; $P = 0.89$) BRD treatment. Percent mortality and removals was also not different ($P = 0.80$ and $P = 0.19$) between treatments.

Pathogen frequency of carriage in nasal swabs

No treatment x day interaction ($P = 0.29$) was observed for BRSV frequency of carriage (Figure 2). However, there was a tendency ($P = 0.09$) for a day effect for BRSV frequency of carriage. Upon arrival, no INJ-R heifers had BRSV detected in nasal swabs, and INT-R had a 3.4% rate of BRSV carriage. On day 14, INJ-R had 2.4% and INT-R had 2.9% BRSV detected in nasal swabs. By d 60, only one heifer in the INT-R group had a positive BRSV sample.

There was no treatment x day interaction ($P = 0.44$) for *H. somni* frequency of carriage (Figure 3); however, there was a day effect ($P < 0.01$). The frequency of carriage of *H. somni* was greater ($P < 0.01$) on d 60 (46.6%) than d 0 (1.2%) or 14 (1.5%).

Carcass outcomes

No differences were observed for quality grade, yield grade or percent qualified for various branded beef programs (Table 3). A difference was observed for both edible and major liver abscess ($P \leq 0.01$); the INT treatment had a reduced number of edible livers (53.33%) compared to INJ, INJ-R and INT-R (62.72%, 66.02%, and 61.94%, respectfully). An increase ($P < 0.01$) in

Table 1: Effect of route of initial vaccination (intranasal vs. parenteral) on d 0 and revaccination on d 14 with an intranasal vaccine on heifer performance.

	Treatment¶					
Item	**INJ**	**INT**	**INJ-R**	**INT-R**	**SEM**	***P*-value**
Heifers, n	880	879	878	880		
Pens, n	12	12	12	12		
Initial Weight, lb.*	608	605	607	606	5.333	0.38
Final Weight, lb.†	1279	1264	1274	1267	7.562	0.14
DMI, lb.‡	17.70	17.79	17.65	17.82	0.286	0.68
ADG, lb.§	3.13	3.08	3.11	3.09	0.035	0.29
G:F||	0.177[a]	0.173[b]	0.177[a]	0.174[b]	0.002	0.04

* Data is presented as deads and removals in.

† Data is presented as deads and removals out.

‡ Dry matter intake = DMI

§ Average daily gain = ADG

|| Gain:feed = G:F

¶ Treatments consisted of Bovilis® Vista® Once on d 0 (INJ; Merck Animal Health, Summit, NJ), Bovilis® Nasalgen® 3-PMH and Bovilis® Vista® BVD CFP on d 0 (INT; Merck Animal Health, Summit, NJ), Bovilis® Vista® Once on d 0 revaccination with Bovilis® Nasalgen® 3 on d 14 (INJ-R; Merck Animal Health, Summit, NJ), and Bovilis® Nasalgen® 3-PMH and Bovilis® Vista® BVD CFP on d 0 revaccination with Bovilis® Nasalgen® 3 on d 14 (INT-R; Merck Animal Health, Summit, NJ). Treatment means with different letter superscripts differ, $P < 0.05$.

major liver abscesses for INT (31.64%) was also observed compared to INJ (25.2%), INJ-R (23.2%) and INT-R (26.3%). A tendency was also observed for minor liver abscesses to be greater for INT ($P = 0.08$).

Hot carcass weight (HCW; $P = 0.21$), back fat ($P = 0.40$), marbling score ($P = 0.93$), and dressing percent ($P = 0.76$) did not differ (Table 4). REA was larger ($P \leq 0.01$) in INJ (13.98 in^2) and INJ-R (14.01 in^2) than INT (13.81 in^2) and INT-R (13.78 in^2).

Discussion

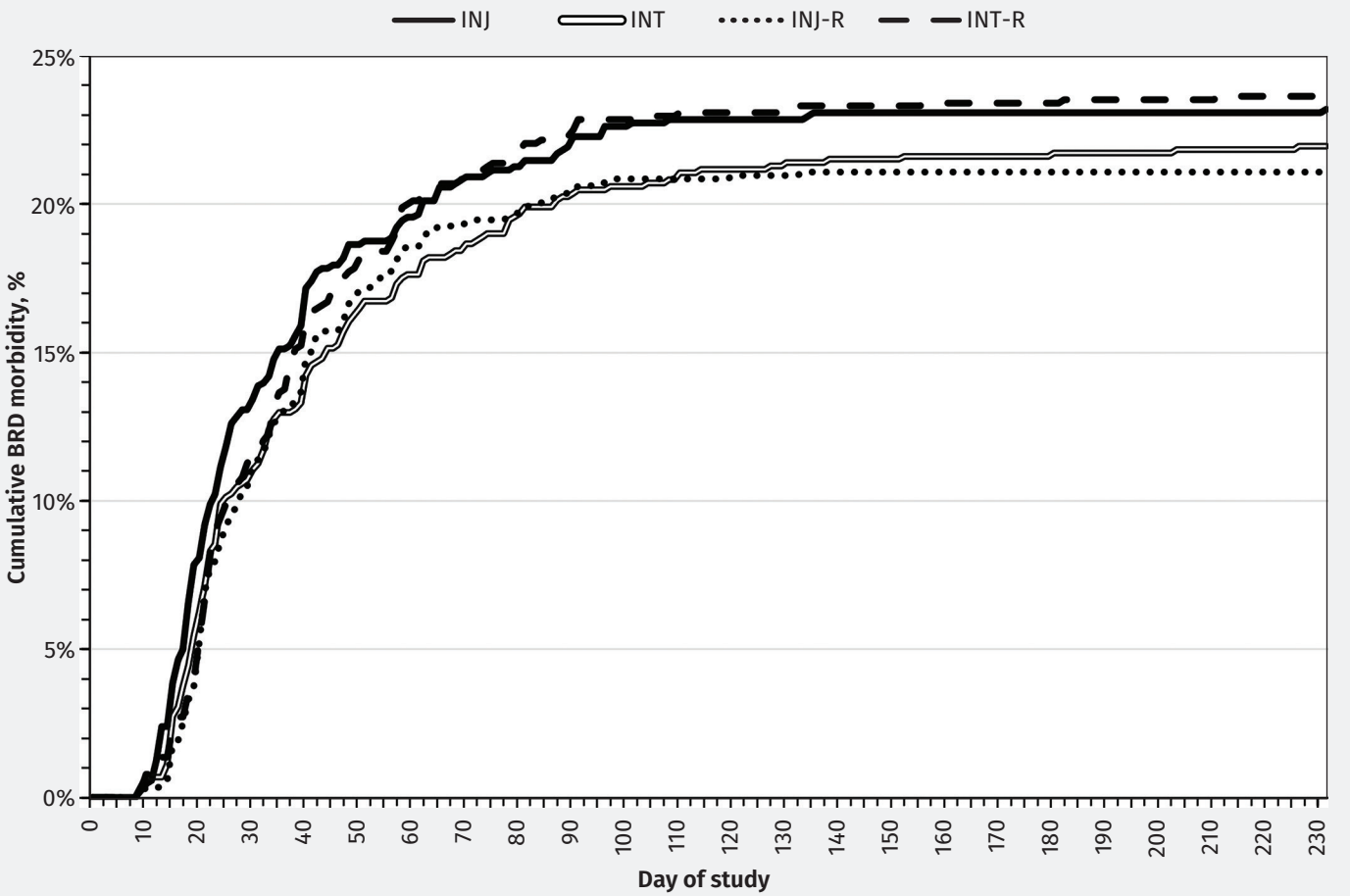
Feedlot performance

Performance results indicate that heifers receiving parenteral respiratory vaccination on arrival had improved feed conversion compared to intranasally vaccinated cohorts; however, elucidation of why the INJ and INJ-R treatments differed from the intranasally vaccinated cattle is difficult. Revaccination is proposed to reduce morbidity and mortality which should lead to an increase in growth performance, but this was not observed in the current study. No differences between the singly vaccinated and revaccinated treatments suggests that revaccination 14 d after arrival was not beneficial in this population of auction-derived feedlot heifers. Intranasal vaccines can prime the immune system and stimulate a local immune response.[13] A local immune response that does not become systemic may be less inflammatory overall, which might transiently improve performance, but we observed INT and INT-R to have reduced feed conversion and numerically less final BW and ADG.

Clinical health outcomes

Results indicate route of vaccine administration and revaccination had no effect on health outcomes under conditions of this study (Table 2). Revaccination is recommended by 69.7% of consulting veterinarians,[4] but the current observations do not support this practice. Furthermore, the findings of this study are like previous publications, where timing of respiratory vaccination,[14] revaccination,[5] or vaccination compared to non-vaccinated control[9] had little effect on health or performance in the feedlot setting. In a study where high-risk calves were vaccinated once or twice, there was a difference observed in the receiving phase for reduced morbidity and mortality for the single MLV vaccination group.[6] A single MLV vaccination could result in less morbidity and mortality due to the handling stress and transient DMI loss cattle experience during and following revaccination. Also, immune functions in stressed cattle are compromised such that MLV antigens are permitted to replicate in host cells to a much greater degree compared with a non-stressed animal with immunocompetence, resulting in a marked increase in the antigenicity of an MLV vaccine administered to the immunosuppressed host.[15]

Figure 1: Cumulative BRD morbidity percentage of heifers administered different vaccine regimens.



Bovilis® Vista® Once on d 0 revaccination with Bovilis® Nasalgen® 3 on d 14 (INJ-R; Merck Animal Health, Summit, NJ), and Bovilis® Nasalgen® 3-PMH and Bovilis® Vista® BVD CFP on d 0 revaccination with Bovilis® Nasalgen® 3 on d 14 (INT-R; Merck Animal Health, Summit, NJ).

Table 2: Effect of route of initial vaccination (intranasal vs. parenteral) on d 0 and revaccination on d 14 with an intranasal vaccine on heifer health.*

	Treatment†					
Item	**INJ**	**INT**	**INJ-R**	**INT-R**	**SEM**	***P*-value**
Heifers, n	880	879	878	880		
Pens, n	12	12	12	12		
BRD1, %	22.84	23.39	23.27	24.31	–	0.95
BRD2, %	10.34	9.16	10.23	9.47	–	0.91
BRD3, %	4.72	4.86	4.92	4.10	–	0.89
Relapse rate, %	37.66	31.73	37.81	37.20	–	0.74
All-cause mortality, %	4.76	3.58	4.00	4.07	–	0.80
Removed, %	4.65	5.75	5.17	3.55	–	0.19
Respiratory mortality, %	3.98	2.80	3.20	2.94	–	0.65

* Data is presented as deads in.

† Treatments consisted of Bovilis® Vista® Once on d 0 (INJ; Merck Animal Health, Summit, NJ), Bovilis® Nasalgen® 3-PMH and Bovilis® Vista® BVD CFP on d 0 (INT; Merck Animal Health, Summit, NJ), Bovilis® Vista® Once on d 0revaccination with Bovilis® Nasalgen® 3 on d 14 (INJ-R; Merck Animal Health, Summit, NJ), and Bovilis® Nasalgen® 3-PMH and Bovilis® Vista® BVD CFP on d 0 revaccination with Bovilis® Nasalgen® 3 in d 14 (INT-R; Merck Animal Health, Summit, NJ).

Figure 2: Effect of respiratory vaccination and route of administration on bovine respiratory syncytial virus prevalence via rtPCR in high-risk, auction-derived feedlot heifers. Bovilis® Vista® Once on d 0 revaccination with Bovilis® Nasalgen® 3 on d 14 (INJ-R; Merck Animal Health, Summit, NJ), and Bovilis® Nasalgen® 3-PMH and Bovilis® Vista® BVD CFP on d 0 revaccination with Bovilis® Nasalgen® 3 on d 14 (INT-R; Merck Animal Health, Summit, NJ). Effect of treatment, *P* = 0.23; day, *P* = 0.09, treatment x day, *P* = 0.29.

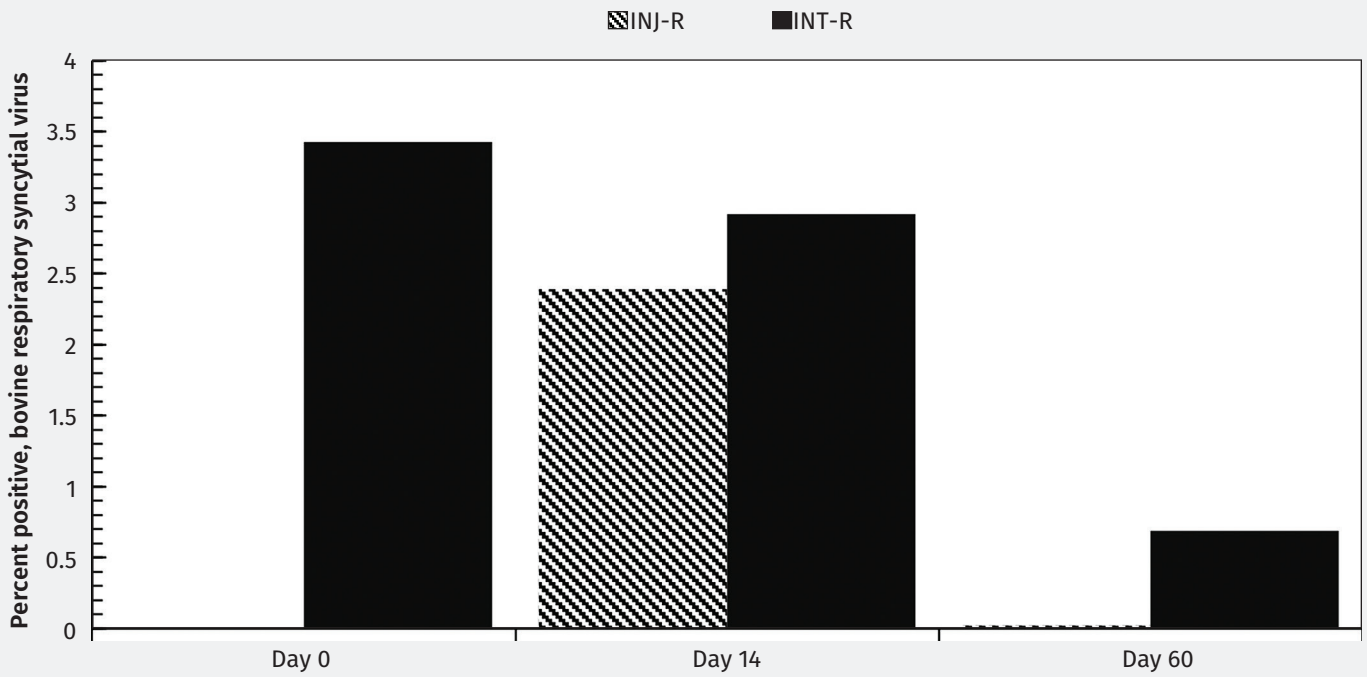
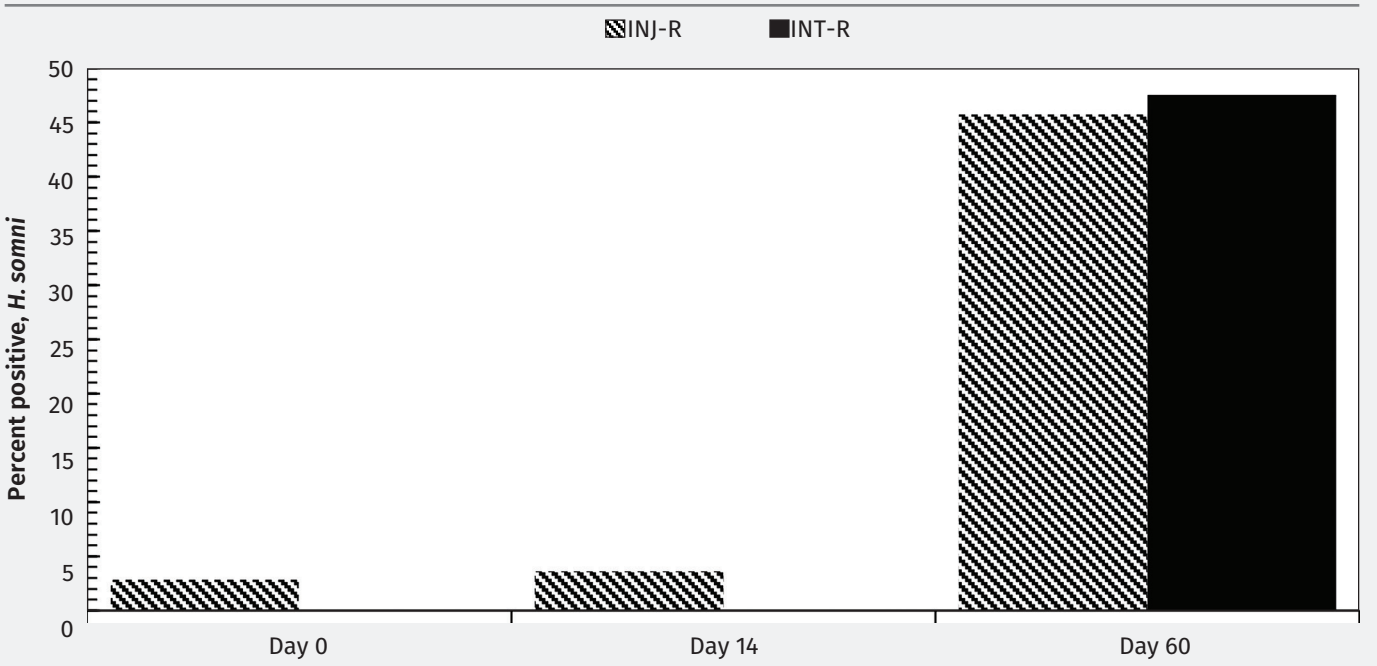


Figure 3: Effect of respiratory vaccination and route of administration on *H. somni* prevalence via rtPCR in high-risk, auction-derived feedlot heifers. Bovilis® Vista® Once on d 0 revaccination with Bovilis® Nasalgen® 3 on d 14 (INJ-R; Merck Animal Health, Summit, NJ), and Bovilis® Nasalgen® 3-PMH and Bovilis® Vista® BVD CFP on d 0 revaccination with Bovilis® Nasalgen® 3 on d 14 (INT-R; Merck Animal Health, Summit, NJ). Effect of treatment, $P = 0.71$; day, $P < 0.01$, treatment x day, $P = 0.44$. Day means with different letter superscripts differ, $P < 0.05$.



Pathogen frequency of carriage in nasal swabs

The results of the frequency of carriage of BRSV agree with the findings of Gershwin,[16] that shedding of BRSV typically begins on d 3 to 4 following infection and rarely endures beyond d 10. The immune response that follows intranasal vaccination may have created an environment that favored *H. somni* colonization because both INT-R and INJ-R received intranasal antigens (including BRSV) upon revaccination. Natural *H. somni* infections typically occur 6 to 10 weeks after feedlot arrival.[9] However, because revaccination included a trivalent intranasal MLV vaccine for both INT-R and INJ-R, it confounded potential differences in *H. somni* between heifers vaccinated on d 0 with INT vs. INJ. This makes it impossible to determine if the increase in *H. somni* prevalence over time in the INJ-R treatment group was affected by the first vaccination with the parenteral MLV vaccination or if it was due to the revaccination with the trivalent intranasal MLV vaccination. Nevertheless, because almost one-half of the heifers were *H. somni* positive on d 60, it indicates important prevalence of this pathogen in the southern U.S. that was previously thought to be more common in the far northern region of the U.S. and Canada.

Carcass outcomes

The study conducted by Step et al.[6] also noted cattle that received a MLV on d 0 and 11 had significantly more liver abscesses than cattle that only received a MLV on d 0. The incidence of liver abscesses in this study with the INT group having statistically more major liver abscesses is difficult to explain, although one reason might be due to differences in microbiome alteration between MLV vaccine route of administration.[9]

Overall, our data indicate route of MLV vaccination in auction-derived heifers (parenteral vs. intranasal) did not clearly impact health or growth in the feedlot. Likewise, revaccination with an intranasal, trivalent MLV on d 14 did not impact health or growth. Reduction in edible livers and increased severe liver abscesses for INT was unexpected, but we speculate that treatment effects on the respiratory and enteric microbiome may be a reason. Whether the slight performance reduction for INT is an artifact of increased liver abscessation, or differences in immunological protection, is unknown. An increase in *H. somni* was observed over time, which is expected because *H. somni* is typically most prevalent several weeks after feedlot arrival. Further research is needed to better understand how intranasal MLV vaccination might impact the respiratory microbiota and the clinical significance of such impact, if any.

Endnotes

[a] Bovilis® Vista® Once SQ, Merck Animal Health, Summit, NJ

[b] Bovilis® Nasalgen® 3-PMH, Merck Animal Health, Summit, NJ

[c] Bovilis® Vista® BVD CFP, Merck Animal Health, Summit, NJ

[d] Bovilis® Nasalgen® 3, Merck Animal Health, Summit, NJ

[e] Bovilis® Vision® 7 with Spur®, Merck Animal Health, Summit,, NJ

[f] Component® TE-IH with Tylan®, Elanco Animal Health, Greenfield, IN

[g] Dectomax® Injectable, Zoetis, Kalamazoo, MI

[h] Safe-Guard®, Merck Animal Health, Summit, NJ

[i] East Emporia Veterinarian Clinic, Emporia, KS

Table 3: Effect of route of initial vaccination (intranasal vs. parenteral) on d 0 and revaccination on d 14 with an intranasal vaccine on heifer carcass characteristics.

	Treatment¶					
Item	**INJ**	**INT**	**INJ-R**	**INT-R**	**SEM**	***P*-value**
Heifers, n	798	798	801	814		
Pens, n	12	12	12	12		
Quality grade, %						
Prime	2.22	1.81	2.44	2.17	–	0.85
Choice	78.11	77.24	76.58	79.10	–	0.65
Select	19.72	18.73	20.25	18.40	–	0.77
Standard	0.73	0.60	0.24	0.59	–	0.60
Yield grade, %						
1	5.22	7.07	7.50	7.54	–	0.23
2	38.84	37.20	35.61	36.33	–	0.58
3	42.72	39.84	43.74	40.95	–	0.40
4	13.38	12.43	11.90	14.16	–	0.55
5	0.76	1.98	0.87	1.36	–	0.15
Liver score, %						
Edible	62.72[a]	53.33[b]	66.02[a]	61.94[a]	–	≤ 0.01
Minor abscess§	11.47	14.52	10.52	11.32	–	0.09
Major abscess‖	25.20[b]	31.64[a]	23.20[b]	26.27[b]	–	≤ 0.01
Flukes	1.77	1.49	2.50	2.61	–	0.35
Telangiectasis	1.25	1.95	2.34	2.20	–	0.42

§ Minor Abscess include A- and A from the Elanco Liver Scoring System

‖ Major Abscess include A+, A+ Adhesion, A+ Open, and A+ Open/Adhesion

¶ Treatments consisted of Bovilis® Vista® Once on d 0 (INJ; Merck Animal Health, Summit, NJ), Bovilis® Nasalgen® 3-PMH and Bovilis® Vista® BVD CFP on d 0 (INT; Merck Animal Health, Summit, NJ), Bovilis® Vista® Once on d 0revaccination with Bovilis® Nasalgen® 3 on d 14 (INJ-R; Merck Animal Health, Summit, NJ), and Bovilis® Nasalgen® 3-PMH and Bovilis® Vista® BVD CFP on d 0 revaccination with Bovilis® Nasalgen® 3 on d 14 (INT-R; Merck Animal Health, Summit, NJ). Treatment means with different letter superscripts differ, $P < 0.05$.

[j] Estrumate®, Merck Animal Health, Summit, NJ

[k] Zuprevo® 18%, Merck Animal Health, Summit, NJ

[l] Revalor® 200, Merck Animal Health, Summit, NJ

[m] Optaflexx® 45, Elanco Animal Health, Greenfield, IN

[n] SDK Laboratory, Hutchinson, KS

[o] Moly Manufacturing Inc., Lorraine, KS

[p] AG-Medix, Mukwonago, WI

[q] Resflor Gold®, Merck Animal Health, Summit, NJ

[r] Baytril® 100, Bayer Animal Health, Shawnee Mission, KS

[s] Bio-Myocin® 200, Boehringer Ingelheim Animal Health, Duluth, GA

[t] CattleTrail, Inc., Dodge City, KS

[u] Continental Plastic Corp., Delevan, WI

[v] Falcon; Corning, Inc., Corning, NY

[w] Texas A&M Veterinary Diagnostic Laboratory, Canyon, TX

[x] SAS version 9.4, SAS Inst., Cary, NC

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Conflicts of interest

D.V. Hardee and T.R. Parks are employed by Merck Animal Health. No other author conflicts are known to exist.

Table 4: Effect of route of initial vaccination (intranasal vs. parenteral) on d 0 and revaccination on d 14 with an intranasal vaccine on heifer carcass performance results.

	Treatment§					
Item	**INJ**	**INT**	**INJ-R**	**INT-R**	**SEM**	***P*-value**
Heifers, n	798	798	801	814		
Pens, n	12	12	12	12		
HCW, lb.*	815	806	813	809	4.625	0.21
REA†, in^2	13.98^a	13.81^b	14.01^a	13.78^b	0.126	≤ 0.01
Back fat, in	0.66	0.67	0.67	0.66	0.009	0.40
REA HWT‡	1.73	1.72	1.73	1.72	0.010	0.52
Marbling score	466	469	467	466	6.299	0.93
Empty body fat, %	31.30	31.52	31.36	31.39	0.135	0.58
Dressing percent, %	63.91	63.71	63.53	63.97	0.004	0.76

* Hot carcass weight = HCW

† Ribeye area = REA

‡ Ribeye hot weight = REA HWT

§ Treatments consisted of Bovilis® Vista® Once on d 0 (INJ; Merck Animal Health, Summit, NJ), Bovilis® Nasalgen®3-PMH and Bovilis® Vista® BVD CFP on d 0 (INT; Merck Animal Health, Summit, NJ), Bovilis® Vista® Once on d 0 revaccination with Bovilis® Nasalgen® 3 on d 14 (INJ-R; Merck Animal Health, Summit, NJ), and Bovilis®Nasalgen® 3-PMH and Bovilis® Vista® BVD CFP on d 0 revaccination with Bovilis® Nasalgen® 3 on d 14 (INT-R; Merck Animal Health, Summit, NJ). Treatment means with different letter superscripts differ, $P < 0.05$.

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