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Corresponding author: M. Claire Windeyer; Email: mcwindey@ucalgary.ca

A systematic review of disease control strategies in beef cow–calf herds, part 2: preweaned calf morbidity and mortality associated with neonatal calf diarrhea and bovine respiratory disease

V. Margarita Sanguinetti[1], Kayla Strong[1], Samuel P. Agbese[1], Cindy Adams[1], John Campbell[2], Sylvia L. Checkley[1], Heather Ganshorn[3] and M. Claire Windeyer[1]

[1]University of Calgary, Faculty of Veterinary Medicine, Calgary, AB, Canada; [2]University of Saskatchewan, Western College of Veterinary Medicine, Saskatoon, SK, Canada and [3]University of Calgary, Libraries and Cultural Resources, Calgary, AB, Canada

Abstract

Preventing neonatal calf diarrhea (NCD) and bovine respiratory disease (BRD) in cow–calf herds is essential to optimizing calfhood health. Disease control can prevent morbidity and mortality; however, evidence concerning the effectiveness of practices to achieve this is limited. The objective of this systematic review was to assess and summarize the evidence on the effectiveness of management practices to prevent calf morbidity and mortality from NCD and BRD in beef cow–calf herds. The population of interest was preweaned beef calves. The outcomes were calf morbidity and mortality caused by NCD and BRD. Only studies reporting naturally occurring diseases were included. Seventeen studies were deemed relevant, 6 studies of which were controlled trials or randomized controlled trials (RCTs), and 11 were observational studies. Most management practices had some evidence to support their use; however, the certainty of the findings was low to very low. Most of the practices were shown to impact both NCD and BRD. Yet, the different levels of consistency in the directionality of the findings suggest that some outcomes are more affected by some practices than others. More well-designed RCTs and cohort studies are required to provide reliable estimates to support recommended practices for cow–calf herds.

Introduction

In cow–calf herds, calf morbidity and mortality affect productivity by increasing treatment costs, reducing weaning weights, and limiting the number of available calves for sale at weaning (Ganaba *et al.*, 1995). In western Canada, the average herd-level treatment risk of preweaning disease is estimated at 9.4% (Pearson *et al.*, 2019a). The leading causes of treatment are neonatal calf diarrhea (NCD) and bovine respiratory disease (BRD) (Ganaba *et al.*, 1995; Murray *et al.*, 2016; Pearson *et al.*, 2019a; Waldner *et al.*, 2013). Furthermore, sick calves have increased mortality risk compared to healthy ones (Busato *et al.*, 1997; Ganaba *et al.*, 1995; Mõtus *et al.*, 2018). Thus, preventing NCD and BRD in preweaned beef calves is critical.

Neonatal calf diarrhea is a multifactorial infectious syndrome that affects the gastrointestinal tract of calves (Acres *et al.*, 1977; Cho and Yoon, 2014; Muktar *et al.*, 2015). In beef calves, clinical cases usually occur during the first month of life (Clement *et al.*, 1995; Smith *et al.*, 2008), although the onset of clinical signs varies depending on the agents involved (Cho and Yoon, 2014). *Escherichia coli* (*E. coli*) (Acres *et al.*, 1977; Myers, 1976), bovine rotavirus (BRoV) (Cornaglia *et al.*, 1992), bovine coronavirus (BCoV) (Torres-Medina *et al.*, 1985), and *Cryptosporidium parvum* (Thomson *et al.*, 2017) are frequently the causative agents of NCD, alone or in combination. Case definitions usually focus on reduced fecal consistency (Myers, 1976), weakness, anorexia, and dehydration (Acres *et al.*, 1977; Wilson *et al.*, 2023). In western Canada, on average 3–5.5% of calves are treated for NCD (Murray *et al.*, 2016; Pearson *et al.*, 2019a; Waldner *et al.*, 2013), but the range of affected calves may vary widely across herds (Waldner *et al.*, 2022). Minimizing the impact of NCD could optimize calf health and increase economic revenue for producers.

Bovine respiratory disease is a multifactorial respiratory syndrome (Taylor *et al.*, 2010). During the preweaning period, it typically affects calves from 3 weeks of age until weaning (United States Department of Agriculture Animal and Plant Health

Inspection Service Veterinary Services National Animal Health Monitoring System, 1997). Clinical disease is triggered by a combined effect of viruses and bacteria (Cuasck *et al.,* 2003), and the disease risk is often enhanced by stress-related factors that cause immunosuppression or sudden changes in environmental conditions (Taylor *et al.*, 2010). Typical pathogens involved include *Mannheimia haemolytica* (*M. haemolytica*), *Pasteurella multocida, Histophilus somni, Mycoplasma bovis*, bovine herpesvirus type 1 (BHV1), bovine respiratory syncytial virus (BRSV), parainfluenza virus type 3 (PIV3), BCoV, and bovine viral diarrhoea virus (BVDV) (Campbell, 2022). Early clinical signs involve depression, loss of appetite, and body temperature above 104°F. More advanced cases may present with difficulty breathing, coughing, and nasal discharge (Kasimanickam, 2010). In western Canada, the average herd-level treatment risk for BRD during the preweaning stage has been estimated between 2.7% and 3.8% (Murray *et al.*, 2016; Waldner *et al.*, 2013). However, its impact also varies across herds (Waldner *et al.*, 2022) and between years (Muggli-Cockett *et al.*, 1992). Therefore, preventing BRD in cow–calf herds is also essential to ensuring good calf health and economic returns to producers.

Given the detrimental effects of NCD and BRD on calf health, disease control strategies are a cornerstone for optimizing the production of calves and ensuring economic returns. Prevention is more beneficial than treatment of affected animals (Thrusfield and Christley, 2018). For instance, the per annum cost of prevention of BRD in beef cow–calf herds in the United States was estimated at $13.74 USD per calf compared to $32.45 USD for treatment (Wang *et al.,* 2018). While identifying practices that should be recommended to control disease in farms is essential to boost cow–calf productivity, there is still a knowledge gap concerning which are these are currently most effective, and this information has not been compiled before. This leads to the question: What is the effectiveness of management practices to prevent beef calf morbidity and mortality caused by NCD and BRD during the preweaning stage?

The objective of this systematic review was to assess and summarize the evidence on the effectiveness of management practices to prevent calf morbidity and mortality from NCD and BRD on beef cow–calf herds. A secondary objective was to assess the generalizability of this evidence to cow–calf operations in western Canada.

Materials and methods

The methods used for this systematic review were described previously (Sanguinetti *et al.*, 2021, 2025) and will be described briefly here. This study followed the preferred reporting items for systematic reviews and meta-analyses reporting guideline (PRISMA 2020) (Page *et al.*, 2021) and a series of articles for conducting systematic reviews in veterinary medicine (O'Connor *et al.*, 2014; O'Connor and Sargeant, 2014; Sargeant *et al.*, 2014a, 2014b; Sargeant and O'Connor, 2014).

Protocol and registration

Before starting the review, a protocol was developed following the PRISMA-P guidelines (Moher *et al.*, 2015) and published in the Digital Repository of the University of Calgary (https://prism.ucalgary.ca) and online with Systematic Reviews for Animals and Food (http://www.syreaf.org/) (Sanguinetti *et al.*, 2021).

Eligibility criteria

Population

The population of interest was preweaned beef calves.

Interventions and comparators

The interventions of interest were practices related to colostrum management, breeding and calving, nutritional management, biosecurity, and vaccination used in calves or pregnant dams. Studies were required to have a concurrent comparison group (i.e., placebo or alternate practice).

Outcomes

The outcomes of interest were treatment for, or morbidity or mortality from NCD and BRD.

Study designs and report characteristics

Eligible study designs were randomized controlled trials (RCTs), controlled trials (CTs), and observational studies that statistically assessed the relationship between an intervention (i.e., practice) and an outcome of interest. Only studies reporting naturally occurring diseases and written in English were included.

Information sources and search strategy

Electronic databases used for the literature search included CAB Abstracts, MEDLINE on the Ovid platform, Web of Science, and ProQuest Dissertations. The first search was carried out on 20/5/2021 and updated on 5/4/2023 to incorporate recent publications. Covidence (Veritas Health Innovation, Melbourne, Australia) was used to import, de-duplicate, and classify studies.

Screening and selection process

Two independent reviewers assessed the relevancy of studies in two stages. The first stage involved title and abstract screening, and the second involved full-text review. Details concerning signalling questions and conflict resolution are shown in the protocol and in the related manuscript (Sanguinetti *et al.*, 2021, 2025).

Data collection process

Data were extracted by two reviewers using Microsoft Excel (Microsoft Corporation, Redmond, WA). During this stage, studies were anonymized by using a numeric code (Table 1). Study-level information and individual practice assessments (PAs) were isolated and extracted from each study. The term PA refers to the statistical assessment between a practice and an outcome of interest. Each PA was identified using an alphanumeric code in accordance with the numeric code given to each study (Tables 4–9; Supplementary material 1). Associations or effects were considered statistically significant if $P \leq 0.05$. The terms statistically significant associations (A) or no statistically significant associations (NA) were used to describe the findings of PAs from observational studies. The terms statistically significant effects (E) or no statistically significant effects (NE) were used to describe the findings of PAs from RCTs and CTs. Preference was given to extracting univariable analyses over multivariable ones if both were reported because of concerns about a lack of independence among practices. If possible, estimates were extracted from tables, focusing on the directionality of findings (i.e., protective or harmful) instead of the specific estimate.

Table 1. Characteristics of studies included in a systematic review on the effect of management practices on pre-weaned calf morbidity and mortality from neonatal calf diarrhea (NCD) and bovine respiratory disease (BRD) in beef cow–calf herds

Paper	First author	Year published	Country and year of the study	Study design	*N*	Interventions assessed	Comparator	Overall incidence risk or rate	Syndrome	Case definition
2	Clement	1993	United States, 1992	Cross-sectional	9846 calves, 58 herds	Breeding and calving management, dam nutrition	Absence of a given practice, alternate practices	Herd-level incidence = 12.6%	NCD	Not defined
3	Dutil	1999	Canada, 1995	Cross-sectional	332 herds	Breeding and calving management	Absence of a given practice, alternate practices	NCD mortality risk = 18.6–28.5%, BRD mortality risk = 12.8–17.5%, Proportion of herds with NCD = 26–68%, Proportion of herds with BRD = 11–54%	NCD and BRD mortality, Herd status for NCD and BRD	Not defined
4	Murray	2016	Canada, 2013	Cross-sectional	142 herds	Multiple	Absence of a given practice, alternate practice	Mean herd-level treatment risk for NCD = 4.9% (95% confidence interval [CI]: 3.9–6.0), mean herd-level treatment risk for BRD = 3.0% (95% CI: 2.1–3.8)	BRD, NCD	Not defined
12	van Donkersgoed	1994	Canada, unspecified dates	RCT	111 calves	Calf vaccination	Unvaccinated, alternative vaccine groups	Treatment risk of BRD = 28%	BRD	Depressed, gaunt, and had clinical signs referable to the respiratory system
13	Assie	2009	France, 1999–2000	Cross-sectional	172 calf batches, 130 farms	Breeding and calving management, calf nutrition, dam nutrition, colostrum management, dam vaccination, calf vaccination, biosecurity	Absence of a given practice, alternate practices	In batches with ≥1 case, incidence rate = 3.59 cases per 1000 calf-days at-risk	BRD	Producer treatments based on "at least one respiratory sign (nasal discharge, dyspnoea, cough) and, in the same calf or another calf of the same batch, at least one general sign (hyperthermia, anorexia, depression) on the same day or the day before". Excluded batches that were treated with metaphylaxis
14	Cornaglia	1992	Argentina, 1986–1988	CT	1: 1024 dams 2: 1473 dams 3: 1556 dams	Dam vaccination	Placebo, alternative vaccine groups	1: 40% Morbidity 2: 34% Morbidity 3: 20% Morbidity	NCD	Not defined in detail (i.e., "signs of diarrhea")

(*Continued*)

Paper	First author	Year published	Country and year of the study	Study design	*N*	Interventions assessed	Comparator	Overall incidence risk or rate	Syndrome	Case definition
15	Myers	1980	Montana, USA; 1978 or 1979	CT	2039 cows, 12 herds	Dam vaccination	Adjuvanted placebo	NCD mortality = 1.47%[a]	NCD, NCD mortality	0: Calves with no signs of enteric disease; 1: Developed transient diarrhea (usually 12–24 h) but not other signs; 2: Diarrheal calf that became dehydrated (sunken eyes) and depressed; 3: Severely dehydrated calves that were too week to stand
16	Cohen	1991	Canada, 1987	CT	226 cows	Dam mineral supplementation	Unvaccinated	Incidence NCD = 25%[a]	NCD	Not defined
17	Guyot	2007	Belgium, unspecified dates	RCT	60 cows, 2 herds	Mineral supplementation dams	Alternate dose and source of selenium (Se)	Incidence of NCD = 19, 29, and 65%, respectively, in groups Y–Se, Na–Se 0.5, and Na–Se 0.1	NCD	Not defined
18	Hanzlicek	2013	United States, 2008	Cross-sectional	443 herds	Breeding and calving management, calf vaccination, dam vaccination, biosecurity, calf nutrition	Absence of a given practice, alternate frequency, alternate practice	Mean percentage of calves affected by BRD = 3.0 ± 7.1%, Mean BRD rate = 1.5 ± 3.7 cases/10,000 calf days (median, 0.18 cases/10,000 calf-days [range, 0–75.0 cases/10,000 calf-days])	BRD	Herd-level rates were defined on the basis of reported counts of calves treated with an antimicrobial for respiratory tract disease and total calf days at risk from birth to weaning
19	Pearson	2019	Canada, 2017	RCT for meloxicam (but cross-sectional for risk factors)	219 calves, 13 herds	Colostrum management	Absence of a given practice, alternate practice	Calf treatment risk = 10%	NCD and BRD combined to treatment	Not defined
20	Waldner	2013	Canada, 2010	Cross-sectional	310 herds	Breeding and calving management, dam vaccination	Absence of a given practice, alternate practices	Median risk of calf treatment NCD = 2.4% (95% CI: 0–17.6), median risk of calf treatment BRD = 0.8% (95% CI: 0–9.8%)	NCD, BRD	Not defined

(*Continued*)

Paper	First author	Year published	Country and year of the study	Study design	*N*	Interventions assessed	Comparator	Overall incidence risk or rate	Syndrome	Case definition
21	Woolums	2018	United States, 2012–2014	Case-control	84 herds	Dam nutrition, calf nutrition, biosecurity, breeding and calving management, dam vaccination, calf vaccination	Absence of a given practice, alternate practices	NA	BRD	Not defined
22	Woolums	2013	United States, 2011	Cross-sectional	459 herds	Multiple	Absence of a given practice, alternate practices	Percentage of cow–calf herds with ≥1 nursing beef calf with signs of respiratory disease = 21.1% (95% CI: 17.1–25.0%), mean number of calves treated for BRD in herds that detected calves with that disease = 8.0 (95% CI: 5.9–10.1), and mean number of calves that died because of BRD in such herds = 1.2 (95% CI: 0.7–1.8).	BRD	Calves are less active and less interested in eating than normal calves. They may cough and have a snotty nose, and have a fever. Their breathing may be faster than normal or harder than normal, and they may breathe with an open mouth. Calves with respiratory disease may get better on their own, they may die, or they may survive but lose weight and look sick for weeks or months (become chronic)
23	Makoschey	2008	France, unspecified dates	RCT	719 calves, 14 herds	Calf vaccination	Unvaccinated, alternative vaccine groups	Eight of 14 study sites had animals with clinical disease. Vaccinated with inactivated BRSV and PI3 group that were exposed to disease = 6.1% treated, vaccinated with Live BRSV = 12.3%, PI3 and controls = 20%	BRD mortality, BRD	Not defined

(*Continued*)

Paper	First author	Year published	Country and year of the study	Study design	*N*	Interventions assessed	Comparator	Overall incidence risk or rate	Syndrome	Case definition
24	Pisello	2021	Italy, 2018–2019	Cross-sectional	202 calves, 9 herds	Breeding and calving management, dam vaccination, colostrum management	Absence of a given practice, alternate practices	BRD risk = 18.3%	BRD	A <6-month-old calf showed cough, nasal/ocular discharge, or laboured breathing was treated with antimicrobials
25	Waldner	2022	Canada, 2017–2018	Cross-sectional	87 herds	Breeding and calving management, calf nutrition, calf vaccination, biosecurity	Absence of a given practice, alternate practices	BRD mean morbidity risk = 4.7%, median = 1%, NCD mean morbidity risk = 3%, median = 1.1%	BRD, NCD	Not defined

RCT, randomized controlled trial; CT, controlled trial; Y–Se, organic selenium; Na–Se, sodium selenite; BRSV, bovine respiratory syncytial virus; PI3, parainfluenza virus type 3.
[a]Estimates calculated by the reviewers from published results (Cohen *et al.*, 1991; Myers *et al.*, 1980)

Risk of bias

The methods used to evaluate the risk of bias were based on the Rob2 tool (Sterne *et al.*, 2019) and ROBINS I tool (Sterne *et al.*, 2016). Two reviewers conducted this assessment. Modifications were made to make them relevant to veterinary medicine (Sargeant and O'Connor, 2014).

Data synthesis

The evidence concerning calf morbidity and mortality from NCD and BRD was summarized using a narrative structure, organized by practices with evidence showing statistically significant associations or effects then practices without statistically significant associations or effects. A summary of findings table was created for all PAs. If the body of evidence for a specific practice had more than three PAs from different studies assessing the same outcomes, the certainty of the body of evidence was assessed using the GRADE approach (Schünemann *et al.*, 2013). This assessment considered consistency in the directionality of findings across PAs (i.e., protective or harmful). Bodies of evidence whose PAs had at least 60–70% of their findings indicating the same direction were considered to have a consistent directionality of findings, those with 40–59% were considered semi-consistent, and those with less than 40% of findings indicating the same direction were considered inconsistent. Also, the GRADE approach assessed how comparable the practices and comparison groups were across PAs and how comparable the productiion conditions in the PAs were relative to those on western Canadian cow–calf operations.

Results

Of the 4942 studies initially retrieved, 17 studies were deemed relevant (Fig. 1). Five studies only reported NCD-related outcomes, seven only BRD-related outcomes, and five studies reported both outcomes separately or NCD and BRD combined (Table 1).

Practices with statistically significant associations or effects detected: Neonatal calf diarrhea

Timing of the calving season

Two out of three PAs reported that early calving herds had higher odds of treating 10% of calves, and calves from early calving herds had a higher risk than those from late calving herds (A: 20a, 2c; NA: 4d (Table 2)). The directionality of findings was consistent, yet the certainty of this evidence was low (Table 3).

Length of the calving season

One out of three PAs found that the odds of a herd having NCD detected were higher in those with longer calving seasons than those with shorter ones (A: 3b; NA: 2b, 4e [Table 2]). The directionality of the findings was inconsistent, and the certainty of the evidence was low (Table 3).

Other breeding and calving season management practices

Three out of four PAs found statistically significant associations of breeding and calving practices with NCD (A: 2a, 25r, 25a (Table 2); NA: 25b [Supplementary material 1]). However, the directionality of the findings for the timing of the breeding and calving of heifers and cows was contradictory across PAs. One PA showed that calves born in herds where heifers were bred before cows had a higher risk of NCD than those born in herds where heifers were not bred before cows (2a). However, another PA reported that calves from herds where heifers calved earlier than cows had a lower risk of NCD than those from herds where this practice was not used (25r). Also, calves from herds that frequently night-checked during the calving season had a higher risk of NCD than those from herds that did infrequent night checks (25a). No statistically significant association was found between routinely bedding cow–calf pairs and NCD in calves (25b).

Nutritional management of dams

Three out of six PAs reported statistically significant findings between dam supplementation and NCD (E: 17a, 17b, 17c; NE: 16a (Table 4); (NA): 2d, 2e [Supplementary material 1]). Three out of four PAs found a beneficial effect of supplementing dams with selenium (Se) (E: 17a, 17b, 17c; NE: 16a). Three of these PAs belonged to the same study, where different sources and doses of Se were compared (17a, 17b, 17c). Overall, fewer calves born from dams supplemented with 0.5 ppm of organic Se by *Saccharomyces cerevisiae* (17c) had NCD compared to those born from dams supplemented with 0.5 ppm of Se as sodium selenite (Na-selenite) (17b) or 0.1 ppm of Se as Na-selenite (17a). No impact was found in feeding corn pre- or post-calving (2d, 2e).

Nutritional management of calves

One out of three PAs found a statistically significant association between nutritional management in calves and NCD (A: 25h; NA: 25g, 4f [Table 4]). Specifically, one PA (25h) evaluating the impact of mineral and vitamin supplementation given to newborn calves showed that calves from herds that gave vitamin D and A injections close to birth had a higher risk of NCD than calves born from herds that did not.

Biosecurity

One out of five PAs found a statistically significant association between biocontainment practices and NCD outcomes (A: 25y (Table 5); NA: 25c, 25d, 25f, 25w [Supplementary material 1]). A single PA reported a statistically significant association between the use of nursery pastures and the herd-level risk of NCD (25y). Still, within this PA, the directionality of findings varied depending on the timing in which NCD was considered. Calves from herds that did not sort their cow–calf pairs had a higher risk of NCD from 24 h of birth until 5 days of age than those from herds that sorted. However, calves from herds that sorted pairs had a higher risk of NCD from 6 days of age until one month than those from herds that did not sort. There was no significant impact of managing cows and heifers together during the winter feeding (25c), winter feeding and calving in one area (25d), animals remaining in the calving area until or close to the end of the calving season (25f), or the number of times pairs were gathered (25w).

Dam vaccination against NCD-related pathogens

Eight out of 10 PAs that assessed the impact of vaccinating dams against pathogens involved in NCD found a statistically significant impact on NCD (E: 14a1, 14a2, 14b1, 14b2, 14c1, 14c2, 15b; NE: 15a; A: 3a; NA: 20b [Table 5]). Seven out of eight PAs showed consistent findings indicating that vaccination using vaccines that contained *E. coli* antigens prevented NCD (E: 14a1, 14a2, 14b1, 14b2, 14c1, 14c2, 15b; NE: 15a). Six PAs belonged to the same multiple-year study in which several variations in how the vaccine was administered were considered including whether vaccination was given to heifers or cows, the percentage of dams vaccinated in the group (0-100%), and the number of vaccine doses given

(14a1, 14a2, 14b1, 14b2, 14c1, 14c2). Calves born in groups where either 100% (14a1) or 50% (14a2) of dams were vaccinated with two doses of vaccine had a lower risk of NCD than calves born to a group of placebo dams (i.e., 0%). Similarly, calves born to a group of 100% vaccinated heifers with two doses (14b1), as well as those born to a group of 100% vaccinated cows with two doses (14b2), had lower risks of disease than those born to groups of placebo heifers and cows (i.e., 0%). Also, calves born to heifers had a higher risk of NCD than those born to cows. This was because calves born to 100% vaccinated heifers with two doses had a higher risk of NCD than those born to 100% vaccinated cows with two doses. Also, calves born to placebo heifers had a higher risk than those born to placebo cows. Calves born to heifers with one vaccine dose had a higher risk of disease than calves born to vaccinated cows with one dose (14c1). However, no differences were found between calves born to cows with two vaccine doses and those born to cows with one vaccine dose (14c2). Similarly, fewer calves born to dams vaccinated with a 4-strain *E. coli* bacterin vaccine died from NCD than calves born to placebo dams (15b). However, herds vaccinated against NCD were reported to have higher odds of detecting NCD and a higher incidence of calf mortality from NCD than unvaccinated herds (3a). The certainty of this body of evidence could not be assessed given that the outcomes reported differed across PAs (i.e., NCD morbidity versus NCD mortality).

Dam vaccination against disease caused by *Clostridium* spp.

A single PA reported that calves from herds that vaccinated dams against clostridial disease during the spring before calving had a lower risk of NCD than those born to unvaccinated dams or dams vaccinated in the fall (A: 20d [Table 5]).

Calf vaccination against NCD-related pathogens

A single PA found that calves from herds that were vaccinated against NCD pathogens had a higher risk of NCD than those from unvaccinated herds (A: 25z [Table 5]).

Practices with statistically significant effects or associations detected: Bovine Respiratory Disease

Colostrum management

One out of six PAs reported that colostrum practices affected BRD outcomes (A: 22e [Table 6]; NA: 4a, 4b, 4c, 13d, 24c [Supplementary material 1]). In one PA, BRD was more frequently detected in herds where colostrum was provided to at least one calf using an oesophageal tube or nipple bottle than those that did not provide colostrum to any calf (22e). However, none of the criteria used to determine whether a calf required colostrum intervention (e.g., verifying if the calf has nursed by observing fullness of udder; 4a, 4b, 4c), the sources of colostrum (e.g. frozen colostrum; 13d), or methods of feeding colostrum (24c) affected the risk or rate of BRD or the odds of a calf having BRD.

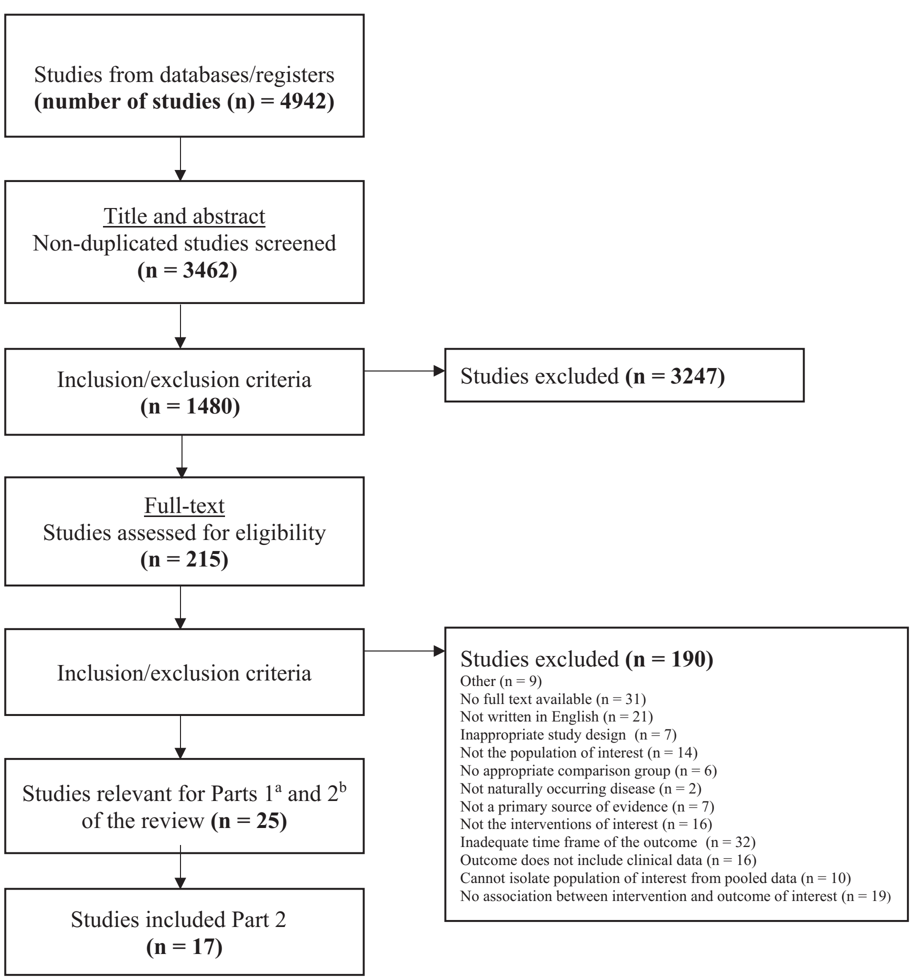

Figure 1. PRISMA flowchart of a systematic review on the effect of management practices on preweaned calf morbidity and mortality from neonatal calf diarrhea (NCD) and bovine respiratory disease (BRD) in beef herds. [a]General mortality; [b]Morbidity and mortality from NCD and BRD.

Table 2. Summary of findings and risk of bias assessment (ROB) for breeding and calving season management practices with significant associations or effects on neonatal calf diarrhea (NCD) from studies within a systematic review on the effect of management practices on preweaned calf morbidity and mortality in beef cow–calf herds

Practice assessment	Details about the practice	Association or effect	Overall ROB
Timing of the calving season			
20a	Start of calving season (first month when 10% of calves were born)	For every 1-month delay, odds of treating 10% of calves decreased (odds ratio (OR) 1.40, 95% confidence interval (CI): 1.07–1.83) ($P = 0.015$)	HIGH
2c	Early versus late calving (began calving before or after March 10)	Calves from early calving herds had a higher risk than those from late calving herds (OR 3.8, 95% CI: 3.2–4.5) ($P < 0.01$)	HIGH
4d	Month that calving began (January/February, March, April, May/June)	No significant association	HIGH
Length of the calving season			
3b	Length of calving season	For large herds, calving season was longer in herds with NCD compared to those without (6.76 months vs 5 months) ($P = 0.002$)	HIGH
2b	Length of the calving season	No significant association	HIGH
4e	Length of the calving season	No significant association	HIGH
Other breeding and calving season management practices			
2a	Heifers bred before cows (Yes, No)	Calves from Yes herds had a higher risk than those from No herds (OR 1.6, 95% CI: 1.4–1.9) ($P < 0.01$)	HIGH
25r	Calving cows and heifers together (Yes, No)	Calves from Yes herds had a higher risk than those from No herds (OR 3.94, 95% CI: 1.29–12) ($P = 0.02$)	HIGH
25a[a]	Night checks for dams during calving (Frequent, Infrequent)	Calves from herds with Frequent had a higher risk than those from Infrequent herds (OR 2.42, 95% CI: 1.29–4.53) ($p = 0.006$)	HIGH

[a]Suspect reverse causation or herds that use these practices have a higher baseline risk than those that do not (Clement *et al.*, 1993; Waldner *et al.*, 2022)

Timing of the calving season

Four out of five PAs found that the timing of the calving season affected BRD (A: 20a, 22j, 25p, 4d; NA: 24a [Table 6]). However, important differences existed between PAs. For example, one PA assessed whether the month that calving started was associated with the herd-level risk of disease (25p), and another assessed the impact of having >50% of calves born in January through April (22j). Overall, the directionality of the findings for herd-level outcomes was semi-consistent across PAs (20a, 22j, 25p, 4d). Two PAs found that herds that calved earlier or during winter and early spring had higher odds of treating 10% of calves and a higher cumulative incidence of disease than those calving later or in the spring (A: 20a, 22j). However, other PAs reported different directionality of findings. Calves from herds that started calving in December or April had a higher risk of disease than those from herds that started in March (25p). A fourth PA reported that the relationship between the timing of the calving season and the herd-level treatment risk of BRD was somewhat affected by other factors, including the incidence of NCD in the herd (4d). Therefore, for herd-level outcomes, the certainty of the findings was low (Table 3).

Length of the calving season

Three out of five PAs found that herds with longer calving seasons had higher odds of detecting BRD, a higher incidence within batches, or calves had a higher risk of BRD mortality than those with shorter seasons (A: 3b, 22c; 13a; NA: 21e, 4e [Table 6]). The directionality of the findings was consistent across PAs, but the overall certainty for the body of evidence on morbidity was low (Table 3).

Intensive calving area

Two out of four PAs reported that calving in intensive calving areas increased the odds of detecting BRD in herds or the incidence in herds (A: 22d, 25s; NA: 21h, 25t (Table 6)). The directionality of findings across PAs was semi-consistent, and the certainty of this evidence was low (Table 3).

Nutritional management

A single PA found that herds that used intensive grazing had higher odds of having over 5% of calves treated for BRD than those that did not use this practice (A: 21a [Table 7]).

Nutritional management of calves

Two out of eight PAs found an impact of nutritional management in calves and BRD outcomes (A: 13c, 22k [Table 7]; NA: 13b, 18i, 25m [Table 7], 4f, 25g, 25h [Supplementary material 1]). Two out of five PAs reported that calf supplementation with concentrate or maize or providing creep feeding was statistically associated with BRD outcomes (A: 13c, 22k; NA: 13b, 18i, 25m). However, the directionality of the findings was inconsistent. One PA reported that in calf batches where calves were fed maize silage, the incidence of BRD was lower than those not feeding silage (13c), while another reported that herds that fed supplemental feed had a higher cumulative incidence of BRD in calves than those that did not supplement (22k). Therefore, the certainty of this body of evidence was low (Table 3). Furthermore, injecting vitamins A, D, E, or Se to

Table 3. Assessment of the certainty of findings of management practices with significant effects or associations using the GRADE approach within a systematic review on the effect of management practices on preweaned calf morbidity and mortality associated with neonatal calf diarrhea (NCD) and bovine respiratory disease (BRD) in beef cow–calf herds

Practice category	Risk of bias	Directionality of results	Intervention, comparison groups, and similarities with western Canada	Imprecision of results	Overall certainty
Timing of the calving season, NCD (Number of practice assessments (n) = 3)	Critically high (Downgraded 2 levels) 3 practice assessments (PAs) (observational) with a high overall risk of bias	Consistent direction (No downgrading) 2 of 3 PAs indicated that herds that calved earlier had a higher frequency	Not consistent in intervention groups and comparison groups, consistently comparable with western Canada (Downgraded 1 level)	No estimate was calculated (Downgraded 1 level)	LOW
Length of the calving season, NCD (n = 3)	Critically high (Downgraded 2 levels) 3 PAs (observational) with a high overall risk of bias	Inconsistent direction (Downgraded 1 level) 1 of 3 PAs indicated that herds with longer season detected NCD more frequently Possible reasons: differing risks of disease	Consistent in intervention groups, comparison groups, and comparability with western Canada (No downgrading)	No estimate was calculated (Downgraded 1 level)	LOW
Timing of the calving season, BRD (herd-level) (n = 4)	Critically high (Downgraded 2 levels) 4 PA (observational) with a high overall risk of bias	Semi-consistent direction (No downgrading) 2 of 4 PAs indicated that herds calving earlier or during winter and early spring had a higher frequency, 1 of 4 PAs indicated that the frequency was lower in those that started calving in March, 1 of 4 indicated that BRD affected NCD. Possible reasons: NCD is an intervening variable between timing of the calving season and BRD outcomes	Not consistent in intervention groups and comparison groups, consistently comparable with western Canada (Downgraded 1 level)	No estimate was calculated (Downgraded 1 level)	LOW
Length of the calving season, BRD (n = 5)	Critically high (Downgraded 2 levels) 4 PA (observational) with a high overall risk of bias, 1 with some concerns	Consistent direction (No downgrading) 3 of 5 PAs indicated that herds with longer calving seasons had a higher frequency	Consistent in intervention groups, comparison groups, and comparability with western Canada (No downgrading)	No estimate was calculated (Downgraded 1 level)	LOW
Calving in an intensive area, BRD (n = 4)	Critically high (Downgraded 2 levels) 4 PA (observational) with a high overall risk of bias	Semi-consistent direction (No downgrading) 2 of 4 PAs indicated that herds that calved in intensive areas had a higher frequency. Possible reasons: different production groups (heifers and cows)	Not consistent in intervention groups and comparison groups, consistently comparable with western Canada (Downgraded 1 level)	No estimate was calculated (Downgraded 1 level)	LOW
Creep feeding and nutritional supplementation of calves, BRD (n = 5)	Critically high (Downgraded 2 levels) 5 PA (observational) with a high overall risk of bias	Inconsistent direction (Downgraded 1 level) 1 of 5 PAs indicated that herds that creep fed had a lower frequency, 1 of 5 indicated a higher frequency. Possible reasons: practice is related to intensive management and bunching of the herd	Consistent in intervention groups and comparison groups, and comparability with western Canada (No downgrading)	No estimate was calculated (Downgraded 1 level)	LOW
Introduction of dams to operations, BRD (n = 4)	Critically high (Downgraded 2 levels) 4 PAs (observational), 3 with a high overall risk of bias and 1 with some concerns	Inconsistent direction (Downgraded 1 level) 1 of 5 PAs indicated that herds that introduced dams had a higher frequency, 1 of 5 indicated lower frequency. Possible reasons: use of other management practices may reduce the risk including vaccination prior to introduction or quarantine	Semi-consistent in intervention groups and comparison groups, consistently comparable with western Canada (No downgrading)	No estimate was calculated (Downgraded 1 level)	LOW
Sorting cow–calf pairs into nursery pastures, BRD (n = 4)	Critically high (Downgraded 2 levels) 4 PA (observational) with a high overall risk of bias	Inconsistent direction (Downgraded 1 level) 1 of 4 PAs indicated that herds that sorted pairs had a lower frequency, 2 of 4 indicated a higher frequency. Possible reasons: reverse-causation, herds with a higher baseline risk use this practice	Not consistent in intervention groups and comparison groups, consistently comparable with western Canada (Downgraded 1 level)	No estimate was calculated (Downgraded 1 level)	VERY LOW

Table 4. Summary of findings and risk of bias assessment (ROB) for nutritional management with significant associations or effects on neonatal calf diarrhoea (NCD) from studies within a systematic review on the effect of management practices on preweaned calf morbidity and mortality in beef cow–calf herds

Practice assessment	Details about the practice	Association or effect	Overall ROB
Nutritional management of dams			
17a	Supplemental feeding of 0.1 ppm of Se as Na-selenite (NaSe0.1), 2 months before to 2 months after calving (Y-Se[c]0.5, NaSe0.1, NaSe0.5)	See 17b and 17c	HIGH
17b	Supplemental feeding of 0.5 ppm of Se as Na-selenite (NaSe0.5), 2 months before to 2 months after calving (Y-Se0.5, NaSe0.1, NaSe0.5)	Within 75 days of birth: NaSe0.5 calves had lower risk than NaSe0.1 (17a) calves (29%, $n = 4$ vs 65%, $n = 11$) ($P < 0.05$)	HIGH
17c	Supplemental feeding of 0.5 ppm of organic Se produced by *S. cerevisiae* CNCM 1-3060 (Selplex, Y-Se0.5), 2 months before to 2 months after calving (Y-Se0.5, NaSe0.1, NaSe0.5)	Within 2 weeks of birth: Y-Se0.5 calves had lower risk than NaSe0.1 (17a) calves (6%, $n = 1$ vs 35%, $n = 6$) Within 75 days of birth: Y-Se0.5 calves had lower risk than NaSe0.1 (17a) calves (19%, $n = 3$ vs 65%, $n = 11$) ($P > 0.05$)	HIGH
16a	Pre-calving SQ injection of Se as sodium selenite and vitamin E (Supplemented, Unsupplemented control)	No significant effect	HIGH
Nutritional management of calves			
25h[a]	Vitamins D and A injection within 2 days of birth (Yes, No)	From 6 days to 1 month: Calves from Yes herds had a higher risk than those from No herds (odds ratio 2.63, 95% CI: 1.19–5.88) ($P = 0.02$)	HIGH
25g	Selenium and vitamin E injections close to birth (Yes, No)	No significant association	HIGH
4f	Administered vitamin and/or mineral injection (Yes, No)	No significant association	HIGH

ppm, parts per million; Se, selenium; Na-selenite, sodium selenite; Y-Se, organic selenium; SQ, subcutaneous; [a]suspect reverse-causation or herds that use these practices have a higher baseline risk than those that do not (Waldner *et al.*, 2022).

Table 5. Summary of findings and risk of bias assessment (ROB) for biosecurity and vaccination practices with significant associations or effects on neonatal calf diarrhea (NCD) from studies within a systematic review on the effect of management practices on preweaned calf morbidity and mortality in beef cow–calf herds

Practice assessment	Details about the practice	Association or effect	Overall ROB
Biosecurity			
25y[a]	Sorting cow–calf pairs from the calving area and into nursery pastures after calving (Yes, No)	From 1 to 5 days: Calves from No herds had a higher risk than those from Yes herds (odds ratio (OR) 2.82, 95% CI: 1.03–7.75) ($P = 0.04$) From 6 days to 1 month: Calves from Yes herds had a higher risk than those from No herds (OR 1.82, 95% CI: 1.08–3.13) ($P = 0.03$)	HIGH
Dam vaccination against NCD pathogens			
14a1	Combine rotavirus–ETEC vaccine administered SQ twice within 30 days to pregnant females in the last trimester (50% Vaccinated, Placebo) $n = 677$, $n = 188$	Lower risk in 50% Vaccinated than Placebo (31% vs 77%) ($P < 0.05$)	HIGH
14a2	Combine Rotavirus-ETEC vaccine administered SQ twice within 30 days to pregnant females in the last trimester (100% Vaccinated, Placebo) $n = 159$, $n = 188$	Lower risk in 100% Vaccinated than Placebo (34% vs 77%) ($P < 0.05$)	HIGH
14b1	Combine Rotavirus–ETEC vaccine administered SQ twice within 30 days to pregnant females in last trimester (100% Vaccinated heifers, 100% Placebo heifers, 14b2 Vaccinated cows) $n = 219$, $n = 226$, $n = 593$	Lower risk in 100% Vaccinated heifers than in 100% Placebo heifers (54% vs 74%) ($P < 0.05$) Higher risk in 100% Vaccinated heifers than in 14b2 100% Vaccinated cows (54% vs 12%) ($P < 0.05$)	HIGH
14b2	Combine Rotavirus–ETEC vaccine administered SQ twice within 30 days to pregnant females in last trimester (100% Vaccinated cows, 100% Placebo cows, 14b1 Placebo heifers) $n = 593$, $n = 415$, $n = 226$	Lower risk in 100% Vaccinated cows than in 100% Placebo cows (12% vs 33%) ($P < 0.05$) Lower risk in Placebo cows than in 14b1 Placebo heifers (33% vs 74%) ($P < 0.05$)	HIGH

(*Continued*)

Table 5. (*Continued.*)

Practice assessment	Details about the practice	Association or effect	Overall ROB
14c1	Combined rotavirus–ETEC vaccine administered SQ within 30 days to pregnant females in the last trimester (Heifers given 1 dose, Placebo heifers, 14c2 cows given 1 dose) $n = 331$, $n = 149$, $n = 303$	No significant difference between Heifers given 1 dose and Placebo heifers Higher risk in Heifers given 1 dose than in 14c2 cows given 1 dose (41% vs 6%) ($p < 0.05$)	HIGH
14c2	Combined rotavirus–ETEC vaccine administered SQ within 30 days to pregnant females in the last trimester (Cows given 1 dose, Cows given 2 doses, Placebo cows) $n = 303$, $n = 254$, $n = 249$	Lower risk in Cows given 1 dose than in Placebo cows (6% vs 21%) ($P < 0.05$) Lower risk in Cows given 2 doses than in Placebo cows (3% vs 21%) ($P < 0.05$) No significant difference between Cows given 1 dose and Cows given 2 doses	HIGH
15b	4-Strain *E. coli* bacterin vaccine (Vaccinated, Placebo)	Fewer calves born to vaccinated cows died from NCD compared to Placebo ($n = 10/676$ vs $n = 16/699$) ($P < 0.025$)	HIGH
15a	K99 *E. coli* bacterin vaccine (Vaccinated, Placebo)	No significant effect	HIGH
3a	Herd vaccination against NCD (Yes, No)	For small herds, Yes herds had greater odds of detecting NCD than No herds (55.6% vs 30.5%) ($P = 0.01$). The risk of NCD mortality was higher in calves from Yes herds than those from No herds (42.9% vs 14.3%) ($P = 0.047$)	HIGH
20b	Use of scours vaccine (Yes, No)	No significant association	HIGH
Dam vaccination against *Clostridium* spp.			
20d	Use of clostridial vaccines in dams	Calves from herds that vaccinated in the fall had a higher risk than those from herds that vaccinated in the spring (OR 1.85, 95% CI: 1.20–2.87) ($P = 0.01$) Calves from herds that do not vaccinate had a higher risk than those from herds that vaccinated in the spring (OR 1.52, 95% CI: 1.04–2.21) ($P = 0.03$)	HIGH
Calf vaccination against NCD pathogens			
25z[a]	Calves vaccinated with oral vaccines against NCD by 2 days of age (Yes, No)	From 1 month to weaning: Calves from Yes herds had a higher risk than those from No herds (OR 4.58, 95% CI: 1.48–14.2) ($P = 0.008$)	HIGH

ETEC, enterotoxigenic *Escherichia coli*; SQ, subcutaneous.
[a]Suspect reverse-causation or herds that use these practices have a higher baseline risk than those that do not (Waldner *et al.*, 2022)

calves near birth was not associated with BRD outcomes (NA: 4f, 25g, and 25h).

Biosecurity

Six out of 12 PAs reported that external biosecurity practices impacted BRD outcomes (A: 22g, 22i, 25x, 18j, 18k, 18l; NA: 21d, 18d, 13i [Table 8], 13j, 21b, 25n [Supplementary material 1]). Five out of eight PAs showed that introducing certain types of cattle to the herd impacted disease and, in most cases, these introductions resulted in herds having higher odds of detection, incidence, or rates than herds that did not introduce cattle, although it varied between PAs as to which production group was actually associated with increased disease (A: 22g, 22i, 25x, 18j, 18k; NA: 21d, 18d, 13i). A higher proportion of herds that introduced any cattle had BRD detected in preweaned calves than those that did not (22g). Similarly, herds that introduced at least one calf to the operation from an outside source had a higher incidence of BRD than those that did not introduce animals (22i). The evidence on this body of evidence could not be assessed. Specifically, the evidence on dam introduction showed inconsistency in the directionality of findings (A: 25x, 18j; NA: 18d, 13i). One PA showed that calves from herds where any cows or calves were purchased during the pre-breeding period or calving season had a higher risk of BRD than those from herds that did not purchase during these periods (25x). Conversely, another PA reported that herds that imported bred heifers had lower BRD rates in calves than those that did not import bred heifers (18j). Therefore, the certainty concerning whether the introduction of dams increased the risk of BRD was low (Table 3). A single PA reported that herds that imported steers had higher BRD rates than those that did not (18k). Also, herds that had 1–2 or >30 visitors each month had higher disease rates than those with 3–5 or 6–30 (18l). No statistically significant relationship was found between the distance to other bovine units (13j), fence line contact with other herds (21b), and the use of communal pastures (25n) and BRD.

Six out of 9 PAs found that biocontainment practices affected BRD outcomes (A: 25w, 25k, 25r, 25y, 22h, 21g; NA: 18h [Table 8], 22f, 12e [Supplementary material 1]). Calves born in herds that gathered cow–calf pairs between calving and pasture turnout had a higher risk of BRD than those born from herds that did not gather pairs (25w). Also, calves born in herds that overwintered and calved in the same area (25k) or calved heifers and cows together (25r) had a higher risk of BRD than those that did not use these practices. Three out of four PAs showed that the use of

Table 6. Summary of findings and risk of bias assessment (ROB) for colostrum, breeding, and calving season management with significant associations or effects on bovine respiratory disease (BRD) from studies within a systematic review on the effect of management practices on preweaned calf morbidity and mortality in beef cow–calf herds

Practice assessment	Details about the practice	Association or effect	Overall ROB
Colostrum management			
22e	A bottle or tube was used to feed colostrum to ≥1 calf (Yes, No)	Higher proportion of Yes herds had BRD detected compared to No herds (38.3%, 95% confidence interval (CI): 29.4–47.2 vs 13.1%, 95% CI: 9.0–17.1) ($P< 0.001$)	HIGH
Timing of the calving season			
20a	Start of calving season (First month when 10% of calves were born)	For every 1-month (mon) delay, odds of treating 10% of calves decreased (odds ratio (OR) 1.79, 95% CI: 1.50- 2.14)	HIGH
22j	>50% of calves born in January through April (Yes, No)	Yes herds had a higher cumulative incidence than No herds (risk ratio (RR) 1.6, 95% CI: 1.1–2.4) ($P = 0.019$)	HIGH
25p	Month that calving started (December (Dec) to February (Feb), March (Mar)(referent), April (Apr) to May)	Before 2 months: Calves in herds that started calving in Dec had a higher risk than those in herds that started in Mar (OR 10.5, 95% CI: 2.87–38.1) ($P = 0.0004$) Calves in herds that started in Apr had a higher risk than those in herds that started in Mar (OR 6.68, 95% CI: 1.53–29.2) ($P = 0.01$) From 2 to 4 months: Calves in herds that started calving in Dec had a higher risk than those in herds that started in Mar (OR 8.51, 95% CI: 3.27–22.2) ($P = 0.0001$) Calves in herds that started in Apr had a higher risk than those in herds that started in Mar (OR 3.26, 95% CI: 1.18–8.98) ($P = 0.02$)	HIGH
4d	Month that calving started (January (Jan)/Feb, Mar, Apr, May/June)	A significant, positive non-linear association between herd-level treatment risk of BRD and herd-level treatment risk of NCD in herds that started calving in Mar ($P = 0.004$) and May/Jun ($P = 0.006$) compared with herds that started in Jan/Feb. Interaction was not significant ($P = 0.1$) for herds starting in Apr compared to Jan/Feb.	HIGH
24a	Birth season (Autumn, Winter, Spring, Summer)	No significant association	HIGH
Length of the calving season			
3b	Length of the calving season (months)	For small herds, herds with BRD had longer calving season than herds without BRD (5.75 months vs 4.04 months) ($P = 0.006$) The longer the calving season, the higher the percentage of calves that died from BRD ($P = 0.05$)	HIGH
22c	Number of months during which calves were born (<3 months, ≥3 months)	Higher proportion of herds with season ≥3 months had BRD detected compared to <3 months herds (25.0%, 95% CI: 20.2–29.9 vs 11.0%, 95% CI: 3.8–18.1) ($P = 0.009$)	HIGH
13a	Season of calving (Narrow Autumn, Broad Autumn, Narrow Winter, Broad Winter) (Autumn (i.e., <November (Nov) 15), Winter (i.e., >Nov 15)) (Narrow (<35 days (d)), Broad (≥35d)	Batches with longer calving seasons were more at risk than those with shorter calving seasons; however, which of these pairwise comparisons is statistically significant is unclear (30/48 vs 23/27 vs 15/31 vs 52/66)[a] ($P \leq 0.25$)	SOME CONCERNS
21e	Duration of the calving season (days)	No significant association	HIGH
4e	Length of the calving season (days)	No significant association	HIGH
Calving area			
22d	>50% of cows or heifers gave birth in confinement (Yes, No)	Higher proportion of Yes herds had BRD detected compared to No herds (31.9%, 95% CI: 22.8–41.0 vs 17.2%, 95% CI: 12.9 21.6) ($P = 0.002$)	HIGH
21h	Calving primiparous cows in a confined area (Yes, No)	No significant association	HIGH
25s	Heifer calving area density (Higher, Lower)	Before 2 months: Calves from Higher herds had a higher risk than those from Lower herds (OR 3.22, 95% CI: 1.28–8.11) ($P = 0.01$)	HIGH
25t	Cow calving areas density (Higher, Lower)	No significant association	HIGH

[a]Some batches were removed because of metaphylactic treatment, but it is unclear if these were from batches having BRD or not having BRD.

Table 7. Summary of findings and risk of bias assessment (ROB) for nutritional management with significant associations or effects on bovine respiratory disease (BRD) from studies within a systematic review on the effect of management practices on preweaned calf morbidity and mortality in beef cow-calf herds

Practice assessment	Details about the practice	Association or effect	Overall ROB
Nutritional management of the herd			
21a	Frequently moved to different pastures to intensively manage grass (Yes, No)	Higher odds of treating >5% calves in Yes herds than No herds (odds ratio (OR) 3.4, 90% confidence interval (CI): 1.4–8.2) ($P = 0.02$)	HIGH
Nutritional management of calves			
13c	Fed maize silage (Yes, No)	Lower incidence in Yes batches than No batches (49/73 vs 71/99) ($P < 0.25$)[a]	HIGH
13b	Fed concentrate (Yes, No)	No significant association	HIGH
22k	Nursing calves fed supplemental feed (e.g., creep feed) (Yes, No)	Higher risk in calves from Yes herds than No herds (risk ratio (RR) 1.7, 95% CI: 1.1–2.4) ($P = 0.007$)	HIGH
18i	Use of creep feeding	No significant association	HIGH
25m	Creep feeding calves before weaning (Yes, No)	No significant association	HIGH

[a]Some batches were removed because of metaphylactic treatment, but it is unclear if these were from batches having BRD or not having BRD.

nursery pastures impacted BRD outcomes (A: 25y, 22h, 21g; NA: 18h). Similarly to what was found for NCD, the directionality of findings across PAs was inconsistent to show that it prevented BRD. One PA found that calves from herds that sorted cow–calf pairs into nursery pastures had a lower risk of BRD than those from herds that did not sort (25y). However, two PAs showed that herds that sorted cow–calf pairs had higher odds of detecting at least one calf (22h) or treating at least 5% of their calves for BRD than those that did not (21g). Therefore, the certainty of this evidence was very low (Table 3). No statistically significant relationship was found between navel dipping (22f) or the frequency of using calving pens to house sick calves (12e) and BRD outcomes.

Dam vaccination against BRD-related pathogens

Two out of four PAs reported that vaccinating dams against BRD-related pathogens impacted BRD outcomes (A: 22b, 25l; NA: 13f, 18b [Table 9]). However, the directionality of findings was contradictory across PAs; thus, there was no consistent evidence proving that vaccination prevented BRD. One PA showed that calves from herds where dams were vaccinated had a lower risk of BRD than those from herds where dams were not vaccinated (25l), while another PA showed that BRD was more frequently detected in herds where dams were vaccinated than those that were not (22b). The certainty of this body of evidence could not be assessed due to differences in the pathogens targeted in the vaccines.

Calf vaccination against BRD-related pathogens

Five out of 11 PAs reported that vaccinating calves against BRD-related pathogens impacted BRD (E: 23a; A: 13e, 22a 25u, 18c; NE: 23b, 12a, 12b, 12c; NA: 18a, 18f [Table 9]). However, substantial differences existed among these PAs. For example, some reported calf-level outcomes (12a, 12b, 12c, 21a, 21b), while others herd- or batch-level ones (13e, 18a, 18c, 18f, 25u, 22a). Besides this, the vaccines used targeted different pathogens (e.g., BRSV in 13e and *Pasteurella* spp. in 18a). There was no consistency in the directionality of the findings showing a beneficial impact of vaccination across PAs. Only one PA reported that vaccinating calves twice with an inactivated BRSV, PIV3, and M. *haemolytica* vaccine reduced the number of calves requiring BRD treatment as well as reduced mortality compared to unvaccinated calves (23a). Conversely, four PAs found that herds or batches that reported vaccinating calves had a higher incidence, odds of detecting, or rates than those that did not vaccinate (13e, 22a, 25u, 18c). The certainty of this body of evidence could not be assessed given differences in outcomes and details concerning the vaccines.

Practices with no statistically significant associations or effects detected with NCD- or BRD-related outcomes

Supplementary material 1 summarizes practices without statistical associations or effects with NCD- or BRD-related outcomes or combined outcomes. These include colostrum management, breeding and calving management, nutritional management of dams and calves, and biosecurity practices.

Risk of bias assessment

This review included 87 PAs from observational studies and 16 from RCTs and CTs (Supplementary materials 2 and 3). For observational studies, 84 PAs had a high overall risk of bias, 3 had some concerns, and none had a low risk of overall bias. For RCTs and CTs, 14 PAs had a high overall risk of bias, two had some concerns, and none had a low risk of bias.

For PAs from observational studies, 77 had a high information bias. This was associated with a lack of details concerning the practices assessed (e.g., frequently moved to different pastures to manage grass intensively [21a]) and not providing case definitions for NCD and BRD (e.g., 2c). Seventy-eight PAs had selective reporting issues (e.g., univariable analyses were not shown (25n) or only practices with statistically significant associations kept in multivariable models were reported [4d]). Furthermore, 34 PAs had a high selection bias (e.g., participants were not selected using systematic methods or a convenience sample was used [4d]).

For PAs from RCTs and CTs, 11 had high risk of selective reporting (e.g. the results of logistic regressions were not shown [17a]). Nine PAs had a high risk of information bias, mainly because no details were provided about the blinding process (e.g., 12a). Similarly, intervention groups were sometimes commingled or not kept independent from each other (e.g., 23a). Also, case definitions were not given for NCD and BRD (e.g., 17a). Eight PAs had a high risk of confounding bias (e.g., there were no details concerning the randomization process [14a]).

Table 8. Summary of findings and risk of bias assessment (ROB) for biosecurity practices with significant associations or effects on bovine respiratory disease (BRD) from studies within a systematic review on the effect of management practices on preweaned calf morbidity and mortality in beef cow–calf herds

Practice assessment	Details about the practice	Association or effect	Overall ROB
Biosecurity			
22g	Introduction of outside cattle of any type to the operation (Yes, No)	Higher proportion of Yes herds had BRD detected than No herds (27.9%, 95% confidence interval [CI]: 22.2–33.6 vs 9.9%, 95% CI: 5.2–14.6) ($P < 0.001$)	HIGH
22i	≥1 calf introduced to the operation from an outside source during previous year (Yes, No)	Higher incidence in Yes herds than No herds (risk ratio [RR] 2.6, 95% CI: 1.2–5.5) ($P = 0.016$)	HIGH
21d	Cattle were added to the herd from outside sources (i.e., herd was open) (Yes, No)	No significant association	HIGH
25x	Any cows or calves purchased during calving season or pre-breeding period (Yes, No)	Before 2 months: Calves from Yes herds had a higher risk than those from No herds (odds ratio [OR] 3.5, 95% CI: 2.06–5.93) ($P < 0.001$) From 2 to 4 months: Calves from Yes herds had a higher risk than those from No herds (OR 4.11, 95% CI: 2.23–7.59) ($P = 0.0001$)	HIGH
18d	Import pre-weaned calves with dams (Yes, No)	No significant association	HIGH
18j	Import bred heifers (Yes, No)	Lower rates in Yes herds than No herds (incidence rate ratio [IRR] 0.40, 95% CI: 0.19–0,82) ($P = 0.013$)[b]	HIGH
13i	Proportion of purchase cows (0%, <10% of dams, ≥10% of dams)	No significant association	SOME CONCERNS
18k	Import weaned steers (Yes, No)	Higher rates in Yes herds than No herds (IRR 2.62, 95% CI: 1.15–5.97) ($P = 0.022$)[b]	HIGH
18l	Number of visitors on the operation in an average month (0 (referent), 1–2, 3–5, 6–30, >30)	Higher rates in herds that had 1–2 visits or >30 visits compared to 3–5 or 6–30 (pairwise comparisons not provided)	HIGH
25w	Number of times cow–calf pairs were gathered between calving and movement to summer pasture (range 0–5)	Before 2 months: Higher risk in calves from herds that gathered more frequently than those that did not (OR 2.17, 95% CI: 1.40–3.37) ($P = 0.0005$)	HIGH
25k	Winter feeding and calving in the same area (Yes, No)	Before 2 months: Calves from Yes herds had a higher risk than those from No herds (OR 6.0, 95% CI: 2.42–14.8) ($P < 0.001$)	HIGH
25r	Calve cows and heifers together (Yes, No)	Before 2 months: Calves from Yes herds had a higher risk than those from No herds (OR 3.55, 95% CI: 2.13–5.94) ($P < 0.0001$)	HIGH
25y	Sorting cow–calf pairs from calving area into nursery pastures after calving (Yes, No)	From 4 months - weaning: Calves from No herds had a higher risk than those from Yes herds (OR 4.89, 95% CI: 1.96–12.2) ($P = 0.0006$)	HIGH
22h[a]	Cow-calf pairs separated into groups by calf age (Yes, No)	Higher proportion of Yes herds had BRD detected than No herds (42.4%, 95% CI: 27.0–59.9 vs 19.2%, 95% CI: 15.0–23.4) ($P = 0.001$)	HIGH
21g[a]	Separation of cow–calf pairs by calf age (Yes, No)	Higher odds of treating 5% of calves in Yes herds than No herds (OR 4.1, 90% CI: 1.7–10) ($P = 0.009$)	HIGH
18h	Separation of cow–calf pairs from pregnant cows (Yes, No)	No significant association	HIGH

[a]Suspect reverse-causation or herds that use these practices have a higher baseline risk than those that did not (Woolums et al., 2018; Woolums *et al.*, 2013)
[b]Multivariable analyses were reported because univariable *p* values were ≤0.30 and were not reported for each variable in the univariable analysis.

Discussion

The overall findings suggest that most practices with statistically significant impacts were common for both NCD and BRD; however, differences concerning consistency in the directionality of findings suggest that their impact on these outcomes may vary. Most of the studies included in this review were observational, and thus the magnitude or directionality of findings are not as reliable as they should be for RCTs. However, given the high risk of bias in many of the RCTs and CTs, the evidence from these study types may also be unreliable. Therefore, although this review was able to summarize many of the practices that may help reduce calfhood morbidity and mortality, the low certainty of evidence means the findings should be interpreted with caution. Therefore, future well-conducted RCTs and observational studies should attempt to minimize bias to provide reliable evidence and support recommended practices.

Table 9. Summary of findings and risk of bias assessment (ROB) for vaccination practices with significant associations or effects on bovine respiratory disease (BRD) from studies within a systematic review on the effect of management practices on preweaned calf morbidity and mortality in beef cow–calf herds

Practice assessment	Details about the practice	Association or effect	Overall ROB
Dam vaccination against BRD pathogens			
22b[a]	Administration of vaccines against BRD pathogens to cows or replacement heifers (Yes, No/Do not know)	Higher proportion of Yes herds had BRD detected than No/Do not know herds (34.9%, 95% confidence intervals [CI]: 27.5–42.3 vs 11.8%, 95% CI: 7.2–16.3) ($P < 0.001$)	HIGH
25l	Vaccinated cows against bacterial BRD pathogens in previous year (Yes, No)	From 4 months - weaning: Calves from No herds had a higher risk than those from Yes herds (odds ratio [OR] 8.07, 95% CI: 1.64–39.7) ($P = 0.01$)	HIGH
13f	Vaccinated cows against bovine viral diarrhoea virus (BVDV) (Yes, No)	No significant association	HIGH
18b	Vaccinated cows against bovine herpes virus 1 (BHV1), BVDV, parainfluenza-3 virus (PI3), and bovine respiratory syncytial virus (BRSV) (Yes, No)	No significant association	HIGH
Calf vaccination against BRD pathogens			
23a	Vaccinated with inactivated BRSV and PI3, and *Mannheimia haemolytica* (MH) vaccine twice at a 4-week interval (Vaccine, Placebo)	Mortality: Lower incidence in Vaccinated calves (0/148 vs 3/65) ($p = 0.00$), Morbidity: Lower odds in Vaccinated calves (OR 0.26, 95% CI: 0.1–0.64) ($P = 0.00$)	SOME CONCERNS
23b	Vaccinated with live BRSV, PI3, and BVDV vaccine twice at a 4-week interval (Vaccine, Placebo)	No significant effect	SOME CONCERNS
12a	Vaccinated with MH and *Histophilus somni* (HS) twice at 3 and 5 weeks of age (Vaccine, 12b, 12c, Placebo)	No significant effect	HIGH
12b	Vaccinated with BRSV vaccine twice at 3 and 5 weeks of age (Vaccine, 12a, 12c, Placebo)	No significant effect	HIGH
12c	Vaccinated with MH, HS, and BRSV vaccine twice at 3 and 5 weeks (Vaccine, 12a, 12b, Placebo)	No significant effect	HIGH
13e[a]	Vaccinated against BRSV (Yes, No)	Yes batches were more at risk than No batches (81/107 vs 39/65) ($P < 0.25$)[b]	HIGH
22a[a]	Administration of vaccines against BRD pathogens to calves before weaning (Yes, No)	Higher proportion of Yes herds had BRD detected than No herds (31.9%, 95% CI: 23.9–39.8 vs 16.3%, 95% CI: 11.5–21.1) ($P < 0.001$)	HIGH
25u[a]	Vaccinated with a bacterial vaccine against BRD before summer pasture (At or near birth, After 1 week and before summer pasture, No vaccine)	Before 2 months: Calves from herds vaccinated at or near birth had a higher risk than those from no vaccine herds (OR 4.42, 95% CI: 1.51–13.0) ($P = 0.007$) From 2 - 4 months: Calves from herds vaccinated at or near birth had a higher risk than those from no vaccine herds (OR 8.55, 95% CI: 4.72–15.5) ($P = 0.0001$) Calves from herds vaccinated after 1 wk and before summer pasture had a higher risk than those from no vaccine herds (OR 2.99, 95% CI: 1.62–5.53) ($P = 0.0005$) From 4 months - weaning: Calves from herds vaccinated after 1 wk and before summer pasture had a higher risk than those from no vaccine herds (OR 39.9, 95% CI: 7.07–225) ($P = 0.0001$)	HIGH
18a	Vaccinated against MH at 22 days to weaned calves (Yes, No)	No significant association	HIGH
18f	Vaccination against BHV1, BVDV, PI3, and BRSV at 22 days to weaned calves (Yes, No)	No significant association	HIGH
18c[a]	Number of times calves vaccinated against BRD between birth and weaning (0, 1, 2, 3)	Higher rates in calves from herds that vaccinated 1 time compared to 0 (incidence rate ratio [IRR] 2.82, 95% CI: 1.04–7.69) Higher rates in calves from herds that vaccinated 2 times compared to 0 (IRR 2.79, 95% CI: 1.09–7.18)	HIGH

[a]Suspect reverse-causation or herds that use these practices have a higher baseline risk than those that did not (Assié *et al.*, 2009; Hanzileck *et al.*, 2013; Waldner *et al.*, 2022; Woolums *et al.*, 2013).
[b]Some batches were removed because of metaphylactic treatment but it is unclear if these were from batches having BRD or not having BRD.

Calves from early calving herds consistently had a higher risk of NCD than calves from later calving herds in studies conducted in the United States and Canada (Clement *et al.*, 1993; Murray *et al.*, 2016; Waldner *et al.*, 2013). This finding aligns with what was described for calf mortality (Sanguinetti *et al.*, 2025). This might be because herds that calve early usually calve, at least partially, inside barns to protect newborn calves from the cold, which typically involves herds being managed more intensively than those calving on pasture (Ganaba *et al.*, 1995; Radostits, 1991). In barns, calves are exposed to an environment more favourable to pathogen transmission between animals (Assié *et al.*, 2009; Doeschl-Wilson *et al.*, 2021). Calves born in winter are also more prone to cold stress, which can decrease the intestinal absorption of immunoglobulins from colostrum (Olson *et al.*, 1980). Similarly, the body of evidence for BRD showed semi-consistent directionality of findings (Murray *et al.*, 2016; Waldner *et al.*, 2013, 2022; Woolums *et al.*, 2013). Hypothetically, for BRD, this semi-consistent directionality of findings could indicate that other factors may be affecting the relationship between the timing of the calving season and BRD (Dohoo *et al.*, 2009). For example, one PA reported that the incidence of NCD in herds influenced the incidence of BRD (Murray *et al.*, 2016), suggesting NCD could be an intervening or moderator variable between the timing of the calving season and BRD (Dohoo *et al.*, 2009).

Herds with longer calving seasons consistently showed that they had higher odds of having BRD detected and a higher incidence of BRD than those from herds with shorter calving seasons (Assié *et al.*, 2009; Dutil *et al.*, 1999; Woolums *et al.*, 2013). These findings align with those described previously for mortality (Sanguinetti *et al.*, 2025). It may be that herds with longer calving seasons have a more heterogeneous crop of calves in terms of age (Larson and Tyler, 2005). Therefore, younger calves are at higher risk of getting sick, given that they are challenged with increasing amounts of pathogens excreted by older calves, which are more resistant to disease (Larson and Tyler, 2005). Limiting the calving season to 80 days can minimize pathogen amplification, reducing the risk of disease (Chenoweth and Sanderson, 2005; WCCS, 2017). In contrast to BRD, only one out of three PAs reported that the odds of detecting NCD were higher in herds with longer seasons compared to those with shorter ones (Clement *et al.*, 1993; Dutil *et al.*, 1999; Murray *et al.*, 2016), and this body of evidence showed inconsistent directionality of findings. This may be because these studies had variable disease risks, and this could affect the impact of the practice (Clement *et al.*, 1993; Dutil *et al.*, 1999; Murray *et al.*, 2016). However, this hypothesis could not be assessed because some studies reported herd-level incidence of NCD (Clement *et al.*, 1993; Murray *et al.*, 2016), while another reported the percentage of herds where NCD was detected (Dutil *et al.*, 1999).

The bodies of evidence on intensive calving and intensive nutritional practices showed that these were associated with an increased risk of disease in calves. Specifically, calving in intensive areas, frequently monitoring cows during night-time, creep-feeding calves, intensive grazing, and calf mineral and vitamin supplementation close to birth were shown to increase the odds of detection of BRD in herds, the cumulative incidence of BRD, or the herd-level incidence of BRD and NCD (Assié *et al.*, 2009; Hanzliceck *et al.*, 2013; Waldner *et al.*, 2022, 2022; Woolums *et al.*, 2018, 2013). In studies conducted in the United States and Canada, findings were semi-consistent for intensive calving areas. Under field conditions, intensive calving practices are largely related to each other. For example, to monitor dams in case they need assistance at calving, they are typically placed in pens or paddocks close to the working facilities, and these sites usually have a high stocking density (Chenoweth and Sanderson, 2005). One hypothetical explanation of why intensive calving practices increase the risk of disease is that close to parturition, dams may shed high amounts of pathogenic agents, including *Cryptosporidium* (Thomson *et al.*, 2019), *Salmonella* (Muñoz-Vargas *et al.*, 2022), or BRoV and BCoV (Bulgin *et al.*, 1989). Therefore, calves born in these sites are exposed to environments with a higher pathogen load than those born in more extensive calving settings and thus pathogen transmission rates may be higher. Besides this, herds that are more intensively managed are more likely to monitor the health status of calves, and consequently, this may be reflected in treating more calves compared to those more extensively managed. Given this, herds that manage calving intensively may need to consider additional practices, such as increased bedding, using nursery pastures (i.e., Foothills calving system), or moving the calving area during the season (i.e., Sandhills calving system) to reduce environmental contamination. However, only one PA found that herds that used nursery pastures had a lower risk of NCD from 1 to 5 days of age than those not using them (Waldner *et al.*, 2022). Yet, no details concerning age differences between calves in the same pasture or stocking density in the pasture were provided. Furthermore, none assessed aspects of the Sandhills calving system. These two practices where calves are segregated by age are important given that they have been promoted in Canada and the US (Radostits and Acres, 1983; United States Department of Agriculture Animal and Plan Health Inspection Service Veterinary Services National Animal Health Monitoring System, 2021). Similarly, intensive nutritional practices increase the bunching of the herd. For example, creep-feeding tends to crowd calves around feed bunks. Therefore, although creep feeding may have benefits on post-weaning morbidity and mortality (Chenoweth and Sanderson, 2005), this practice may be detrimental during the preweaning stage if not done with attention to environmental conditions that may promote the spread of pathogens.

A limited body of evidence showed that the source of Se used to supplement dams affected the incidence of NCD in calves (Guyot *et al.*, 2007). Supplementing with organic Se was more beneficial than Na-selenite, regardless of the dose used. This is likely because organic forms of Se have higher absorption and bioavailability (Arshad *et al.*, 2021; Gunter *et al.*, 2003), and these have been associated with higher concentrations in blood and milk than those supplemented with inorganic forms (Slavik *et al.*, 2013). Still, the benefits of Se supplementation of dams appear to be more evident in enhancing reproduction (Gunter *et al.*, 2003) than in benefitting calfhood health, given that the latter is more indirect. There are a number of additional factors that can impact if calves benefit from dam supplementation. These include the product itself (i.e., bioavailability), the dams' initial mineral status, the efficiency of the mineral to pass through the placenta (Gooneratne and Christensen, 1989; Pavlata *et al.*, 2003), colostrum, and milk (Slavik *et al.*, 2013), and finally, the ability of the calf to nurse from its dam.

While none of the biosecurity practices assessed were associated with prevention of NCD or BRD, several practices were shown to be risk factors that increase the incidence of disease in herds. In general terms, introduction of animals to the herd increased the incidence of BRD (Hanzlicek *et al.*, 2013; Waldner *et al.*, 2022; Woolums *et al.*, 2013). Similarly, another study not included in this review found that introducing more than 10 bulls in the herd increased the odds of NCD and BRD outbreaks (Wennekamp *et al.*, 2021). This study was excluded from this review because the outbreak definition included other animals besides preweaned beef calves. Possible explanations for why the introduction of animals increases the risk of BRD include that purchased cattle are usually transported, which triggers stress, affects immunocompetence, and increases pathogen shedding (Chen *et al.*, 2022; Taylor *et al.*, 2010). Additionally, upon arrival, unless new purchases are quarantined, these are commingled with the herd, where social mixing takes place and exposes the herd to new pathogens (Chen *et al.*, 2022; Hubbard *et al.*, 2021). However, the specific body of evidence assessing the introduction of dams did not show consistent directionality of findings (Assié *et al.*, 2009; Hanzileck *et al.*, 2013; Waldner *et al.*, 2022). One study reported that herds that introduced bred heifers had a lower rate of BRD than those that did not (Hanzileck *et al.*, 2013). This inconsistency could be because other management practices that were not reported could have potentially mitigated the impact of the introduction. For example, maybe these herds that introduced heifers had a set of disease control practices in place when introducing them, including purchasing from one trusted source, avoiding long-distance travelling, vaccination prior to introduction, and quarantining animals upon arrival (Chenoweth and Sanderson, 2005; Sanguinetti *et al.*, 2025; Santinello *et al.*, 2024; Wennekamp *et al.*, 2021).

The directionality of findings for the use of nursery pastures and calf vaccination against BRD-related pathogens was inconsistent in showing that these practices prevented BRD (Assié *et al.*, 2009; Hanzileck *et al.*, 2013; Makoschey *et al.*, 2008; Van Donkersgoed *et al.*, 1994; Waldner *et al.*, 2022; Woolums *et al.*, 2013). As mentioned before, the use of nursery pastures or a series of calving pastures is intended to segregate calves by age to reduce the pathogen challenge to which newborn calves are exposed. This prevents newborn calves from being exposed to high pathogen concentrations in their environments (Chenoweth and Sanderson, 2005) and thus helps reduce the risk of disease in calves. Vaccination may enhance antigen-specific immunity (Thrusfield and Christley, 2018) and decrease the probability or severity of disease, including NCD and BRD (Callan and Garry, 2002). Similar to the findings of this review, two other reviews that included challenge studies found scarce evidence to support or refute the practice (Chamorro and Palomares, 2020; Theurer *et al.*, 2015). Reasons for the conflicting directionality of findings of the bodies of evidence of these two practices could be related to the fact that in some scenarios, herds that use these practices have a higher risk of disease than those that do not (Waldner *et al.*, 2022). In this review, most studies are cross-sectional and cannot provide evidence on the temporal relationship between exposure and outcome (Van der Stede, 2014; Dohoo *et al.*, 2009); thus, estimates are prone to reverse causation. Future RCTs or cohort studies could provide evidence on temporality and help elucidate the impact of various disease control practices. The cohort study design could be particularly beneficial given that it would be somewhat difficult to randomize cattle for some of the practices mentioned, such as calving pasture management and the biosecurity practices outlined above.

The directionality of findings could also be affected by the disease risk impacting the effectiveness of the practices. For example, PAs compiled for calf vaccination came from studies with disease risks varying from 3% to 28% (Hanzileck *et al.*, 2013; Makoschey *et al.*, 2008; Van Donkersgoed *et al.*, 1994). Nevertheless, no clear pattern showed that PAs with significant associations or effects came from studies with higher disease risk compared to those with non-significant associations or effects from studies with lower disease risks, as seen elsewhere (Sanguinetti *et al.*, 2025). Another potential reason for the inconsistent directionality of findings for vaccination is the interference by maternal antibodies when attempting to vaccinate calves (Windeyer and Gamsjäger, 2019). For example, an RCT where calves were subcutaneously vaccinated twice from 3 to 5 weeks of age did not find a significant benefit of vaccination (Van Donkersgoed *et al.*, 1994). However, no details were provided concerning dam vaccination nor the transfer of passive immunity (TPI) in these calves. Therefore, calf vaccination against BRD-related pathogens is likely an area that requires more well-conducted RCTs to help determine for which herds this practice is more beneficial to be implemented, as well as optimum timing and routes of administration. This is because there is some evidence that parenteral vaccination in the face of maternal antibodies may activate the cell-mediated response (Platt *et al.*, 2009) and prime the immune system (Endsley *et al.*, 2003), while intranasal vaccination may circumvent maternal antibodies and offers more immediate protection to calves (Ellis *et al.*, 2013). Similarly, more research is needed to optimize the use of the nursery pastures or a series of calving pastures, as mentioned previously for NCD.

Vaccinating dams using vaccines that contained *E. coli* agents reduced the risk of NCD morbidity and mortality (Cornaglia *et al.*, 1992; Myers, 1980). This aligns with the findings of another systematic review, which included dairy studies (Maier *et al.*, 2022). Calves born from vaccinated dams have higher serum antibodies targeting *E. coli* and reduced odds of morbidity and mortality compared to those born from unvaccinated dams (Gamsjäger *et al.*, 2023a; Wileman *et al.*, 2011). Therefore, by vaccinating dams according to label instructions (Compendium of Veterinary Products-Canada edition, 2021) and ensuring that the TPI is adequate (Gull, 2022; Tizard, 2021), dam vaccination containing *E. coli* agents may help prevent NCD.

A limited body of evidence indicated that vaccinating dams against clostridial disease reduced the risk of NCD and that vaccination against BRD-related pathogens prevented BRD (Waldner *et al.*, 2013, 2022). Another scoping review also described a scarcity of findings to support clostridial vaccination for NCD prevention (Maier *et al.*, 2022). However, vaccination of dams against clostridial pathogens has been described as the most helpful practice to prevent NCD caused by *Clostridium perfringens* types C and D (Gull, 2022). Furthermore, an expert consensus study conducted in western Canada reported that dam vaccination was useful to prevent calf mortality 'very much for most herds' (Sanguinetti *et al.*, 2025). Similarly, calves with higher antibody titers against BHV1, PIV3, and BVDV had lower odds of being treated or dying than those with lower antibody titers (Gamsjäger *et al.*, 2023a). Therefore, dam vaccination against clostridial pathogens and BRD-related agents may be beneficial, although reliable evidence is still lacking.

The overall strategy used in this review to retrieve relevant studies seemed appropriate for most practices; however, it may have been somewhat limited for retrieving colostrum management studies. The exclusion criteria removed studies where calf morbidity and mortality were not recorded for at least three months of age, meaning that colostrum studies that followed calves for a shorter period of time were not included. A recent systematic review assessing TPI in beef and dairy calves reported that cohort and RCTs had an average follow-up of 75.5 days long (Thompson and Smith, 2022). Among the included studies, most were cross-sectional studies with most doing follow-up during the entire preweaning period and did not report statistically significant associations with the outcomes of interest (Assié *et al.*, 2009; Murray *et al.*, 2016; Pearson *et al.*, 2019b; Pisello *et al.*, 2021; Woolums *et al.*, 2013). However, cross-sectional studies are known to provide evidence of associations and not causation (Dohoo *et al.*, 2009), and most of them analysed their findings using multivariable models, the limitations of which have been extensively discussed elsewhere (Sanguinetti *et al.*, 2025). Therefore, it is likely that these non-significant findings are related to the study design and statistical methods used rather than colostrum management not impacting NCD and BRD. Additionally, many colostrum studies assessed either the relationship between colostrum management and TPI (Gamsjäger *et al.*, 2023b) or the relationship between the TPI and health outcomes (Dewell *et al.*, 2006; Gamsjäger *et al.*, 2023a), but not the relationship between colostrum management and health. The intermediate outcome of TPI is relevant because calves with failed TPI have a higher risk of morbidity and mortality than those with adequate TPI (Homerosky *et al.*, 2017; Raboisson *et al.*, 2016; Thompson and Smith, 2022; Todd *et al.*, 2018; Windeyer *et al.*, 2014; Wittum and Perino, 1995). However, the inclusion criteria stated that only studies assessing the direct relationship between practices and morbidity and mortality could be included. Finally, other syndromes besides NCD and BRD, such as arthritis and omphalitis (Filteau *et al.*, 2003; Waldner and Rosengren, 2009), were often included in morbidity outcomes, and these studies violated the inclusion criteria, again affecting the retrieval of relevant colostrum management studies. Given these limitations, the findings for colostrum management in this review may be unreliable, and there is still a gap in knowledge concerning recommended colostrum practices to prevent NCD and BRD.

Conclusions

This review compiled evidence concerning the impacts of management practices on calf health and its potential implications for guiding recommendations for western Canadian beef cow-calf herds. Evidence showed that many breeding and calving management, nutritional management, biosecurity, and vaccination can impact beef calf health. However, the consistency in the directionality of findings depended on the specific outcome NCD or BRD, suggesting that the impact of practices may vary depending on the outcome assessed. Furthermore, the impact of practices may also vary depending on other management, host, and environmental factors that were not assessed in the reported studies. Overall, the certainty of the bodies of evidence was low, meaning that more well-executed RCTs and cohort studies are needed to provide reliable evidence on the directionality of findings and the magnitude of their effects.

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