Determining frequency of mortality by cause and association with days-of-age categories at 2 commercial calf ranches

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Abstract

Limited information is available describing mortalities of dairy and beef-dairy-cross calves in commercial calf ranches. Study objectives were to report frequency of gross mortality diagnoses at necropsy in commercial calf ranches and to determine potential associations of age with diagnosis. Full systematic necropsies (n = 211) were performed at 2 Kansas calf ranches by field technicians with confirmed diagnoses by a single veterinarian. Mortality diagnoses were categorized as gastrointestinal (GI), respiratory (RESP), septicemia or other based on gross lesions. A subset of calves had age data (n = 145) which were categorized as (1 to 29, 30 to 59, 60 to 89, and greater than 90 days). A generalized linear model was used to evaluate probability of being classified as RESP or GI diagnoses based on breed type, sex and age categories. Gross necropsy revealed 71.1% (150/211) of all mortalities were categorized as RESP, 18.5% (39/211) as GI, 7.1% (15/211) as septicemia, and 3.3% (7/211) as other. Breed type and sex were not associated with probability of RESP or GI diagnosis. Calves greater than 60 days of age were at greater ($P < 0.05$) risk (88 ± 4%) for RESP diagnoses compared to calves less than 30 days (37 ± 8%). Probability of GI diagnosis (46 ± 8%) was greater ($P < 0.05$) for calves less than 30 days compared to calves between 60 and 89 days (5 ± 3%). The frequency of multiple disease processes emphasizes the importance of necropsy to determine diagnosis in each case. These data add valuable information about mortalities in commercial calf ranches.

Key words: calf ranch mortality, bovine respiratory disease, beef-dairy-cross, necropsy

Introduction

Breeding practices in the dairy industry have evolved with the introduction of using sex-selected semen from beef sires to produce beef-dairy-cross calves (BOD). These BOD cattle have improved attributes for commercial production of beef while also providing added value to bull calves born at dairies. According to the National Association of American Breeders, from 2022 to 2023, dairy semen sales decreased by 2.5 million units, while beef semen sales increased by about 1.5 million units.[16] In 2023, U.S. dairy producers shifted to female-sex-selected dairy semen, which led sales at 8.4 million units, followed by male-sex-selected beef at 7.9 million units, and last, conventional dairy semen at 7 million units. Similar to dairy calves, young BOD calves are raised from 1 day of age without the dam. In the last several years, this process has evolved, and to increase production efficiency and specialization of management, BOD calves are often transported to a calf ranch or growing operation. A calf ranch can be defined as an operation that raises calves from as young as 1 day of age to a targeted weight which is dictated by the marketing plans for those calves. Some calf ranches raise cattle until weaning only, while others raise them through a longer growth phase. Unlike other phases of cattle production, limited information exists on frequency of mortality causes in the calf ranch phase. There have been previous reports of mortality data and findings in the beef cow-calf sector as well as the dairy industry.[10,12] With the increase in BOD animals, little to no previous literature has reported on causes of mortality for these young calves and if there are differences in pathology compared to straightbred dairy calves.

Identifying specific contributing factors to mortalities is key to creating targeted prevention and intervention programs. Disease syndromes vary in frequency based on many factors including: animal age, exposure risks and production-management. Accurately identifying disease in moribund calves and cause of mortalities can provide calf ranches with more information for management and health care decisions. Gross necropsy can be a valuable diagnostic tool to identify major pathological conditions and specific organ systems affected. Gross necropsy also gives producers more information about disease processes at time of death. Accurate diagnosis allows producers to better understand most frequent diseases on their operation and tailor preventive health programs to match disease syndromes. Additionally, gross necropsy diagnosis can be compared to clinical diagnosis in an effort to evaluate clinical diagnostic accuracy. Previous literature has shown that gross necropsy findings are often different than diagnoses made by producers visually assessing the live animal prior to death and based on treatment records.[2,6] Understanding frequencies of specific disease syndromes is important in order for preventive and therapeutic measures to be targeted in the correct areas. For example, gross necropsies allow the producers to know if the most common type of respiratory disease is acute vs. chronic vs. embolic, which would each potentially require different interventions such as identifying disease earlier, different treatment protocols, or changing management of tubing calves.

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Respiratory disease is the most frequent disease diagnosed in deceased feedyard cattle, but in pre-weaned beef cattle, the leading cause of mortality varies by age class.[3,7,13] This same finding has been well-documented in pre-weaned dairy heifers, but limited work has evaluated causes of mortality in large calf ranches, or specifically evaluated mortality causes in BOD cattle.[1,8,11,12,14]

The objectives of this research were to report the frequency of causes of mortality by gross necropsy in young cattle on commercial calf ranches and to determine the association of breed type (dairy vs. BOD), sex and days of age with mortality diagnosis as determined by gross necropsy. Causes of mortality for the purpose of this study were determined by gross pathological findings, rather than etiologic agent. Secondarily, causes of mortality were described by breed type. Finally, the relationship between age and cause of mortality was investigated to determine the probabilities of different final diagnoses upon gross necropsy. The hypothesis was that the proportion of gastrointestinal (GI) mortalities will decrease and that other causes of mortality will increase with age.

Materials and methods

The Kansas State University Institutional Animal Care and Use Committee (IACUC) was contacted regarding the project and no approval was needed due to evaluations of only deceased animals.

This cross-sectional observational study was designed with animal as the experimental unit to determine frequency of mortality causes in commercial calf ranches. Calf ranches (n = 2) in the central High Plains region of the U.S. were identified for participation, and deceased cattle were necropsied between June 15, 2023, and July 15, 2023. Mortalities were enrolled in the study on a convenience basis with necropsies conducted between 8 am and 3 pm each day. Not all cattle at each operation were necropsied each day due to time constraints. Cattle were evaluated for outward signs of autolysis (e.g., tissue color, smell, texture), and only cattle with no or minimal gross autolysis were enrolled.

Full, systematic necropsies were performed as described in previous work by two field technicians (CC, CB) with confirmation of all diagnoses by a veterinarian (BJW).[5] Findings from each necropsy were recorded through a form (see supplemental form) including evaluation of all major organ systems and describing specific pathology(ies) observed. A specific individual identifier (ear tag) and multiple digital photographs were recorded for each animal.

Each animal evaluation was initiated with an external examination including identifying sex, breed type and any outward signs of disease including swellings or signs of musculoskeletal conditions. The animal was then fully opened to evaluate internal organs and body systems, including: oral cavity, esophagus, larynx pharynx, trachea, lungs, liver, abomasum, rumen, large and small intestine, kidney, bladder and heart. Gross pathological lesions were recorded, and the summation of findings was used to generate the final diagnoses which were categorized into GI, RESP, septicemia or other. Gastrointestinal diseases included inflammation and/or hemorrhage of the digestive tract, bloat, peritonitis, ulcerations on the mucosal surface of the digestive tract, abnormal digestive contents, and/or scours. In some cases, the presence of scours was confirmed based on external evidence on the hindquarters of the animal. Septicemia was diagnosed based on the appearance of major organs including lungs or heart observed to have signs consistent with septicemia or toxemia (Figure 1). In septicemia cases, petechiae and ecchymosis were often identified on both pulmonary and cardiac tissues.

Respiratory diseases were determined based on the gross examination of the pulmonary surface and cut sections of the lungs. In all cases, the lungs were removed in their entirety for full examination. Respiratory pathologies were sub-categorized into 4 major groupings: acute bronchopneumonia, chronic bronchopneumonia, bronchopneumonia with an interstitial pattern (BIP), and aspiration/embolic pneumonia (Figure 2). Bronchopneumonia diagnosis was based on multiple characteristics including consolidated, firm lung lobes, presence of fibrin tags/adhesions, and presence of pulmonary abscesses. Pathological characteristics were not all present in every case and the extent of lesions varied by case. Bronchopneumonia cases were further categorized into acute or chronic based on the extent and type of lesions present. Cases with severe abscessation, large areas of consolidation, fibrinous adhesions, and most of the lung volume impacted were considered chronic. The diagnosis of BIP has been reported in feedyard cattle and is described as cattle with characteristics of both bronchopneumonia and interstitial pneumonia.[5] Typically, in BIP cases, bronchopneumonia is diagnosed in the cranioventral region of the lungs with interstitial pneumonia in the caudodorsal regions. A final RESP diagnosis of aspiration/embolic pneumonia was based on finding pulmonary abscesses in varied parts of the lung without a specific pattern or area of consolidation. Cases not classified as GI, septicemia, or RESP were classified in the other category which included congenital defects (hernia, organ malformation) and cases where no diagnosis was apparent by gross necropsy.

Figure 1: Example of lungs from calf diagnosed with septicemia based on gross necropsy at a commercial calf ranch.

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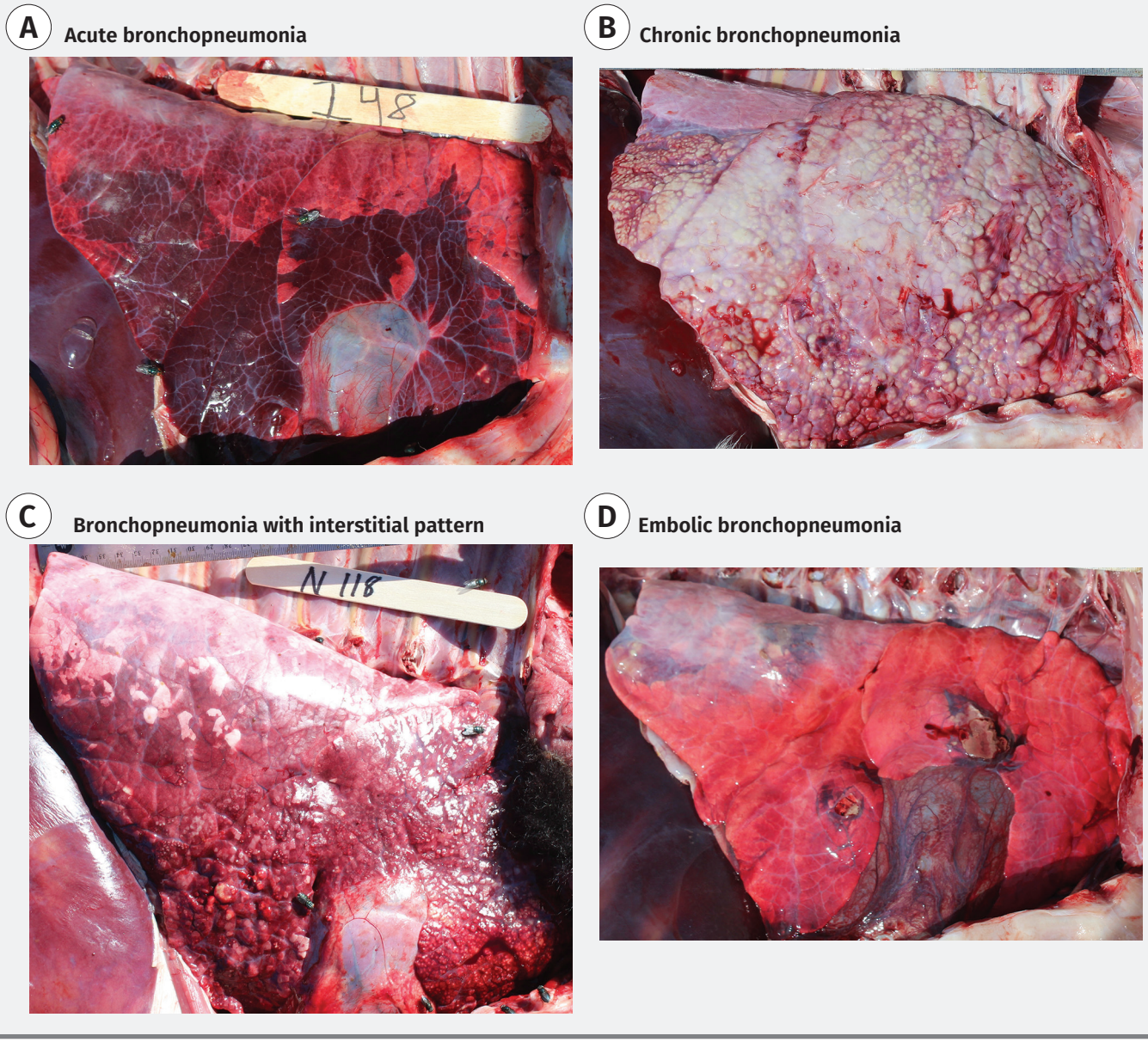
Figure 2: Example of each type of respiratory pathology (RESP) diagnosed from gross necropsy at 2 commercial calf ranches, including: acute bronchopneumonia **(2a)**, chronic bronchopneumonia **(2b)**, bronchopneumonia with interstitial pattern **(2c)**, and embolic bronchopneumonia **(2d)**.



Statistical analysis

Descriptive statistics were performed on cases (n = 211) relative to known demographic information. Due to lack of age information, 66 cases were removed prior to statistical assessment for probabilities of diagnoses by age. A generalized linear model using the glm function from the statistics package of R studio was used to evaluate the probability of being classified as a RESP diagnosis.[4] Breed type, sex and days-of-age categories were included to determine the likelihood of a RESP diagnosis for each factor. Categories for age included less than 30 days, 30 to 59 days, 60 to 89 days, and greater than 90 days. A second generalized linear model using the glm function in R studio was used to evaluate the likelihood of being classified as a GI diagnosis in calves that died. Similarly, breed type, sex and days-of-age categories were included to evaluate the likelihood of association between these factors and a GI diagnosis. Calf ranch was not included as a random effect in either model because the cases with known days of age were all from the same calf ranch.

Results

Two hundred and eleven necropsies were performed. Cattle demographics are shown in Table 1. Days-of-age information was collected for 145 calves, with values ranging from 2 to 150 days. Frequency of final diagnosis by disease category for each case necropsied can be seen in Table 2.

Relative to age categories, 28.3% (41/145) of cases were less than 30 days, 14.5% (21/145) were between 30 and 59 days, 44.1% (64/145) were between 60 and 89 days, and 13.1% (19/145) were greater than 90 days. The median age for GI diagnoses was 12 days. For “other”, the median age was 16 days, and for

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Table 1: The proportion of mortalities by sex and breed type (n = 211) with a subset of mortalities (n = 145) having days of age at death from 2 Kansas calf ranches. Necropsies were performed between June 15 and July 15, 2023.

	Category	Count	Percent total
Sex	Heifer	99	46.9%
	Steer	112	53.1%
Breed type	Beef × Dairy	115	54.5%
	Dairy	96	45.5%
Days of age	Less than 29	41	28.3%
	30 to 59	21	14.5%
	60 to 89	64	44.1%
	Greater than 90	19	13.1%

Table 2: Frequency of final diagnosis by disease category for cases necropsied (n = 211) at 2 Kansas calf ranches. Necropsies were performed between June 15 and July 15, 2023.

Final Diagnosis	Cases	% of Cases
Respiratory		
Acute bronchopneumonia	29	13.7%
Chronic bronchopneumonia	104	49.3%
Bronchopneumonia with interstitial pattern	9	4.3%
Embolic pneumonia	8	3.8%
Gastrointestinal	39	18.5%
Other/Unknown	7	3.3%
Septicemia	15	7.1%
Total	211	100.0%

septicemia and RESP diagnoses, the median age was 61 and 71, respectively. The temporal distributions of cases for each diagnosis at time of gross necropsy are depicted in Figure 3.

Descriptively, specific to RESP diagnoses and age, 60% (9/15) of cases in calves less than 30 days were acute bronchopneumonia, 20% (3/15) were aspiration/embolic pneumonia, 20% (3/15) were chronic bronchopneumonia, and there was no bronchopneumonia with interstitial pattern cases. For calves between 30 and 59 days of age, 20% (3/15) were acute bronchopneumonia, 0% were aspiration/embolic pneumonia, 7% (1/15) were bronchopneumonia with an interstitial pattern, and 73% (11/15) were chronic bronchopneumonia diagnoses. Similarly, chronic bronchopneumonia accounted for the greatest percentage (82%; 46/56) of cases in calves between 60 and 89 days, followed by acute bronchopneumonia (11%; 6/56), bronchopneumonia with an interstitial pattern (5%, 3/56), and finally, aspiration/embolic pneumonia (2%; 1/56). For calves greater than 90 days, 6% (1/18) of cases were acute bronchopneumonia, 6% (1/18) were aspiration/embolic pneumonia, 17% (3/18) were aspiration/embolic pneumonia, and the remaining 72% (13/18) were chronic bronchopneumonia.

Two generalized linear models were used to evaluate the probability of RESP or GI diagnoses in calves that died being associated with breed type, sex and age categories. Breed and sex were not associated with the probability of RESP ($P = 0.32$, $P = 0.62$, respectively) or GI ($P = 0.16$, $P = 0.85$, respectively) diagnoses at gross necropsy. The probability of RESP and GI diagnoses was associated ($P < 0.001$, $P < 0.001$, respectively) with age category. Calves greater than 60 days were at greater ($P < 0.001$) risk (88 ± 4%) for RESP diagnoses compared to calves less than 30 days (37 ± 8%), but calves between 30 and 59 days were not different in risk from the other two groups (70 ± 11%). In contrast, probability of GI diagnosis (46 ± 8%) was greater ($P < 0.05$) for calves less than 30 days compared to calves between 60 and 89 days (5 ± 3%). Calves between 30 to 59 days and greater than 90 days were not different in risk from the other two groups (14 ± 8%; 6 ± 6%, respectively). Probability of RESP or GI diagnoses at time of necropsy based on age can be seen in Figures 4 and 5, respectively.

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Figure 3: Violin plot with boxplot overlay depicting the temporal distributions of each diagnosis at time of gross necropsy at one Kansas calf ranch (n = 145).

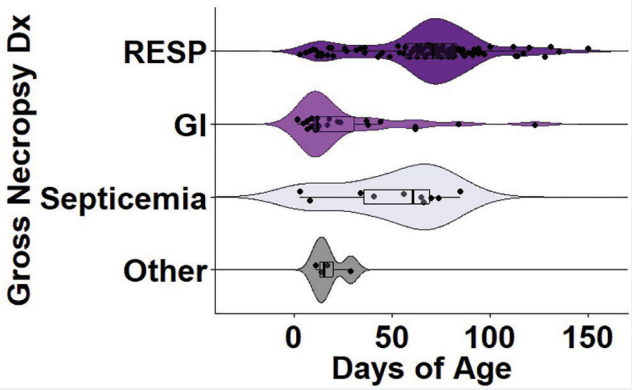


Figure 4: Probability of respiratory diagnosis in calves (n = 145) that died by days-of-age category at one Kansas calf ranch.

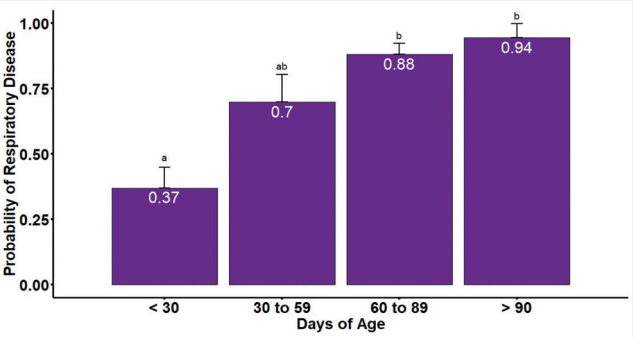
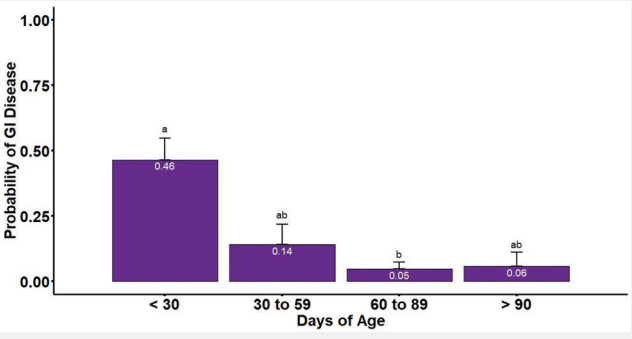


Figure 5: Probability of gastrointestinal (GI) diagnosis in calves (n = 145) that died by days-of-age category at one Kansas calf ranch.



Discussion

Causes of mortality in dairy and BOD calves have been poorly defined in previous literature with very limited verification through post-mortem evaluations such as systematic necropsies.[2,11,12] In 2007 and 2014, it was reported that approximately 10% of operations in the U.S. with deaths in pre-weaned or weaned heifers performed necropsies on the mortalities, and on those operations, less than 5% of those deaths were necropsied to determine cause of death.[12] Given this information, many causes of death for dairy heifer calf mortalities could be misclassified when they are based upon previous treatment records rather than gross necropsy findings. A study conducted as part of the calf component of the National Animal Health Monitoring System (NAHMS) Dairy 2014 study reported that approximately one-fourth of enrolled calves died from unknown causes, highlighting the importance of identifying and classifying cause of death through necropsy.[9]

The majority of mortalities in the present research were classified as RESP (71.1%; 150/211), with GI as the second highest recorded cause of death at 18.5% (39/211). These findings are consistent with previous studies, highlighting that RESP and GI diseases are the most common contributors to calf mortalities.[1,8,14,17] According to the NAHMS data from 2015, the most frequent causes of death for calves across all operations were respiratory problems (26.9%), followed by calving-related problems (17.8%) and digestive problems (15.4%).[10] However, when looking at calf death loss by type of operation, dairies reported a higher percentage of calf mortalities due to digestive problems (28.1%) compared to beef operations (9.6%). Beef operations had a lower percentage of deaths due to respiratory diagnoses (23.0%) compared to dairies (32.7%), mixed (36.1%), or other (36.3%) operations which were primarily feedlots and stockers.[10,13] A mixed operation was defined as an operation with more than 5 beef cows and more than 5 milk cows, or if the number of beef and milk cows were equal. It is worth noting that the NAHMS survey did not include information about age of calves related to cause of death, and the present study found an association between risk of respiratory or GI diagnoses with age categories. Similar to mortality, other findings reflect the same perception that GI problems and respiratory disease account for the majority of calf morbidity.[9,15,18] Performing necropsies provides more accurate information than recording causes of death based on clinical diagnosis, which should help identify potential management routes for interventions.

In 2019, McConnel et al. performed 210 necropsies on dairy heifer calves at a 25,000-head dairy calf ranch with calves originating from multiple dairies and reported treatment-based diagnoses and necropsy-based diagnoses.[2] In addition, tissue samples were collected at time of necropsy and submitted to a laboratory for histopathology diagnosis. Categorized by age, 88% (184/210) of necropsy cases were less than 30 days, 9% (19/210) were between 30 and 60 days, and 3% (7/210) were weaned and greater than 60 days. Through input from calf health managers and treatment records, almost two-thirds (65%; 137/210) of the deaths were categorized as due to diarrhea or diarrhea and respiratory, and an additional 16% (34/210) were attributed to respiratory disease alone. In contrast, necropsy-based postmortem diagnoses categorized 21% (44/210) of deaths due to diarrhea or diarrhea and respiratory disease and only 6% (13/210) to respiratory disease alone. The "other digestive" category contained almost 50% (104/210) of

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cases due to necrotizing, ulcerative enteritis and typhlitis. The kappa statistic reported for agreement between cause of death based on treatment records and necropsy-based postmortem evaluation was 0.22, indicating fair agreement. Similar to the present data when considering age, there was a greater number of GI diagnoses in calves less than 30 days; however, the current study saw increased RESP diagnoses compared to what McConnel et al. reported. The discrepancies between McConnel's findings and the present data could be due to differences in populations, such as breed, the differences in age distribution of cases, in management practices, in time and duration of transportation of calves to the calf ranch facilities, as well as the method and time period of enrollment of cases. Even so, the findings of previous literature support that diagnosing causes of death based on prior treatment records compared to performing necropsies can lead to inaccuracies in the reported frequency of causes of mortalities.

Relative to age, probability of finding RESP disease upon gross necropsy was greater ($P < 0.001$) for calves greater than 60 days compared to calves less than 30 days. In contrast, the risk of GI-related diagnoses was greater ($P < 0.001$) in calves less than 30 days compared to calves between 60 and 89 days. This supports previous reports in young dairy heifers of higher risk of GI-related problems in the first three weeks of life and highest risk of pneumonia later in the calf's life at 10 weeks of age.[1,6,9]

Similar trends can be seen by Windeyer et al. morbidity data of dairy heifer calves, where incidence risk for neonatal calf diarrhea was 21.2% before 14 days, then decreased to 1.8% between 14 and 35 days.[18] For BRD, incidence risk was 7.7% for calves younger than 14 days and increased to 8.0% and 9.5% for calves between 14 and 35 days, and greater than 35 days, respectively.[18] While the present study did not break down the age categories to the extent of Windeyer et al., the trends remain similar with greater proportions of GI cases in younger calves compared to increased RESP cases in older calves. These previous findings support the finding that at a younger age, less than 30 days, calves are at greater risk for GI disease and at an older age, specifically greater than 60 days, their risk for RESP disease increases. However, it is important to note that while the probability of GI disease was greatest in calves less than 30 days old (46%), respiratory disease also played a significant role for this age category with a probability of 37%, and therefore should also be taken into consideration when creating and implementing preventive and therapeutic protocols.

In this study, necropsies were performed on calves at varied days of age, sexes and breeds. Multiple pathologic conditions were diagnosed and no single risk factor tested clearly delineated the diagnosis. This work illustrates the importance of necropsy to evaluate health outcomes and ideally, these gross diagnoses could be used in conjunction with clinical diagnoses to improve management decisions. Gross necropsy is an important tool to identify actual cause of death.

Limitations of this study include that cases were recorded based on availability of deceased animals during a limited period of approximately 5 weeks in 2 different calf ranches. Therefore, the prevalence of cause of death diagnoses may vary based on season or location which cannot be evaluated in this study. Additionally, calf history which included age information was limited, leading to a smaller number of cases that met inclusion criteria for statistical analysis of association between cause of death and age category. Unfortunately, treatment information and clinical diagnoses were also not included in calf history. Another limitation includes the lack of histopathologic examination for laboratory confirmation of diagnoses due to budgeting, time and labor constraints. It can be difficult to differentiate between subsets of GI diseases without confirmatory diagnostic lab work, thus the authors categorized any GI disease as a GI diagnosis due to the lack of diagnostics. Similarly, diagnosing septicemia without additional diagnostic insight is difficult at best; however, all diagnoses in this study were based solely on gross necropsy findings.

Conclusions

Gross necropsy can be a valuable tool to identify pathological conditions and describe cause of death in mortalities at commercial calf ranches. Necropsy findings can be utilized to tailor preventive and therapeutic programs to specific situations. There is a need for further research regarding morbidity and mortality of dairy and BOD calves being raised on commercial calf ranch operations. The frequency of GI and RESP diagnoses in mortalities at calf ranches in this study were similar to what is reported in morbidities and mortalities among dairy heifer calves. However, while GI disease was most common in the first 30 days of age with a probability of 46%, respiratory disease played a significant role in the disease process during this time period as well with a probability of 37%. Finding both major disease processes in young calves at relatively high frequencies emphasizes the importance of necropsy when evaluating clinical diagnostic and therapeutic programs. While not directly comparable to previous literature, the information found in this study contributes to the small amount of knowledge surrounding mortalities at commercial calf ranches and could potentially help producers with building preventive and therapeutic protocols. Gross necropsy has value as an outcome evaluation tool for individual operations to customize health protocols based upon the disease syndromes identified at death. This is an important sector of the industry that continues to grow as the number of BOD animals increases. Thus, the need for further research to comprehensively describe health data is imperative for improving morbidity and mortality at the calf ranch.

Conflicts of interest

Authors report no conflicts of interest.

Contribution

All authors contributed to the design, analysis and writing of the current study.

Funding

This project was partially funded through the Beef Cattle Institute.

References

1. Agerholm JS, Basse A, Krogh HV, et al. Abortion and calf mortality in danish cattle herds. *Acta Vet Scand.* 1993;34:371-377.

2. McConnel CS, Nelson DD, Burbick CR, et al. Clarifying dairy calf mortality phenotypes through postmortem analysis. *J Dairy Sci.* 2019;102:4415-4426.

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3. Miles DG. Overview of the North American beef cattle industry and the incidence of bovine respiratory disease (BRD). *Anim Health Res Rev.* 2009;10:101-103.

4. R Core Team. R: A Language and Environment for Statistical Computing. 2023. Available at: **https://www.R-project.org/**

5. Schmidt PH, White BJ, Finley A, et al. Determining frequency of common pulmonary gross and histopathological findings in feedyard fatalities. *Vet Sci.* 2023;10. Available at: **https://search.ebscohost.com/login.aspx?direct=true&db=agr&AN=IND608270841&site=ehost-live**

6. Sivula NJ, Ames TR, Marsh WE, et al. Descriptive epidemiology of morbidity and mortality in Minnesota dairy heifer calves. *Prev Vet Med.* 1996;27:155-171.

7. Smith RA, Step DL, Woolums AR. Bovine Respiratory Disease. *Vet Clin North Am Food Anim Pract.* 2020;36:239-251.

8. Svensson C, Lundborg K, Emanuelson U, et al. Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. *Prev Vet Med.* 2003;58:179-197.

9. Urie NJ, Lombard JE, Shivley CB, et al. Preweaned heifer management on U.S. dairy operations: Part V. Factors associated with morbidity and mortality in preweaned dairy heifer calves. *J Dairy Sci.* 2018;101:9229-9244.

10. USDA. Cattle and Calves Death Loss in the United States Due to Predator and Nonpredator Causes, 2015. Fort Collins, CO: USDA–APHIS–VS–CEAH; 2015.

11. USDA. Dairy 2007, Heifer Calf Health and Management Practices on U.S. Dairy Operations. Fort Collins, CO: USDA:APHIS:VS, CEAH; 2010.

12. USDA. Dairy 2014, Trends in Dairy Cattle Health and Management Practices in the United States, 1991-2014. Fort Collins, CO: USDA–APHIS–VS–CEAH; 2021.

13. USDA. NAHMS Beef '97 Part II: Reference of 1997 Beef Cow-Calf Health and Health Management Practices. USDA:APHIS:VS; 1997:1-43.

14. Virtala A-MK, Mechor GD, Gröhn YT, et al. Morbidity from nonrespiratory diseases and mortality in dairy heifers during the first three months of life. *J Am Vet Med Assoc.* 1996;208:2043-2046.

15. Walker WL, Epperson WB, Wittum TE, et al. Characteristics of dairy calf ranches: Morbidity, mortality, antibiotic use practices, and biosecurity and biocontainment practices. *J Dairy Sci.* 2012;95:2204-2214.

16. Weiker JL. 2023 Semen Sales Report Reflects Global Trends. Madison, WI: National Association of Animal Breeders; 2024. Available at: **https://www.naab-css.org/news/2023-semen-sales-report-reflects-global-trends**

17. Winder CB, Kelton DF, Duffield TF. Mortality risk factors for calves entering a multi-location white veal farm in Ontario, Canada. *J Dairy Sc.i* 2016;99:10174-10181.

18. Windeyer MC, Leslie KE, Godden SM, et al. Factors associated with morbidity, mortality, and growth of dairy heifer calves up to 3 months of age. *Prev Vet Med.* 2014;113:231-240.

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Supplemental Form

Autolysis:	
None	Moderate
Slight	Extreme

KSU-CVM BCI Research Necropsy Record 2023

Assign. Case #:		**Feed yard:**		**Euthanized:**	Yes No
Indv.Tag #:		**Lot:**		**Necropsied by:**	
Tag Color:		**2nd ID:**		**Recorded by:**	
Breed:	N X M Z	**Date/Time:**		**Pictures by:**	

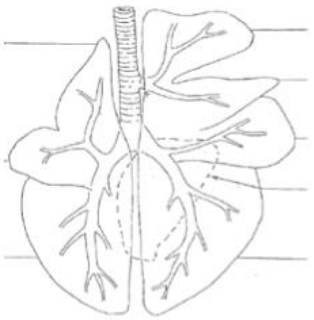
External Examination

Sex:	Steer Heifer	Lactating:	Yes / No
Flesh:	Thin Moderate Fat	Mastitis:	Yes / No
Est. Time of Death:			

Integumentary	WNL		Picture 1: Initial
Oral Cavity		Ulcerations Blunted Papillae Petechia	
Additional Findings			

Esophagus, Trachea, Heart	WNL		Picture 2 (heart-coronary a.)
Esophagus		Ulcers Hemorrhagic	
Larynx/Pharynx		Necrosis Infection Ulcer Hemorrhage Fibrinous	
Tracheal Contents/ Mucosa		Froth Reflux Hemorrhagic Fibrinonecrotic Ulcers Edema Infection	Picture 3 (heart ventricles)
Pericardial Effusion/ Sac		Fibrinous Mucoid Purulent Sanguineous Serous Serosanguinous Thickened Adhesions	
Heart Score	1	2 3 4 5	Sample ☐
Widest circumference (cm)			
Cut pt circumference (cm)			
Heart weight (grams)			
Myocardium/Endocardium		Necrosis Petechia Ecchymosis Dilated Ventricle Myocarditis Endocarditis	

Lungs	WNL		Picture 4: right side	R CV weight (grams):
Pleural Effusion		Fibrinous Mucoid Purulent Sanguineous Serous Serosanguineous		
Pleural Effusion volume		Mild Moderate Severe	Picture 5: whole	R CD weight (grams):
Bronchopneumonia Fibrinous Pleuritis AIP BIP Granulomatous Embolic Pneumonia Pulmonary Hemorrhage/Petechia Pulmonary Edema			2 Samples ☐ (R CV and CD)	
Acute Chronic Can Not Tell				
Abscess		Small Medium Large / Few Moderate Many		
Adhesions		Present		



Total %: _____
*Calculated following necropsy

1

Study Protocol

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Case # _____

Lung Comments:

GI Tract	WNL		Picture 6: mucosa	GI Fixed Sample
SI Serosa		Red Black	1: normal 2: abnormal papillae 3: healed 4: active/healed 5: active	Duodenojejunal Junction ☐ Colon ☐ Lesion: SI ☐ LI ☐
SI Mucosa		Ulcers Hemorrhagic Thickened		
SI Content		Gas Purulent Fluid		
SI Lesion		Obstructed Inflamed Parasites Neoplasia		
LI Serosa		Red Black		
LI Mucosa		Ulcers Hemorrhagic Thickened		
LI Content		Gas Purulent Fluid		
LI Lesion		Obstructed Inflamed Parasites Neoplasia		
Rumen Score	1	2 3 4 5	Picture 7: mucosa	Rumen Fixed Sample
Rumen Contents		Froth Full Empty Bloated Fluid		
Rumen Mucosa		Ulcers Hemorrhagic Thickened Parakeratosis	Rumen pH:	Ventral Sac ☐ Lesion ☐
Abomasal Mucosa		Ulcers Hemorrhagic Thickened		

Abdomen	WNL			
Mesenteric LN		Enlarged Hemorrhagic		
Peritoneal Fluid		Fibrinous Mucoid Purulent Sanguineous Serous Serosanguinous		
Adhesions		Liver SI LI Forestomach Other		
Liver Color		Nutmeg Congested Jaundiced Pale Scars Flukes Enlarged	Picture 8	Liver Sample :
Liver Abscess Grade		O A A+		Surf. Area: ☐ Lesions: ☐
Kidney		Enlarged Contracted Infarcts Petechia Abscess Infection Stones		
Bladder/Urine		Ecchymosis Calculi Cystitis Pale Dark Brown Hemorrhage Exudate Ruptured Stones		
Reproductive		Infected Adhesions Pregnant		Ovary Sample: ☐
Spleen		Swollen Contracted Infarcted Enlarged		

Musculoskeletal	WNL	
Extremities:		LH RH LF RF
Lesion:		Swollen Trauma Muscle Necrosis Ecchymosis

Diagnosis:

Additional Comments:

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