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Research Article

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Determining Health, Performance, and Economic Value of Using a Remote Early Disease Identification System Compared to Conventional Method for Diagnosis of Bovine Respiratory Disease

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Abstract

The present trial was conducted to evaluate potential health, performance, and economic differences between calves monitored with Remote Early Disease Identification (REDI) and Conventional Visual Observation (CON). Seven replicates of high risk cattle (n=614) for bovine respiratory disease were used in the trial. In each replicate, calves were randomly allocated to REDI or CON diagnostic modality and monitored for 30 days. Performance and health outcomes were evaluated for each replicate. Net economic returns were calculated for each replicate based on health and performance outcomes combined with calf prices. A separate economic analysis was performed to evaluate the sensitivity of net returns between the REDI and CON to fluctuation in calf prices. The number of calves initially treated for BRD tended (P=0.09) to be lower in REDI compared to CON, and the percentage of second treatments, and third treatments (P<0.01) were lower for the REDI group compared to the CON group. The REDI group had higher (P<0.01) first treatment success (85.9% ± 6.1) compared to CON (63.3% ± 0.1). No other performance, health, or economic differences were identified (P>0.10). As calf prices were increased, the difference in net returns between the diagnostic modalities increased; however, the magnitude of change was relatively minor. The REDI system showed health advantages which could translate to long-term value in animal welfare. No performance or economic differences were identified in this short-term trial, but further research may elicit longer term implications.

Keywords: Bovine respiratory disease; Diagnostic methods; Economics

Abbreviations: BRD: Bovine Respiratory Disease; BW: Body Weight; CH: Number of Cattle Deemed Chronically Ill; CO: Cost for Observer; CON: Conventional Visual Observation; CP: Chronic Animal Price; CR: Cost for REDI System; FC: Feed Cost; NR: Net Returns; PP: Purchase Price; PW: Purchase Weight; SP: Sale Price; SW: Sale Weight; TC: Treatment Costs; REDI: Remote Early Disease Identification; US: United States; YD: Yardage

Introduction

Bovine Respiratory Disease (BRD) is the most common and economically important disease in beef cattle [1,2]. Current diagnostic methods rely almost exclusively on human visual observation resulting in misclassifications and potential delays in diagnosis [3,4]. Visual observation is commonly combined with rectal temperature resulting in low prognostic indicator of case outcome [5].

Cattle behavior may be continuously monitored to be indicative of the health or wellness state [6]. Continuous behavior monitoring technologies are available to remotely monitor calves to identify morbid animals more accurately compared to traditional observation methods [7-9]. One system specifically, Remote Early Disease Identification (REDI), has proven to be more accurate than human observers in identifying cattle with BRD resulting in earlier treatment of sick animals, better treatment response, and improved antimicrobial stewardship by only treating the truly ill animals [9-11]. REDI consists of continuous cattle movement monitoring generating locational, behavioral and social indices allowing a disease classification engine to determine BRD status for an individual animal.

While technologies are available to identify the health or wellness state of an animal with improved diagnostic accuracy, the cost benefit relationship of implementing these systems needs to be evaluated compared to traditional methods [12]. Previous studies have indicated there is a potential limit in the cost of the automated systems to economically implement into field settings [13,14]. The objective of the study was to evaluate potential health, performance, and economic differences between calves monitored with REDI and conventional visual observation (CON). Our hypothesis was calves in the REDI group would have improved net economic returns compared to CON. These results will be important to determine the value of implementing the REDI system into commercial settings.

Materials and Methods

A pen-level randomized, controlled clinical trial was conducted with replicates in multiple locations. The trial protocol and study procedures were reviewed and approved by the Professional Beef Services, LLC, Institutional Animal Care and Use Committee. Two locations were selected for study participation. At each location, a pen

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was equipped with the REDI monitoring hardware and a pen of the same capacity and configuration was selected as CON pen.

Sample size calculation

Net returns per animal for each treatment group was considered the primary outcome for the research study, and was used to determine sample size calculation estimates. A $7.00 per animal difference between treatment groups was used to calculate sample size with standard deviation equal to 5.00. Alpha was set at 0.05, and beta set to 0.20 for the sample size calculation estimates using an R Core Team 2016 commercial software package.

Study population

The study population was cattle deemed at high risk for BRD and was procured through commercial sale barn markets and transported greater than 10 h to study sites. The target population consisted of steers, heifers, or bulls with arrival weights ranging from 181 to 272 kg. Within each replicate, the same gender was used for both treatment groups (male or female). If bulls were included in an arrival group, they were not castrated until after the trial period.

Treatment group assignment and application

The experimental unit for this project was pen (or housing group), and all treatments were applied at pen level. At arrival all cattle received processing procedures including antimicrobial metaphylaxis with gamithromycin (Zactran, Merial, Ltd, Duluth, GA, 6 mg per kg of BW), internal and external parasite control, vaccination for viral respiratory pathogens, and clostridial immunizations. The processing procedures were the same within both the CON and REDI groups in each replicate. Upon arrival, cattle from each cohort (load) were randomly allocated to REDI or CON groups. Cattle assigned to the REDI group were tagged with a REDI system tag at arrival and placed in the REDI pen.

Calves in REDI pens were treated for BRD based solely on the REDI system determination of health status [7,9,10]. The REDI system is a real-time location system which continuously captures calf behavior and activity in the pen [9]. Algorithms are used to evaluate calf behavior and activity indices to more accurately determine health status compared to visual observation [7,9]. Cattle in CON pens were observed daily by experienced personnel for any signs of clinical illness including depression, anorexia, nasal discharge, and lack of rumen fill, and treatment decisions were based on observed clinical illness and rectal temperatures >39.4°C [15-17].

Calves were eligible for treatment 5 days after metaphylaxis or 3 days after a previous treatment. In both the REDI and CON groups, florfenicol (Nuflor, Merck Animal Health, Madison, NJ, 40 mg per kg of BW) was the initial BRD therapy. Cattle requiring a 2nd or 3rd BRD treatment were treated with tulathromycin (Draxxin, Zoetis Inc., Kalamazoo, MI 2.5 mg per kg of BW) and oxytetracycline (Biomycin 200, Boehringer Ingelheim, St. Joseph, MO, 4.5 mg per kg of BW) respectively. In both REDI and CON pens, identification and treatment for all other disease conditions were conducted in accordance with the standard feedyard health protocols.

REDI configuration (REDI group only)

The REDI pen was equipped and data managed as in previous research, and all BRD identification for the REDI group was conducted remotely using REDI [9,10]. Each pen had multiple sensors surrounding the housing perimeter. Each calf received a REDI tag and the location engine software calculated the time of arrival of signals between sensors and tags to calculate location of each calf in the pen at 5 second intervals. Data were transferred from sensors to a local server where initial calculations of movement, proximity and social indices are performed prior to uploading of aggregated data to the cloud server. The cloud server applied the REDI disease classification engine to generate calf BRD status reports indicating which calves should be removed from the pen for daily treatments [9].

Data collection

All calves were weighed individually at arrival and trial conclusion (~30 days post-arrival) to determine changes in BW. The REDI system was used to monitor and identify BRD for the first 30 days after arrival. Health events and treatments were recorded including individual animal identification, cohort number, date, event type (first, second, or third treatment for BRD; treatment for other disease), amount of antimicrobial used, and rectal temperature at the time of evaluation. A calf treated three times for BRD was defined as a chronic. Responses to treatments were recorded and calculated using the definitions in Table 1. Necropsies were performed on all cattle that died during the trial. Both REDI and CON calves were fed the same ration within replicate and location, and the amount of feed delivered to each pen was recorded daily in order to calculate feed intake and gain feed.

Economic model

The approach was to calculate overall net returns for each pen of cattle with the different diagnostic modalities (REDI or CON). Health and performance data collected during the trial were used as inputs for the economic model. Net returns were calculated for each cohort with the following formula:

Net returns (NR)=(Sale price (SP) × Sale weight (SW))−(Purchase price (PP) × Purchase weight (PW))−Feed cost (FC)−Yardage (YD)−Treatment cost (TC)−(Number of cattle deemed chronically ill (CH) × Chronic animal price (CP))−Cost for observer (CO)−Cost for REDI system (CR).

All feeder calf prices were obtained through the Missouri Weekly Weighted Average Feeder Cattle Report of the Agricultural Marketing Service from the United States Department of Agriculture (Agricultural Marketing Service: United States Department of Agriculture. Missouri Statewide Combined Feeder Cattle Wtd Avg, 2016). To minimize variation among replicates due to market fluctuations, the report from March 11, 2016 was used to establish SP and PP. For each replicate, prices were determined to the nearest 45 kg breakpoint and applied to all cattle in each replicate. The PW and SW were calculated based on individual cattle weights collected at arrival and trial completion.

Therapy response variable	Description
1st BRD pull	First time a calf was identified and treated for BRD following metaphylaxis (and post-metaphylaxis interval)
2nd BRD pull	An animal that meets treatment requirement for therapy 2 within 21 days of 1st pull for BRD
3rd BRD pull	An animal that meets treatment requirement for therapy 3 within 21 days of second therapy
Treatment success	An animal that is fully recovered following initial therapy 1 treatment, no additional therapy required and the animal did not die during study period
Chronic	An animal that receives 3 treatments for BRD or is deemed unfit to continue with cohort

Table 1: Definitions of calculated therapy response variables.

The average ration cost as fed was $77 per metric ton, and FC was determined by multiplying the pounds of feed fed to each pen by the ration cost. Total pounds fed were not available for pens in replicate 2; therefore, total pounds fed for replicate 2 were estimated based upon average gain to feed ratio of the other replicates included in the analysis. Yardage was assumed as $0.40 per animal per day on feed [18,19]. Average TC was calculated based on estimated product cost ($23.60), and an additional $2.00 for labor and facilities charges [20]. Any animal treated ≥3 times during the study was considered CH. Labor costs associated with observation (CO) were calculated based on 15 min of observation time (CON) or 5 min observation time (REDI) once daily with employee cost estimated at $18 per hour. The cost of the REDI system (CR) was estimated as US $10 per animal based upon projected system cost estimation and installation fees.

Statistical analysis

The diagnostic modalities (REDI and CON) were applied to the cohort-level and all evaluations were conducted using this experimental unit. The outcomes of interest included the results of the health and performance data as well as the economic model. Data were imported into R Core Team 2016 and linear mixed models were utilized to evaluate association of continuous variables (net returns, average daily gain) with the applied diagnostic modality. Generalized logistic regression models were used to calculate the probability of binomial outcomes of interest (morbidity, treatment success, and mortality) and potential associations with diagnostic modality. Random effects were included in each model for study site and replicate. Main effects were considered significant with $P \leq 0.05$.

Value of diagnostic modality at different calf prices

A separate economic analysis was performed to evaluate the difference in NR between the REDI and CON diagnostic modalities when the calf prices were changed. For each replicate, the PP and SP described above were changed by $10 per 45.5 kg of BW increments from baseline values used for the economic analysis. Range of values evaluated was from US -$80 per 45.5 kg of BW to US $80 per 45 kg of BW change from baseline for each replicate. The NR at the different cattle price intervals were calculated using the same formula described previously. Within each interval and replicate, the NR from the CON was subtracted from the NR for the REDI treatment group.

Results

Sample size calculation estimates were 8 replicates for each treatment group. The number of calves within each diagnostic modality ranged from 32 to 78 for each replicate. The number of calves within each diagnostic modality was the same within each replicate. Nine replicates at two locations were initiated, and seven replicates with 614 animals in each treatment group resulted in data for analysis. Two replicates of cattle (total of 4 pens and 174 animals) that did not complete the trial due to technical difficulties with the system. In each case there was a hardware/ software communication problem which was subsequently resolved, but not resolved in a time period to allow complete data collection from these trials. Two of the replicates were completed at 1 of the study sites, the remaining 5 replicates were performed at the other study site. Replicates 1, 3, 4, 5, and 7 were female calves; and replicates 2 and 6 consisted of male calves.

The REDI system illustrated lower probability of second and third treatment and a greater probability of first treatment success when compared to CON ($P<0.01$; Table 2). The number of calves initially treated for BRD tended ($P=0.09$) to be lower for the REDI group compared to the CON group. No other differences in performance or health were identified. Economic outcomes were evaluated for potential associations with treatment group (Table 3). No statistical difference ($P=0.25$) in net returns (US $/animal) or other economic variables were identified between REDI and CON treatment groups. Differences in net returns between REDI and CON treatment groups by fluctuating calf prices from baseline values are displayed in Figure 1. As calf prices increased, the difference in net returns between the diagnostic modalities increased.

Discussion

High-risk beef calves were able to be obtained for the study with naturally occurring disease challenge to evaluate the diagnostic modalities. Previous research has evaluated the health and performance outcomes comparing conventional management with metaphylaxis to calves monitored with the REDI system without metaphylaxis [15]. To the authors' knowledge, this is the first study evaluating the use of a continuous behavior monitoring system in addition to metaphylaxis in high risk calves.

	REDI	**CON**	***P* value**
Average arrival weight (kg)	225.7 ± 16.5	226.3 ± 16.5	0.79
Average end weight (kg)	252.3 ± 21.7	253.3 ± 21.7	0.73
Average daily gain (kg/d)	0.87 ± 0.29	0.89 ± 0.29	0.59
Average weight gain (kg/animal)	26.2 ± 8.3	25.7 ± 8.3	0.47
Total feed delivered as fed (kg)	10454.3 ± 2127.9	10660.7 ± 2127.9	0.23
Gain:feed	0.1 ± 0.02	0.1 ± 0.02	0.36
BRD 1st treatments (%)	17.9 ± 5.2	23.6 ± 6.3	0.09
BRD 2nd treatments (%)	0.8 ± 0.9	3.7 ± 4	<0.01
BRD 3rd treatments (%)	0.2 ± 0.2	1.1 ± 1.1	0.01
Mortality risk (%)	0.6 ± 0.7	0.7 ± 0.9	0.62
Treatment success (%)	85.9 ± 6.1	63.3 ± 0.1	<0.01
Average days on feed 1st treatment (days)	13.1 ± 2.1	13 ± 2.1	0.96
Average rectal temperature at 1st treatment (°C)	40.4 ± 0.22	40.4 ± 0.22	0.93
Average body weight at 1st treatment (kg)	225 ± 20.34	228.4 ± 20.34	0.37
Average doses antimicrobial/animal (n)	0.25 ± 0.19	0.41 ± 0.19	0.21

Table 2: Model-adjusted least square means ± SE pen-level health and performance outcomes based on diagnostic method (REDI: Remote Early Disease Identification System; CON: Conventional Visual Observation). Statistical model included fixed effect for treatment group and random effects for study site and replicate.

	REDI	**CON**	***P* value**
Initial cattle value (US $/animal)	1226.74 ± 360.99	1219.92 ± 360.99	0.68
End cattle value (US $/animal)	1287.34 ± 361.98	1268.73 ± 361.98	0.35
Feed cost (US $/animal)	27 ± 5.39	26.47 ± 5.39	0.23
Yardage cost (US $/animal)	16.91 ± 5.25	17 ± 5.25	0.14
Treatment cost (US $/animal)	7.87 ± 5.13	12.17 ± 5.13	0.35
Cost chronics (US $/animal)	6.66 ± 15.04	22.27 ± 15.01	0.29
Net returns (US $/animal)	-4.65 ± 58.27	-21.56 ± 58.27	0.25

Table 3: Model-adjusted least square means ± SE pen-level economic outcomes based on diagnostic method (REDI: Remote Early Disease Identification System; CON: Conventional Visual Observation). Statistical model included fixed effect for treatment group and random effects for study site and replicate.

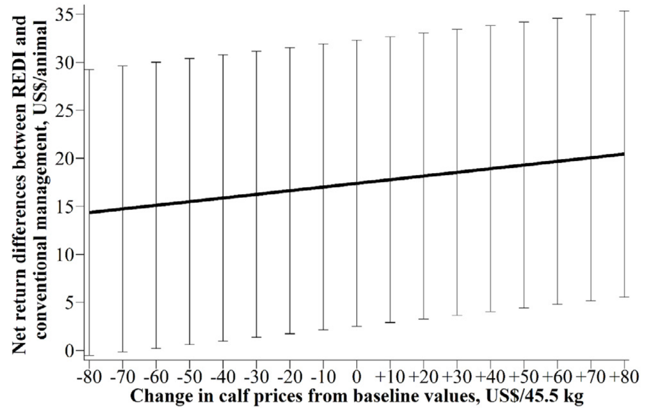

Figure 1: Difference in average (±SE) net returns between Remote Early Disease Identification (REDI) and Conventional Visual Observation (CON) diagnostic methods for bovine respiratory disease by change in calf prices from baseline values. Baseline prices were established from the March 11, 2016 Missouri weekly weighted average feeder cattle report of the agricultural marketing service from the United States, Department of Agriculture based upon sex, average arrival weight, and average sale weight for each replicate. Purchase price and sale price were simultaneously increased or decreased at US $10 per 45.5 kg.

No difference identified in performance outcomes between treatment groups was expected. The relatively small sample size based on experimental units (n=7) and short duration of the trial (30 days) resulted in decreased ability to identify a difference between treatment groups for performance outcomes. The majority of BRD incidence occurs during the first 45 days on feed [21,22]. Numerically, the performance outcomes between treatment groups were similar though. Further research is needed to monitor calves to closeout to identify long-term performance differences between treatment groups.

The decrease in the percentage of calves treated for BRD 1, 2, and 3 times in the REDI group compared to the CON group provides some interesting results. In this study, both treatment groups were metaphylactically administered antimicrobials to reduce the incidence of BRD consistent with industry practices [23]. Meta-analysis of the use of metaphylaxis has been shown to reduce morbidity 53% and mortality 47% [24]. Even with use of metaphylaxis decreasing the morbidity in the study, the REDI system tended to identify fewer animals morbid compared to CON. Diagnosis of BRD based upon visual observation has been shown to have relatively low diagnostic sensitivity and specificity [3,4,25]. The low diagnostic sensitivity and specificity of the visual observation method results in false negative (truly diseased animal which appears clinically healthy) and false positive (truly healthy animal which appears clinically diseased) [26]. The REDI system has been shown to have greater diagnostic sensitivity and specificity values compared to visual observation resulting in a greater percentage of calves correctly classified [7,12].

The greater treatment success in the REDI treatment group compared to the CON group is consistent with correctly identifying the morbid and healthy animals. The REDI system has been able to identify morbid animals 0.75 days before visual observation [9]. The earlier identification of morbid animals results in improved treatment efficacy [27,28]. The improved treatment success and earlier identification of morbid animals should result in more judicious use of antimicrobials through fewer total treatments. Previous research has shown the REDI system has decreased the average doses of antimicrobial per animal compared to visual observation with metaphylaxis [15]; however in the previous study, metaphylaxis of antimicrobials was only performed to the visual observation group which is different from the current study [10]. Additional research evaluating the use of continuous behavior monitoring systems and relationship with antimicrobial use is needed.

A conservative rectal temperature cut-off of >39.4°C was used for case definition of BRD in the CON whereas rectal temperature was not included in REDI case definition [15]. Case definition of BRD in the REDI group was determined entirely based upon behavioral indices [9]. The conservative rectal temperature utilized as part of the case definition for CON may be a potential reason for the increase in the percentage of calves treated for BRD 1, 2, and 3 times compared to the REDI group by identifying animals which may not have been truly morbid [12]; however treatment success was still greater in the REDI treatment group compared to CON. If more BRD cases were identified and treated in the CON group which were not truly morbid, then treatment success should have been greater in the CON group compared to REDI due to apparent spontaneous cure. No differences were identified in average rectal temperature at first pull for BRD across treatment groups. Diagnoses and treatment outcomes evaluated in the current study further demonstrate the improved diagnostic accuracy of the REDI system compared to CON as previously described [7,9,10].

Not being able to detect a difference in NR between treatment groups was unexpected, but likely influenced by the large variability in net returns among replicates. Further research is needed with additional cohorts evaluated to determine if a difference in NR truly exists between treatment groups. Standardized cattle price estimates were used to decrease the variability of NR due to the temporal market cycle [29,30]. Previous research indicated the cost of implementing a continuous behavior monitoring system had to be less than US $3.50 per animal to be economically profitable compared to conventional visual observation methods [14]. In the current study, costs for the REDI system were US $10 per animal. These costs were determined based upon expected price to implement the diagnostic modality in a commercial feedlot or background setting. Additional research is needed to determine if the numerical economic differences observed truly represents outcomes from different populations [31].

The direction of change in difference of NR between REDI and CON groups at different calf prices was expected. The price of calves was not very sensitive to the difference in NR between the diagnostic modalities evaluated. The sensitivity results are consistent with previous studies [13,14]. The decision to implement a continuous behavior monitoring system to identify calves with BRD appears to not be greatly influenced by the price of cattle.

Potential limitations of the study include the relative small sample size and short duration to evaluate the long-term performance and health implications of the REDI system compared to CON. Mortality risk is the primary driver for NR, and commonly does not occur until later in the feeding period [13,32,33]. Longer term studies in a variety of environments need to be performed to fully evaluate the potential differences among the diagnostic modalities.

Overall, calves in the REDI group had decreased percentage of calves treated 1, 2, and 3 times; and improved treatment efficacy. No economic statistical differences were identified, but REDI calves had a numerical advantage of $16.91 per animal including the cost of the monitoring system. Additional research is necessary to evaluate if the numerical economic differences observed between treatment groups truly exist. The REDI system showed advantages which could translate to long-term value in animal welfare and potential economic advantages.

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