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Lightning related fatalities in livestock: Veterinary expertise and the added value of lightning location data

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A R T I C L E I N F O

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A B S T R A C T

Although lightning strike is an important cause of sudden death in livestock on pasture and among the main reasons why insurance companies consult an expert veterinarian, scientific information on this subject is limited. The aim of the present study was to provide objective information on the circumstantial evidence and pathological findings in lightning related fatalities (LRF), based on a retrospective analysis of 410 declarations, examined by a single expert veterinarian in Flanders, Belgium, from 1998 to 2012. Predictive logistic models for compatibility with LRF were constructed based on anamnestic, environmental and pathological factors. In addition, the added value of lightning location data (LLD) was evaluated. Pathognomonic singe lesions were present in 84/194 (43%) confirmed reports. Factors which remained significantly associated with LRF in the multivariable model were age, presence of a tree or open water in the near surroundings, tympany and presence of feed in the oral cavity at the time of investigation. This basic model had a sensitivity (Se) of 53.8% and a specificity (Sp) of 88.2%. Relying only on LLD to confirm LRF in livestock resulted in a high Se (91.3%), but a low Sp (41.2%), leading to a high probability that a negative case would be wrongly accepted as an LRF. The best results were obtained when combining the model based on the veterinary expert investigation (circumstantial evidence and pathological findings), together with the detection of cloud-to-ground (CG) lightning at the time and location of death (Se 89.1%; Sp 66.7%).

Introduction

Lightning strike is an important cause of sudden death in cattle on pasture (Finelle and Tartera, 2001). Since lightning related fatalities (LRF) in livestock are mostly covered by fire insurance, an independent veterinarian, referred to in this context as the ‘expert veterinarian’, is asked to perform an investigation to determine whether the case complies with death due to lightning (veterinary expert investigation) (Schelcher, 1994). Over the last 10–15 years the importance of forensic veterinary medicine has increased, mostly because of an increasing tendency for owners to seek compensation for animal losses (Cooper and Cooper, 2008). In practice, LRF is among the most frequent reasons for forensic veterinary medicine, confronting not only veterinary specialists in forensic medicine, but also local veterinary practitioners.

Despite its importance, very little scientific information is available to help expert veterinarians in their judgment of LRF insurance cases (Best, 1967; Appel, 1991; Schelcher and Tartera, 2001; Van Alstine and Widmer, 2003; Zele et al., 2006; Gomes, 2012), with only three studies emphasising the task of the expert veterinarian (Schelcher, 1994; Volat, 1994; Finelle and Tartera, 2001). Lightning related injury or death may occur through five primary mechanisms: (1) direct strikes are the most straightforward; (2) side flashes emanating from tall objects (e.g. trees) hit by lightning are possible; (3) ground currents (step potentials or step voltages) occur with each strike and are the most common mechanism in four-legged species; after injection of current into the earth, a potential gradient develops, which can initiate current entering the animal from one set of feet, leaving the body by the other set of feet; in contrast to human beings, this current crosses essential organs, such as the heart and liver, more frequently causing death (Gomes, 2012); (4) contact, from touching long conductors, such as railings, cables and fences; and (5) upward leaders, which emanate from high ground and tall objects when downward leaders approach ground; even if upward leaders do not connect with a downward leader, they

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can be fatal. More details on the different mechanisms can be found in Cooper (1984, 2002) and Gomes (2012).

Singe lesions (lightning burn lesions) and the presence of feed in the oral cavity as a sign of apoplectic death historically have been reported in >80% of LRF cases (Kahn and Line, 2005). However, in the field, veterinarians are confronted with many LRF declarations which do not show pathognomonic singe lesions. Moreover, some farmers attempt to confuse the investigation by creating false circumstantial evidence, which holds little risk, since penalties for false declarations are usually mild. Also, in many regions, different veterinarians perform a limited annual number of LRF investigations. The consequence is that, in the absence of pathognomonic signs, confirmation or declination of an LRF case by a veterinarian consulted by the insurance company is likely to be an empiric decision, driven to some degree by chance. Also, second opinions by independent assessors are seldom consulted for LRF declarations, at least not in Belgium.

To deal with this issue, several expert veterinarians contact their National Meteorological Service to check whether lightning impacts were detected at the time and location of the suspected death. Lightning data mainly consist of cloud-to-ground (CG) lightning. This information is not used systematically by the expert veterinarian, since consultation implies additional costs for the insurance company. Whether detection or non-detection of CG discharges are reliably associated with LRF in livestock has never been evaluated. Therefore, the primary aim of the present study was to provide objective information on anamnestic, environmental and pathological findings in LRF cases, based on a large data set involving 410 declarations, spread over 15 years of veterinary expert investigation, for insurance companies in Flanders, Belgium. Predictive models for LRF in livestock were constructed and the possible added value of using lightning location data (LLD) to confirm LRF cases was evaluated.

Materials and methods

Study design

A retrospective case series of declared LRF cases based on the records available in the archives of a veterinary expertise and advice agency (DEAB, Merelbeke, Belgium) was analysed. In Flanders, the number of specialised expert veterinarians is estimated at 15, based on their regular contact with the Royal Meteorological Institute of Belgium (RMIB) concerning LRF. The available archive represents one of the largest expert practices in Flanders, covering a 15 year period from 1998 to 2012.

The inclusion criterion to determine the relevant cases for analysis was defined as: 'any animal reported to the insurance company with suspicion of death by lightning and subsequently investigated by the expert veterinarian'. The expert investigation in this study was always performed by the same veterinarian following a standardised approach. First, the owner was interviewed to obtain a detailed case history. Next, the environmental conditions in which the animal was found were inspected. Finally, pathological examination of the cadaver was performed. Pathological examination was in most cases, for sanitary reasons and economy, limited to a thorough visual inspection of posture, abdominal distension, eyes, skin and mucosae, combined with palpation. If the expert veterinarian could not base a decision on the information obtained by these methods, a standardised field postmortem examination was performed (Vanneste et al., 2011).

If any doubt remained after the postmortem examination, the RMIB was contacted to confirm whether or not there had been CG activity in the environment at the probable time of death. All cases that remained doubtful after this approach were given the benefit of the doubt and classified as positive for LRF.

In all 410 cases, the Lightning Location System (LLS) of the RMIB (Poelman et al., 2013) was used to check whether CG activity was observed at the location and suspected time of interest; this information was added to the data set. The performance of the LLS has been tested against ground-truth data using high-speed video and electrical field measurements (Poelman et al., 2013), resulting in a median location accuracy (LA) of 1.0 km and a flash detection efficiency (DE) of 92% in Belgium. A time window of 3 days before and 1 day after the suspected time of death was applied, to account for the difficulty in pinpointing the exact moment of death. A radius of 10 km around the indicated location was examined.

The records were checked for 23 parameters potentially associated with LRF (Table 1). The parameters were divided into three sets. The first set consisted of anamnestic parameters involving both the animal and timing of the LRF declaration, the second set included environmental parameters at the time of inspection and the third set consisted of pathological findings. An object (e.g. tree, water) was considered to be in the near surroundings of a suspect case if present within a 10 m radius around the cadaver. The interval from death to expert investigation was calculated by subtracting the date of the reported death by the farmer from the date of the investigation. The occurrence of an LRF declaration within 3 days of another declaration was determined by comparing the date of declaration with the date of the previous and next case in the data set.

Table 1
Gross postmortem diagnoses in 141 declined (negative) declarations of lightning related fatalities in livestock.

Diagnosis	Number[a]	%[b]
Respiratory system	26	33
Bacterial bronchopneumonia	14	18
Verminous bronchopneumonia	2	3
Aspiration pneumonia	3	4
Pulmonary hemorrhage	3	4
Asphyxiation	2	3
Drowning	2	3
Cardiovascular system	4	5
Cardiomyopathy	3	4
Aortic rupture	1	1
Gastrointestinal system	24	30
Peritonitis post-Caesarian section	9	11
Traumatic reticuloperitonitis	5	6
Perforating abomasal ulceration	4	5
Intestinal volvulus	3	4
Enterotoxaemia	2	3
Iatrogenic ruminal tear	1	1
Urinary system	1	1
Urethral rupture	1	1
Reproductive system	12	15
Toxic mastitis	5	6
Uterine rupture	3	4
Dystocia	3	4
Toxic endometritis	1	1
Miscellaneous	13	16
Bluetongue	2	3
Dehydration	2	3
Taxus baccata intoxication	2	3
Trauma	1	1
Pregnancy toxaemia	1	1
Leucosis	1	1
Abscess with toxaemia	1	1
Septicaemia	3	4
No gross diagnosis	57	
Advanced postmortem decomposition	4	

[a] A final diagnosis could be made in 80/141 cases.
[b] Expressed over the total number of postmortem examinations with a diagnosis ($n = 80$).

Statistical analysis

Significant associations between the predictor variables were determined using the χ^2 test, with significance set at $P < 0.05$. Special attention was paid to parameters associated with the presence of singe lesions, which are regarded as pathognomonic for LRF. To predict which parameters were associated with confirmation of an LRF case by the expert veterinarian, a multivariable logistic regression model was built. Of the 23 parameters, four could not be included in the model building process, since they only occurred in either the positive or negative decisions, leaving 19 parameters for model building purposes (Table 1). These four parameters were the presence of singe lesions, the presence of a tree with signs of recent lightning impact, the presence of a filled gastrointestinal tract or the presence of typical gross lesions at postmortem examination. To estimate the seasonal effect, a binary variable was constructed involving the known risk months for lightning storms (May–September) compared to the other months (Poelman et al., 2012).

In the first step, all factors were tested univariably for their association with 'confirmation as an LRF case by an expert veterinarian' and factors with a P value <0.20 were withheld for the multivariable model. This multivariable model was built stepwise backwards, progressively excluding non-significant predictors. Significance was set at $P < 0.05$ and $P < 0.10$ was considered to be a trend. Associations between significant predictors were tested using the χ^2 test and by Fisher's exact test for small sample sizes. All biologically relevant interactions between two main effects were tested. Model validity was based on the Hosmer–Lemeshow test for logistic models.

To determine the added value of lightning detection data provided by the LLS for the confirmation of LRF cases, the sensitivity (Se) and specificity (Sp) of the basic model (without parameters documenting lightning detection) and models containing CG were compared. The probability that each case would be classified