

Perinatal rib fractures in 18 calves delivered from Holstein dams

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ABSTRACT

Cranial rib fractures during dystocia and the ensuing callus formations in calves often cause tracheal stenosis. Rib fractures may affect the lung since ribs tend to fracture above the costochondral junction during delivery. Considering that calving assistance rates for dystocia are high, calves with fractured ribs may develop respiratory disease which results in economic loss. The objective of this study was to elucidate the contribution of rib fractures to economic loss through respiratory disease in calves. Of 163 sick calves delivered from Holstein-Friesian dams included in this study, a total of 18 rib fractured calves was found, giving an incidence of rib fracture in sick calves of 11.0%. There were significant differences in incidence by the rib involved, indicating the 2nd to 7th ribs tend to break. Many of the rib fractured calves showed dyspnea and pyrexia. In this study, four of five scanned or necropsied calves had pneumonia lesions despite the fact that these four calves did not have tracheal stenosis. Rib fractured calves sold at below market value with a median difference from average sale price of minus 64,861 yen. Survival analysis indicated an overall association between rib fracture and time to death. In this study, we demonstrated that rib fractures happened most frequently in the 2nd to 7th ribs, and these cases tended to cause pneumonia, which decreased sale prices and longevity. Farmers should work to reduce risks and rates of dystocia so as to lessen economic loss and poor welfare in calves due to rib fractures.

1. Introduction

Perinatal rib fractures occur during delivery in calves, foals, and humans, sometimes causing fatal conditions. Cranial rib fractures and the ensuing callus formations often cause tracheal stenosis in calves (Fingland, Rings & Vestweber, 1990; Jelinski & Vanderkop, 1990; Rings, 1995). Fractured rib ends in foals can lacerate blood vessels in the thoracic cavity and puncture thoracic organs, including the lung, heart, and diaphragm, and these conditions can lead to hemothorax and pneumothorax (Reynolds, 1930; Sprayberry & Barrett, 2015). The prevalence of perinatal rib fractures is 23.0% in dying calves (Schuijt, 1990), 5.1% to 20.1% in foals (Jean, Laverty, Halley, Hannigan & Léveillé, 1999; Schambourg, Laverty, Mullim, Fogarty & Halley, 2003), and less than 0.25% in infants (Thomas, 1977). Assistance during delivery, including in dystocia, and neonates from primiparous dams should be considered as high risk factors for rib fractures (Jean et al., 1999; Rizzolo & Coleman, 1989; Schuijt, 1990).

Cranial rib fractures may cause lung injuries other than tracheal stenosis in calves. Callus formations in calves associated with rib fractures and subsequent tracheal stenosis are well documented; the clinical signs include wheezing, cough, dyspnea, and tachypnea (Fingland et al., 1990; Jelinski & Vanderkop, 1990; Rings, 1995). Ribs, however,

tend to fracture above the costochondral junction of the 2nd to 7th ribs in foals, and the most frequent accompanying pathological finding is contusion of the lung (Jean et al., 2007; Schambourg et al., 2003). The same mechanism possibly occurs in calves because the locations of rib fractures are likely to be the same (Braun, Ohlerth, Sydlar, Wehrli & Gerspach, 2009; Jelinski & Vanderkop, 1990; Kelly & Rowan, 1993). In fact, bronchopneumonia was reported in 1 of 2 rib fractured calves with tracheal stenosis at the age of 4 weeks (Braun et al., 2009).

Respiratory diseases have a negative impact on the beef cattle industry. Death of calves as well as reduced performance of diseased cattle through reduced weight gain, increased cost of weight gain, reduced carcass value, and treatment costs both lead to economic losses (Fulton et al., 2002). Dystocia born calves are reported to have increased numbers of respiratory diseases and mortality up to 30 days of age compared to those born by eutocia calving (Lombard, Garry, Tomlinson & Garber, 2007). Considering high calving assistance rates (Mee, 2008), rib fractured calves delivered by assisted or dystocia calving possibly lead to economic loss due to respiratory diseases.

The objective of the present study was to elucidate the effect of rib fractures in calves on health and economic outcomes. Two issues were addressed: 1) how a fractured rib affected the respiratory organs, trachea, and lung, as well as prognosis, and 2) the extent of the economic

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loss due to rib fractures. To address these issues, we diagnosed rib fractures, scanned or necropsied calves with rib fractures, and recorded information about sale prices and longevity to analyze the economic effect of rib fractures.

2. Materials and methods

2.1. Animals and herds

The present experiment was approved by the Animal Research Ethics Committee of Chiba Prefectural Federated Agricultural Mutual Aid Association. A total of 163 calves that were delivered from Holstein-Friesian dams following artificial insemination or embryo transfer were included in this study following consultation with the Western Veterinary Clinical centre located in northwestern Chiba Prefecture (Japan) at less than 90 days old for treatment of anorexia, dyspnea, and diarrhea from November 2016 to November 2018. The calves were 31 Holstein-Friesians, 82 Holstein-Friesian × Japanese Black crosses, and 50 Japanese Blacks (beef breed) with a median age of 23 days (range, 0 to 68 days) from 28 dairy farms. The calves were tied with a rope around the neck on 19 farms or reared individually in pens on 9 farms, and all calves were fed milk and formula after birth with gradual weaning at 50 to 60 days old. A total of 18 rib fractured calves from three Holstein-Friesians, six Holstein-Friesians × Japanese Black crosses, and nine Japanese Blacks with a median age of 13 days (range, 0 to 51 days) originating from 12 dairy farms were identified (Table 1).

2.2. Diagnosis of rib fractures

Rib fractures were diagnosed by palpation, a method having sensitivity of 63% and specificity of 62% in foals (Jean et al., 2007). With calves standing, the first author, who has more than 10 years' experience in clinical practice, routinely and bisymmetrically palpated pairs of ribs of 162 calves in order to determine the incidence of rib fractures, and one calf was palpated after diagnosis by computed tomography (CT). Ribs that curved abnormally were depressed towards the thoracic cavity or had callus formations were diagnosed as fractures (Jean et al., 2007; Rings, 1995). The existence of costochondral junctions was confirmed, but since costal cartilage was not palpated, dislocation was not evaluated. Computed tomography (Aquilion ONE, Canon Medical Systems, Otawara, Japan) of the chest was performed under sedation of 2 mg/kg of xylazine (Ceractal® 2% injection solution, Bayer, Leverkusen, Germany) at Nihon University in Calf 4, 5, and 13. Five rib fractured calves eventually died during treatment periods and thoracic necropsy was performed on Calf 1 and 10 with consent of the farmers.

2.3. Interviews

Farmers were interviewed retrospectively regarding presentation at birth, degree of calving difficulty, and sale price (yen) at the Chiba livestock market of the rib fractured calves that were sold after the diagnosis of rib fractures. The conditions of calving were graded by the first author on a 4-point scale (Vincze et al., 2018) as follows: eutocia (unobserved and unassisted calving), light dystocia, mild dystocia, and severe dystocia. Some farmers used a pocket block and tackle in dystocia.

2.4. Treatments

Diagnosed calves were treated by veterinarians, except for supportive treatment with electrolytes for diarrhea by farmers. Internal fixation and costectomy to treat rib fractures were not conducted. Inflammatory diseases, including bronchitis, pneumonia, otitis media, peri-arthritis, and infectious diarrhea, were repeatedly treated with antibiotics such as a streptomycin (12.5 mg/kg/d) and penicillin (10,000 unit/kg/d) mixture, oxytetracycline (10 mg/kg/d), and

enrofloxacin (5 mg/kg/d) until resolved, as well as flunixin (2 mg/kg/d) or non-steroidal anti-inflammatory drug mixture (Neos P, TOA Biopharma, Tokyo, Japan). Each antibiotic was administered for up to 5 days. Two cases of metacarpal fractures, including Calf 13, were caused by forceful pulling during dystocia and treated by external fixation immediately after birth. Inactive calves after resolution of main symptoms were diagnosed as having weak calf syndrome (WCS) and were treated only once with vitamins (vitamin A, 5000 IU/kg; vitamin D, 500 IU/kg; vitamin E, 0.5 IU/kg) and iron dextran (1 g/kg).

2.5. Statistical methods

R statistical software (R version 3.4.0) was used for all statistical analyses. Data were tested for normality using the Shapiro–Wilk test to ascertain whether parametric or nonparametric analyses were appropriate. Non-normally distributed data were summarized as a median (interquartile range). *P* values less than 0.05 were considered statistically significant. Differences among groups of the number of rib fractures were analyzed using the Wilcoxon rank-sum test. Differences in the incidence of rib fractures among breeds, or the sides and the order of ribs, and differences in positive rates of symptoms among groups were statistically analyzed using Fisher's exact test, followed by the Benjamini and Hochberg comparison method. The rib fracture incidence by rib order was calculated by including the total number of fractured ribs with a particular rib order in the numerator and the total number of ribs with a particular rib order in the denominator ($n = 326$). The median difference from the average sale price was statistically analyzed by using the one-sample Wilcoxon rank-sum test.

2.6. Economic analysis

In this analysis, the cost of rib fractures was limited to the difference from the average sale price at the Chiba livestock market. Thirteen rib fractured calves, excluding five dead calves, were sold at the market or by farmers at the age of 36 to 84 days. As breed and sex of calves are factors in market sale price, average sale price for each breed and sex was obtained from the Chiba livestock market (<http://www.chiba-kachiku.com/>). The sale price of the five dead calves was set at 0 yen; each average sale price by breed and sex for the day nearest to when the calf died was obtained from the above website.

2.7. Survival analysis

Survival analysis was designed as a matched case control study. Rib fractured calves (RibFrac, $n = 18$) were those diagnosed as having rib fracture by palpation, computed tomography, or necropsy, as described above. Control calves (control, $n = 107$) were those confirmed as having normal ribs by palpation. Control calves were matched to RibFrac calves based on breed (Holstein-Friesian, Japanese Black, and Holstein-Friesian × Japanese Black cross breed) and symptoms (Table 1). The remaining 38 calves without rib fractures were removed from the survival analysis due to having different breed or symptoms from RibFrac calves. Control calves were conservatively treated as described above. Information about transfer and longevity of the calves was identified from the National Livestock Breeding Center Database, Japan. Because the effect of rib fractures on survival was assessed within a year, the survival time was limited to the first 365 days. The survival rate was estimated using the Kaplan-Meier estimator as implemented in the R package 'survival' (package for survival version 2.41–3; Therneau & Lumley, 2017).

3. Results

The incidence of rib fracture in calves was 11.0% (18/163) overall with the following breakdown by breed: Holstein-Friesian, 9.7% (3/31); Holstein-Friesian × Japanese Black cross, 7.3% (6/82); and

Table 1
Clinical characteristics of 18 calves with rib fractures.

Calf	Breed of calves	Sex	Presentation at birth	Degree of dystocia ¹⁾	Parity of dam	Rib fracture location	Number of fractured ribs	Age at diagnosis (days)	Age at death (days)	Clinical observations
1	Holstein	Male	Posterior	Mild	Multiparous	R2-6	5	10	17-2)	Diarrhea, dyspnea, pyrexia
2	Holstein	Male	Anterior	Slight	Multiparous	R2-6	5	24	- 3)	Dyspnea
3	Holstein	Male	Posterior	Severe	Primiparous	R7-10, L2-7	10	13	-	Diarrhea, dyspnea, pyrexia
4	Holstein × Japanese Black	Male	Posterior	Mild	Multiparous	RL2-8	14	34	-	Dyspnea, pyrexia
5	Holstein × Japanese Black	Male	Posterior	Severe	Multiparous	L5-7	3	17	-	Diarrhea, pyrexia
6	Holstein × Japanese Black	Male	Unknown	Eutocia	Multiparous	R3-7	5	19	-	Dyspnea, pyrexia
7	Holstein × Japanese Black	Male	Unknown	Eutocia	Primiparous	R13	1	15	-	Periarthritis
8	Holstein × Japanese Black	Female	Unknown	Eutocia	Primiparous	R5-8	4	26	-	Periarthritis
9	Holstein × Japanese Black	Male	Unknown	Eutocia	Multiparous	R2-7, L2-7	12	13	-	Diarrhea, dyspnea
10	Holstein × Japanese Black	Female	Anterior	Severe	Primiparous	L1-10	10	51	62-2)	Diarrhea, dyspnea, pyrexia
11	Holstein × Japanese Black	Female	Unknown	Eutocia	Primiparous	L5-7	3	7	-	Diarrhea, dyspnea, pyrexia
12	Holstein × Japanese Black	Male	Posterior	Mild	Primiparous	L2-4	3	1	-	Dyspnea
13	Holstein × Japanese Black	Male	Anterior	Severe	Primiparous	R2-8, L2-7	13	22	-	Dyspnea, metacarpal fracture, pyrexia
14	Holstein × Japanese Black	Female	Anterior	Slight	Primiparous	R12-13	2	12	201	Diarrhea, dyspnea, otitis media, pyrexia
15	Holstein × Japanese Black	Male	Anterior	Slight	Primiparous	R12-13, L11-12	4	9	35	WCS ⁴⁾
16	Holstein × Japanese Black	Male	Anterior	Slight	Multiparous	R13	1	0	-	Pyrexia, WCS ⁴⁾
17	Holstein × Japanese Black	Male	Unknown	Eutocia	Multiparous	R13	1	7	36	Diarrhea, WCS ⁴⁾
18	Holstein × Japanese Black	Male	Anterior	Slight	Primiparous	R3-7	5	11	60	Dyspnea, pyrexia

Abbreviations: R, Right rib; L, Left rib; WCS, Weak calf syndrome.

¹⁾ Calving conditions based on retrospective interviews with the farmer and graded by the first author.

²⁾ Thoracic necropsy was performed.

³⁾ Death event was not reported to the National Livestock Breeding Center database.

⁴⁾ Calves that remained inactive after resolution of main symptoms were diagnosed as WCS.

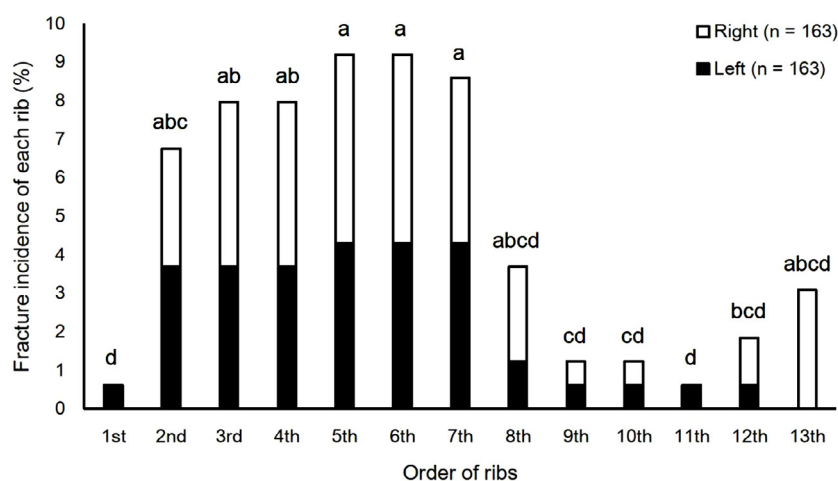


Fig. 1. Location of rib fractures detected by palpation. The rib fracture incidence by rib order was calculated by including the total number of fractured ribs with a particular rib order in the numerator and the total number of ribs with a particular rib order in the denominator ($n = 326$). Different letters above the incidences indicate statistically significant differences among ribs; incidences with the same letter are not significantly different.

Japanese Black, 18.0% (9/50). There were no significant differences in incidence among breeds or the side of body of broken rib ($P = 1$, for both). The incidence of fracture for each rib is shown in Fig. 1. There were significant differences in incidence among rib order, indicating that the 2nd to 7th ribs tend to break more often.

The median number of fractured ribs was 4.5 (3.0–8.75). This number was higher in severe dystocia (10.00, interquartile range 8.25–10.75, $n = 4$) than in eutocia (3.50, interquartile range 1.50–4.75, $n = 6$), or slight to mild dystocia (4.50, interquartile range 2.75–5.00, $n = 8$), but these differences were not significant. Delivery was assisted by veterinarians for three of the rib fractured calves with dystocia (Calf 4, 5, and 13). Most of the rib fractured calves presented with dyspnea (12/18) and pyrexia (<39.5 °C, 11/18). Eleven of 13 calves that had fractured 1st to 10th ribs presented with dyspnea, whereas only one of five calves with fractured 11th to 13th ribs showed dyspnea ($P < 0.05$); nine of 13 calves that had fractured 1st to 10th ribs presented with pyrexia, whereas two of five calves with fractured 11th to 13th ribs showed pyrexia ($P = 0.33$). The median age at treatment for calves with dyspnea and/or pyrexia ($n = 14$) was 12.00 (7.00–19.75). Two out of 14 rib fractured calves with dyspnea and/or pyrexia died due to severe pneumonia at 60 and 62 days old (Calf 18 and 10, respectively). Calf 1 presented with dyspnea and pyrexia and was euthanized at 17 days of age because of chronic diarrhea. Calf 15 was diagnosed with WCS after birth and died suddenly at 35 days old; Calf 17 was diagnosed with chronic diarrhea and WCS and was euthanized at 36 days old due to development of neurological symptoms including opisthotonus and nystagmus. Calf 14 died at 201 days for unknown reasons after the calf was sold.

CT scans and thoracic necropsy were performed to confirm rib fractures and to elucidate the effects on the trachea and lung in our 1st to 4th, and 8th cases. CT scans of three calves (Calf 4, 5, and 13) are shown in Fig. 2. None showed tracheal stenosis (Fig. 2A, C, E) but showed callus formations at the site of rib fractures (Fig. 2B, D, F) and inflammatory signs in the lung around fractured ribs in two of three calves (Fig. 2B, F), indicating the presence of pneumonia.

Thoracic necropsied images of two calves (Calf 1 and 10) are shown in Fig. 3. Calf 1 and 10 had five and six callus formations, respectively, that projected toward the thoracic cavity (Fig. 3A, C). Bronchopneumonia was present in the cranial and middle lobes of the right lung of Calf 1 (Fig. 3B); suppurative and necrotic pneumonia was present in the right and left lungs of Calf 10 (Fig. 3D). Furthermore, the projected parts in the 4th to 6th ribs of Calf 10 compressed the left lung. None showed tracheal stenosis.

Among 45 fractured ribs in five cases of CT scans and necropsy, fractures were significantly more frequent in the middle part (34/45, 75.6%) than in the proximal part (2/45, 4.4%) or the distal part (9/45, 20.0%). Proximal fractures occurred in the 2nd and 3rd ribs; middle

fractures occurred in the 1st to 10th ribs; distal fractures occurred in the 2nd to 6th ribs. Callus formation was recognized in 29 ribs at 16 to 61 days old (64.4%), whereas ventral fractures were completely separated from the dorsal part in 6 ribs at 22 days old (13.3%, Calf 13).

Five rib fractured calves died at 17 to 62 days old due to having a diagnosis as described above, 12 were sold at the Chiba livestock market, and one calf was sold for no payment by farmers due to chronic cough (Calf 4). Disposition and sale price information of the calves are shown in Table 2. The median difference from the average sale price at the market was minus 64,861 yen (minus 337,314–8,265 yen), meaning that rib fractured calves were sold at a significantly lower price ($P < 0.05$). Survival analysis was performed to evaluate the effect of rib fractures on health. Kaplan-Meier curves (Fig. 4) indicated an overall association between rib fractures and time to death ($P_{\text{logrank}} < 0.05$).

4. Discussion

In the present study, we found rib fractures in 11.0% (18/163) of sick calves, and rib fractures occurred especially at the 2nd to 7th ribs, tended to cause pneumonia, and decreased sale prices and longevity. The trachea at the thoracic inlet was reported to become stenotic due to cranial rib fractures and ensuing callus formations in calves (Fingland et al., 1990; Jelinski & Vanderkop, 1990; Rings, 1995). Here, we reported four cases of rib fractured calves with pneumonia at the sites of rib fractures by CT and necropsy despite no diagnosis of tracheal stenosis (Calf 1, 4, 10, and 13).

Rib fractures of the calves in this study were likely caused from pressure in the birth canal at delivery. Rib fractures were reported in 23.0% (54/235) of calves that died perinatally (Schuijt, 1990) and in 20.9% (55/263) of living newborn foals (Jean et al., 1999). Bovine perinatal fractures of long bones such as the metatarsus/metacarpus, tibia, and radius/ulna especially occur due to forceful and unskilled pulling in severe dystocia (Pentecost, Niehaus & Anderson, 2016). The calves in this study were raised separately from their dams starting a maximum of 8 h after birth, meaning that the possibility of being trampled or kicked by the dam was present but low; other traumatic events causing damage to the ribs were not reported by the farmers. Many of the fractures in the ribs were in a straight line, indicating that rib fractures happened due to pressure in the birth canal during delivery. The lower incidence of rib fractures reported here was mainly due to the later age of diagnosis and potential misdiagnosis by palpation. Calves that were severely affected by rib fractures likely died shortly after birth (Schuijt, 1990) and were not included in this study. In addition, cases of rib fractures may have been underestimated by overlooking incomplete or oblique fractures because ultrasonography is reported to be more accurate than radiography and palpation in humans and newborn foals (Griffith et al., 1999; Jean et al., 2007). On the

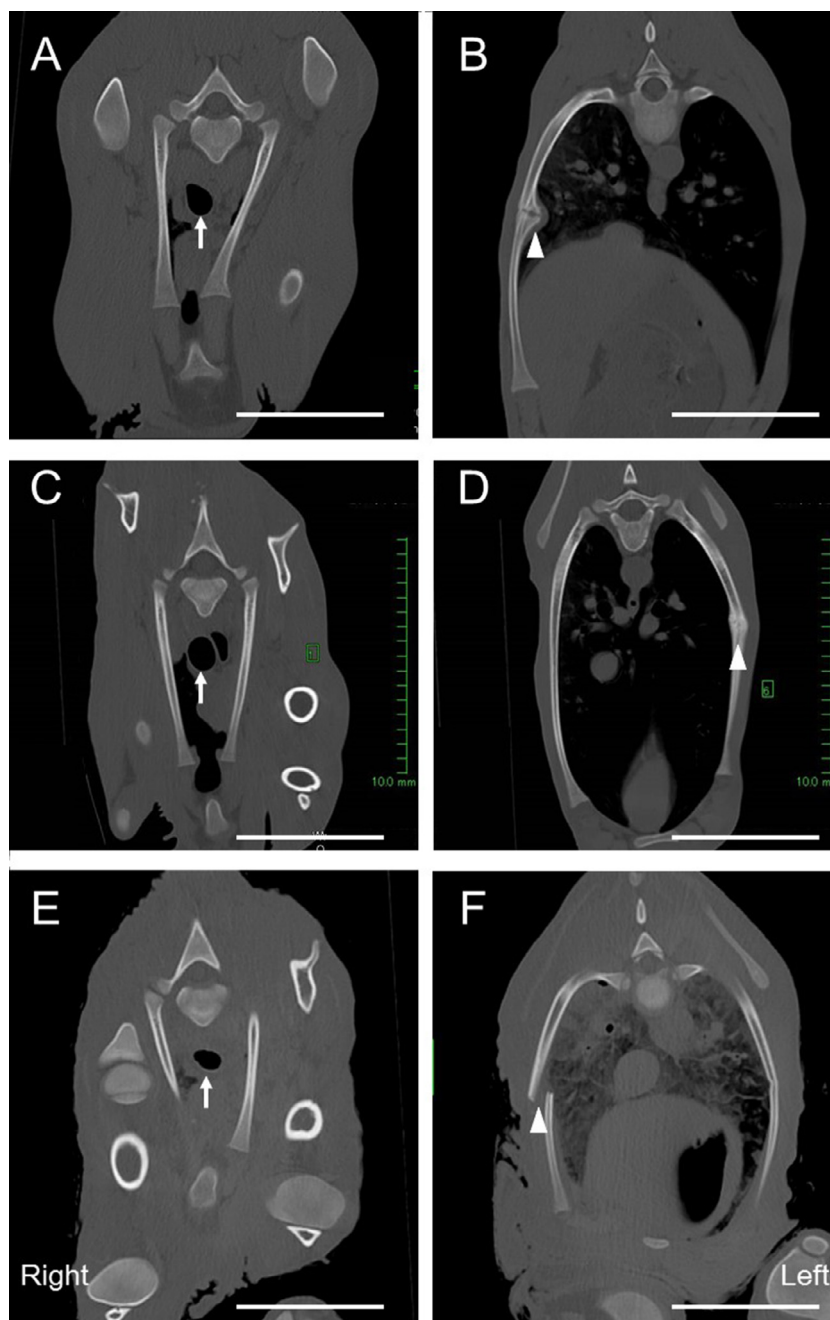


Fig. 2. CT images in Calf 4 (A and B), 5 (C and D), and 13 (E and F). Cross sections of trachea are shown at the site of the 1st rib (arrows; A, C, and E). Callus formation and fractured rib ends are recognized (arrowheads; B, D, and F). Scale bar: 100 mm.

other hand, the incidence may be overestimated because rib fractured calves were so ill that farmers sought treatment for the conditions that were likely caused by the broken rib. The possibility of being trampled or kicked by the dam should be considered. Interestingly, we found rib fractures in six cases of eutocia out of 18 cases although misgrading of calving should be considered due to retrospective interviews, meaning that rib fractures occur in eutocia as well as in dystocia. It is unclear why the six calves born in eutocia had fractured ribs in this study. Since four out of six calves were male and half of their dams were primiparous, it may be due to fetopelvic disproportion (Mee, 2008). Dystocia scoring used in this study was developed to evaluate the difficulty or ease of deliveries from the viewpoint of farm workers (Mee, 2008; Vincze et al., 2018). Dystocia scoring may not necessarily indicate pressure in the birth canal on neonates at delivery.

Rib fractured neonates, not necessarily with tracheal stenosis,

tended to present with dyspnea at a later stage. Cranial rib fractures including at the 1st or 2nd rib and subsequent tracheal stenosis have been well reported in calves (Fingland et al., 1990; Hidaka et al., 2016; Jelinski & Vanderkop, 1990). Four out of five scanned or necropsied calves (Calf 1, 4, 10, and 13), however, presented with pneumonia at the sites of rib fractures in this study, despite four calves not having tracheal stenosis; this clearly indicates that perinatal rib fractures trigger respiratory disease other than tracheal stenosis at later stages after birth. The dorsal or ventral fragments of fractured ribs was reported to orient medially or axially in foals due in part to negative pressure of the thorax cavity (Jean et al., 2007; Sprayberry, Bain, Seahorn, Slovis & Byars, 2001). Pulmonary contusion was the most frequent condition in rib fractured foals diagnosed at 3 days old and younger (Sprayberry et al., 2001). Braun reported callus formations and bronchopneumonia in one of two rib fractured calves

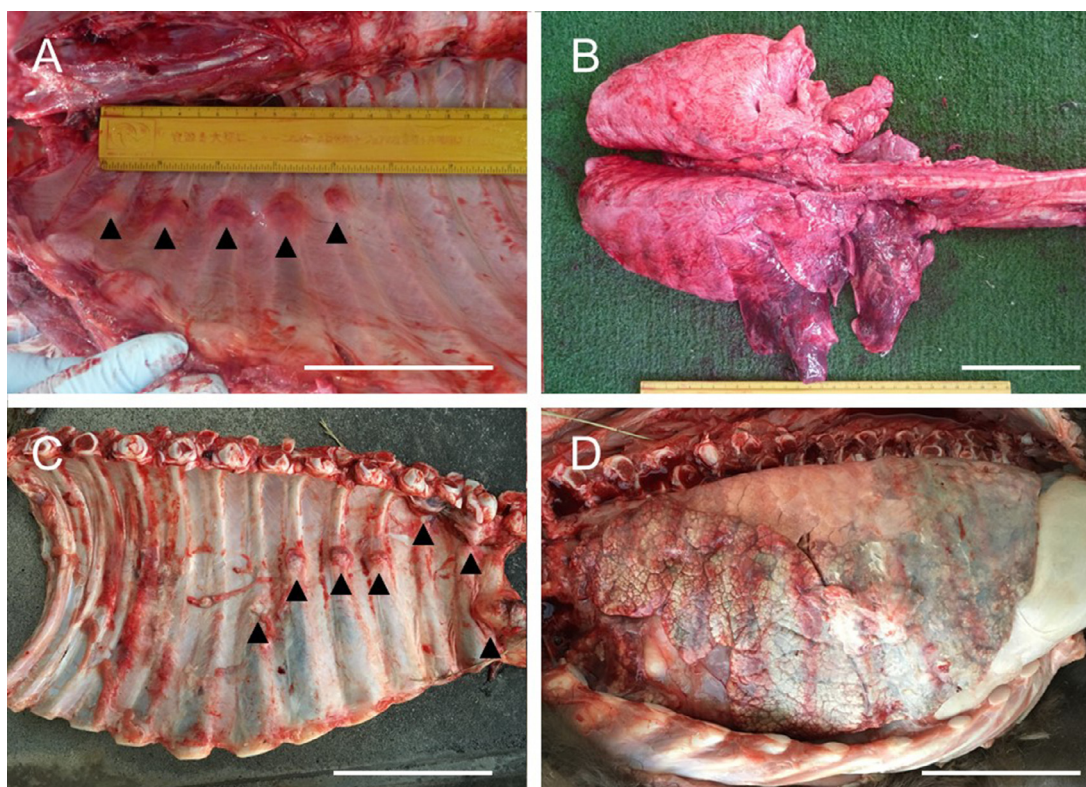


Fig. 3. Thoracic necropsied images in Calf 1 (A and B) and 10 (C and D). Callus formations (arrow heads) and pneumonia are shown. Scale bar: 100 mm.

Table 2
Disposition and sale price for 18 calves with rib fractures.

Calf	Disposition	Sale price (yen)	Average sale price for the same breed and sex (yen)	Difference from average sale price (yen)
1	Died	0	141,758	-141,758
2	Sold	218,160	195,750	22,410
3	Sold	129,600	171,729	-42,129
4	Sold	0	374,972	-374,972
5	Sold	333,720	375,151	-41,431
6	Sold	245,160	305,805	-60,645
7	Sold	243,000	312,076	-69,076
8	Sold	126,360	230,388	-104,028
9	Sold	324,000	332,134	-8134
10	Died	0	513,909	-513,909
11	Sold	486,000	472,269	13,731
12	Sold	669,600	558,840	110,760
13	Sold	389,880	614,218	-224,338
14	Sold	745,200	553,410	191,790
15	Died	0	585,587	-585,587
16	Sold	775,440	596,030	179,410
17	Died	0	648,080	-648,080
18	Died	0	631,980	-631,980
Average		260,340	423,004	-162,665

with tracheal stenosis at the age of 4 weeks (Braun et al., 2009). These findings suggest that prolonged pulmonary contusion deteriorated by callus formations induces partial damage to the lung and may cause pneumonia. The benefit of surgical stabilization compared with internal therapy for extensive rib fractures has been documented in humans and includes the lower incidence of pneumonia mainly due to shorter intubation duration (Tanaka et al., 2002). Tanaka pointed out that surgical stabilization allows not only restoration of rib cage deformity, but also preservation of intercostal muscle function, improving the respiratory function of patients. Calves born to dams having severe dystocia had higher cortisol concentrations after birth, greater odds of respiratory disease and mortality, and required more treatment than

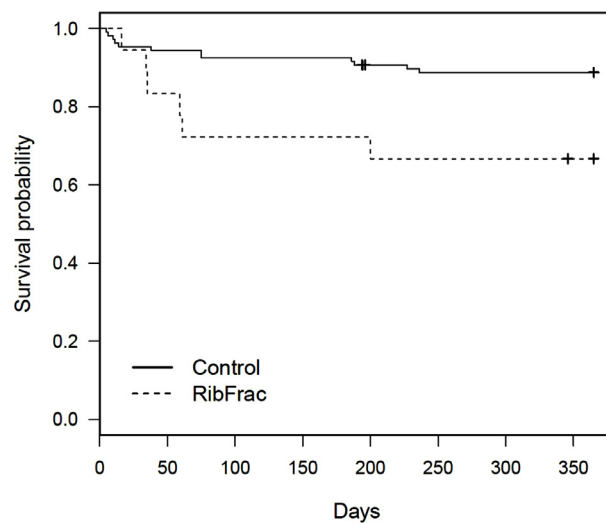


Fig. 4. Proportion of living calves up to 1 year of age. Control group (n = 107) and RibFrac group (n = 18) were divided by diagnosis of palpation.

calves with normal deliveries (Barrier et al., 2013; Lombard et al., 2007; Muggli-Cockett, Cundiff & Gregory, 1992). Thus, subsequent callus formation caused by cranial rib fractures may cause relative tracheal stenosis, damage the lung, deteriorate pulmonary functions, and increase the incidence of respiratory disease, including pneumonia, at later stages after birth.

Rib fractures in calves affected with pneumonia may need surgical treatment. Internal fixation techniques for rib fractures have been reported in newborn foals (Bellezzo, Hunt, Provost, Bain & Kirker-Head, 2004; Downs & Rodgerson, 2011; Kraus, Richardson, Sheridan & Wilkins, 2005). We treated rib fractured calves conservatively because the fractured ribs already had callus formation at the time of diagnosis

in many cases, but the median sale price and survival rate were significantly lower than average sale price. The costs of rib fractures were even higher when considering veterinarian, drug, and labor costs associated with increasingly intensive treatments. These potential economic losses through conservative treatment imply the importance of surgery for rib fractures. Partial costectomy to treat fractured ribs was reported to improve respiration after surgery in all the three calves with tracheal collapse and stenosis at 1 to 6 months old (Hidaka et al., 2016). This operation may be adapted to rib fractured calves with pneumonia, although proficient operators, surgical facilities that can anaesthetize with isoflurane, and careful nursing are necessary. Surgical stabilization compared to internal therapy for extensive rib fractures was effective to prevent pneumonia in humans (Tanaka et al., 2002). Local veterinarians should diagnose rib fractures after birth and consider surgical operations to reduce losses and poor welfare of rib fractured calves.

In the present study, we demonstrated negative effects of rib fractures on calves after birth using pathological findings and univariate analyses. Nevertheless, our data should be carefully interpreted due to the presence of a number of potential sources of bias that affect analyses, such as the population of calves, differences in herd management decisions, and conservative treatments, potential improper diagnoses of rib fractures, and the small number of scanned or necropsied calves (five animals). In particular, the diagnosis method of palpation could be critical. The possibility of misdiagnosis of rib fractures was likely low, since we palpated at a median age of 23 days, which is later than in previous reports (Jean et al., 1999; Schuh & Killeen, 1988) and many of the calves had already formed calluses at the fracture points. Further analyses in other herds using ultrasonography are required to confirm rib fractures in eutocia and the negative effects of rib fractures on calves.

5. Conclusions

Rib fractures occurred particularly in the 2nd to 7th ribs, tended to cause pneumonia, and resulted in decreased sale prices and longevity; therefore, it is important for farmers and veterinarians to discover these disorders after birth with accurate diagnosis. To decrease economic loss caused by rib fractures in calves, the development of simple surgical procedures before callus formation is required.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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