

# Effect of intravenous calcium and oral sodium phosphate in cows with parturient paresis<sup>1</sup>

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## Summary

The goal of this study was to determine whether oral administration of sodium phosphate in conjunction with intravenous calcium is more efficacious than intravenous calcium alone for the treatment of parturient paresis. Thirty cows with parturient paresis were examined and treated by the same veterinarian. The cows were divided randomly into two groups of 15 cows each. Cows in group A received 500 ml of a 40 per cent calcium borogluconate solution containing 15.65 g calcium gluconate and borogluconate, with a supplement of 6 per cent magnesium hypophosphite (9.85 g magnesium hypophosphite) intravenously over a period of approximately 15 min. Cows in group B received the same treatment as well as 350 g of monobasic sodium phosphate (70 g inorganic phosphate,  $\text{NaH}_2\text{PO}_4 \cdot 2 \text{H}_2\text{O}$ , Streuli) dissolved in 0.5 litres of distilled water orally via a stomach tube. After treatment, the heart rate, respiratory rate, rectal temperature, superficial body temperature, rumen motility, appetite and defecation of the cows were monitored every hour for eight h. The cows' attempts to rise and their ability to stand were also noted. Initially, the results of clinical examination and serum electrolyte analyses did not differ between the two groups of cows. Within one hour of treatment, stupor was not observed in any of the cows. The general demeanour after treatment did not differ significantly between the two groups. In both groups, the average rectal temperature increased within two hours of the initiation of treatment, from  $38.0 \pm 0.95^\circ\text{C}$  to  $38.5 \pm 0.40^\circ\text{C}$ . There was no significant difference in the recovery rate between the groups. Of the 30 cows, 22 (73.3 per cent) stood within eight hours of treatment (10 cows from group A and 12 cows from group B). The type of treatment did not affect the time required to stand: cows in group A stood within  $47.3 \pm 44$  minutes and cows in group B stood within

## Kombinierte Behandlung der Gebärparese mit Kalzium intravenös und Natriumphosphat per os

Das Ziel der vorliegenden Arbeit war es, bei Kühen mit Gebärparese abzuklären, ob die kombinierte Verabreichung von Natriumphosphat per os und von Kalzium intravenös wirksamer als die alleinige intravenöse Kalziumapplikation ist. 30 Kühe mit Gebärparese wurden durch die gleiche Tierärztin untersucht und behandelt. Die Kühe wurden in 2 Gruppen à 15 Tiere eingeteilt. Die Kühe der Gruppe A erhielten 500 ml einer 40%igen Kalziumborogluconatlösung über einen Zeitraum von 15 Minuten intravenös. Die Kühe der Gruppe B wurden gleich behandelt. Zusätzlich wurde ihnen 350 g Natriumphosphat (70 g anorganischer Phosphor,  $\text{NaH}_2\text{PO}_4 \cdot 2 \text{H}_2\text{O}$ , Streuli AG, Uznach), gelöst in 0.5 l destilliertem Wasser mit der Schlundsonde peroral verabreicht. Nach der Behandlung wurden das Allgemeinbefinden, die Herzfrequenz, die Atemfrequenz, die rektale Temperatur, die Körperoberflächentemperatur, die Pansenmotorik, die Futteraufnahme und der Kotabsatz während 8 Stunden stündlich protokolliert. Ebenfalls festgehalten wurden die Aufstehversuche und die Zeit bis zum definitiven Aufstehen. Initial unterschieden sich die klinischen Befunde und die Serumelektrolyte der beiden Gruppen nicht signifikant. Innerhalb einer Stunde nach der Behandlung war keine Kuh mehr stuporös. Das Allgemeinbefinden der Tiere in beiden Gruppen unterschied sich nach der Behandlung ebenfalls nicht signifikant. Bei beiden Gruppen stieg die durchschnittliche rektale Temperatur innerhalb von 2 Stunden nach Behandlungsbeginn von  $38.0 \pm 0.95^\circ\text{C}$  auf  $38.5 \pm 0.40^\circ\text{C}$  an. Die Erholungsraten der beiden Gruppen unterschieden sich nicht signifikant. Von den 30 Kühen konnten innerhalb von 8 Stunden 22 (73.3 %) wieder stehen (10 Kühe der Gruppe A und 12 Kühe der Gruppe B). Die Behandlungsart hatte keinen signifikanten Einfluss auf die Zeit bis zum Aufstehen: Kühe der Gruppe A standen innerhalb von

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24.2 ± 32 minutes after the start of treatment. Our findings do not support the hypothesis that oral treatment with 350 g of sodium phosphate together with intravenous infusion of calcium in cows with parturient paresis results in an improved outcome, even though all the cows had hypophosphataemia as well as hypocalcaemia.

**Keywords:** cattle, parturient paresis, hypophosphataemia, therapy, sodium phosphate

47.3 ± 44 Minuten, Kühe der Gruppe B innerhalb von 24.2 ± 32 Minuten auf. Unsere Ergebnisse konnten die Hypothese nicht untermauern, dass die kombinierte Behandlung der Gebärparesie mit 350 g Natriumphosphat per os und 500 ml einer Kalziumborogluconatlösung intravenös zu einer Verbesserung des Therapieerfolgs führt, obschon alle Kühe sowohl eine Hypophosphatämie als auch eine Hypokalzämie aufwiesen.

**Schlüsselwörter:** Rind, Gebärparesie, Hypophosphatämie, Therapie, Natriumphosphat

## Introduction

Parturient paresis is a common disorder of high-producing dairy cows. Affected cows usually have decreased serum concentrations of calcium and inorganic phosphorus, whereas a decrease in the calcium concentration alone is rare (Martig, 2002; Salis, 2002; Jehle, 2004; Braun et al., 2004, 2006). However, it is not known whether a decreased serum concentration of phosphorus is a cause of parturient paresis, and the role of inorganic phosphorus in the pathogenesis of parturient paresis has been questioned (Oetzel, 1988; Goff, 2000). The main causes of hypophosphataemia include reduced intestinal absorption, which is attributable to decreased intake, malabsorption or vitamin D deficiency; increased renal excretion due to elevated parathormone release, and transcellular electrolyte imbalance (Dru Forrester and Moreland, 1989). In cattle with left displacement of the abomasum, reduced feed intake is the main cause of hypophosphataemia (Grünberg et al., 2005). Severe hypophosphataemia can have grave clinical consequences. In cows with parturient paresis, low levels of phosphorus affect skeletal muscle causing generalised myopathy characterised by weakness, muscle necrosis and myoglobinuria (Dru Forrester and Moreland, 1989). These signs are the result of an energy deficiency caused by insufficient phosphorus. Phosphorus, which is necessary for the synthesis of adenosine triphosphate ATP and 2,3-DPG (Visser 't Hooft et al., 2005). Adenosine triphosphate is also required to maintain the integrity of cell membranes and cell shape and deformability. This makes nearly every organ system susceptible to the effects of hypophosphataemia (Visser 't Hooft et al., 2005). It is not clear whether hypophosphataemia requires specific treatment in cattle with parturient paresis. The standard therapy consists of rapid intravenous infusion of a calcium solution, which may also contain phosphorus and other substances (Radostits et al., 2000; Martig, 2002). In these solutions, phosphorus is in the form of water-soluble phosphite, which has no therapeutic

significance (Cheng et al., 1998). Phosphate, which is metabolized by the cow, precipitates in calcium-containing solutions and is therefore not added to calcium solutions. Thus, for cows with hypophosphataemia, oral administration of sodium phosphate has been recommended (Oetzel, 1988). Cheng et al. (1998) reported that oral administration of sodium phosphate to healthy cows with mild hypophosphataemia resulted in a marked increase in the serum concentration of inorganic phosphorus within one hour of administration. In a field study of cows with parturient paresis, oral administration of a gel containing calcium and 45 g of phosphorus in combination with intravenous calcium did not improve the outcome (Gelfert et al., 2004). Furthermore, the administration of this same oral preparation to healthy cows did not increase the serum concentration of inorganic phosphate (Horner and Staufenbiel, 2004). Based on these conflicting results, the goal of the present study was to determine whether oral administration of sodium phosphate in conjunction with intravenous calcium is more efficacious than intravenous calcium alone for the treatment of parturient paresis in cows.

## Animals, Material and Methods

### Cows

From January 1, 2004, to April 30, 2005, 30 cows with parturient paresis were examined and treated by the same veterinarian (J. D.) at the Veterinary Ambulatory Clinic, University of Zurich, as part of her DrMedVet thesis. The cows originated from different farms and had become ill within 23 hours of calving (0 to 23 hours). The cows ranged in age from 4 to 10 years (mean ± standard deviation = 7.1 ± 1.65 years) and consisted of 15 Simmental, 8 Swiss Braunvieh and 7 Holstein Friesian cows. All the cows underwent a thorough clinical examination as described by Rosen-

berger (1990). Parturient paresis was diagnosed on the basis of the presence of typical clinical signs (Radostits et al., 2000). The diagnosis and treatment of parturient paresis occurred 1.0 to 14.0 h ( $4.3 \pm 2.5$  h) after the beginning of the animals' inability to stand. This period of time did not differ significantly between the two treatment groups.

### Blood and urine analyses

Samples of blood were collected from all the cows for the determination of total calcium, ionised calcium, inorganic phosphorus and magnesium in serum. Urine samples were tested for the presence of ketone bodies.

### Treatment

The cows were divided randomly into two groups of 15 cows each. Cows in group A received 500 ml of a 40 per cent calcium borogluconate solution containing 15.65 g calcium gluconate and borogluconate, with a supplement of 6 per cent magnesium hypophosphite (9.85 g magnesium hypophosphite) (Calcanyl-40MP, Gräub AG, Niederwangen, Switzerland) intravenously over a period of approximately 15 min. Cows in group B received the same treatment as well as 350 g of monobasic sodium phosphate (70 g inorganic phosphate,  $\text{NaH}_2\text{PO}_4 \cdot 2 \text{H}_2\text{O}$ , Streuli) dissolved in 0.5 litres of distilled water orally via a stomach tube. After treatment, the heart rate, respiratory rate, rectal temperature, superficial body temperature, rumen motility, appetite and defecation of the cows were monitored every hour for eight h. The cows' attempts to rise and their ability to stand were also noted.

### Statistics

The data were analysed by means of StatView 5.0 (SAS Institute). Frequencies, means and standard deviations were calculated, and all data were tested for normal distribution. No significant difference from a

normal distribution was found. Therefore, parametric tests were used for further evaluation of the results. Groups were compared using factorial and repeated analysis of variance, Student's *t* test and the chi-squared test.

## Results

### Clinical findings before treatment

The results of clinical examination did not differ between the two groups of cows. Based on the cows' history, appetite was normal in two cows, reduced in five and absent in 23. Fifteen cows had a normal demeanour, 13 were apathic, and two were stuporous. The stuporous cows were in lateral recumbency, the remaining twenty-eight cows were in sternal recumbency. The rectal temperature was significantly decreased ( $37.3 \pm 1.03^\circ \text{C}$ ) in cows that were apathetic or stuporous, compared with the cows whose demeanour was normal ( $38.5 \pm 0.49^\circ \text{C}$ ,  $P < 0.01$ , Student's *t* test). The heart rate varied from 48 to 108 bpm ( $79.7 \pm 14.9$  bpm), and the respiratory rate ranged from 16 to 76 breaths/minute ( $28.9 \pm 12.7$  breaths/minute). The superficial body temperature was lower than normal in 21 cows. The muzzle was dry in 12 cows, and there was scleral engorgement in twelve. Rumen motility was reduced in 17 cows and absent in 10. Intestinal motility was reduced in 15 and absent in 9 cows. There was no defecation in 17 cows. Nine cows had a retained placenta. Ketone bodies were detected in the urine of one cow. A detailed description of the clinical findings was published by Dumelin (2005).

### Serum concentration of electrolytes

The results of electrolyte analyses did not differ significantly between the two groups. The concentrations of total calcium, ionised calcium and inorganic phosphorus were lower than normal in all the cows (Tab 1). There were significant correlations between

Table 1: The concentrations of total calcium, ionised calcium, inorganic phosphorus and magnesium in 30 cows with parturient paresis measured before treatment.

Variable	Mean $\pm$ sd (range)	Finding	Number of cows
Calcium (mmol/l)	$1.06 \pm 0.37$ (0.57 – 1.99)	Normal ( $> 2.01$ ) Low ( $< 2.00$ )	0 30
Ionised calcium (mmol/l)	$0.59 \pm 0.19$ (0.31 – 0.97)	Normal ( $> 1.06$ ) Low ( $< 1.05$ )	0 30
Inorganic phosphorus (mmol/l)	$0.48 \pm 0.30$ (0.15 – 1.27)	Normal ( $> 1.31$ ) Low ( $< 1.30$ )	0 30
Magnesium (mmol/l)	$1.33 \pm 0.29$ (0.96 – 1.97)	Normal ( $> 0.81$ ) Low ( $< 0.80$ )	30 0

the concentrations of total calcium and ionised calcium ( $r = 0.97$ ,  $P < 0.01$ ), and between total calcium and inorganic phosphorus ( $r = 0.40$ ,  $P < 0.05$ ). The ionised form was on average 56.3 per cent of the total concentration of calcium.

### Clinical course after treatment

Within one hour of treatment, stupor was no longer observed in any cows. The distribution of the demeanour after treatment did not differ significantly between the two groups. In both groups, the average rectal temperature increased within two hours after the initiation of treatment, from  $38.0 \pm 0.95^\circ\text{C}$  to  $38.5 \pm 0.40^\circ\text{C}$ . The heart and respiratory rates, before treatment  $79.7 \pm 14.9$  and  $28.8 \pm 12.7$  per minute, respectively, did not change significantly during the eight-hour period of observation. A cardiac arrhythmia occurred in three cows, but disappeared several minutes after treatment.

In all the cows, feed intake resumed after the start of treatment, and they all had normal rumen motility three hours after treatment. All 17 cows that had not defecated at the time of clinical examination had done so by  $1.5 \pm 1.07$  hours after the start of treatment. There was no significant difference in gastrointestinal findings between the groups.

There was no significant difference in the recovery rate between the groups. Of the 30 cows, 22 (73.3 per cent) stood within eight h of treatment (10 cows from group A and 12 cows from group B). The type of treatment did not affect the time required to stand: cows in group A stood within  $47.3 \pm 44$  min and cows in group B stood within  $24.2 \pm 32$  min after the start of treatment.

Of the eight cows that were unable to stand up within eight hours of treatment, four (two from each group) stood within 24 hours of treatment by administering an additional 500 ml of the calcium solution intravenously (300 ml) and subcutaneously (200 ml). The other four cows did not rise after a second treatment and became downer cows (Radostits et al., 2000). These cows were placed on deep bedding, rolled from side to side every eight hours and, at times, lifted with cow lifters; specific electrolyte disorders in these cows were also corrected. One (from group A) of the four cows stood 36 hours after the start of treatment; however, the other three cows (two cows of group A and one cow of group B) were euthanased two to three days after the start of treatment.

Of 22 cows that stood after treatment, six (two from group A and four from group B) became recumbent again eight to twenty-four h later. These cows were treated with 500 ml of calcium solution, administered intravenously over 15 min, after which time they were able to stand again. Two other cows (one from each

group) were treated with calcium solution (300 ml intravenously and 200 ml subcutaneously) 8 and 24 h, respectively, after the initial treatment because they appeared weak, although they were able to stand. The clinical signs resolved after the second treatment.

The initial concentrations of total and ionised calcium in cows that stood within eight hours of the initiation of treatment ( $n = 22$ ; calcium  $1.14 \pm 0.37$  mmol/l, ionised calcium  $0.64 \pm 0.18$  mmol/l) were significantly higher than those of cows that did not stand within eight hours of initiation of treatment ( $n = 8$ ; calcium  $0.82 \pm 0.26$  mmol/l, ionised calcium  $0.45 \pm 0.13$  mmol/l,  $P < 0.01$ ). Of the 30 cows with parturient paresis, 14 (47 %) were cured after one treatment. In 13 cows (43 %), two or more treatments were required, and three cows (10 %) did not stand despite repeated treatments, and were euthanased.

### Discussion

The clinical signs of the cows with parturient paresis in the present study were comparable to those described in standard text books (Bostedt, 1993; Radostits et al., 2000; Hunt and Blackwelder, 2002; Martig 2002). In all cows the serum concentrations of both calcium and phosphorus were lower than normal, which is in agreement with other published data (Bostedt, 1973; Radostits et al., 2000; Martig, 2002).

The success rates were the same for both methods of treatment. The overall success rate was 90 per cent and was considered good; however, it should be noted that only 14 (47 per cent) cows responded to a single treatment and that 13 (43 per cent) cows required two or more treatments. The success rate of a single treatment for parturient paresis varies from 43 to 66 per cent (Bostedt et al., 1979; Meschke, 1997; Radostits et al., 2000; Salis, 2002; Jehle, 2004; Braun et al., 2004). It was interesting to note that the initial concentrations of total and ionised calcium in cows that stood within eight hours of initiation of treatment were higher than those of cows that did not stand within this same time period. This is in agreement with the findings of other authors; cows that did not respond to initial treatment with intravenous calcium infusion had lower levels of inorganic phosphorus as well as calcium compared with cows that stood after one treatment (Stolla et al., 2000). In contrast, previous studies at our clinic showed that there was no correlation between outcome and the initial serum concentration of electrolytes (Salis, 2002; Jehle, 2004).

Our findings did not support the hypothesis that oral treatment with 350 g of sodium phosphate (70 g inorganic phosphate) together with intravenous infusion of calcium in cows with parturient paresis results in an improved outcome, even though all the cows had hypophosphataemia as well as hypocalcaemia.

Clinically, oral sodium phosphate had no additional positive effect on outcome, which was identical to that of cows treated with intravenous infusion of calcium alone. The success rate after one treatment in the present study was 47 per cent, which was the same as

that reported in previous studies (Salis, 2002; Jehle, 2004). Whether the amount of sodium phosphate administered in the present study was insufficient or additional treatments would have altered the outcome requires further investigation.

### Traitement combiné de la parésie post partum avec du calcium intraveineux et du phosphate de sodium oral

Le but du présent travail était de savoir si le traitement combiné par application orale de phosphate de sodium et intraveineuse de calcium est plus efficace que l'application intraveineuse de calcium uniquement. Trente vaches atteintes de parésie post partum ont été examinées et traitées par la même vétérinaire. Elles ont été divisées en deux groupes de 15 animaux chacun. Les vaches du groupe A ont reçu 500 ml d'une solution à 40% de borogluconate de calcium en 15 minutes par voie intraveineuse. Les vaches du groupe B ont reçu le même traitement ainsi que 350 grammes de phosphate de sodium (70% de phosphore anorganique  $\text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$ , Streuli AG, Uznach, Suisse) dissout dans 0.5 litre d'eau distillée et appliqués oralement avec une sonde. Après le traitement, l'état général, les fréquences cardiaques et respiratoires, les températures rectale et superficielle, l'activité de la pensée, la prise de nourriture et la défécation ont été enregistrés chaque heure durant 8 heures. On a également noté les essais de relever et le temps jusqu'au relever définitif. A l'origine, les paramètres cliniques et les électrolytes sériques des deux groupes ne se différenciaient pas de façon significative. Aucune vache n'était plus somnolente une heure après le traitement. L'état général des animaux des deux groupes ne se différenciait pas non plus de façon significative après le traitement. Dans les deux groupes, la température rectale, deux heures après le début du traitement, augmentait de  $38.0 \pm 0.95^\circ \text{C}$  à  $38.5 \pm 0.4^\circ \text{C}$ . Le taux de récupération des deux groupes ne se différenciait pas de façon significative. 22 (73.3%) des 30 vaches ont pu se lever dans les 8 premières heures (10 du groupe A et 12 du groupe B). Le mode de traitement n'a pas d'influence significative sur le temps jusqu'au relever: les vaches du groupe A se sont levées en  $47.3 \pm 44$  minutes, celle du groupe B en  $24.2 \pm 32$  minutes. Ces constatations ne permettent pas d'accréditer l'hypothèse qu'un traitement combiné de la parésie post partum avec du phosphate de sodium et du borogluconate de calcium améliore les résultats thérapeutiques bien que toutes les vaches aient souffert aussi bien d'une hypophosphatémie que qu'une hypocalcémie.

### Trattamento combinato con calcio per via intravenosa e di fosfato di sodio per via orale in caso di febbre lattea

Scopo del presente lavoro è di chiarire se in caso da febbre lattea nelle mucche, la somministrazione combinata di fosfato di sodio per via orale e di calcio per via intravenosa sia più efficace dell'applicazione unica di calcio per via intravenosa.

30 mucche affette da febbre lattea sono state esaminate e trattate dallo stesso medico veterinario. Le mucche sono state suddivise in 2 gruppi di 15 animali. Le mucche del gruppo A hanno ricevuto 500 ml di una soluzione al 40% di gluconato di calcio boro in uno spazio di 15 minuti per via intravenosa. Le mucche del gruppo B sono state trattate nello stesso modo. Inoltre hanno ricevuto 350 g di fosfato di sodio (70 g fosforo anorganico,  $\text{NaH}_2\text{PC}_4 \cdot 2 \text{H}_2\text{O}$ , Streuli AG, Uznach, Svizzera), dissolto in 0.5 l di acqua distillata amministrata oralmente con una sonda. Dopo il trattamento sono stati protocollati ogni ora, durante 8 ore, lo stato generale, la frequenza cardiaca, la frequenza respiratoria, la temperatura rettale, la temperatura della superficie corporea, i movimenti ruminali, la presa di mangime e gli escrementi. Inoltre si è ancora preso in considerazione le prove per alzarsi e il tempo fino alla tenuta in piedi definitiva. Inizialmente i risultati clinici e gli elettroliti serici dei due gruppi non erano differenziabili significativamente. Nello spazio di un'ora dopo il trattamento nessuna mucca era più inebetita. Lo stato generale degli animali nei due gruppi dopo il trattamento non si differenziava significativamente. Dopo l'inizio del trattamento, in entrambi i gruppi e in un lasso di tempo di 2 ore, la media della temperatura rettale aumentava da  $38.0 \pm 0.95^\circ \text{C}$  a  $38.5 \pm 0.40^\circ \text{C}$ . La percentuale di ristabilimento nei due gruppi non si differenziava in modo significativo. Delle 30 mucche, 22 (73.3%) erano già in piedi dopo 8 ore (10 mucche del gruppo A e 12 del B). Il tipo di trattamento non influiva significativamente sul tempo impiegato nell'alzarsi. Mucche del gruppo A erano in piedi entro  $47.3 \pm 44$  minuti, quelle del gruppo B entro  $24.2 \pm 32$  minuti. I nostri risultati non hanno consolidato l'ipotesi che il trattamento combinato, nel caso di febbre lattea, di 350 g di fosfato di sodio per via orale e 500 ml di una soluzione di gluconato di calcio boro per via intravenosa, portasse ad un maggior successo della terapia anche se tutte le mucche mostravano una ipofosfatemia e una ipocalcemia.

## References

- Bostedt, H.*: Blutserumuntersuchungen bei festliegenden Rindern in der frühpuerperalen Periode. 1. Mitteilung: Untersuchungen über den Gehalt an Calcium, anorganischem Phosphor und Magnesium im Blutserum festliegender Rinder. *Berl. Münch. Tierärztl. Wschr.* 1973, 86: 344–349.
- Bostedt, H.*: Stoffwechselerkrankungen in der frühen puerperalen Periode. In: J. Richter, R. Götze Tiergeburtshilfe. 4. Aufl.. Hrsg. E. Grunert und K. Arbeiter. Paul Parey, Berlin, 1993, 431–450.
- Bostedt, H., Wendt, V., Prinzen, R.*: Zum Festliegen des Milchrindes im peripartalen Zeitraum – klinische und biochemische Aspekte. *Prakt. Tierarzt* 1979, 60: 18–34.
- Braun, U., Salis, F., Siegwart, N., Hässig, M.*: Slow intravenous infusion of calcium in cows with parturient paresis. *Vet. Rec.* 2004, 154: 336–338.
- Braun, U., Jehle, W., Siegwart, N., Bleul, U., Hässig, M.*: Behandlung der Gebärparese mit hochdosiertem Kalzium. *Schweiz. Arch. Tierheilk.* 2006, 148: 121–129.
- Cheng, Y.-H., Goff, J. P., Horst, R. L.*: Restoring normal blood phosphorus concentrations in hypophosphatemic cattle with sodium phosphate. *Veterinary Medicine* 1998, 97: 383–388.
- Dru Forrester, S., Moreland, K. J.*: Hypophosphatemia. *J. Vet. Int. Med.* 1989, 3: 149–159.
- Dumelin, J.*: Behandlung von Kühen mit Gebärparese mit Natriumphosphat und Kalzium. Dissertation, Universität Zürich, 2005.
- Gelfert, C.-C., Dallmeyer, M., Staufenberg, R.*: Effekte einer zusätzlichen oralen Phosphorgabe auf den Behandlungserfolg peripartal festliegender Milchkühe. *Prakt. Tierarzt* 2004, 85: 116–124.
- Goff, J. P.*: Pathophysiology of calcium and phosphorus disorders. *Vet. Clin. North Am. [Food Animal Pract.]* 2000, 16: 319–337.
- Grünberg, W., Constable, P., Schröder, U., Staufenberg, R., Morin, D., Rohn, M.*: Phosphorus homeostasis in dairy cows with abomasal displacement or abomasal volvulus. *J. Vet. Int. Med.* 2005, 19: 894–898.
- Horner, S., Staufenberg, R.*: Der Einfluss verschiedener therapeutisch nutzbarer Wirkstoffe zur Phosphorsubstitution auf den Phosphorgehalt im Blut. *Prakt. Tierarzt* 2004, 84: 666–673.
- Hunt, E., Blackwelder, J. T.*: Bovine parturient paresis (Milk fever, hypocalcemia). In: *Large Animal Internal Medicine*. Eds. B. P. Smith. Mosby, St. Louis, 2002, 1248–1254.
- Jehle, W.*: Behandlung der Gebärparese des Rindes mit hochdosiertem Kalzium. Dissertation, Universität Zürich, 2004.
- Martig, J.*: Hypokalzämische Gebärlähmung. In: *Innere Medizin und Chirurgie des Rindes*. 4. Aufl.. Hrsg. G. Dirksen, H.-D. Gründer und M. Stöber. Parey Buchverlag, Berlin, 2002, 1245–1254.
- Meschke, A.*: Zur Gebärparese des Rindes – über die Wirksamkeit verschiedener Behandlungsmethoden und deren Einflüsse auf ausgewählte Blutparameter. Dissertation, Universität Giessen, 1997.
- Oetzel, G. R.*: Parturient paresis and hypocalcemia in ruminant livestock. *Vet. Clin. North Am. [Food Animal Pract.]* 1988, 4: 351–361.
- Radostits, O. M., Gay, C. C., Blood, D. C., Hinchcliff, K. W.*: Parturient paresis (milk fever). In: *Veterinary Medicine. A Textbook of the Diseases of Cattle, Sheep, Pigs, Goats and Horses*. W. B. Saunders, London, 2000, 1420–1435.
- Rosenberger, G.*: Die klinische Untersuchung des Rindes. 2. Aufl.. Paul Parey, Berlin, 1990.
- Salis, F.*: Untersuchungen zur Behandlung der Gebärparese beim Rind mittels Kalziuminfusion im Sturz bzw. im Dauertropf. Dissertation, Universität Zürich, 2002.
- Stolla, R., Schulz, H., Martin, R.*: Veränderungen im Krankheitsbild des peripartalen Festliegens beim Rind. *Tierärztl. Umschau* 2000, 55: 295–299.
- Visser't Hooft, K., Drobatz, K. J., Ward, C. R.*: Hypophosphatemia. *Comp. Cont. Educ. Pract. Vet.* 2005, 27: 900–911.

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