

Abscessing bronchopneumonia in foals – the adequate treatment period and its determination

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Summary: The objective of the present study was to analyse whether a treatment duration of 2 weeks in cases of abscessing bronchopneumonia in foals is sufficient for a complete recovery without relapses. Antimicrobial treatment with durations of 4 weeks and more for foals is empirical practice on many farms with endemic foal pneumonia. In the prospective, randomised blind study foals with an abscess score of 1.5 to 19.5 cm (moderate pneumonia) at sonography of the thorax were included in group 1 (n = 92, treatment: rifampin/tulathromycin). If the abscess score was ≥ 20 cm (severe pneumonia), foals were allocated to group 2 (n = 73, treatment: rifampin/azithromycin). The treatment duration (2, 4 or 6 weeks) in groups 1 and 2 depended on the random assignment to these subgroups. Tracheobronchial aspirates from foals with pneumonia were randomly tested for bacterial pathogens by microbiological culture. In enrolled foals clinical examination was done once weekly and WBC counting and ultrasound examination of the lung twice weekly. Foals that required a treatment change because findings worsened or stagnated or the occurrence of another disease, they were taken out of the study (n = 15/165). Such an exclusion of the study was classified as treatment failure and the data from these foals were processed separately until their removal from the study. In foals with moderate or severe pneumonia, about 75% recovered after two weeks of treatment and 25% needed longer therapy. Clinical signs almost completely regressed during the first two weeks of treatment. The WBC count was not helpful in assessing the course of pneumonia. Three of 150 foals had a recurrence of pneumonia three or more weeks after the end of treatment. The duration of treatment of 2 weeks of moderate and severe abscessing bronchopneumonia seems sufficient in most foals. The younger a foal is at the day of diagnosis of pneumonia, the more likely it will require more than 2 weeks of therapy or even the treatment will fail. Altogether, the duration of therapy should be tailored to the patient and unnecessary prolonged use of antibiotics can be avoided.

Keywords: foal, pneumonia, treatment period, ultrasonographic examination

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Introduction

Abscessing bronchopneumonia is a frequent and significant disease of foals on breeding farms. *Rhodococcus equi* (*R. equi*) and *Streptococcus equi subsp. zooepidemicus* are often the bacteria responsible for pulmonary disorders in foals between 3 weeks and 5 months of age and induce similar clinical findings (Hoffmann et al. 1993, Lavoie et al. 1994).

The use of a macrolide antibiotic in combination with rifampin for the treatment of *R. equi* pneumonia is well validated. In recent years, newer-generation macrolides, such as azithromycin and clarithromycin (Giguère et al. 2004), as well as tulathromycin (Venner et al. 2007, Rutenberg et al. 2017), have replaced erythromycin in combination with rifampin. Recent evidence suggests that the resistance to macrolides and rifampin in *R. equi* isolates is increasing (Giguère et al. 2017), which raises the question how antibiotics can be used in a more targeted way, including the tailored choice of the drugs and the appropriate duration of treatment.

Parameters used to guide the decision on the duration of treatment include the resolution of clinical findings (Prescott et al. 1985), resolution of abnormalities detected by thoracic findings at sonography of the thorax and plasma fibrinogen (Giguère 2010). The suggestions in literature for successful therapy vary between 2–12 weeks (Giguère 2010), to 4–9 weeks (Giguère 2001) and 6–8 weeks (Prescott et al. 1985) depending on the severity of the initial lesions and the response to therapy. Monitoring of the sick foals including ultrasonographic, haematological and clinical examinations can help to reduce the number of affected foals treated without increasing the foals losses (Cohen et al. 2002, Muscatello et al. 2007, Arnold-Lehna et al. 2019). However, there are some concerns that a too early discontinuation of the therapy may lead to relapses (Giguère et al. 1997).

The objective of the present study was to analyse whether a treatment duration of 2 weeks is sufficient for a complete recovery without relapses on a farm with endemic bronchopneumonia in foals.

Materials and methods

Study population

The study was a prospective, randomised and blinded clinical trial during the 2018 breeding season on a Warmblood stud. The stud has a history of foal pneumonia due to *R. equi*. Multiple former studies performed at the stud showed that *R. equi* was isolated from tracheobronchial aspirates of 39% ($n = 17/44$) to 54% ($n = 118/217$) of the foals with ultrasonographic evidence of pneumonia (Venner et al. 2007, Venner et al. 2007). In the context of another study during 2018, *R. equi* was also isolated in the tracheal aspirate of foals with pneumonia on the same farm (Hennig 2020 in print). As part of the randomised pathogen examination of tracheobronchial aspirates of foals suffering from pneumonia, 26 foals of the current study were sampled. In nine foals, *R. equi* was detected and in 18 foals *Streptococcus equi subsp. zooepidemicus*; in the sample of one foal, both pathogens were detected.

General monitoring of the foals on the stud

Every foal was submitted to a weekly examination from birth to the age of 5.5 months, including measurement of the body temperature, evaluation of nasal discharge and mandibular lymph nodes, auscultation of trachea and lung, the white blood cell (WBC) count and a thoracic ultrasonography. The pulmonary ultrasound examination was performed by using portable equipment with a 7.5 MHz linear transducer (Esaote Tringa Linear, Milano, Italy). This involves ultrasonography of both sides of the thorax in each intercostal space and documentation of pleural oriented lesions in dorsal, middle, and ventral sections of the lungs. A pulmonary abscess was defined as a hypoechoic area of consolidation. The diameter of all consolidations with a diameter above 0.5 cm were added to a total abscess score in cm.

Study design and inclusion criteria

The foals that were included in the study were randomly allocated to six groups. Foals, older than 4 weeks and without signs of dyspnoea, were included as soon as a moderate to severe pneumonia ($n = 165$) was diagnosed by sonography (Table 1). The number of foals admitted per group corresponds to the expected number of affected foals with the respective severity of pneumonia per year at the stud.

Every foal with an abscess score above 15 cm and below 20 cm was allocated to group 1 ($n = 92$) and was treated with rifampin (10 mg/kg PO, q 24 h) and tulathromycin (2.5 mg/kg IM, q 7 days) and was considered to have a moderate pneumonia. In the case of an abscess score ≥ 20 cm, the foals were allocated to group 2 ($n = 73$) and received a treatment with rifampin and azithromycin (both: 10 mg/kg PO, q 24 h) and were considered to have a severe pneumonia. The duration of therapy in each group depended on the random assignment to the subgroups 1a and 2a (2 weeks), 1b and 2b (4 weeks) or 1c and 2c (6 weeks). Due to the organisation of the stud, the treatment duration of 2 weeks ranged between

13 and 19 days, the four-week period varied between 27 and 33 days and the six-week period between 41 and 47 days. The examining vets were not aware of the foal's allocation to the groups.

In participating foals, clinical examination was done once weekly. Twice weekly, the WBC were counted and the diameter of lung lesions measured at ultrasonographical examination of the lung. Antibiotic therapy was ended, if no more consolidations were seen at the sonography of the lung. Otherwise, the treatment was extended for 14 days. After ending the treatment, the examinations were continued once a week up to the age of five and a half months.

Table 1 Data from the 165 foals in the study from group 1 (moderate pneumonia) and group 2 (severe pneumonia). | Daten der 165 Fohlen in der Studie aus Gruppe 1 (mittelgradige Pneumonie) und Gruppe 2 (hochgradige Pneumonie).

	group 1	group 2
total participating foals	$n = 92$	$n = 73$
foals with successful treatment	$n = 90$	$n = 60$
foals removed from the study	$n = 2$	$n = 13$
range of abscess score at day of diagnosis	15–19.5 cm	20–34.5 cm
median abscess score at day of diagnosis	16 cm	22.5 cm
median clinical score at day of diagnosis	3	4
median age of the foals at day of diagnosis	100 days	111 days

Table 2 Clinical score | Klinischer Score

Characteristic	Findings	Score
nasal discharge	normal	0
	serous	1
	mucous, purulent	2
body temperature	Normal ($\leq 38.9^\circ\text{C}$)	0
	Mildly elevated ($39.0\text{--}39.4^\circ\text{C}$)	1
	Highly elevated ($\geq 39.5^\circ\text{C}$)	2
mandibular lymph node	normal	0
	enlarged	1
lung auscultation	normal	0
	moderately exacerbated (raw sounds)	1
	extremely exacerbated (rattle, rhonchus)	2
trachea auscultation	normal	0
	moderately exacerbated (raw sounds)	1
	extremely exacerbated (rattle, rhonchus)	2
maximum clinical score achievable		9

Exclusion criteria

Foals that developed dyspnoea in the course of treatment or if clinical and sonographic findings worsened or stagnated and they required a change in treatment because of these findings or another disease, they were taken out of the study (n = 15/165). If a foal was excluded of the study due to these findings, this was considered a treatment failure and the data from these foals were processed and analysed separately until their removal from the study.

Data collection

The following clinical parameters were collected for each foal included in the study and were assigned a clinical score (Table 2): rectal temperature, nasal discharge, lymph node size and auscultation of trachea and lungs. This clinical score, the WBC count and the abscess score determined by thoracic sonography, the age of the foals at day of diagnosis, the treatment duration and recurrence rates were recorded. The results of all examinations were summarised in time blocks by assigning several days to weekly segments (Figure 1). Since the foals at the stud cannot all be examined on the same day, this classification made it possible to assign every bi-weekly examinations to one of these half-weekly intervals.

Data analysis

The statistical analyses of the data were accomplished using the Statistical Analysis System for Windows SAS®, version 9.4, by using the SAS® Enterprise Guide® version 7.1 Client. An error probability of P < 0.05 was assumed for the statistical tests performed in order to detect significant differences. The abscess score, the clinical score, the age of the foals at diagnosis and the WBC count of the foals were tested for normal distribution by the Shapiro-Wilk test. In consequence, the median and the percentiles (25th; 75th) in brackets were used.

Comparisons of the number of foals recovering in the planned duration of treatment with the number of foals who needed a prolongation of therapy in the different subgroups were performed using the Fisher’s exact test (reliable results even with a fewer number of observations) and binomial test (Chi-square test for specified proportions) to compare the subgroups. Furthermore, a logistic regression was used to analyse and compare the development of the categorical variables of the clinical parameters. The effect of the time after initiation of treatment on the values abscess score, clinical score and WBC count was analysed with the Friedman test (permutation test) with a post hoc Sidak test for multiple pairwise comparisons. The Kruskal-Wallis test and Wilcoxon two-sample test were used to compare abscess score, clinical score and WBC count between independent groups and subgroups. To

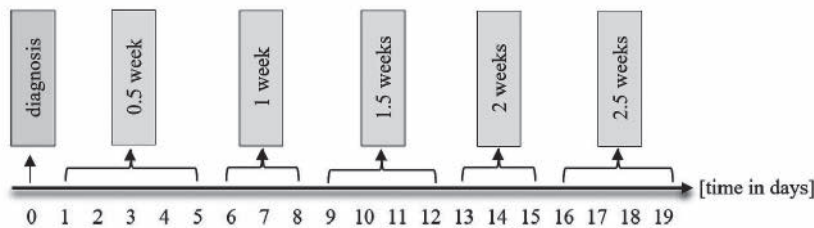


Fig. 1 Examination days of foals with pneumonia during the treatment period summarised in blocks based on weekly time. | Untersuchungstage von Fohlen mit Pneumonie während des Behandlungszeitraums zusammengefasst in Blöcken basierend auf der Wochenzeit.

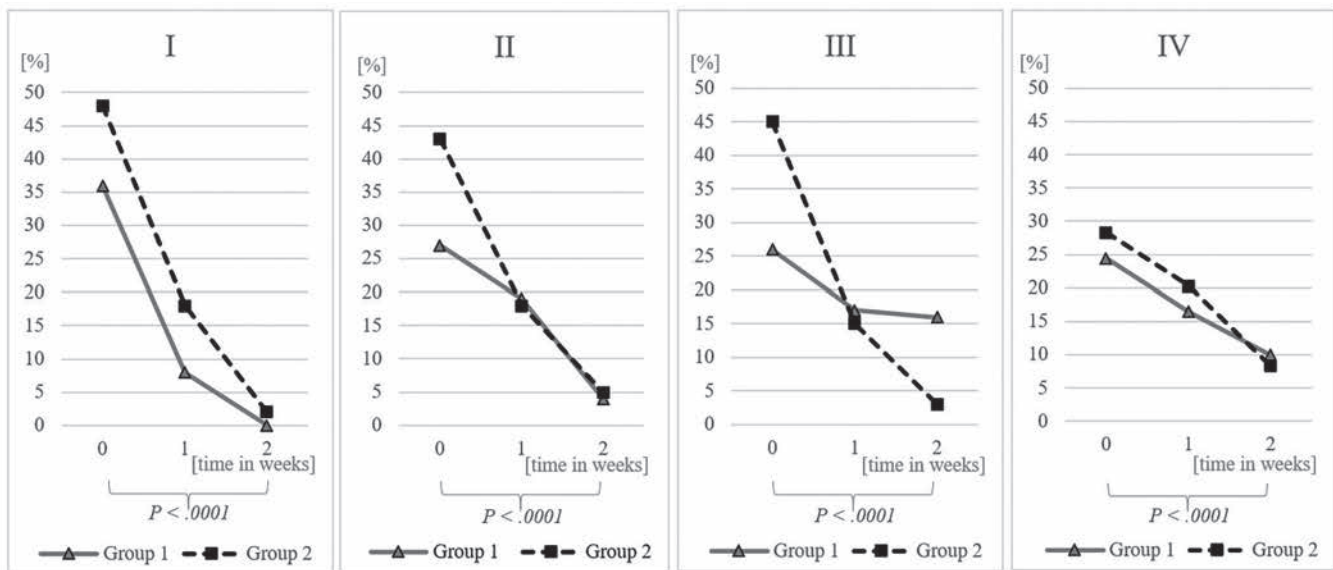


Fig 2 Number of foals (in percent) within group 1 (moderate pneumonia, n = 90) and group 2 (severe pneumonia, n = 60) showing clinical findings during treatment (I: body temperature, II: auscultatory lung findings, III: auscultatory trachea findings, IV: mucosal-purulent nasal discharge). | Anzahl der Fohlen (in Prozent) innerhalb der Gruppe 1 (mittelgradige Pneumonie, n = 90) und der Gruppe 2 (hochgradige Pneumonie, n = 60) welche klinische Befunde während der Behandlung gezeigt haben (I: erhöhte Körpertemperatur, II: auskultatorischer Lungenbefunde, III: auskultatorische Trachealbefunde, IV: schleimig-eitriger Nasenausfluss).

determine whether there was a causality between age of the foals at diagnosis of pneumonia and response to treatment the Kruskal-Wallis variance analysis was performed.

Results

Clinical findings and WBC count during treatment

The clinical score in both groups was significantly higher ($P \leq 0.0001$) on the day of diagnosis compared to the following examination at half-weekly intervals after the initiation of therapy (Figure 3B). Initially, the clinical score of foals with severe pulmonary changes was higher than the one of foals with moderate pneumonia ($P = 0.004$). The individual clinical findings (e.g. body temperature, nasal discharge, auscultation of trachea and lung) in both groups also decreased significantly during the first 2 weeks of therapy ($P < 0.0001$). Almost all foals returned to normal clinical findings after the first 2 weeks of treatment (Figure 2). The WBC count on the day of diagnosis of pneumonia and the following 2 weeks of treatment did not differ significantly between both groups and subgroups. Regardless of severity of pneumonia, the highest counts were found 0.5 week or 1 week after the initiation of treatment (Figure 3C).

Abscess score during therapy

The abscess score at diagnosis in foals with moderate pneumonia (group 1) ranged between 15 and 19.5 cm (median 16 cm) and in foals with severe pneumonia (group 2), foals with an abscess score from 20 to 34.5 cm (median 22.5 cm). The score in both groups decreased significantly between the day of diagnosis and 1.5 weeks of treatment (Figure 3A). There were no differences in the change in the abscess score between the subgroups within the groups. Despite different

Table 3 Treatment duration (A: end of treatment after planned duration, without the need for prolongation, B: prolongation of 2 weeks, C: two times prolongation of 2 weeks, a total of 4 weeks prolongation) of group 1 (moderate pneumonia, $n = 90$) and group 2 (severe pneumonia, $n = 60$) (subgroups a: 2 weeks treatment, b: 4 weeks treatment, c: 6 weeks treatment). The upper number represents the frequency; the below the percentage distribution within each subgroup. | *Behandlungsdauer (A: Behandlungsende nach geplanter Dauer, ohne Verlängerungsbedarf, B: Verlängerung um 2 Wochen, C: zweimalige Verlängerung um 2 Wochen, insgesamt 4 Wochen Verlängerung) der Untergruppen Gruppe 1 (mittelgradige Pneumonie, $n = 90$) und Gruppe 2 (hochgradige Pneumonie, $n = 60$) (a: 2 Wochen Behandlung, b: 4 Wochen Behandlung, c: 6 Wochen Behandlung). Die obere Zahl stellt die Häufigkeit dar, die untere die prozentuale Verteilung innerhalb jeder Untergruppe.*

Subgroup	A	B	C	Total
1a	23	7	0	30
	76.7%	23.3%	0.0%	
1b	29	1	0	30
	96.7%	3.3%	0.0%	
1c	30	0	0	30
	100.0%	0.0%	0.0%	
Total group 1	82	8	0	90
	91.1%	8.9%	0.0%	
2a	15	5	0	20
	75.0%	25.0%	0.0%	
2b	19	0	1	20
	95.0%	0.0%	5.0%	
2c	20	0	0	20
	100.0%	0.0%	0.0%	
Total group 2	54	5	1	60
	90.0%	8.3%	1.7%	

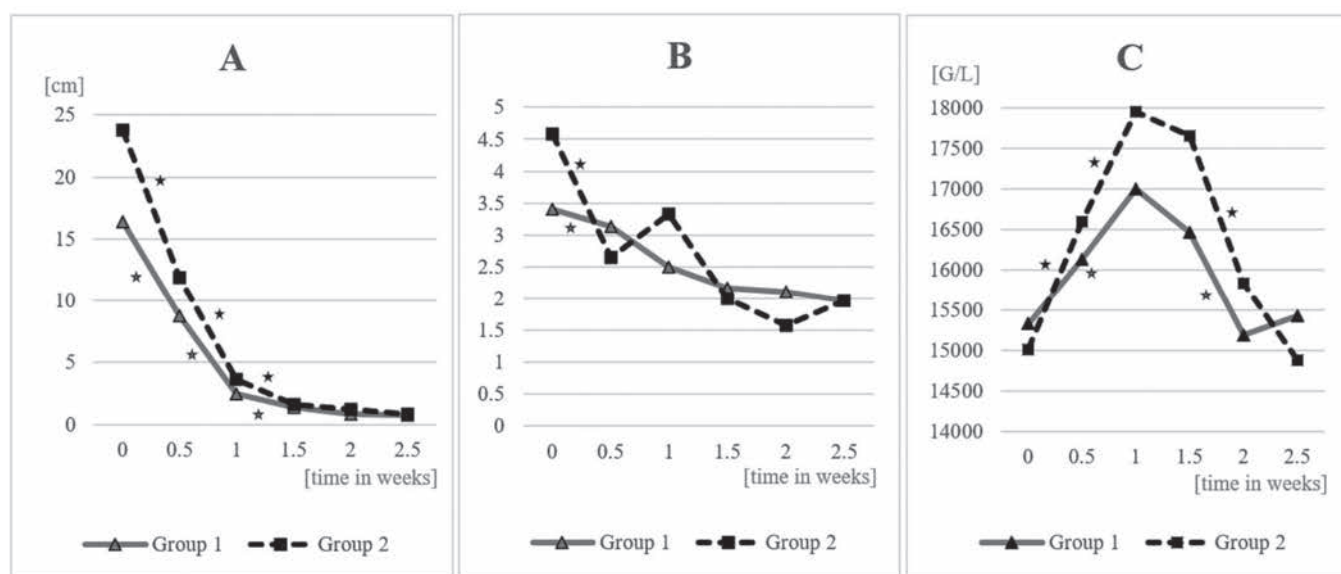


Fig. 3 Abscess score in cm (A), clinical score (B) and white blood cell count in G/L (C) during treatment in foals (group 1, moderate pneumonia, rifampin/tulathromycin, $n = 90$ / group 2, severe pneumonia, rifampin/azithromycin, $n = 60$). Significant differences in progress of each group are marked with *. | *Abszess-Score in cm (A), klinischer Score (B) und Anzahl der weißen Blutkörperchen in G/L (C) während der Behandlung bei Fohlen (Gruppe 1, mittelgradige Pneumonie, Rifampin/Tulathromycin, $n = 90$ / Gruppe 2, hochgradige Pneumonie, Rifampin/Azithromycin, $n = 60$). Signifikante Unterschiede im Verlauf der einzelnen Gruppen sind mit * gekennzeichnet.*

treatment protocols according to the severity of the pneumonia, no difference in the development of the abscess score during the treatment period was found. (Figure 4).

Response to treatment and recurrence rates

In foals in group 1 (moderate pulmonary changes; n = 90), the consolidations detected at sonography of the lung resolved after 2 weeks of treatment in 76.7% (n = 23/30) of foals from group 1a (duration of treatment: 2 weeks). In this subgroup, 23.3% (n = 7/30) of the foals needed a prolonged treatment of 2 weeks to recover. In group 1b (duration of treatment: 4 weeks), 96.7% (n = 29/30) of the foals recovered during the planned 4 weeks of treatment and in group 1c (duration of treatment: 6 weeks) 100% (n = 30/30) of the foals recovered during the 6 weeks of treatment. There was no significant dif-

ference between the number of foals, which recovered after the planned duration of treatment in each subgroup (Table 3) in foals with moderate pneumonia (group 1), in which foals were treated with rifampin and tulathromycin. More foals of subgroup 1a needed a prolongation of treatment than in subgroups 1b and 1c (P = 0.03/P = 0.008). The treatment could have been stopped after 2 weeks of time for 73% (n = 22/30) of the foals of group 1b, respectively, 80% (n = 24/30) of the foals of group 1c as their sonographic findings had fully resolved by then. One foal treated for a duration of 2 weeks developed a new pneumonia 77 days after the end of the first treatment period.

The foals in group 2 (severe pulmonary changes; n = 60) were treated with rifampin and azithromycin. In subgroup 2a (duration of treatment: 2 weeks), 75% (n = 15/20) of the foals recovered within 2 weeks of therapy, 25% (n = 5/20)

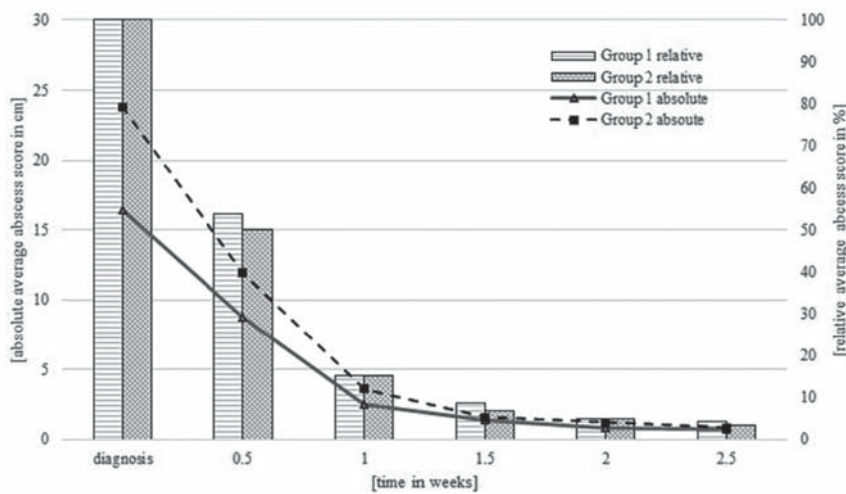


Fig. 4 Abscess score in cm (absolute average) and abscess score in percent (relative average) of group 1 (moderate pneumonia, n = 90) and group 2 (severe pneumonia, n = 60) in the first 2.5 weeks of treatment. | Abszess-Score in cm (absoluter Durchschnitt) und Abszess-Score in Prozent (relativer Durchschnitt) von Gruppe 1 (mittelgradige Pneumonie, n = 90) und Gruppe 2 (hochgradige Pneumonie, n = 60) in den ersten 2,5 Wochen der Behandlung.

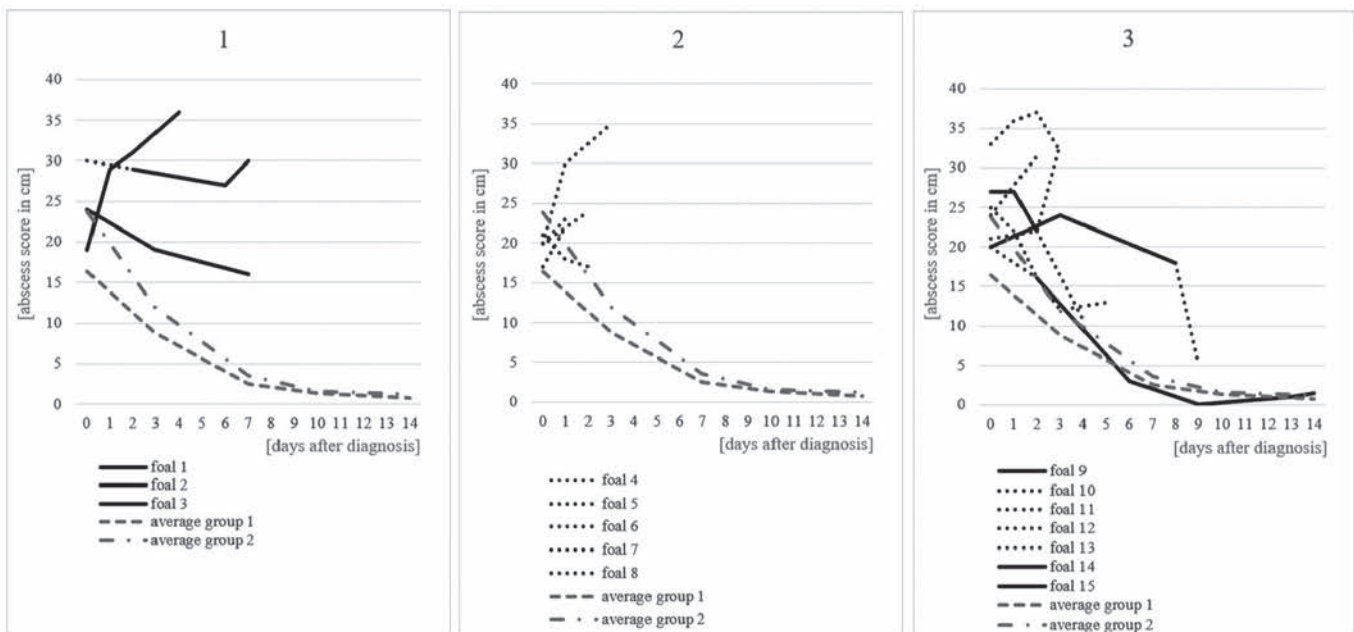


Fig. 5 Abscess score during treatment in the removed foals needing a change of antimicrobial treatment (1), foals developing dyspnoea (2) and foals with an additional interstitial pneumonia (3). The average course of the foals of group 1 and 2 is included for orientation. The dotted line represents foals with hyperthermia. | Abszess-Score während der Behandlung bei den ausgeschiedenen Fohlen, die einen Wechsel der antimikrobiellen Behandlung benötigten (1), Fohlen, die Dyspnoe entwickelten (2) und Fohlen mit einer zusätzlichen interstitiellen Pneumonie (3). Zur Orientierung ist der durchschnittliche Verlauf der Fohlen der Gruppe 1 und 2 eingezeichnet. Die gestrichelte Linie stellt Fohlen mit Hyperthermie dar.

needed a prolongation of 2 weeks (Table 3). In group 2b (duration of treatment: 4 weeks) 95% (n = 19/20) of the foals recovered during the planned 4 weeks of treatment and in group 2c (duration of treatment: 6 weeks) 100% (n = 20/20) of the foals recovered during the 6 weeks of treatment. There was no significant difference between the rates of foals recovering in their planned treatment duration ($P = 0.49/0.87/0.39$). The number of foals needing a prolongation of treatment was significantly lower in subgroup 2b (duration of treatment: 4 weeks) and 2c (duration of treatment: 6 weeks), as almost all foals recovered during the predetermined treatment duration ($P = 0.025$). One foal from group 2b needed a double prolongation. It would have been possible to end the therapy for 65% (n = 13/20) of the foals from group 2b and 80% (n = 16/20) of the foals from group 2c after a duration of 2 weeks as after this time, the lungs were without ultrasonographic findings. Two foals with severe pneumonia showed a relapse: one foal 24 days after a treatment of 4 weeks and the other one 79 days after a treatment of 2 weeks.

Foals removed from the study

Fifteen foals (two foals with moderate pneumonia and 13 foals with severe pneumonia) were removed from the study. Three foals were removed after 4 to 7 days of treatment, because their abscess score increased or stagnated (Figure 5, Chart 1). Five foals were removed as they developed dyspnoea within the first three days of treatment (Figure 5, Chart 2). All these foals had fever ($> 39.5^{\circ}\text{C}$) up to the day of developing dyspnoea and their abscess score did not improve during the therapy. Seven foals developed an interstitial pneumonia between day 1 and day 14 after initiation of therapy (Figure 5, Chart 3).

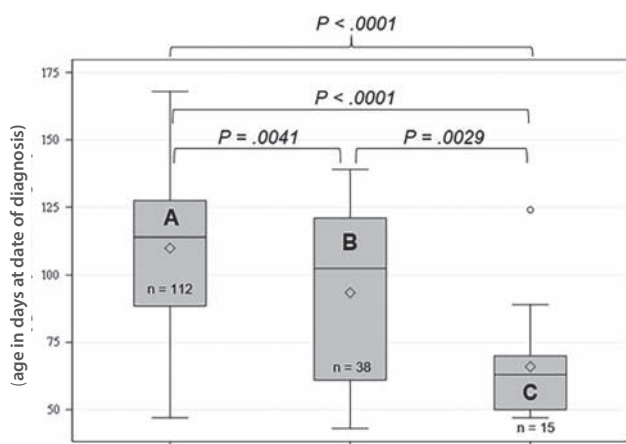


Fig. 6 Age (in days) of the foals at diagnosis of pneumonia in correlation with response to treatment. Group A: foals which showed no more pulmonary findings at ultrasonography after 2 weeks of treatment, group B: all foals that needed a treatment longer than 2 weeks, group C: foals that were removed from the study. | *Alter (in Tagen) der Fohlen bei Diagnose der Pneumonie in Korrelation mit dem Ansprechen auf die Behandlung. Gruppe A: Fohlen, die nach 2 Wochen Behandlung keinen Befund mehr im Ultraschall zeigten, Gruppe B: alle Fohlen, die eine Behandlung länger als 2 Wochen benötigten, Gruppe C: Fohlen, die aus der Studie ausgeschieden sind.*

Association between age at diagnosis and response to treatment

The age of the foals at diagnosis was evaluated in relation to their response to treatment. The foals of subgroup 1a and 2a, which needed no prolongation of therapy and all foals, who had recovered within 2 weeks of treatment were joined in group A without considering their allocation to subgroup b or c. All foals needing treatment longer than 2 weeks were allocated to group B. Foals, who were removed from the study, were allocated to group C. 165 foals were allocated into one of these groups: A (n = 112), B (n = 38) and C (n = 15). The foals that recovered after 2 weeks of treatment were 114 days old (25th/75th: 88.5/127.5) at diagnosis, whereas the foals for which a two-week therapy was not sufficient were 102.5 days old (25th/75th: 61/121) and, therefore, significantly younger at the time of diagnosis ($P = 0.004$). Compared to the foals from group A and B, the foals in group C were also significantly younger again ($P < 0.0001/P = 0.003$) with an age of 63 days at diagnosis (25th/75th: 50/70). In summary, the older the foal was at diagnosis of pneumonia the better was the response to treatment (Figure 6; $P < 0.0001$).

Discussion

The shorter and tailored therapy, which can be extended individually beyond a two-week interval, allows antibiotics to be used more purposefully. The best method to minimise the further development of resistance problems arising, which have intensified in recent years (Giguère et al. 2017), especially on farms where antimicrobial mass treatment was applied after establishing screening programmes (Burton et al. 2013), is to limit the use of antimicrobial agents to individuals that really benefit from their use, to choose the adequate drugs and the proper duration of treatment (Venner et al. 2013).

The success of treatment of an abscessing bronchopneumonia due to *R. equi* depends on different factors: age of the foal (Venner et al. 2013), severity of the initial lesions, the subclinical detection and the response to the selected antimicrobial agent (Giguère 2001). The current study included foals from a stud with well-organised monitoring and, thus, the foals with pneumonia were detected early, which might be a factor that helps reducing the treatment duration (Muscatello 2012). Furthermore, it must be emphasised that in any foal with pneumonia, treatment must be chosen with consideration of the isolation of pathogens from respiratory samples. In a breeding farm with endemic rhodococcosis, it is obligatory to regularly sample sick foals in order to identify the pathogens and make the adequate choice of antimicrobial drugs. The resistogram is not applicable to *R. equi* as an intracellular pathogen due to the lack of transferability of in vitro sensitivity to in vivo situation.

The duration of treatment required to heal pneumonia due to *R. equi* in foals is described between 2 and 12 weeks (Giguère 2010), but also 4 and 9 weeks (Giguère 2001) or 6 and 8 weeks (Prescott et al. 1985), where longer duration is generally chosen in order to prevent relapses. In the current study, 75% of the foals with abscessing bronchopneumonia recovered completely after a treatment duration of 2 weeks, with no difference between foals with moderate (rifampin/

tulathromycin) or severe (rifampin/azithromycin) pulmonary lesions. Therapy could be stopped after the planned duration in almost all cases. However, the ultrasound examination in many foals with long therapy duration of 4 or 6 weeks showed a complete recovery of pleural lesions already after 2 weeks of treatment. The change in the abscess score during the first 2 weeks after treatment initiation shows that both antimicrobial combinations have led to a fast therapeutic success in the severity of pneumonia in which they were used. The question whether the two antibiotic protocols are similarly efficient needs to be examined in further studies.

However, the possibility of treatment failure must be considered in each case. In the current study, fewer foals needed a change of antimicrobial drugs in the moderately ill group (2.2%) compared to the severely affected foals (17.8%). This might be associated to the fact that early treatment of foals with pneumonia enhances and facilitates the chances of a successful response to the therapy (Chaffin 2006). In a previous study, the response to treatment in foals with higher abscess scores was also worse than in foals with comparatively lower abscess scores (Venner et al. 2012), which further confirms the importance of severity of pulmonary lesions for assessing the response to treatment. Foals with therapy failure did not show a decrease in abscess score and frequently showed fever. Hence, the monitoring via clinical and sonographic examination during treatment, especially in the initial phase, is essential for early detection of treatment failure.

Three of 150 foals showed a relapse of pneumonia in the current study. The time up to recurrence of pneumonia was 24, 77 and 79 days, respectively; therefore, it is questionable whether it was a relapse or a new infection. The risk of reoccurrence of pneumonia that may occur if treatment is discontinued too early (Giguère et al. 1997, Slovis et al. 2005) seems, on the base of the data of the current study, very small.

In addition to the ultrasonographic findings, clinical signs and blood parameters are used to guide the duration of treatment (Prescott et al. 1985, Muscatello et al. 2007). Moreover, foals often appear clinically healthy before the lung consolidations are resolved, as has been shown previously (Falcon et al. 1985, Slovis et al. 2005). Looking at the development of the clinical signs, the abnormal findings quickly regressed within the first 2 weeks of therapy, but the severity of pneumonia is not necessarily correlated with clinical signs as was shown before (Falcon et al. 1985, Slovis et al. 2005). Consequently, the clinical findings alone cannot reliably help to answer the question of the appropriate duration of treatment. The WBC count was recommended in a previous study on diagnostics and early detection (Giguère et al. 2003). On the other hand, the current results suggest that the WBC count, as it does not correlate to the abscess score, is not a reliable parameter for the assessment of response to treatment in cases of pneumonia in foals.

Furthermore, the age of the foals at the time of diagnosis might influence the duration of treatment and the risk of treatment failure. The current data show that the foals who recovered after 2 weeks of treatment were significantly older than those, which required more than 2 weeks of therapy. All foals

with treatment failure were significantly younger at the time of diagnosis than the foals who responded well to therapy. This suggests that older foals are more likely to clear infection more effectively during treatment, as has been observed before in an experimentally induced *R. equi* pneumonia in which spontaneous resolution was more likely in older foals than in neonates (Martens et al. 1989, Venner et al. 2012). Therefore, the course of therapy in very young foals should be monitored very precisely in order to detect a possible treatment failure.

Conclusions

The results of the current study show that a duration of treatment of 2 weeks of foals with bronchopneumonia with moderate pulmonary changes (treated with tulathromycin/rifampin) and severe pulmonary changes (treated with azithromycin/rifampin) leads to a complete recovery in 75% of the cases. In addition, there is no increased risk of recurrence in the current approach. As the foals affected in this study are patients in which diagnosis was made early due to a monitoring programme of the stud, care should be taken in extending those statements on the length of time required in cases of severe and later diagnosed pneumonia. Nonetheless, the response to treatment should be monitored by ultrasonography of the lung, especially in the first week after initiation of therapy to detect cases of treatment failure. The younger a foal becomes ill, the more likely it will require more than 2 weeks of therapy or even the treatment will fail. Decision to stop the treatment should include clinical and sonographic findings of the lung. This approach describes an individually tailored treatment that supports the efforts of using antimicrobials only as long as necessary for a successful treatment of pneumonia in foals.

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