Case Report

Streptobacillus sp. isolated from a cat with pneumonia

Tobias Eisenberg,¹ Anne Nesseler,¹ Werner Nicklas,² Viola Spamer,¹ Helga Seeger¹ and Michael Zschöck¹

Correspondence

T. Eisenberg

tobias.eisenberg@lhl.hessen.de

¹Hessian State Laboratory, Schubertstrasse 60/Haus 13, 35392 Gießen, Germany

²German Cancer Research Center, Im Neuenheimer Feld 280, 69120 Heidelberg, Germany

Introduction: *Streptobacillus moniliformis* causes rat-bite fever, an underdiagnosed zoonosis occurring worldwide. A variety of animals including livestock and exotic mammals are known to be susceptible hosts for this species, but little information is available regarding infection in companion animals.

Case presentation: Following the necropsy of a domestic cat, bacteria displaying substantial characteristics of *Streptobacillus* sp. were cultured from pneumonic lung tissue. *Streptobacillus*-like morphological features observed included strictly microaerophilic pleomorphic Gram-negative rods with bulbar swellings that grew exclusively in the presence of serum. Significant shared biochemical properties included negative reactions for cytochrome oxidase, catalase, urease, nitrate reduction and indole production, as well as broad antimicrobial susceptibility. These characteristics are all indicative of *Streptobacillus moniliformis*. However, 16S rRNA gene sequencing revealed only 98 % sequence homology to type strain DSM 12112. A mass spectrometry analysis confirmed the affiliation of the domestic cat isolate described in this study with bacteria of the genus *Streptobacillus*, but matrix-assisted laser desorption/ionization time-of-flight mass spectrometry indicated that it differed from nine reference strains of *Streptobacillus moniliformis* isolated from various sources and host species.

Conclusion: This is the first evidence for clinical disease caused by a streptobacillary infection in a domestic cat.

Keywords: cat; feline; pneumonia; rat-bite fever; *Streptobacillus*.

Received 7 November 2013

Accepted 13 April 2014

Introduction

The genus *Streptobacillus* (Leptotrichiaceae, Fusobacteriales) comprises the monotypic *Streptobacillus moniliformis* (Elliott, 2007; Gaastra *et al.*, 2009), one of two aetiological organisms causing the bacterial zoonosis rat-bite fever (RBF). RBF is predominantly transmitted through rodent bites and scratches or through direct or indirect contact with rodent faeces and urine (Bleich & Nicklas, 2008; Hayashimoto *et al.*, 2008; Torres *et al.*, 2003). The zoonosis generally referred to as RBF involves two similar yet distinct syndromes caused by two different pathogens: *Spirillum minus* and *Streptobacillus moniliformis*. *Spirillum minus* infection [due to lack of type or reference strains, it

is not listed in the Approved List of Bacterial Names at <http://www.bacterio.net/>; (Elliott, 2007; Gaastra *et al.*, 2009)], also known as sodoku, is more prevalent in Asia than in Western Europe and is not covered in this study. However, *Streptobacillus moniliformis* is a primary pathogen in humans and may cause RBF or food-borne Haverhill fever. The acute disease symptoms in humans include fever, malaise, muscle pain, articular inflammation, septicaemia, and maculopapular, petechial or pustular rash after exposure to the bacteria through a bite or scratch by rats or through the ingestion of water or food contaminated by rat excrement (Gaastra *et al.*, 2009). Other rodent species like gerbils, squirrels, spinifex hopping mice and guinea pigs are also susceptible to *Streptobacillus moniliformis* infection, and mice may strain-dependently develop clinical disease. Rats are usually asymptomatic (Wullenweber *et al.*, 1990), but abscess formation caused by *Streptobacillus moniliformis* infection has been described (Rohde *et al.*, 2008). Approximately 50–100 % of wild rats carry *Streptobacillus moniliformis* in their oro- or nasopharynx and shed the pathogen with saliva and urine (Ditchfield *et al.*, 1961; Elliott, 2007;

The GenBank/EMBL/DBJ accession number for the partial 16S rRNA gene of isolate 131000547 is HG421076.

This article is dedicated to Professor Dr. Dieter Manz in honour of his 80th birthday. The Hessian Ministry for the Environment, Climate Change, Agriculture and Consumer Protection (HMUKLV).

Abbreviations: MALDI-TOF MS, matrix-assisted laser desorption/ionization time-of-flight mass spectrometry; RBF, rat-bite fever

Washburn, 1995). Nevertheless, isolation of *Streptobacillus moniliformis* from rat urine and faeces is not always successful (Freundt, 1956; Wullenweber *et al.*, 1990). *Streptobacillus* infection has also been reported on a few occasions from livestock (calves, a pig and domestic turkey), as well as from zoo animals (non-human primates and a koala) (Boyer *et al.*, 1958; Gaastra *et al.*, 2009; Glünder *et al.*, 1982; Gourlay *et al.*, 1982; Mohamed *et al.*, 1969; Russell & Straube, 1979; Smallwood, 1929; Valverde *et al.*, 2002; Yamamoto & Clark, 1966). Most reports on isolates derived from livestock lack genetic data and are focused mainly on pathogen morphology or zoonotic symptoms alone. Pathological findings in infected ruminants include pneumonia in calves and isolations from seminal vesicles of bulls, whilst domestic turkeys also display polyarthritis, synovitis, tendon sheath swellings and joint lesions. Notably, a bite by an asymptomatic pig led to RBF-like disease in a woman (the epidemiological data is summarized by Gaastra *et al.*, 2009). Carnivorous animals regularly feeding on rats and mice, such as dogs, weasels and ferrets, are known reservoirs of *Streptobacillus moniliformis* and are therefore possible vectors for human infection (Gaastra *et al.*, 2009; Gordon & Jones, 1999; Peel, 1993; Wouters *et al.*, 2008). The role of cats as carriers and transmitters of *Streptobacillus moniliformis* to humans remains speculative, despite their frequent exposure to rats. The only known case study lacks culture-based or serological confirmation (Gascard *et al.*, 1967). Detection of *Streptobacillus moniliformis* often seems to be attributed to colonization rather than infection, thus stressing the role of resident or latent oral flora in wild or pet rodents or in dogs and cats. Recently, a closely related *Streptobacillus* sequence, COT-370, was detected in a canine oral microbiome project (Dewhirst *et al.*, 2012). Currently, only two reports of clinical infection by *Streptobacillus moniliformis* in dogs exist (Das, 1986; Ditchfield *et al.*, 1961). One dog was reported as displaying acute gastroenteritis, arthritis, skin rash, pneumonia and endocarditis, symptoms similar to those of Haverhill fever (Ditchfield *et al.*, 1961). The other case described *Streptobacillus moniliformis* from an abscess aspirate (Das, 1986).

We report here for the first time, to our knowledge, an infection in a cat displaying clinical symptoms of fatal pneumonia which could be attributed to a streptobacillary infection.

Case report

In January 2013, a cat that had been found dead on a dairy farm was submitted for necropsy. Post-mortem examination revealed an acute bronchopneumonia with pronounced acute oedema and congestion of the lungs and a marbled and beige-coloured myocardium with multifocal haemorrhages on the endo- and epicardium. Liver, spleen and kidneys showed acute congestion. No abnormalities such as wounds, scratches, ulcers or rashes were noted on the skin, which are common sequelae of RBF in humans. Histopathological examination of the lungs revealed an acute suppurative to fibrinous, focally

Fig. 1. Lung showing acute suppurative and fibrinous pneumonia with pronounced acute congestion and multifocal desquamation of type II pneumocytes and alveolar macrophages in alveolar lumina. Fibrin exudate (*), neutrophils (arrowhead) and type II pneumocyte desquamation (•) are indicated. Haematoxylin and eosin stain; magnification 20 ×.

necrotizing pneumonia with multifocal desquamation of type II pneumocytes and alveolar macrophages (Fig. 1). In the heart, an acutely suppurative and fibrinous endocarditis and myocarditis with acute congestion, oedema and single necrotizing foci were noticed (Fig. 2).

Diagnosis

Upon necropsy, viral and molecular examinations were carried out for the presence of feline calicivirus (cell culture), feline herpesvirus 1, *Mycoplasma* spp. and

Fig. 2. Heart (left ventricular wall) showing acute suppurative and fibrinous myocarditis with acute interstitial congestion ($\leftarrow\!\!\leftarrow$), oedema and haemorrhage (○). Fibrin exudate (*) and neutrophils (arrowhead) are indicated. Haematoxylin and eosin stain; magnification 20 ×.

Chlamydia spp. using PCR, all with negative results. A low-grade mixed concomitant flora that included *Streptococcus canis*, *Pseudomonas* sp. and α -haemolytic streptococci was isolated from liver, spleen, lung, heart, kidney and intestines. No growth of mycoplasmas could be observed in samples from lung tissue, but cultures for haemophilic bacteria showed high growth of strictly microaerophilic organisms on Columbia blood agar with 5 % sheep blood (CSBA; Oxoid) after 3 days of incubation at 37 °C in the presence of 10 % CO₂. Colonies were tiny, drop like, shiny and slightly convex, measuring 0.1–0.4 mm in diameter. Colonies appeared slightly α -haemolytic on CSBA (after 3 days of incubation) but developed a faint β -haemolysis after 5 days. Some colonies showed the typical ‘fried-egg’ appearance seen in L-forms. Microscopic morphological features were indicative of Gram-negative, pleomorphic, fusiform to filamentous, non-spore forming, non-encapsulated, non-acid-fast rods that were arranged in chains and clumps, also sometimes displaying irregular, lateral bulbar swellings. Conventional biochemical testing of isolate 131000547 from this study (all substrates Becton Dickinson) revealed broad accordance with the known

pattern (Edwards & Finch, 1986; Wullenweber, 1995) (Table 1). Key reactions were negative for cytochrome oxidase, catalase, urease, nitrate reduction and indole production. In liquid medium (e.g. trypticase soy broth), with the addition of 20 % cattle serum (Oxoid), streptobacillary growth could be detected after 2–4 days as typical ‘puff-ball’ or ‘bread crumb-like’ appearance (Elliott, 2007; Gaastra *et al.*, 2009).

Antimicrobial susceptibility testing was performed by disc diffusion on CSBA and respective discs (Oxoid) following DIN 58940 (German standard) criteria after 72 h of incubation at 37 °C in a microaerophilic atmosphere. Isolate 131000547 turned out to be inhibited *in vitro* by penicillin, ampicillin, oxacillin, amoxicillin-clavulanate, cephalotin, cephalexin, cefazoline, erythromycin, lincomycin, streptomycin, gentamicin, neomycin, tetracycline, enrofloxacin, florfenicol and chloramphenicol. Intermediate resistance to ciprofloxacin and resistance to polymyxin B and sulfamethoxazole-trimethoprim was also revealed.

For PCR analysis, thermolysates of freshly subcultured isolate 131000547 as well as strain NCTC 11941 (positive

Table 1. Biochemical and phenotypical characteristics of *Streptobacillus moniliformis* as determined from the literature (Edwards and Finch, 1986; Elliott, 2007; Gaastra *et al.*, 2009; Kimura *et al.*, 2008; Wullenweber, 1995), as well as of field isolate 131000547 from this study +, positive; –, negative; D, variable; [+/-], weak reaction.

Test	<i>Streptobacillus moniliformis</i>	<i>Streptobacillus</i> sp. isolate 131000547
Oxidase	–	–
Katalase	–	–
Indol	–	–
Nitrate	–	–
Arabinose	–	–
Cellobiose	+	–
Dulcitol	–	–
Fructose	+	+
Galactose	+	+
Glucose	+	+
Inosit	–	–
Lactose	–	–
Maltose	+	+
Mannitol	–	–
Mannose	+	+
Melibiose	–	–
Raffinose	–	–
Sucrose	–	–
Salicin	[+]	–
Sorbit	–	–
Trehalose	–	–
Xylose	–	–
Urease	–	–
Alkaline phosphatase	+	+
Esculin	[–]	–
Haemolysis of sheep erythrocytes	D	+
Motility	–	–
Arginine-dihydrolase	+	–
Ornithine-decarboxylase	–	–
Lysine-decarboxylase	–	–

control) were centrifuged (12 000 g, 10 min) and 1 µl of the supernatants was used for subsequent PCR with S5 (5'-CATACTCGGAATAAGATGG-3') and AS2 (5'-GCTTAGCTCCTCTTTGTAC-3') primers (Kimura *et al.*, 2008). Species-specific PCR resulted in a distinct 269 bp band for isolate 131000547 (Fig. 3).

Amplification of the 16S rRNA gene yielded a sequence length of 1425 bp using primers rRNA A (5'-AGAGTT-TGATCATGGCTCAG-3') and rRNA H [5'-AAGGAG-GTGATCCAGCCGCA-3' (Edwards *et al.*, 1989)]. Briefly, DNA was extracted from a bacterial pure culture (Maxwell 16 FFPE Plus LEV Purification kit; Promega). The PCR product was purified with a QIAquick PCR Purification kit (Qiagen) and sequenced by GATC Biotech (Konstanz, Germany). Sequence analysis carried out by BLAST N revealed 98 % sequence similarity to *Streptobacillus* sp. canine oral taxon 370 clone 2B078 partial 16S rRNA gene (GenBank accession no. JN713542.1; Dewhirst *et al.*, 2012) and *Streptobacillus moniliformis* strains KWG2 and KWG24 partial 16S rRNA gene (GenBank accession nos AB330759 and AB330760, respectively; Kimura *et al.*, 2008) from wild rats. Sequence overlap with the type strain of *Streptobacillus moniliformis* was 97 %.

Matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS) was performed on a MALDI-TOF MS Biotyper v.3.3.1.0 with the respective database (DB 4613; BrukerDaltonics), which comprised 24 spectra from *Streptobacillus moniliformis* (DSM 12112^T).

The comparison of MALDI-TOF MS spectra obtained by the direct smear and the extraction method for sample

preparation revealed differences between the cat's isolate compared with nine reference strains of *Streptobacillus moniliformis* from various sources and host species (Fig. 4). Nevertheless, mass spectrometry could confirm the affiliation of isolate 131000547 to the genus *Streptobacillus*.

Discussion

Only two case reports involving dogs focus on susceptibility and clinical relevance of *Streptobacillus moniliformis* in companion animals. One of these dogs displayed Haverhill fever-like symptoms including acute gastroenteritis, arthritis, skin rash, pneumonia and endocarditis after feeding on presumably contaminated items from rubbish (Ditchfield *et al.*, 1961). The other case report involved a scapula abscess aspirate (Das, 1986) for which growth characteristics and antibiotic susceptibility testing were not fully in accordance with those of *Streptobacillus moniliformis*. We present here the first evidence for a streptobacillary infection in a domestic cat that succumbed to fatal pneumonia and endocarditis. In light of the extremely high prevalence of *Streptobacillus moniliformis* in rats (close to 100 %; Gaastra *et al.*, 2009) and the regular exposure of domestic cats to wild rodents, it is striking that no other incidences of streptobacillary infections in domestic felines exist. In humans, the risk of acquiring a streptobacillary infection after a rat bite or scratch is indicated as 10 % (Hagelskjaer *et al.*, 1998), whereas the subsequent mortality rate of an untreated bite can be as high as 13 % (Wullenweber, 1995). It is possible that, much like in humans, infections are underdiagnosed in pets due to the oversight of rodent bites, occurrence of non-specific clinical symptoms, fastidious growth, non-notifiable disease and broad chemotherapeutic susceptibility.

A hypothesis presented recently is that dogs may be naturally colonized by other, as-yet-undescribed species of *Streptobacillus* (Dewhirst *et al.*, 2012). The cat described in this study originated from a farm with an abundance of rats and, similarly, could have simply aspirated an uncommon strain of *Streptobacillus moniliformis* through the oral cavity. Comparable case reports exclusively link streptobacillosis to respiratory infection in both a guinea pig and a koala (Kirchner *et al.*, 1992; Russell & Straube, 1979). Although no direct morphological features consistent with pulmonary streptobacillosis were detected during histopathological examination, no infectious agents for pneumonia other than *Streptobacillus moniliformis* could be cultivated or detected by culture, necropsy or histopathology. This suggests a major role for this pathogen as the causative agent. Unfortunately, as only lung tissue was cultivated microaerophilically, we cannot completely rule out a septicemic cause of streptobacillary infection. Although no routine tests for feline leucosis virus and feline immunodeficiency virus were carried out in this case, no characteristic signs of viral infection such as emaciation or tumoral growth were detected.

Fig. 3. Species-specific PCR for the detection of *Streptobacillus moniliformis* according to Kimura *et al.* (2008) using primers S5 and AS2. M, 1000 bp marker; lane 2, no-template control; lane 3, isolate 131000547 from this study; lane 4, *Streptobacillus moniliformis* strain NCTC 11941; lane 5, *Seibaldella termitidis* (negative control)

Fig. 4. Dendrogram including all main spectra peak lists of the phylum Fusobacteria available in the Bruker Taxonomy Database. '*Streptobacillus* sp_CVUAS_6430,2' (= *Streptobacillus* sp. 131000547 from a cat from this study) and '*Sealdella termitidis* CVUAS 6431,2' are database entries. Spectra of *Streptobacillus* sp. 131000547 and *Streptobacillus moniliformis* were measured using the direct transfer protocol. The dendrogram was generated using the BioTyper MSP Dendrogram Creation Standard Method (v.1.4) of the MALDI Biotyper OC Software (v.3.1, build 66); ATCC, American Type Culture Collection; NCTC, National Collection of Type Cultures; DSM, Deutsche Sammlung für Mikroorganismen; IPDH, Institut für Geflügelkrankheiten der Tierärztlichen Hochschule Hannover; CVUAS, CVUA Stuttgart.

Biochemical properties of the isolate examined in this study were consistent with assigned field and reference strains of *Streptobacillus moniliformis* (Table 1), but phenotypic variations within this species are known to occur (Edwards and Finch, 1986; Elliott, 2007; Gaastra *et al.*, 2009; Kimura *et al.*, 2008; Wullenweber, 1995). Some previous studies have also noticed the occurrence of haemolysis in *Streptobacillus moniliformis* (Ditchfield *et al.*, 1961; Wullenweber *et al.*, 1992). With respect to previous antimicrobial studies, our isolate did not significantly differ from *Streptobacillus moniliformis*. It showed resistance only to polymyxin B and sulfamethoxazole-trimethoprim, and intermediate resistance to ciprofloxacin, suggesting a good starting point for chemotherapeutic treatment. Besides a broad susceptibility of *Streptobacillus moniliformis*, specific strains of this pathogen have been reported to show resistance to nalidixic acid, polymyxin B, cephalosporins, aminoglycosides, sulfamethoxazole-trimethoprim, cotrimoxazole, tobramycin, norfloxacin, levofloxacin and ciprofloxacin (Cunningham *et al.*, 1998; Frans *et al.*, 2001; Freunek *et al.*, 1997; Rygg & Bruun, 1992; Wullenweber, 1995) or intermediate sensitivity to fluoroquinolones (Rygg & Bruun, 1992; Wullenweber, 1995). In addition to classic diagnostic tools such as biochemistry, morphology and molecular analysis, this is the first instance where MALDI-TOF MS was employed to identify *Streptobacillus moniliformis*. Whereas all field and reference strains could clearly be assigned with high accuracy, isolate 131000547 clustered closely but could not correctly be identified at the species level (Fig. 4). This can be explained by the presence of only a single strain represented by 24 spectra in the manufacturer's database, therefore not providing detailed coverage of the full spectral variance of this pathogen (M. Timke, personal communication). However, the possibility exists that the pathogen represents an undescribed species of *Streptobacillus*, as we found additional circumstantial evidence regarding phenotype (e.g. fermentation of cellobiose and arginine) and genotype (16S rRNA gene). Additional studies to clarify this situation are currently underway.

RBF represents a significant public health threat that might be underdiagnosed in species other than the known host animals, in particular in domestic pets. Despite frequent prey-mediated close contact to *Streptobacillus moniliformis*, cats appear not to be particularly prone to infection. We have shown for the first time here that domestic cats are nevertheless susceptible to streptobacillary infection and clinical disease. Future research should elucidate the role of domestic cats as a reservoir for *Streptobacillus moniliformis* and their immune response towards this pathogen.

Acknowledgements

We thank Anna Mohr for the excellent technical assistance and Barbara Gamb for the unsurpassed literature service. Norman Mauder (CVUA Stuttgart), Markus Timke (Bruker) and Twan Leenders (Jamestown, USA) are acknowledged for creating the cluster

analysis, discussing MALDI-TOF MS data and improving an earlier version of the manuscript, respectively. The authors declare no conflicts of interest.

References

- Bleich, A. & Nicklas, W. (2008). [Zoonoses transmitted by mouse and rat maintained as laboratory or pet animals]. *Berl Münch Tierärztl Wochenschr* **121**, 241–255 (in German).
- Boyer, C. I. J., Bruner, D. W. & Brown, J. A. (1958). A *Streptobacillus*, the cause of tendon-sheath infection in turkeys. *Avian Dis* **2**, 418–427.
- Cunningham, B. B., Paller, A. S. & Katz, B. Z. (1998). Rat bite fever in a pet lover. *J Am Acad Dermatol* **38**, 330–332.
- Das, A. M. (1986). *Streptobacillus moniliformis* isolated from an abscess of a dog. *Ind J Comp Microbiol Immunol Infect Dis* **7**, 115.
- Dewhirst, F. E., Klein, E. A., Thompson, E. C., Blanton, J. M., Chen, T., Milella, L., Buckley, C. M., Davis, I. J., Bennett, M. L. & other authors (2012). The canine oral microbiome. *PLoS One* **7**, e36067.
- Ditchfield, J., Lord, L. H. & McKay, K. A. (1961). *Streptobacillus moniliformis* infection in a dog. *Can Vet J* **2**, 457–459.
- Edwards, R. & Finch, R. G. (1986). Characterisation and antibiotic susceptibilities of *Streptobacillus moniliformis*. *J Med Microbiol* **21**, 39–42.
- Edwards, U., Rogall, T., Blocker, H., Emde, M. & Bottger, E. C. (1989). Isolation and direct complete nucleotide determination of entire genes. Characterization of a gene coding for 16S ribosomal RNA. *Nucleic Acids Res* **17**, 7843–7853.
- Elliott, S. P. (2007). Rat bite fever and *Streptobacillus moniliformis*. *Clin Microbiol Rev* **20**, 13–22.
- Frans, J., Verhaegen, J. & Van Noyen, R. (2001). *Streptobacillus moniliformis*: case report and review of the literature. *Acta Clin Belg* **56**, 187–190.
- Freundt, E. A. (1956). *Streptobacillus moniliformis* infection in mice. *Acta Pathol Microbiol Scand* **38**, 231–245.
- Freunek, K., Turnwald-Maschler, A. & Pannenbecker, J. (1997). [Caused rat bite fever by *Streptobacillus moniliformis* infection]. *Monatsschr Kinderheilkd* **145**, 473–476 (in German).
- Gaastra, W., Boot, R., Ho, H. T. & Lipman, L. J. (2009). Rat bite fever. *Vet Microbiol* **133**, 211–228.
- Gascard, E., Vignoli, R., Moulard, J. C. & Salvadori, J. M. (1967). [Case of febrile eruption after a cat bite: *Streptobacillus moniliformis* septicemia?]. *Mars Med* **104**, 861–864 (in French).
- Glünder, G., Hinz, K. H. & Stiburek, B. (1982). [Joint disease in turkeys caused by *Streptobacillus moniliformis* in Germany]. *Dtsch Tierärztl Wochenschr* **89**, 367–370 (in German).
- Gordon, I. J. & Jones, E. S. (1999). I smell a rat. *Hosp Med* **60**, 682–683.
- Gourlay, R. N., Flanagan, B. F. & Wyld, S. G. (1982). *Streptobacillus actinoides* (Bacillus actinoides): isolation from pneumonic lungs of calves and pathogenicity studies in gnotobiotic calves. *Res Vet Sci* **32**, 27–34.
- Hagelskjaer, L., Sorensen, I. & Randers, E. (1998). *Streptobacillus moniliformis* infection: 2 cases and a literature review. *Scand J Infect Dis* **30**, 309–311.
- Hayashimoto, N., Yoshida, H., Goto, K. & Takakura, A. (2008). Isolation of *Streptobacillus moniliformis* from a pet rat. *J Vet Med Sci* **70**, 493–495.
- Kimura, M., Tanikawa, T., Suzuki, M., Koizumi, N., Kamiyama, T., Imaoka, K. & Yamada, A. (2008). Detection of *Streptobacillus* spp. in feral rats by specific polymerase chain reaction. *Microbiol Immunol* **52**, 9–15.

- Kirchner, B. K., Lake, S. G. & Wightman, S. R. (1992). Isolation of *Streptobacillus moniliformis* from a guinea pig with granulomatous pneumonia. *Lab Anim Sci* **42**, 519–521.
- Mohamed, Y. S., Moorhead, P. D. & Bohl, E. H. (1969). Natural *Streptobacillus moniliformis* infection of turkeys, and attempts to infect turkeys, sheep, and pigs. *Avian Dis* **13**, 379–385.
- Peel, M. M. (1993). Dog-associated bacterial infections in humans: isolates submitted to an Australian reference laboratory, 1981–1992. *Pathol* **25**, 379–384.
- Rohde, J., Rapsch, C. & Fehr, M. (2008). Case report: Abscess by *Streptobacillus moniliformis* in a rat (English translation). *Prakt Tierarzt* **89**, 466–473 (in German).
- Russell, E. G. & Straube, E. F. (1979). Streptobacillary pleuritis in a koala (*Phascolarctos cinereus*). *J Wildl Dis* **15**, 391–394.
- Rygg, M. & Bruun, C. F. (1992). Rat bite fever (*Streptobacillus moniliformis*) with septicemia in a child. *Scand J Infect Dis* **24**, 535–540.
- Smallwood, R. P. (1929). Rat bite fever from the bite of a pig. *Brit Med J* **29**, 1159.
- Torres, L., Lopez, A. I., Escobar, S., Marne, C., Marco, M. L., Perez, M. & Verhaegen, J. (2003). Bacteremia by *Streptobacillus moniliformis*: first case described in Spain. *Eur J Clin Microbiol Infect Dis* **22**, 258–260.
- Valverde, C. R., Lowenstine, L. J., Young, C. E., Tarara, R. P. & Roberts, J. A. (2002). Spontaneous rat bite fever in non-human primates: a review of two cases. *J Med Primatol* **31**, 345–349.
- Washburn, R. G. (1995). *Streptobacillus moniliformis* (rat-bite fever). In *Principles and practice of infectious diseases*, Vol. 2, pp. 2084–2086. Edited by G. L. Mandell, J. E. Bennett & R. G. Dolin, New York: Churchill Livingstone.
- Wouters, E. G., Ho, H. T., Lipman, L. J. & Gaastra, W. (2008). Dogs as vectors of *Streptobacillus moniliformis* infection? *Vet Microbiol* **128**, 419–422.
- Wullenweber, M. (1995). *Streptobacillus moniliformis* – a zoonotic pathogen. Taxonomic considerations, host species, diagnosis, therapy, geographical distribution. *Lab Animal* **29**, 1–15.
- Wullenweber, M., Kaspereit-Rittinghausen, J. & Farouq, M. (1990). *Streptobacillus moniliformis* epizootic in barrier-maintained C57BL/6J mice and susceptibility to infection of different strains of mice. *Lab Anim Sci* **40**, 608–612.
- Wullenweber, M., Jonas, C. & Kunstyr, I. (1992). *Streptobacillus moniliformis* isolated from otitis media of conventionally kept laboratory rats. *J Exp Anim Sci* **35**, 49–57.
- Yamamoto, R. & Clark, G. T. (1966). *Streptobacillus moniliformis* infection in turkeys. *Vet Rec* **79**, 95–100.