Liver Abscess Associated with *Streptococcus suis* Serotype 4 in a Duroc Boar

Koka TAKIZAWA¹, ², Masahiro KUSUMOTO³, Toshiyuki MATSUURA¹, Tomoko NAGAI¹, Yoshifumi KOBAYASHI⁴, Naoto IMAI⁵ and Tomoyuki SHIBAHARA⁶  ⁷*

¹ Gunma Livestock Health Laboratory (Maebashi, Gunma 371-0103, Japan)
² Gunma Prefectural Seibu Livestock Hygiene Service Center (Takasaki, Gunma 370-0074, Japan)
³ Kyushu Research Station, National Institute of Animal Health, National Agriculture and Food Research Organization (NARO) (Chuzan, Kagoshima 891-0105, Japan)
⁴ Narita Branch 1st Animal Inspection Division, Animal Quarantine Service (Narita, Chiba 282-0011, Japan)
⁵ Fukushima Prefectural Kenchu Livestock Hygiene Service Center (Koriyama, Fukushima 963-8041, Japan)
⁶ Division of Pathology and Pathophysiology, National Institute of Animal Health, National Agriculture and Food Research Organization (NARO) (Tsukuba, Ibaraki 305-0856, Japan)
⁷ Department of Veterinary Science, Graduate School of Life and Environmental Sciences, Osaka Prefecture University (Izumisano, Osaka 598-8531, Japan)

Abstract
A 7-month-old Duroc boar exhibited anorexia and dark-bloody diarrhea. Despite antimicrobial therapy including enrofloxacin (fluoroquinolones) and tylosin (macrolides), the boar died. Gross examination showed hepatic abscesses. Histological examination showed chronic multifocal necrotizing and suppurative hepatitis with colonies of Gram-positive cocci. Necrosis was observed in the center of affected areas. The lesions were composed of numerous neutrophils, macrophages, a few lymphocytes, and fibroblasts. Dense fibrous connective tissue surrounded these necrotizing and suppurative lesions. Several cocci were also detected in the multifocal necrotic foci in the liver. The bacteria isolated from the hepatic abscesses were confirmed to be *Streptococcus suis* serotype 4 based on the results of 16S rRNA gene sequencing and agglutination tests with antisera. Immunohistochemically, the cocci observed in the hematoxylin and eosin and Gram-stained sections of the liver abscess were strongly positive for *S. suis* serotype 4. Antimicrobial susceptibility testing showed that the isolate was resistant to third generation cephalosporins. Thus, a diagnosis of unique streptococcosis caused by *S. suis* serotype 4 was made. The typical clinical manifestation of *S. suis* infection involves meninges, endocardium, joints, and the lungs. The present boar is the first natural case of porcine liver abscess caused by *S. suis* serotype 4.

Discipline: Animal health

Additional key words: antimicrobial susceptibility testing, gene sequencing, immunohistochemistry, pig, streptococcosis

Introduction

*Streptococcus suis*, an encapsulated Gram-positive bacterium, is an emerging zoonotic pathogen that causes invasive infections in pigs and humans (Okura et al. 2016). It is composed of phenotypically and genetically diverse strains (Okura et al. 2016). *S. suis* serotypes 2, 3, 7, and 9 are the most frequently isolated from diseased pigs; however, the distribution of serotypes from clinical cases differs depending on geographic location (Goyette-Desjardins et al. 2014). Serotypes 2 and 3 are the most prevalent serotypes in North America, while serotype 9 is the most frequently isolated serotype in Europe (Goyette-Desjardins et al. 2014). In pigs, cases involving other serotypes have rarely been reported.

*S. suis* can cause a variety of conditions, including meningitis, sepsis, endocarditis, arthritis, and pneumonia in young pigs (Gottschalk et al. 2010, Goyette-Desjardins...
et al. 2014, Staats et al. 1997), and asymptomatic pigs frequently carry the bacterium in their upper respiratory tract and tonsils (Han et al. 2001). To date, there have been no natural cases of liver abscess associated with S. suis serotype 4 reported in boars in Japan or anywhere else in the world.

The purpose of this case study was to describe the clinical and histopathological features of atypical Streptococcus infection characterized by liver abscess in a boar. 16S rRNA gene sequence data were used to clarify the taxonomic classification of Streptococcus-like organisms isolated from the animal. Antimicrobial susceptibility was examined in an attempt to identify effective therapy.

Materials and methods

1. Animal

In December 2015, a 64-day-old male Duroc piglet was moved as a boar candidate from a farm in another area to a farm with 40 sows, 55 suckling pigs, 100 weaned pigs, 120 growing pigs, and 115 finishing pigs in Gunma Prefecture, located in the central part of Honshu Island (Japan’s main island). At the age of 71 days, the piglet was vaccinated against Aujeszky’s disease. No history of disease or medical/surgical treatment was identified at that time. At the age of 7 months, on the 2nd of June 2016, the boar suddenly exhibited anorexia and abnormal stools, including dark-bloody diarrhea. Despite antimicrobial therapy that included enrofloxacin (fluoroquinolones) and tylosin (macrolides), the boar died on the 6th of June 2016. No clinical abnormalities were observed in any other pigs on the farm.

2. Histological and immunohistochemical examination

At necropsy, tissue samples of the liver, spleen, kidney, heart, lung, stomach, intestines (duodenum, jejunum, ileum, cecum, colon, and rectum), lymph nodes (hepatic, splenic, renal, parotid, submandibular, hilar, inguinal, subiliac, superficial cervical, and mesenteric), tonsil, gallbladder, adrenal gland, trachea, pancreas, central nervous system (cerebrum, middle brain, cerebellum, pons, and medulla oblongata) were fixed in 10% neutral-buffered formalin. Fixed tissues were embedded in paraffin wax, sectioned (approximately 3-µm thick), and then stained for histological examination with hematoxylin and eosin (H&E) and Gram stain.

Immunohistochemistry was performed to detect the S. suis serotype 4 antigen. Formalin-fixed, paraffin-embedded tissues (liver, kidney, tonsil, stomach, and intestines) were cut into 3-µm-thick sections, treated with 3% hydrogen peroxide in methanol (to suppress endogenous peroxidase activity), and then treated with 0.1% actinase E solution and incubated at 37°C for 20 min for antigen retrieval. The tissues were then incubated with rabbit anti-S. suis serotype 4 primary antibody at a dilution of 1 in 8192 (Statens Serum Institut, Copenhagen, Denmark) for 30 min at room temperature, and subsequently reacted with a secondary antibody (Histofine Simple Stain MAX-PO MULTI; Nichirei Bioscience Inc., Tokyo, Japan). After rinsing with phosphate buffered saline, the specimens were incubated with aminothiol carbazole (AEC) substrate solution (Histofine Simple Stain AEC solution; Nichirei Bioscience Inc., Tokyo, Japan) at room temperature for 5 min, and then counterstained with hematoxylin. Simultaneously, sections of hepatic tissues into which S. suis serotype 1 (strain NCTC 10237), 2 (strain NCTC 10234), 1/2 (strain NCTC 2651), 4 (present isolate), 7 (strain 8074), 9 (strain 22083), or 14 (strain 13730) had been injected were immunolabeled as positive controls. Negative controls were obtained by skipping the primary antibody.

For the detection of the porcine circovirus (PCV-2) antigen, formalin-fixed, paraffin-embedded tissues including the liver, spleen, kidney, lungs, stomach, ileum, tonsils, and lymph nodes (hepatic, splenic, renal, subiliac, superficial cervical, parotid, mandibular, inguinal, mesenteric, and tracheobronchial) were also cut in 3-µm-thick sections. Mouse monoclonal antibodies against PCV-2 (kindly provided by Dr. T. Suzuki, National Institute of Animal Health, NARO, Japan) were used with the commercial kit as described.

3. Bacteriological examination

For bacterial culture, tissue samples of the liver abscess, liver, spleen, kidney, heart, lung, and brain were inoculated onto 5% sheep blood agar and deoxycholate-hydrogen sulfide-lactose (DHL) agar, then incubated at 37°C under 5% CO2, and aerobic or anaerobic conditions for 18 h.

A simple identification kit (rapid ID 32 STREP V4.0; bioMerieux SA, Marcy-l’Étoile, France) was used to identify the isolates. To confirm the species of the isolates, we extracted the genomic DNA from bacterial colonies using a DNA extraction kit (InstaGene Matrix; Bio-Rad Laboratories, Hercules, CA, USA) in accordance with the manufacturer’s instructions. 16S rRNA genes derived from the isolates were analyzed to identify the bacteria (Therese et al. 2009). We also determined the serotype of the strain via agglutination tests using antisera (Gottschalk et al. 1989, Han et al. 2001).

To test antimicrobial susceptibility, we performed
Porcine Liver Abscess Associated with Streptococcus suis Serotype 4

the Kirby-Bauer disk diffusion test on S. suis serotype 4 isolated from the liver, using Mueller-Hinton agar with 5% sheep blood and antimicrobial disks (Sensi-disk; Becton, Dickinson and Company, NJ, USA) in accordance with the recommendations of the Clinical and Laboratory Standards Institute (CLSI) (Clinical and Laboratory Standards Institute, 2014). The antimicrobials tested were oxacillin (1 μg), penicillin (10 μg), ampicillin (10 μg), cefotaxime (30 μg), ceftriaxone (30 μg), ceferpine (30 μg), vancomycin (30 μg), erythromycin (15 μg), azithromycin (15 μg), clarithromycin (15 μg), tetracycline (30 μg), doxycycline (30 μg), levofoxacin (5 μg), moxifloxacin (5 μg), ofloxacin (5 μg), gatifloxacin (5 μg), trimethoprim-sulfamethoxazole (1.25/23.75 μg), chloramphenicol (30 μg), rifampin (5 μg), clindamycin (2 μg), and linezolid (30 μg).

Results

1. Gross pathology

For a diagnosis, necropsy was performed on the animal at the Gunma Livestock Health Laboratory. Gross necropsy examination of the animal showed liver abscesses (Fig. 1), enlargement of systemic lymph nodes, pale and firm kidneys, ulceration in the cardiac part of the stomach, and dark-bloody watery contents in the intestine (middle jejunum to colon). Multiple white-yellow foci up to about 20 mm in diameter were evident in the liver. An ulcer of approximately 60 mm in diameter was detected in the cardiac part of the stomach. No gross lesions were found in other organs, including the intestines and central nervous system.

2. Histological and immunohistochemical findings

Histological examination showed multifocal encapsulated abscesses in the parenchyma of the liver (Fig. 2). Necrosis was observed in the center of affected areas. The lesions were composed of numerous neutrophils, macrophages, a few lymphocytes, and fibroblasts. Dense fibrous connective tissue surrounded these abscesses. Numerous Gram-positive cocci were detected in the abscesses and multifocal necrotic foci in the liver.

In the other organs, lymphoid tissues (ileal Peyer’s patches and systemic lymph nodes) were characterized by lymphocyte depletion as well as macrophage, epithelioid cell and multinucleated giant cell infiltration. Ulceration in the cardiac part of the stomach was accompanied by several Gram-positive cocci and Gram-negative bacilli. Interstitial nephritis was also detected, with a proliferation of connective tissue. No abnormalities were detected in any of the other organs.

Immunohistochemically, the cocci observed in the H&E and Gram-stained sections of the liver abscess were strongly positive for S. suis serotype 4, as were the cocci in the positive control slide containing S. suis serotype 4 (Fig. 3). The reactions were detected in the liver, but not in the other organs examined. The rabbit polyclonal antibody to S. suis serotype 4 reacted immunohistochemically with S. suis serotype 4, but not with S. suis serotypes 1, 2, 1/2, 7, 9, or 14. PCV-2 antigen was detected in the cytoplasm of macrophages in the tonsils, ileal Peyer’s patches, and lymph nodes (subiliac, superficial cervical, and hepatic), but not in the other organs examined.

Fig. 1. Gross findings of the liver showing multiple white-yellow foci (arrows).
Bar = 5 cm.

Fig. 2. Hepatic foci demonstrating abscess surrounded by extensive fibrous tissue.
H&E, Bar = 100 μm.
3. Bacteriological findings

The colonies were α-hemolytic, 1 to 2 mm in diameter, grayish white, and spherical in appearance. Gram-positive streptococci were isolated from the liver abscesses. The isolates were identified as *S. suis* II by the simple identification kit (profile number 73073561170, 99.7% identity). Sequences of the amplified 16S rRNA gene regions of all isolates were identical to *S. suis* strains GZ0565 and DN13 (accession numbers CP017142 and CP015557, respectively). The isolates were *S. suis* serotype 4. No bacteria were isolated from any of the other tissue samples.

The strain showed resistance to penicillins (oxacillin and penicillin), the third generation cephalosporins (cefotaxime and ceftriaxone), macrolides (erythromycin and azithromycin), tetracyclines (tetracycline and doxycycline), trimethoprim-sulfamethoxazole, and lincomycin (clindamycin) (Table 1).

Discussion

These results indicated that the liver abscess was associated with *S. suis* serotype 4. The typical clinical manifestation of *S. suis* infection involves meninges, endocardium, joints, and the lungs (Gottschalk et al. 2010, Goyette-Desjardins et al. 2014, Staats et al. 1997). Although *S. suis* serotype 4 has previously been

---

**Table 1. Antibiotic susceptibilities of *Streptococcus suis* isolate**

<table>
<thead>
<tr>
<th>Antimicrobial agent</th>
<th>Disk content (μg)</th>
<th>Inhibition ring (mm)</th>
<th>Breakpoint (sensitive ≧ mm)</th>
<th>Result*</th>
</tr>
</thead>
<tbody>
<tr>
<td>oxacillin</td>
<td>1</td>
<td>10</td>
<td>20</td>
<td>R</td>
</tr>
<tr>
<td>penicillin</td>
<td>10</td>
<td>16</td>
<td>24</td>
<td>R</td>
</tr>
<tr>
<td>ampicillin</td>
<td>10</td>
<td>27</td>
<td>24</td>
<td>S</td>
</tr>
<tr>
<td>cefotaxime</td>
<td>30</td>
<td>22</td>
<td>24</td>
<td>R</td>
</tr>
<tr>
<td>ceftriaxone</td>
<td>30</td>
<td>21</td>
<td>24</td>
<td>R</td>
</tr>
<tr>
<td>cefepime</td>
<td>30</td>
<td>26</td>
<td>24</td>
<td>S</td>
</tr>
<tr>
<td>vancomycin</td>
<td>30</td>
<td>19</td>
<td>17</td>
<td>S</td>
</tr>
<tr>
<td>erythromycin</td>
<td>15</td>
<td>15</td>
<td>16</td>
<td>R</td>
</tr>
<tr>
<td>azithromycin</td>
<td>15</td>
<td>10</td>
<td>14</td>
<td>R</td>
</tr>
<tr>
<td>clarithromycin</td>
<td>15</td>
<td>19</td>
<td>17</td>
<td>S</td>
</tr>
<tr>
<td>tetracycline</td>
<td>30</td>
<td>–</td>
<td>25</td>
<td>R</td>
</tr>
<tr>
<td>doxycycline</td>
<td>30</td>
<td>14</td>
<td>25</td>
<td>R</td>
</tr>
<tr>
<td>levofloxacin</td>
<td>5</td>
<td>22</td>
<td>14</td>
<td>S</td>
</tr>
<tr>
<td>moxifloxacin</td>
<td>5</td>
<td>24</td>
<td>15</td>
<td>S</td>
</tr>
<tr>
<td>ofloxacin</td>
<td>5</td>
<td>19</td>
<td>13</td>
<td>S</td>
</tr>
<tr>
<td>gatifloxacin</td>
<td>5</td>
<td>24</td>
<td>18</td>
<td>S</td>
</tr>
<tr>
<td>trimethoprim-sulfamethoxazole</td>
<td>23.75/1.25</td>
<td>–</td>
<td>16</td>
<td>R</td>
</tr>
<tr>
<td>chloramphenicol</td>
<td>30</td>
<td>21</td>
<td>21</td>
<td>S</td>
</tr>
<tr>
<td>rifampin</td>
<td>5</td>
<td>24</td>
<td>17</td>
<td>S</td>
</tr>
<tr>
<td>clindamycin</td>
<td>2</td>
<td>–</td>
<td>16</td>
<td>R</td>
</tr>
<tr>
<td>linezolid</td>
<td>30</td>
<td>25</td>
<td>21</td>
<td>S</td>
</tr>
</tbody>
</table>

*S: sensitive, R: resistant*
implicated in septicemia and bronchopneumonia (Baig et al. 2015, Chaturvedi et al. 1999, Perch et al. 1983, Wang et al. 2014) in diseased piglets, the present case is the first to demonstrate S. suis serotype 4 as a cause of liver abscess in an adult boar.

In the case reported herein, tuberculosis, Trueperella pyogenes infection, and Actinobacillus pleuropneumoniae serotype 2 infection (Ohba et al. 2008) were also suspected as differential diagnoses. However, the results of bacterial isolation, identification, genetic sequencing of the isolate, and immunohistochemical analysis ruled out these pathogens and confirmed a diagnosis of liver abscess due to S. suis. The relationship between the organisms and diarreah was unclear in the present case.

Young piglets are at risk of S. suis infection and may develop the characteristic lesions within a few days (Gottschalk et al. 2010, Goyette-Desjardins et al. 2014). In our case, the lymphoid depletion and immunosuppression associated with PCV-2 (Meng 2013) were likely predisposing factors for the liver abscess associated with S. suis serotype 4.

Streptococcus sp. are usually found in the tonsils of pigs and immunosuppressed piglets are more likely to develop streptococcosis (Jensen et al. 2010, Maxie & Robinson 2007). The most interesting finding of this case was the presence of unique hepatic lesions associated with S. suis serotype 4. In a previous experimental study, the intravenous inoculation of piglets with S. suis serotype 4 proved fatal and histopathological examination revealed suppurrative reaction in various organs, including the liver, lungs and spleen (Chaturvedi et al. 1999). The present findings support that S. suis serotype 4 causes suppurrative reaction in various organs in natural cases. On the basis of these findings, we speculate that the abscess was formed when the causative cocci were transferred haemogenously from the upper respiratory tract and tonsils, which may have been the site of the original lesion, to the liver.

In this study, no S. suis serotype 4 antigen was detected in other organs, including the tonsils, and the source of infection could not be identified. Perhaps the liver abscess in this study developed as a consequence of bacteremia associated with S. suis serotype 4.

The S. suis identified in our study was resistant to penicillins, third generation cephalosporins, macrolides, tetracyclines, trimethoprim-sulphamethoxazole, and the lincomycins. Varela et al. reviewed the antimicrobial resistance patterns of S. suis isolates from various countries and reported variations thereof by country (Varela et al. 2013). They reported that the rates of resistance to penicillins (0-27%) and cephalosporins (0-23%) tended to be lower than the rates of resistance to tetracyclines (8-100%), macrolides (0-91%), lincomycins (0-100%), and trimethoprim-sulphamethoxazole (0-60%). The resistance of this strain to third generation cephalosporins is particularly important as cephalosporins are used in both humans and animals. Resistance to penicillin is also significant to veterinary practices. Although this strain was susceptible to fourth generation cephalosporin cefepime, particular attention should be paid to the further evolution of cephalosporin resistance in S. suis serotype 4.

To the authors’ knowledge, this is the first reported natural case of porcine liver abscess due to S. suis serotype 4. S. suis is composed of phenotypically and genetically diverse strains (Okura et al. 2016). Moreover, S. suis is important in public health and also in the field of veterinary medicine (Gottschalk et al. 2010, Goyette-Desjardins et al. 2014, Staats et al. 1997, Wertheim et al. 2009). Therefore, additional studies are necessary to confirm the differences in pathogenicity among the conventional strains of S. suis and the strain isolated in this study.

Acknowledgments

The authors wish to thank the staff of the Gunma local government for their useful advice and technical support, and are particularly grateful for the assistance in histopathology provided by Dr. M. Osaki, Mr. M. Kobayashi, Ms. M. Shimada (National Institute of Animal Health, National Agriculture and Food Research Organization, Japan), Ms. M. K. Tosaki (Tochigi Prefecture Kenou Livestock Hygiene Service Center), and Ms. T. Manchanayake (Division of Pathology, Veterinary Research Institute, Sri Lanka).

References


Goyette-Desjardins, G. et al. (2014) Streptococcus suis, an