within 6 months; for patient A, AST returned to reference range within 6 months and ALT within 7 months (Figure). Because the patients were asymptomatic at the time of rebound, we did not perform liver biopsies.

Each patient had acquired yellow fever in Ilha Grande, Brazil, as had 11 other nonvaccinated travelers to Brazil in 2018 (3), before vaccination against yellow fever was recommended for travelers to the states of São Paulo and Rio de Janeiro. For each of the 2 patients reported here, illness was similar: relatively mild disease despite jaundice and severe cytolyis (AST >1,200 IU/L, ALT >1,500 IU/L at diagnosis), known risk factors associated with higher mortality rates (4). For each patient, hepatic cytolyis rebounded ≈2 months after the initial peak, with no clinical symptoms and no detection of other pathogens. Previous reports have described liver cytolyis during yellow fever as being acute, decreasing rapidly on days 9–15, then reaching the upper limits of the reference range on day 16, and some persisting up to 2 months (5). Liver biopsy results have shown that liver lesions can persist up to 2 months (6).

We report persistent hepatitis over 6 months with a rebound of hepatic cytolyis after 2 months. In comparison, relapse has been described for ≈3% of patients with hepatitis A (7) with a biphasic peak of ALT (7,8) and detection of hepatitis A virus RNA in plasma (9), both 4–8 weeks after the first peak.

In terms of the cause of the hepatic cytolyis rebound in the 2 patients reported here, neither had taken a hepatotoxic drug during the rebound period, and results of deep sequencing for eukaryotic pathogens and autoimmune antibodies were negative. However, major yellow fever virus neutralizing activities were detected. Thus, the rebound could be attributed to host immune response to yellow fever virus rather than to another pathogen or to direct effects of the virus itself. In summary, our results show that yellow fever can induce persistent hepatitis with a rebound of liver cytolyis, probably an immune response to the yellow fever virus.

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References


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Comparative Analysis of Whole-Genome Sequence of African Swine Fever Virus Belgium 2018/1

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DOI: https://doi.org/10.3201/eid2506.190286

We analyzed the whole-genome sequence of African swine fever virus Belgium 2018/1. The strain fits into the European genotype II (>99.98% identity). The high-coverage sequence revealed 15 differences compared with an improved African swine fever virus Georgia 2007/1 sequence. However, in the absence of genetic markers, no spatial or temporal correlations could be defined.
African swine fever (ASF) is one of the most pathogenic viral diseases of swine leading to clinical and pathomorphological signs of a viral hemorrhagic fever (1). In 2007, ASFV was introduced into Georgia (2) and thereafter into numerous eastern European and European Union (EU) countries (3), as well as Asia (China, Mongolia, and Vietnam) (World Organization for Animal Health–World Animal Health Information database, http://www.oie.int/wahis_2/public/wahid.php/Wahidhome/Home/indexcontent, 2019 Feb 21).

In September 2018, the African swine fever virus (ASFV) was introduced into Belgium (3,4); as of April 28, 2019, 719 cases have been reported by Belgium’s Federal Agency for the Safety of the Food Chain (http://www.afsc.be/ppa/actualite/belgique).

Samples from the first 2 cases were taken for analysis to the Belgium National Reference Laboratory for ASF at Sciensano, Brussels, and were later confirmed by the ASF EU Reference Laboratory (EURL) in Valdeolmos, Spain. Partial sequencing at the EURL revealed a p72 genotype II with CVR-1, IGR-2, and MGF1 variants. Initial assessments of virus type and epidemiology were published by Garigliany et al. (4) to share the data without delay. Subsequently, samples were transferred to the Friedrich-Loeffler-Institut, Greifswald, Germany, for whole-genome sequencing.

We prepared samples and sequenced them on an Illumina MiSeq (https://www.illumina.com), as previously described (5). In addition, we enriched DNA libraries for Illumina sequencing for ASFV specific target sequences using an ASFV-specific myBaits kit (Arbor Biosciences, https://arborbiosci.com). We analyzed the resulting sequence data by mapping against an improved ASFV Georgia 2007/1 sequence (International Nucleotide Sequence Database Collaboration accession no. FR682468.2) using Newbler 3.0 software (6); we assembled the identified ASFV-specific reads using SPAdes 3.13.0 (7).

For the assembly of the inverted terminal repeat (ITR) regions, we mapped the reads against the individual ASFV Georgia 2007/1 ITR regions using Newbler and manually assembled them with the ASFV Belgium 2018/1 sequence in Geneious 11.1.5 (Biomatters, https://www.geneious.com). For validation, we mapped all reads along the final contig using Newbler; the result was a median unique depth of 292 with an interquartile range of 42. We annotated the sequence according to the improved ASFV Georgia 2007/1 sequence, using Glimmer3 in Geneious. We aligned different available ASFV whole-genome sequences using MAFFT 7.388, and we performed a phylogenetic analysis using IQ-TREE v1.6.5 (8,9). The whole-genome sequence is available from the International Nucleotide Sequence Database Collaboration databases under study accession no. PRJEB31287 and sequence accession no. LR536725.

The ASFV Belgium 2018/1 whole-genome sequence has a length of 190,599 bp. Comparison with the improved ASFV Georgia 2007/1 sequence revealed 15 differences, for an overall sequence identity of 99.98% at the nucleotide level. The detected differences included 4 nucleotide transitions, 5 nucleotide transversions, 5 changes in homopolymer regions, and 1 integration of a repeat into a previously described variable intergenic region (10) (Table).

Altogether, 4 differences in annotated genes are non-synonymous; 2 cause a frameshift, thereby truncating the MGF110-1L gene and changing the amino acid sequence of the DP60R protein; and 9 differences were identified in non-coding regions (Table). The differences in the ITR regions must be viewed carefully because of the low coverage in these particular parts of the genome, but the differences in the core regions are well supported by the sequencing data (Table). The differences at the specific positions 7,061; 44,586; 134,524; and 170,827 were also identified in the ASFV-SY2018 (China), Estonia 2014, Kashino 04/13 (Russia), and Pol 16/17 (Poland) sequences, and position 170,827 also in ASFV strain Odintsovo 02/14 (Russia). Further genetic differences could be identified in 7 so-called poly G/C regions. Whether these are artifacts originating from sequencing or the analyzed genomes or pose real differences remains to be determined by the analysis of further sequences from Belgium and other countries, which is in progress.

Finally, the alignment of all publicly available eastern European whole-genome sequences, as well as ASFV-China, shows that all these genomes are nearly identical with identities of more than 99.9% (Appendix Figure, http://wwwnc.cdc.gov/EID/article/25/6/19-0286-App1.pdf).

In conclusion, we provide a whole-genome analysis of ASFV from Belgium, which could show a high overall identity to recent ASFV strains from eastern Europe and China. We also identified locations showing differences from ASFV Georgia 2007/1 in single nucleotides, as well as a previously described repeat insertion. However, because the low mutation rate and the corresponding high genetic stability of the eastern European ASFV strains have hindered the definition of reliable genetic markers thus far, the currently available whole-genome information does not allow for further statements regarding correlations in space and time, and does not provide enough evidence for a more detailed mapping of strain origin. Although MGF110 was assigned a possible function in preparing the endoplasmic reticulum for viral morphogenesis (11), in the absence of any observations regarding virus attenuation in the field, no conclusion can be drawn on the effect of the observed differences. Therefore, further in vitro and in vivo characterizations using the ASFV Belgium 2018/1 isolate are needed.

In the future, more high-quality whole-genome ASFV sequences might allow identification of genetic markers that could aid high-resolution molecular epidemiology. Coordinated efforts to improve data sharing, together
Table. Differences in the whole-genome sequence of ASFV Belgium2018/1 and the improved ASFV Georgia2007/1 reference genome*

<table>
<thead>
<tr>
<th>Position</th>
<th>Type</th>
<th>Difference</th>
<th>Coverage</th>
<th>Gene</th>
<th>Synonymous/nonsynonymous</th>
<th>ORF change</th>
<th>Gene</th>
</tr>
</thead>
<tbody>
<tr>
<td>121</td>
<td>Transversion</td>
<td>G121C</td>
<td>AAAGAT</td>
<td>AAACAT</td>
<td>44</td>
<td>ITR</td>
<td>NA</td>
</tr>
<tr>
<td>129</td>
<td>Transversion</td>
<td>A129T</td>
<td>AAATA</td>
<td>AATAA</td>
<td>47</td>
<td>ITR</td>
<td>NA</td>
</tr>
<tr>
<td>479</td>
<td>Variation</td>
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<td>9 × T</td>
<td>10 × T</td>
<td>767</td>
<td>ITR</td>
<td>NA</td>
</tr>
<tr>
<td>1393</td>
<td>Variation</td>
<td>+C</td>
<td>9 × C</td>
<td>10 × C</td>
<td>1375</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>6786</td>
<td>Variation</td>
<td>–T</td>
<td>9 × T</td>
<td>8 × T</td>
<td>1755</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>7061</td>
<td>Transition</td>
<td>C7061T</td>
<td>CCCAG</td>
<td>CCTAG</td>
<td>1556</td>
<td>MGF 110–13L</td>
<td>Trp197Stop</td>
</tr>
<tr>
<td>15688</td>
<td>Variation</td>
<td>+3C</td>
<td>17 × C</td>
<td>20 × C</td>
<td>127</td>
<td>MGF 110–13L</td>
<td>Frameshift</td>
</tr>
<tr>
<td>17640</td>
<td>Variation</td>
<td>+2G</td>
<td>10 × G</td>
<td>12 × G</td>
<td>1117</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>17854</td>
<td>Variation</td>
<td>+G</td>
<td>9 × G</td>
<td>10 × G</td>
<td>1304</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>19807</td>
<td>Variation</td>
<td>–G</td>
<td>7 × G</td>
<td>6 × G</td>
<td>1238</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>20017</td>
<td>Variation</td>
<td>–2G</td>
<td>16 × G</td>
<td>14 × G</td>
<td>832</td>
<td>ASFV G</td>
<td>NA</td>
</tr>
<tr>
<td>21815</td>
<td>Variation</td>
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<td>11 × G</td>
<td>1184</td>
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<td>NA</td>
</tr>
<tr>
<td>27439</td>
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<td>–T</td>
<td>10 × T</td>
<td>9 × T</td>
<td>1895</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>44586</td>
<td>Transition</td>
<td>A44586G</td>
<td>TGAAA</td>
<td>TGGAA</td>
<td>1292</td>
<td>MGF 505–7R</td>
<td>Lys323Glu</td>
</tr>
<tr>
<td>73282</td>
<td>Variation</td>
<td>–T</td>
<td>9 × T</td>
<td>8 × T</td>
<td>1241</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>134524</td>
<td>Transition</td>
<td>T134524C</td>
<td>CATTG</td>
<td>CACAT</td>
<td>1665</td>
<td>NP419L</td>
<td>Asp414Ser</td>
</tr>
<tr>
<td>145080</td>
<td>Transition</td>
<td>G145080A</td>
<td>GAGCC</td>
<td>GAAGG</td>
<td>1266</td>
<td>D117L</td>
<td>Pro84Leu</td>
</tr>
<tr>
<td>170827</td>
<td>Transition</td>
<td>T170827A</td>
<td>GATGG</td>
<td>GAAGG</td>
<td>1263</td>
<td>I267L</td>
<td>Ile195Phe</td>
</tr>
<tr>
<td>190138</td>
<td>Variation</td>
<td>+A</td>
<td>9 × A</td>
<td>10 × A</td>
<td>3021</td>
<td>DP60R</td>
<td>Frameshift</td>
</tr>
<tr>
<td>173402</td>
<td>Repeat</td>
<td>+TATATAG</td>
<td>NA</td>
<td>+TATATAG</td>
<td>1731</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>190478</td>
<td>Transversion</td>
<td>T190478A</td>
<td>TATTT</td>
<td>TAATT</td>
<td>49</td>
<td>ITR</td>
<td>NA</td>
</tr>
<tr>
<td>190486</td>
<td>Transversion</td>
<td>C190486G</td>
<td>ATCTT</td>
<td>ATGTT</td>
<td>49</td>
<td>ITR</td>
<td>NA</td>
</tr>
</tbody>
</table>

* Differences are shown in bold and underlined. ASFV, African swine fever virus; ITR, inverted terminal repeat; NA, not applicable; ORF, open reading frame.
† International Nucleotide Sequence Database Collaboration accession nos: ASFV Georgia 2007/1, FR682468.2; ASFV Belgium 2018/1, LR536725.

with harmonized protocols under quality assurance, are of utmost importance to interpret results correctly and aid the fight against ASF.

Acknowledgments

The authors thank Patrick Zitzow for excellent technical assistance. The rapid and efficient support from the EURIL (M. Arias, Valdeolmos, Spain) was highly appreciated. The authors from Belgium also thank the excellent collaboration with the Walloon Region.

Dr. Forth is a biologist and postdoctoral researcher at the Friedrich-Loeffler-Institut, Greifswald, Germany. His work focuses mainly on ASFV whole-genome sequencing, molecular epidemiology, and virus evolution.

References

11. Netherton C, Rouillier L, Wileman T. The subcellular distribution of multigene family 110 proteins of African swine fever virus is...
Highly Pathogenic Swine Getah Virus in Blue Foxes, Eastern China, 2017

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DOI: https://doi.org/10.3201/eid2506.181983

We isolated Getah virus from infected foxes in Shandong Province, eastern China. We sequenced the complete Getah virus genome, and phylogenetic analysis revealed a close relationship with a highly pathogenic swine epidemic strain in China. Epidemiologic investigation showed that pigs might play a pivotal role in disease transmission to foxes.

Getah virus (GETV; genus Alphavirus, family Togaviridae) is a mosquitoborne RNA virus that causes death in young piglets, miscarriage in pregnant sows, and mild illness in horses (1–3). Serologic surveys show that the infection might occur in cattle, ducks, and chickens (4); some evidence suggests that GETV can infect humans and cause mild fever (5,6).

In September 2017, twenty-five 5-month-old blue foxes at a farm in Shandong Province in eastern China showed symptoms of sudden fever, anorexia, and depression; 6 of the 25 animals had onset of neurologic symptoms and died on the third day of illness. We collected blood samples from 45 healthy and 25 ill foxes. We subjected the tissue samples from dead animals, including the brains, lungs, spleens, kidneys, livers, intestines, hearts, and stomachs, to hematoxylin and eosin staining. Microscopic examination confirmed the presence of typical lesions in cerebral cortices with mild neuronal degeneration and inflammatory cell infiltration in vessels, as well as severe hemorrhagic pneumonia, congestion, and hemorrhage with a large number of erythrocytes in the alveolar space (Figure) (1). No obvious lesions were found in other organs.

We used supernatants of homogenized brain and lung tissues from each dead fox to inoculate Vero cells, as described previously (7). We observed a cytopathogenic effect within 72 hours. We observed numerous spherical, enveloped viral particles, ≈70 nm in diameter, after negative staining in a transmission electron microscope. To identify potential viral pathogens, we performed reverse transcription PCR (RT-PCR) to detect a panel of viruses, including canine distemper virus, canine parvovirus, canine coronavirus, and canine adenovirus. However, we detected none of these classical endemic viruses.

During the investigation, farmers reported that the foxes had been fed on organs from symptomatic pigs. We therefore tested for the presence of African swine fever virus, pseudorabies virus, porcine reproductive and respiratory syndrome virus, classical swine fever virus, Japanese encephalitis virus, porcine circovirus type 2, porcine circovirus type 3, porcine cytomegalovirus, and alphavirus by using the primers for those viruses (Appendix Table 2, https://wwwnc.cdc.gov/EID/article/25/6/18-1983-App1.pdf). RT-PCR using universal primers for alphavirus (M2w-cMw3) produced a 434-bp amplicon when we tested all samples from dead foxes. Sanger sequencing of the amplicon and a BLAST search (https://blast.ncbi.nlm.nih.gov/Blast.cgi) identified the sequence as that of GETV.

To further investigate the epidemic GETV infection, we performed quantitative RT-PCR by using RNA from all fox samples, as described elsewhere (7). Lung samples from all 6 dead foxes were positive, whereas only 2 samples from the remaining 19 ill foxes were also positive. None of the samples from healthy foxes were positive (Appendix Tables 1, 3). We measured serologic neutralizing antibodies by using a GETV isolate from a symptomatic fox, as previously described (8,9). Results showed no neutralizing antibody (<1:2) in healthy blue foxes (group 1) and variable levels of neutralizing antibodies (1:2 to 1:256) in ill foxes (groups 2–4) (Appendix Table 3). Samples from ill foxes with lower antibody titers had higher copies of RNA (groups 2–4). Spearman correlation analysis revealed a significant negative correlation between antibody titers and viral RNA copy numbers ($r^2 = 0.952$; $p<0.01$).

We obtained the complete genome of the novel GETV SD1709 strain (GenBank accession no. MH106780) by using a conventional RT-PCR method (10). SD1709 genome sequence comparisons showed high identity with the porcine GETV strain (HuN1) at the nucleotide (99.6%) and deduced amino acid (99.7%–99.8%) sequences (Appendix Table 4). Furthermore, phylogenetic analysis of the