Shiga Toxin 2A–Encoding Bacteriophages in Enteragggregative Escherichia coli O104:H4 Strains

To the Editor: In 2011, enteragggregative Escherichia coli (EAEC) O104:H4 strains that produce Shiga toxins (EAEC-STEC) caused an outbreak of hemorrhagic disease affecting nearly 4,000 patients in Europe (1). During 2001–2013, several countries reported infections caused by EAEC O104:H4 and EAEC-STEC O104:H4 strains (1–9). Genomic analysis of EAEC and EAEC-STEC O104:H4 strains revealed high similarity, and it has been suggested that EAEC-STEC O104:H4 strains evolved from EAEC O104:H4 strains by uptake of Stx toxin 2 (Stx2)–producing bacteriophages (3,4).

We investigated Stx-2 subunit A (Stx-2A) bacteriophages in a group of epidemiologically unrelated EAEC-STEC O104:H4 strains isolated from animals and food in Germany (collection of the National Reference Laboratory for Escherichia coli). One phage genome (P13374) was sequenced (2). The Stx-2A bacteriophages were highly similar in morphologic features, restriction endonuclease profiles, chromosomal integration sites, and superinfection immunity (2,3) and showed <65% similarity to Stx phages from non-O104 strains. Major genetic differences between the bacteriophages we investigated and other Stx phages were found in the genes for DNA replication, DNA metabolism, and in the immunity region (2,3).

We identified 2 genes, orf15 and cl_P13374, that were specific to Stx-2A bacteriophages found in EAEC-STEC O104:H4 strains (10). These genes were found in only 14 (5.8%) of 241 Stx-2A–positive non-O104 STEC strains. Viable Stx-2A bacteriophages isolated from 4 bovine non-O104 STEC strains were similar to Stx-2A bacteriophages from EAEC-STEC O104:H4 strains for all features described above (10). Similar to P13374, one of the bovine phages (P13803) lysogenized an Stx-negative EAEC O104:H4 strain and converted it into an EAEC-STEC–producing Stx-2A bacteriophage (10).

Our results provide experimental evidence that EAEC-STEC O104:H4 have evolved by uptake of a distinct type of Stx-2A bacteriophage. Bovine STEC harboring Stx-2A bacteriophages are able to transduce Stx-2A genes to EAEC O104:H4 are found worldwide, and phage-mediated transfer of Stx-2A can occur in the environment (10). Thus, the emergence of EAEC-STEC O104:H4 does not appear to be the result of introduction of the strains from areas to which they are endemic. Instead, the process may have occurred spontaneously by phage transduction, which could explain why EAEC-STEC O104:H4 infections were found at different locations and at different times. Regardless of time or place, however, these strains show characteristic differences in their prophage and plasmid profiles, which may serve as indicators of epidemiologic origin (1–4). Investigation of EAEC-STEC O104:H4 strains from sporadic cases of human infection could reveal these markers and help differentiate between strains that were introduced from other areas and strains that were newly generated by phage transduction.

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References

1. Beutin L, Martin A. Outbreak of Shiga toxin–producing Escherichia coli (STEC) O104:H4 infection in Germany causes a paradigm shift with regard to human pathogenicity of STEC strains. J Food Prot. 2012;75:408–18. http://dx.doi.org/10.3118/jfpp.75.3.408

2. Beutin L, Hammerl JA, Strauch E, Reetz J, Dieckmann R, Kelner-Burgos Y, et al. Spread of a distinct Stx-2encoding phage prototype among Escherichia coli O104:H4 strains from outbreaks in Germany, Norway, and Georgia. J Virol. 2012;86:10444–55. http://dx.doi.org/10.1128/JVI.00986-12

3. Ahmed SA, Aowski J, Baldwin C, Bishop-Lilly KA, Biswas B, Broomall S, et al.; Threat Characterization Consortium. Genomic comparison of Escherichia coli O104:H4 isolates from 2009 and 2011 reveals plasmid and prophage heterogeneity, including Shiga toxin encoding phage stx2. PLoS ONE. 2012;7:e48228. http://dx.doi.org/10.1371/journal.pone.0048228

4. Rasko DA, Webster DR, Sahl JW, Bashir A, Boisen N, Scheutz F, et al. Origins of the E. coli strain causing an outbreak of hemolytic-uremic syndrome in Germany. N Engl J Med. 2011;365:709–17. http://dx.doi.org/10.1056/NEJMoa1106920

5. Scavia G, Morabito S, Tozzoli R, Michelacci V, Marziano ML, Minelli F, et al. Similarity of Shiga toxin–producing Escherichia coli O104:H4 strains from Italy and Germany. Emerg Infect Dis. 2011;17:1957–8. http://dx.doi.org/10.3201/eid1710.111072

6. King LA, Nogareda F, Weill FX, Mariani-Kurkdjian P, Loukiadis E, Gault G, et al. Outbreak of Shiga toxin–producing Escherichia coli O104:H4 associated with organic fenugreek sprouts, France, June 2011. Clin Infect Dis. 2012;54:1588–94. http://dx.doi.org/10.1093/cid/cis255

7. Centers for Disease Control and Prevention. Outbreak of Escherichia coli O104:H4 infections associated with sprout consumption—Europe and North America, May–July 2011. MMWR Morb Mortal Wkly Rep. 2013;62:1029–31.

8. Dallman TJ, Chattaway MA, Cowley LA, Doumith M, Tewolde R, Wooldridge DJ, et al. An investigation of the diversity of strains of enteragggregative Escherichia coli isolated from cases associated with a large multi-pathogen foodborne outbreak in the UK. PLoS ONE. 2014;9:e98103. http://dx.doi.org/10.1371/journal.pone.0098103

9. Guy L, Jernberg C, Arvén Norling J, Ivarsson S, Hedenström I, Melefors Ö, et al.; Threat Characterization Consortium. Genomic comparison of Escherichia coli O104:H4 outbreak population. PLoS ONE. 2013;8:e63027. http://dx.doi.org/10.1371/journal.pone.0063027

10. Beutin L, Hammerl JA, Reetz J, Strauch E. Shiga toxin–producing Escherichia coli strains from cattle as a source of the Stx2a bacteriophages present in
testing revealed hematocrit within reference range (43.9%), thrombocytopenia (27,000 cells/mm³), elevated levels of liver enzymes (alanine transaminase 347 IU/L, aspartate transaminase 139 IU/L), creatinine (1.2 mg/dL), and urea (40 mg/dL). Laboratory testing ruled out malaria, leptospirosis, and dengue. About 24 hours after hospitalization, the patient experienced hypotension, progressive dyspnea, and acute respiratory distress. Thoracic radiographs revealed bilateral diffuse alveolar pulmonary infiltrates. Despite empirical treatment with antimicrobial drugs, mechanical ventilation, and inotropic therapy, the patient’s clinical condition deteriorated and he died on day 6 after illness onset.

The patient, who had no history of travel, resided on a submerged region in the western floodplain of the Solimões-Amazon River, Amazonas, a state with low population density (6.2 persons/square mile), in a rural area of Careiro da Várzea Municipality (3°11′53″S, 59°52′18″W), where access is possible only by boat. He had a history of contact with rodents not only at home but also in the boat he used. A serum sample collected on day 6 after illness onset was evaluated for hantavirus by serologic and PCR testing. ELISA result was positive for IgM and IgG against recombinant nucleocapsid protein (N) of the Juquitiba virus (6). Viral genome was detected by reverse transcription PCR, and the complete genomic small segment sequence, designated LH60_11/Hu (GenBank accession no. KF584259), was determined (7). This sequence was compared with a reference panel of sequences that covered the diversity of most hantaviruses in South America and was subjected to phylogenetic analysis by MrBayes software version 3.1.2 (8). Nucleotide and amino acid sequence similarities between all taxa for the partial N gene were calculated by using MegAlign version 5.05 (DNASTAR, Inc.; Madison, WI, USA). The best-fit evolution-