Genetically Different Highly Pathogenic Avian Influenza A(H5N1) Viruses in West Africa, 2015

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To trace the evolution of highly pathogenic influenza A(H5N1) virus in West Africa, we sequenced genomes of 43 viruses collected during 2015 from poultry and wild birds in 5 countries. We found 2 co-circulating genetic groups within clade 2.3.2.1c. Mutations that may increase adaptation to mammals raise concern over possible risk for humans.

In December 2014, a strain of highly pathogenic avian influenza (HPAI) A(H5N1) virus responsible for deaths among poultry was detected in southwestern Nigeria, specifically in a live bird market in Lagos State (1). Since then, other outbreaks have occurred in Nigeria, and the HPAI A(H5N1) virus has also been officially reported in Burkina Faso (February 2015) and Niger, Ghana, and Côte d’Ivoire (April 2015), to date causing the death of ≈1.6 million birds (2).

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Previous HPAI A(H5N1) epidemics in West Africa occurred in 2006–2008 and involved exclusively viruses of clade 2.2 (3). So far, a full-genome characterization is publicly available for only 1 HPAI A(H5N1) virus, collected in Nigeria in early 2015 (4) and classified as clade 2.3.2.1c. To our knowledge, this clade has not been previously detected in Africa. Since 2009, this clade has been widely circulating in domestic and wild birds in several countries in Asia (5); in 2010, it was reported in Europe (6) and in 2014, in the Middle East (7). In 2015, clade 2.3.2.1c was detected in rooks, chickens, and dalmatian pelicans in Russia, Bulgaria, and Romania, respectively (8). To trace the evolution of HPAI A(H5N1) virus in West Africa, we examined the genetic characteristics of 43 such viruses collected during January–August 2015 in all affected countries in West Africa.

The Study

From January through October 2015, a total of 248 samples (organ tissue and swab samples) from poultry and wild birds suspected of being infected with HPAI A(H5N1) virus in 6 countries in West Africa were sent for diagnostic confirmation to the World Organisation for Animal Health Reference Laboratory and the Food and Agriculture Organization of the United Nations Reference Center for Animal Influenza at the Istituto Zooprofilattico Sperimentale delle Venezie. Consistent with the laboratory test results provided by the submitting national veterinary laboratories, the presence of HPAI A(H5N1) virus was confirmed for 5 countries: Nigeria, Burkina Faso, Niger, Côte d’Ivoire, and Ghana. All samples positive for influenza A(H5N1) virus were sequenced by using Illumina MiSeq (San Diego, CA, USA) technology; complete coding sequences were obtained for 39 viruses, and the partial genome was obtained for 4 others (Table). To obtain consensus sequences later submitted to public databases (accession numbers in Table), we processed reads as described in Monne et al. (9). We performed phylogenetic analyses for each genome segment by using PhyML 3.0 (10), incorporating a general time reversible model of nucleotide substitution with a gamma distribution of among-site rate variation (with 4 rate categories) and a subtree pruning and regrafting branch-swapping search procedure. The topology of the 8 phylogenetic trees shows that viruses collected from West...
### Table. Epidemiologic information for sequenced samples from poultry and wild birds positive for influenza A(H5N1) virus, West Africa*

| Name | Sequenced genome | Collection date | Country, location | DB | Accession nos. |
|------|-----------------|----------------|------------------|----|---------------|
| A/chicken/Ghana/15VIR5480-3/2015 | Complete | 2015 Jul 28 | Ghana, Greater Accra | GB | KU971453–60 |
| A/partridge/Ghana/15VIR5480-5/2015 | Complete | 2015 Jul 27 | Ghana; Greater Accra | GB | KU971461–68 |
| A/chicken/Ghana/15VIR5480-7/2015 | Complete | 2015 Jul 28 | Ghana, Greater Accra | GB | KU971469–76 |
| A/chicken/Ghana/15VIR5480-10/2015 | Complete | 2015 Aug 7 | Ghana | GB | KU971397–04 |
| A/chicken/Ghana/15VIR5480-12/2015 | Complete | 2015 Jul 27 | Ghana, Greater Accra | GB | KU971405–12 |
| A/chicken/Ghana/15VIR5480-14/2015 | Complete | 2015 Aug 7 | Ghana, Greater Accra | GB | KU971413–20 |
| A/duck/Ghana/15VIR5480-16/2015 | Complete | 2015 Jul 27 | Ghana, Greater Accra | GS | EPI687323; EPI719449–55 |
| A/chicken/Ghana/15VIR5480-18/2015 | Complete | 2015 Aug 7 | Ghana, Greater Accra | GB | KU971421–28 |
| A/chicken/Ghana/15VIR5480-22/2015 | Complete | 2015 Aug 7 | Ghana, Greater Accra | GS | EPI687324; EPI719911–17 |
| A/duck/Ghana/15VIR5480–24/2015 | Complete | 2015 Jul 27 | Ghana, Greater Accra | GB | KU971429–36 |
| A/chicken/Ghana/15VIR5480-26/2015 | Complete | 2015 Aug 7 | Ghana, Greater Accra | GB | KU971437–44 |
| A/chicken/Ghana/15VIR5480-27/2015 | Complete | 2015 Aug 7 | Ghana, Greater Accra | GB | KU971445–52 |
| A/chicken/Niger/15VIR2060-1/2015 | Complete | 2015 Apr 2 | Niger, Maradi | GB | KU971301–08 |
| A/chicken/Niger/15VIR2060-12/2015 | Complete | 2015 Apr 2 | Niger, Maradi | GB | KU971309–16 |
| A/chicken/Niger/15VIR2060-14/2015 | Complete | 2015 Apr 2 | Niger, Maradi | GB | KU971317–24 |
| A/chicken/Niger/15VIR2060-15/2015 | Complete | 2015 Apr 2 | Niger, Maradi | GB | KU971325 |
| A/chicken/Niger/15VIR2060-5/2015 | Complete | 2015 Apr 2 | Niger, Maradi | GB | KU971326–33 |
| A/chicken/Niger/15VIR2060-6/2015 | Complete | 2015 Apr 2 | Niger, Maradi | GB | KU971334–40 |
| A/chicken/Niger/15VIR2060-7/2015 | Complete | 2015 Apr 2 | Niger, Maradi | GB | KU971341–48 |
| A/chicken/Niger/15VIR2060-8/2015 | Complete | 2015 Apr 2 | Niger, Maradi | GB | KU971349–56 |
| A/chicken/Ivory_Coast/15VIR2742-5/2015 | Partial | 2015 Apr 30 | Côte d’Ivoire, Bouaké-Quartier Broukro | GB | KU971578–84 |
| A/turtledove/Ivory_Coast/15VIR2742-7/2015 | Complete | 2015 Apr 30 | Côte d’Ivoire, Bouaké-Quartier Broukro | GB | KU971585–92 |
| A/duck/Ivory_Coast/15VIR2742-2/2015 | Complete | 2015 Apr 13 | Côte d’Ivoire, Bouaké-Quartier Koko | GB | KU971562–69 |
| A/chicken/Ivory_Coast/15VIR2742-3/2015 | Complete | 2015 Apr 13 | Côte d’Ivoire, Bouaké-Quartier Koko | GB | KU971570–77 |
| A/chicken/Burkina_Faso/15VIR1774-1/2015 | Partial | 2015 Mar 12 | Burkina Faso, CPAVI in Ouagadougou | GB | KU971477–83 |
| A/chicken/Burkina_Faso/15VIR1774-2/2015 | Complete | 2015 Mar 12 | Burkina Faso, CPAVI in Ouagadougou | GB | KU971484–91 |
| A/domestic_bird/Burkina_Faso/15VIR1774-22/2015 | Complete | 2015 Mar 10 | Burkina Faso, Sanguï Province | GB | KU971492–99 |
| A/domestic_bird/Burkina_Faso/15VIR1774-23/2015 | Complete | 2015 Mar 10 | Burkina Faso, Sanguï Province | GB | KU971500–07 |
| A/domestic_bird/Burkina_Faso/15VIR1774-24/2015 | Complete | 2015 Mar 10 | Burkina Faso, Sanguï Province | GB | KU971508–15 |
| A/domestic_bird/Burkina_Faso/15VIR1774-25/2015 | Complete | 2015 Mar 10 | Burkina Faso, Sanguï Province | GB | KU971516–23 |
| A/chicken/Burkina_Faso/15VIR1774-33/2015 | Complete | 2015 Mar 23 | Burkina Faso, Koubri | GB | KU971524–31 |
| A/chicken/Burkina_Faso/15VIR1774-35/2015 | Complete | 2015 Mar 23 | Burkina Faso, Koubri | GS | EPI584232; EPI719904–10 |
| A/chicken/Burkina_Faso/15VIR1774-36/2015 | Complete | 2015 Mar 23 | Burkina Faso, Koubri | GB | KU971532–39 |
| A/chicken/Burkina_Faso/15VIR1774-37/2015 | Complete | 2015 Mar 23 | Burkina Faso, CPAVI in Ouagadougou | GB | KU971540–47 |
| A/chicken/Burkina_Faso/15VIR1774-38/2015 | Partial | 2015 Mar 12 | Burkina Faso, CPAVI in Ouagadougou | GB | KU971548–53 |
| A/chicken/Burkina_Faso/15VIR1774-4/2015 | Complete | 2015 Mar 12 | Burkina Faso, CPAVI in Ouagadougou | GB | KU971554–61 |
| A/chicken/Nigeria/15VIR339-1/2015 | Complete | 2015 Jan 2 | Nigeria, Lagos State | GB | KU971593–00 |
| A/chicken/Ghana/15VIR2588-10/2015 | Complete | 2015 May 8 | Ghana, Greater Accra | GB | KU971357–64 |
| A/chicken/Ghana/15VIR2588-11/2015 | Complete | 2015 May 4 | Ghana, Greater Accra | GB | KU971365–72 |
| A/chicken/Ghana/15VIR2588-4/2015 | Complete | 2015 May 4 | Ghana, Greater Accra | GB | KU971373–80 |
| A/chicken/Ghana/15VIR2588-5/2015 | Complete | 2015 May 4 | Ghana, Greater Accra | GB | KU971381–88 |
| A/chicken/Ghana/15VIR2588-8/2015 | Complete | 2015 May 4 | Ghana, Greater Accra | GB | KU971397–96 |
| A/chicken/Ghana/15VIR2588-9/2015 | Complete | 2015 May 4 | Ghana, Greater Accra | GS | EPI632942; EPI719456–82 |

*CPAVI, Centre de Promotion de l’Aviculture Villageoise; DB, database; GB, GenBank; GS, The Global Initiative on Sharing All Influenza Data; HA, hemagglutinin.
Africa in 2015 belong to clade 2.3.2.1c and cluster separately from HPAI A(H5N1) viruses collected from West Africa during the 2006–2008 epidemic (Figure). Specifically, the analyzed viruses grouped with those that have been circulating in Eurasia since 2013 and showed the highest similarity with H5N1 subtype viruses collected in Europe and the Middle East from late 2014 through early 2015. As previously described for influenza A(H5N1) virus (4), the viruses from West Africa that we analyzed displayed the same genetic constellation of the A/Alberta/01/2014 virus; the polymerase basic protein 2 segment originated from a reassortment event with subtype H9N2. The hemagglutinin (HA) phylogenetic tree (Figure) shows that the viruses from West Africa constitute 2 main groups, here named WA1 and WA2, supported by high bootstrap values (>73%) and a genetic similarity of 98%–99.1%. WA1 is the most heterogeneous group (identity 98.7%–100%) and contains sequences from all affected countries in West Africa (Nigeria, Niger, Côte d’Ivoire, Burkina Faso, and Ghana). WA2 comprises sequences collected in April 2015.

Figure. Maximum-likelihood phylogenetic tree of the hemagglutinin gene segment of highly pathogenic avian influenza (H5N1) viruses from West Africa. Strain colors indicate country of collection (inset). The 2 identified groups (WA1 and WA2) are indicated by boxes (black and gray, respectively). Clades are indicated at right; sequences from the 2006–2008 epidemic (clade 2.2) in West Africa were used as an outgroup. Numbers at the nodes represent bootstrap values >60%, obtained through a nonparametric bootstrap analysis that used 100 replicates. Scale bar indicates nucleotide substitutions per site.
from Niger and Côte d’Ivoire only (identity 99.4%–100%) and clusters together with subtype H5N1 collected during January–March 2015 from wild birds in Europe (Bulgaria and Romania). Of note, viruses in the WA2 group are more closely related to those from Europe (similarity 99.30%–99.65%) than to those in the WA1 group (similarity 97.95%–99.12%), suggesting the occurrence of at least 2 independent introductions of subtype H5N1 in West Africa. Viruses in the WA1 and WA2 groups were isolated in 1 city in Niger and 1 city in Côte d’Ivoire, which suggests their possible co-circulation in the same geographic area.

As with the HA gene, we identified the 2 West Africa groups in all the other phylogenies (supporting bootstrap values >74%), except for the tree of the nonstructural gene segment, in which WA2 does not form a monophyletic group. Unfortunately, only the HA gene segment of the viruses from Europe that clusters with the WA2 group is available in the public database, making the source of the internal genes of the WA2 viruses impossible to trace.

The analysis of molecular markers indicates that all viruses showed mutations D94N (except for A/chicken/Ghana/5480-14/2015), S133A, and S155N (H5 numbering) in the HA protein; these mutations have been shown to increase virus binding to α2,6 sialic acid (11). In addition, the analysis of internal proteins identified a mutation associated with enhanced replication efficiency (NP N319K) (11) in all WA2 viruses from Niger. Moreover, the alternative reading frame of the polymerase basic protein 1 of the WA2 viruses is truncated (57 aa long), as it is in the Asian and European progenitors. This truncation is common among influenza A viruses of mammals and in HPAI A(H5N1) viruses, and it has been associated with increased virulence in mammals (12).

Conclusions
We demonstrated that a reassortant HPAI A(H5N1) clade 2.3.2.1c virus was responsible for infections in 5 West Africa countries. The influenza (H5N1) viruses from West Africa show a close phylogenetic relationship with the HPAI A(H5N1) viruses identified in Europe and the Middle East during late 2014–2015, indicating a Eurasian origin of their progenitors. The route of introduction of this virus is difficult to establish because West Africa offers wintering sites for wild birds coming from the southern Russian regions, Europe, and western Asia (13), and it imports live birds from countries in Europe and Asia (14).

As with previous epidemics (2006–2008), when distinct introductions and multiple reassortment events were identified (3,15), we were able to detect the co-circulation of 2 distinct genetic clusters in Côte d’Ivoire and Niger, which suggests that there might have been at least 2 separate introductions into West Africa. However, the limited amount of genetic data available makes it impossible to pinpoint how these viruses entered the continent and spread so widely, and it is not easy to determine the exact number of introductions and where they have occurred in West Africa. Additional virus data from affected countries would help elucidate the epidemiology and the evolution of this virus in this part of the continent.

Of note, all the viruses from West Africa display the same genetic constellation of a strain (A/Alberta/01/2014) isolated from a human, a Canada resident who had returned from China. These viruses contain mutations that have been described as being associated with an enhanced binding affinity for α2,6 sialic acid or with increased virulence in mammals.

As during the 2006–2008 HPAI A(H5N1) epidemics, West Africa countries are again facing devastating economic and social consequences from these infections. It is imperative for regional and international organizations to join forces in generating and making available detailed genetic and epidemiologic information that can be used to better trace the spread and evolution in West Africa of influenza A(H5N1) virus and to provide input for informed decisions on control measures and resource allocation.

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Dr. Tassoni is a biotechnologist at the Istituto Zootopifilattico Sperimentale delle Venezie. His primary research interests include studying the molecular phylogeny and the evolutionary dynamics of viruses.

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EID Podcast: Novel Eurasian Highly Pathogenic Avian Influenza A H5 Viruses in Wild Birds, Washington, USA, 2014

Novel Eurasian lineage avian influenza A(H5N8) virus has spread rapidly and globally since January 2014. In December 2014, H5N8 and reassortant H5N2 viruses were detected in wild birds in Washington, USA, and subsequently in backyard birds. When they infect commercial poultry, these highly pathogenic viruses pose substantial trade issues.

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EMERGING INFECTIOUS DISEASES
Genetically Different Highly Pathogenic Avian Influenza A(H5N1) Viruses in West Africa, 2015

Technical Appendix

**Technical Appendix Table.** Global Initiative on Sharing All Influenza Data (GISAID) accession numbers, submitting laboratories, and authors of the sequences used in study of genetically different highly pathogenic avian influenza A(H5N1) viruses in West Africa, 2015*

| Segment ID  | Segment | Country | Collection date | Isolate name                      | Originating Lab                                                                 | Submitting Lab                                                                 | Authors                                                                 |
|-------------|---------|---------|----------------|-----------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| EPI592605   | HA      | Bulgaria| 2015 Jan 23    | A/dalmatian pelican/Bulgaria/4/2015 | NDRVMI (National Diagnostic and Research Veterinary Medical Institute)          | Animal and Plant Health Agency (APHA)                                        | Thomas, S; Seekings, A; Essen, S; Manvell, R; Goujgoulova, G; Oreshkova, L; Banks, J; Brown, I |
| EPI592416   | HA      | Bulgaria| 2015 Jan 23    | A/dalmatian pelican/Bulgaria/3/2015 | NDRVMI (National Diagnostic and Research Veterinary Medical Institute)          | Animal and Plant Health Agency (APHA)                                        | Thomas, S; Seekings, A; Essen, S; Manvell, R; Goujgoulova, G; Oreshkova, L; Banks, J; Brown, I |
| EPI594492   | HA      | Bulgaria| 2015 Jan 30    | A/chicken/ Bulgaria/5409/15        | NDRVMI (National Diagnostic and Research Veterinary Medical Institute)          | Animal and Plant Health Agency (APHA)                                        | Thomas, S; Seekings, A; Essen, S; Manvell, R; Goujgoulova, G; Oreshkova, L; Banks, J; Brown, I |
| EPI594491   | HA      | Bulgaria| 2015 Jan 30    | A/chicken/ Bulgaria/5408/15        | NDRVMI (National Diagnostic and Research Veterinary Medical Institute)          | Animal and Plant Health Agency (APHA)                                        | Thomas, S; Seekings, A; Essen, S; Manvell, R; Goujgoulova, G; Oreshkova, L; Banks, J; Brown, I |
| EPI594490   | HA      | Bulgaria| 2015 Jan 30    | A/chicken/ Bulgaria/5407/15        | NDRVMI (National Diagnostic and Research Veterinary Medical Institute)          | Animal and Plant Health Agency (APHA)                                        | Thomas, S; Seekings, A; Essen, S; Manvell, R; Goujgoulova, G; Oreshkova, L; Banks, J; Brown, I |
| EPI559770   | HA      | China   | 2015 Jan 04    | A/whooper swan/Henan/SMX3/2015(H5N1)| CAS Key Laboratory of Pathogenic Microbiology and Immunology, Institute of Microbiology, Chinese Academy of Sciences | Institute of Microbiology, Chinese Academy of Sciences                        | Not applicable                                                          |
| EPI559727   | HA      | China   | 2015 Jan 04    | A/whooper swan/Henan/SMX1/2015(H5N1)| CAS Key Laboratory of Pathogenic Microbiology and Immunology, Institute of Microbiology, Chinese Academy of Sciences | Institute of Microbiology, Chinese Academy of Sciences                        | Not applicable                                                          |
| EPI559910   | HA      | China   | 2015 Jan 05    | A/whooper swan/Henan/SMX9/2015(H5N1)| CAS Key Laboratory of Pathogenic Microbiology and Immunology, Institute of Microbiology, Chinese Academy of Sciences | Institute of Microbiology, Chinese Academy of Sciences                        | Not applicable                                                          |
| Segment ID | Segmen | Country        | Collection date | Isolate name                     | Originating Lab                                                                                           | Submitting Lab                                      | Authors                                                                 |
|------------|--------|----------------|-----------------|----------------------------------|----------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------------------------------------------------------------------|
| EPI559789  | HA     | China          | 2015 Jan 05     | A/whooper swan/Henan/SMX4/2015(H5N1) | Institute of Microbiology, Chinese Academy of Sciences CAS Key Laboratory of Pathogenic Microbiology and Immunology, Institute of Microbiology, Chinese Academy of Sciences | Institute of Microbiology, Chinese Academy of Sciences | Not applicable                                                         |
| EPI560202  | HA     | China          | 2015 Jan 05     | A/environment/Henan/SMX1/2015(H5N1) | Institute of Pathogen Biology, Taishan Medical College                                                  | Institute of Microbiology, Chinese Academy of Sciences | Shi, Weifeng; Bi, Yuhai                                                  |
| EPI594560  | HA     | Romania        | 2015 Mar 26     | A/pelican/Romania/12449/2015   | Institute for Diagnosis & Animal Health Agency (IDAH)                                                  | Thomas, S; Puranik, A; Londt, B; Essen, S; Manveil, R; Onita, I; Neicul, A; Cioranu, R; Motu, R; Banks, J; Brown, I | Ivan, Susloparov; Vasily, Marchenko; Natalya, Goncharova; Andrey, Shipovalov; Alexander, Durymanov; Tatyana, Ilyicheva; Alexander, Ryzhikov |
| EPI631928  | HA     | Russian Federation | 2015 May 07   | A/rook/Sartlan/42/2015       | State Research Center of Virology and Biotechnology Vector                                             | State Research Center of Virology and Biotechnology Vector | Ivan, Susloparov; Vasily, Marchenko; Natalya, Goncharova; Andrey, Shipovalov; Alexander, Durymanov; Tatyana, Ilyicheva; Alexander, Ryzhikov |
| EPI631920  | HA     | Russian Federation | 2015 May 07   | A/rook/Dovolnoe/50/2015      | State Research Center of Virology and Biotechnology Vector                                             | State Research Center of Virology and Biotechnology Vector | Ivan, Susloparov; Vasily, Marchenko; Natalya, Goncharova; Andrey, Shipovalov; Alexander, Durymanov; Tatyana, Ilyicheva; Alexander, Ryzhikov |
| EPI631912  | HA     | Russian Federation | 2015 May 07   | A/rook/Chany/32/2015         | State Research Center of Virology and Biotechnology Vector                                             | State Research Center of Virology and Biotechnology Vector | Ivan, Susloparov; Vasily, Marchenko; Natalya, Goncharova; Andrey, Shipovalov; Alexander, Durymanov; Tatyana, Ilyicheva; Alexander, Ryzhikov |
| EPI623563  | HA     | United Arab Emirates | 2014 Dec 01   | A/Duck/Dubai/2459/2014     | Friedrich-Loeffler-Institut                                                                             | Friedrich-Loeffler-Institut                         | Chen, H.; Chan, KH.; Wong, PC.; C.Y.P.                                  |
| EPI623571  | HA     | United Arab Emirates | 2014 Dec 07   | A/Falcon/Dubai/2506/2014    | Friedrich-Loeffler-Institut                                                                             | Friedrich-Loeffler-Institut                         | Chen, H.; Chan, KH.; Wong, PC.; C.Y.P.                                  |
| EPI603561  | HA     | United Arab Emirates | 2014 Dec 07   | A/Sea Gull/Dubai/AR3443–25041/2014 | Friedrich-Loeffler-Institut                                                                             | Friedrich-Loeffler-Institut                         | Naguib, M.M.; Wernery, U.; Harder, T.                                    |
| EPI603577  | HA     | United Arab Emirates | 2014 Dec 07   | A/Quail/Dubai/AR3445–25043/2014 | Friedrich-Loeffler-Institut                                                                             | Friedrich-Loeffler-Institut                         | Naguib, M.M.; Wernery, U.; Harder, T.                                    |
| EPI603569  | HA     | United Arab Emirates | 2014 Dec 07   | A/Stone curlew/Dubai/AR3444–25042/2014 | Friedrich-Loeffler-Institut                                                                             | Friedrich-Loeffler-Institut                         | Naguib, M.M.; Wernery, U.; Harder, T.                                    |
| EPI603553  | HA     | United Arab Emirates | 2014 Nov 17   | A/Falcon/Dubai/AR3430–2293/2014 | Friedrich-Loeffler-Institut                                                                             | Friedrich-Loeffler-Institut                         | Naguib, M.M.; Wernery, U.; Harder, T.                                    |
| Segment ID | Segment | Country            | Collection date | Isolate name                        | Originating Lab                                                                 | Submitting Lab                                                                 | Authors                                                                 |
|------------|---------|--------------------|-----------------|-------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------|
| EPI623555  | HA      | United Arab Emirates | 2014 Nov 30    | A/Hoabara/Dubai/2455.5/2014         | Friedrich-Loeffler-Institut Crick Worldwide Influenza Centre                      | University of Ghana                                                          | Chen, H.; Chan, KH.; Wong, PC.; Woo, C.Y.P.                            |
| EPI643194  | HA      | Ghana              | 2015 Jan 01     | A/chicken/Ghana/FJ152511/2015       | University of Ghana                                                              | Friedrich-Loeffler-Institut Crick Worldwide Influenza Centre                  | Not applicable                                                        |
| EPI556504  | HA      | Nigeria            | 2015 Jan 01     | A/chicken/Nigeria/15VIR339–2/2015   | National Veterinary Research Institute                                            | Istituto Zooprofilattico Sperimentale Delle Venezie                           | Joannis, T.; Ahmed, M.; Meseko, C.; Shittu, I.; Solomon, P.; Luka, P.; Olorunshola, B.; Tassoni, L.; Schivo, A.; Ormelli, S.; Monne, I. |
| EPI425248  | HA      | Vietnam            | 2012 Jan 30     | A/chicken/Vietnam/NCVD-1177/2012    | National Centre of Veterinary Diagnostics                                        | Centers for Disease Control and Prevention Centers for Disease Control and Prevention | Not applicable                                                        |
| EPI425376  | HA      | Vietnam            | 2012 Feb 17     | A/duck/Vietnam/NCVD-1234/2012       | National Centre of Veterinary Diagnostics                                        | Centers for Disease Control and Prevention Centers for Disease Control and Prevention | Not applicable                                                        |
| EPI425472  | HA      | Vietnam            | 2012 Feb 16     | A/chicken/Vietnam/NCVD-1247/2012    | National Centre of Veterinary Diagnostics                                        | Centers for Disease Control and Prevention Centers for Disease Control and Prevention | Not applicable                                                        |
| EPI425616  | HA      | Vietnam            | 2012 Mar 02     | A/chicken/Vietnam/NCVD-1489/2012    | National Centre of Veterinary Diagnostics                                        | Centers for Disease Control and Prevention Centers for Disease Control and Prevention | Not applicable                                                        |
| EPI425787  | HA      | Vietnam            | 2011 Sep 07     | A/chicken/Vietnam/NCVD-1040/2011    | National Centre of Veterinary Diagnostics                                        | Centers for Disease Control and Prevention Centers for Disease Control and Prevention | Not applicable                                                        |
| EPI425827  | HA      | Vietnam            | 2011 Sep 08     | A/chicken/Vietnam/NCVD-1059/2011    | National Centre of Veterinary Diagnostics                                        | Centers for Disease Control and Prevention Centers for Disease Control and Prevention | Not applicable                                                        |
| EPI500771  | HA      | Canada             | 2014 Jan 03     | A/Alberta/01/2014                   | Provincial Laboratory of Public Health for Southern Alberta                      | Public Health Agency of Canada (PHAC)                                          | Li, Yan; Bastien, Nathalie; Fonseca, Kevin; Tipples, Graham; Pabbaraju, Kanti; Tellier, Raymond; Wong, Sallene; Tang, Julian W.; Drews, Steven J. |

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