Active Tracing and Monitoring of Contacts Associated With the First Cluster of Ebola in the United States

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Background: Following hospitalization of the first patient with Ebola virus disease diagnosed in the United States on 28 September 2014, contact tracing methods for Ebola were implemented.

Objective: To identify, risk-stratify, and monitor contacts of patients with Ebola.

Design: Descriptive investigation.

Setting: Dallas County, Texas, September to November 2014.

Participants: Contacts of symptomatic patients with Ebola.

Measurements: Contact identification, exposure risk classification, symptom development, and Ebola.

Results: The investigation identified 179 contacts, 139 of whom were contacts of the index patient. Of 112 health care personnel (HCP) contacts of the index case, 22 (20%) had known unprotected exposures and 37 (30%) did not have known unprotected exposures but interacted with a patient or contaminated environment on multiple days. Transmission was confirmed in 2 HCP who had substantial interaction with the patient while wearing personal protective equipment. These HCP had 40 additional contacts. Of 20 community contacts of the index patient or the 2 HCP, 4 had high-risk exposures. Movement restrictions were extended to all 179 contacts; 7 contacts were quarantined. Seven percent (14 of 179) of contacts (1 community contact and 13 health care contacts) were evaluated for Ebola during the monitoring period.

Limitation: Data cannot be used to infer whether in-person direct active monitoring is superior to active monitoring alone for early detection of symptomatic contacts.

Conclusion: Contact tracing and monitoring approaches for Ebola were adapted to account for the evolving understanding of risks for unrecognized HCP transmission. HCP contacts in the United States without known unprotected exposures should be considered as having a low (but not zero) risk for Ebola and should be actively monitored for symptoms. Core challenges of contact tracing for high-consequence communicable diseases included rapid comprehensive contact identification, large-scale direct active monitoring of contacts, large-scale application of movement restrictions, and necessity of humanitarian support services to meet nonclinical needs of contacts.

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Ebola Contact Monitoring in the United States

**EDITORS’ NOTES**

**Context**
After confirmation of the first case of Ebola virus disease diagnosed in the United States, contact tracing and monitoring were instituted.

**Contribution**
Challenges included the need for rapid response in a setting of evolving knowledge, institution of direct active monitoring and movement restriction for a large number of contacts, and provision of mental health and other supports. Quarantine was necessary in only a few cases.

**Implication**
Contact tracing of the first case of U.S.-diagnosed case of Ebola was unprecedented in complexity. This experience may be useful in future instances of exposure to highly communicable diseases.

Factors and consistent symptoms. Potential Ebola exposure risk factors included contact with a patient who had laboratory-confirmed Ebola or who had traveled from countries affected by the Ebola outbreak. The extensive symptom criteria included temperature of 101.5°F or greater (≥38.6°C); 1 or more of the following symptoms: severe headache, sore throat, malaise, muscle pain, diarrhea, vomiting, rash, or unexplained bleeding within 21 days after exposure or travel; and no alternative diagnosis. Confirmed patients had Ebola virus detected in a blood sample by real-time reverse-transcription polymerase chain reaction performed at the CDC (12).

Contact tracing was initiated for possible and confirmed Ebola cases. A contact was defined as any person, irrespective of use of personal protective equipment, who touched the skin, blood, or other body fluid of a symptomatic patient with confirmed Ebola; had been within 3 feet of a symptomatic patient with Ebola for more than 15 minutes; or who interacted with a possibly contaminated health care environment.

Contacts whose Ebola exposures occurred outside of health care settings were designated as community contacts. Community contacts who interacted with the patient between symptom onset and admission were identified by interviewing patients with Ebola, their household members, and other reported potential contacts. Identification and monitoring of additional possible community contacts of patient 3 from a visit to Ohio are described elsewhere (13, 14).

**Table 1. Ebola Exposure Categories to Determine Public Health Actions—Dallas, Texas, 2014**

<table>
<thead>
<tr>
<th>Exposure Category</th>
<th>Definitions</th>
<th>Public Health Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High risk</strong></td>
<td>Percutaneous (e.g., needle stick) or mucous membrane exposure to blood or body fluids of patient with Ebola. Direct skin contact with, or exposure to blood or body fluids of a patient with Ebola without recommended PPE of at least that recommended by CDC as of 9/28/14. Processing blood or body fluids of a patient with confirmed Ebola without recommended PPE or standard biosafety precautions.</td>
<td>Active monitoring† of community contacts began 9/28/14, with change to direct active monitoring‡ of all contacts in this category beginning 10/1/14.</td>
</tr>
<tr>
<td><strong>Some risk</strong></td>
<td>Household contact with a patient with Ebola. Close contact with a patient with Ebola in health care facilities or community settings: being within approximately 3 ft (1 m) of a patient with Ebola or within the patient’s room or care area for a prolonged period (defined as &gt;15 min) while not wearing recommended PPE of at least that recommended by CDC as of 9/28/14. Direct brief contact (e.g., shaking hands) with a patient with Ebola while not wearing recommended PPE.</td>
<td>Active monitoring† of community contacts began 9/28/14, with change to direct active monitoring‡ of all contacts in this category beginning 10/1/14.</td>
</tr>
<tr>
<td><strong>No known exposure</strong></td>
<td><strong>Higher risk</strong> Substantial in-room contact with the patient and/or contaminated environment for ≥1 d, with reported PPE of at least that recommended by CDC as of 9/28/14. Lower risk Substantial in-room contact on 1 d OR limited in-room contact with patient on ≥1 d or contaminated surfaces on ≥1 d, with reported PPE of at least that recommended by CDC as of 9/28/14. Least risk Contact outside of room with potentially contaminated areas (e.g., anteroom), equipment, or specimens (e.g., laboratory) with reported PPE of at least that recommended by CDC as of 9/28/14.</td>
<td>Self-monitoring¶ as of 10/1/14, with change to direct active monitoring† by 10/14/14.</td>
</tr>
</tbody>
</table>

CDC = Centers for Disease Control and Prevention; PPE = personal protective equipment.

*Based on extant CDC movement and monitoring guidance in use on 28 September 2014, accessed 29 August 2014.
† Active monitoring: contacts monitored by public health by phone, with 2 daily symptom checks, reported by phone at least once daily.
‡ Active direct monitoring: contacts monitored by public health, with 2 daily symptom checks (at least 1 in-person).
§ CDC definition of “no known exposure” as of 28 September 2014: having been in a country in which an Ebola outbreak occurred within the past 21 d and having had no exposures.
¶ Further risk stratifications within the “no known exposure” category were created on 12 October 2014 for health care personnel who had direct or indirect contact with a patient with Ebola but did not have exposures consistent with the “high risk” or “some risk” definitions.
¶ Self-monitoring: contacts check their own temperature twice daily and monitor themselves for other symptoms. Health care provider contacts caring for patients with Ebola in the medical intensive care unit additionally underwent observed temperature checks at the beginning and end of their shifts, until 14 October 2014.

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Contacts whose Ebola exposures occurred outside of health care settings were designated as community contacts. Active monitoring required that contacts report twice-daily oral temperature measurements and presence of possible Ebola symptoms to public health teams. All contacts in the “high risk” or “some risk” exposure groups underwent direct active monitoring, with at least 1 in-person check daily. Twice-daily self-monitoring for fever and symptoms was initially recommended for all contacts in the “no known exposure” risk group; however, after patient 2’s Ebola diagnosis, all contacts in the “no known exposure” category were transitioned to direct active monitoring.

Contacts whose Ebola exposures occurred during ambulance transport or at the hospital were designated as health care contacts. Ambulance transport contacts were identified through emergency medical services. The HCP contacts were identified through the hospital’s human resources department from a combination of information provided by department managers, records of staff movement from location-tracking badge tags, security sign-in sheets, and prospective logs used to document HCP participating in the care of the patients with Ebola.

**Table 2. Exposures of Community Contacts of Patients With Ebola—Dallas, Texas, 2014***

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Patient 1 (n = 17), n (%)</th>
<th>Patients 2 and 3 (n = 3), n (%)</th>
<th>Total (n = 20), n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shared residence</td>
<td>4 (24)</td>
<td>3 (100)</td>
<td>7 (35)</td>
</tr>
<tr>
<td>Shared bed with symptomatic patient before Ebola diagnosis</td>
<td>1 (6)</td>
<td>2 (67)</td>
<td>3 (15)</td>
</tr>
<tr>
<td>Primary caregiver</td>
<td>1 (6)</td>
<td>0</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Cleaned patient’s room</td>
<td>2 (12)</td>
<td>1 (33)</td>
<td>3 (15)</td>
</tr>
<tr>
<td>Cleaned bathroom used by patient</td>
<td>1 (6)</td>
<td>0</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Washed patient’s laundry</td>
<td>0</td>
<td>1 (33)</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Direct, skin-to-skin contact</td>
<td>4 (24)</td>
<td>3 (100)</td>
<td>7 (35)</td>
</tr>
<tr>
<td>Brief hug†</td>
<td>5 (29)</td>
<td>2 (67)</td>
<td>7 (35)</td>
</tr>
<tr>
<td>1–6 h in room‡</td>
<td>17 (100)</td>
<td>3 (100)</td>
<td>20 (100)</td>
</tr>
<tr>
<td>&gt;6 h in room‡</td>
<td>9 (53)</td>
<td>3 (100)</td>
<td>12 (60)</td>
</tr>
<tr>
<td>Adults aged ≥18 y in room with patient for ≥15 min, with no other exposures</td>
<td>4 (24)</td>
<td>0</td>
<td>4 (20)</td>
</tr>
<tr>
<td>Children aged &lt;18 y in room with patient for ≥1 h, with uncertain direct contact</td>
<td>5 (29)</td>
<td>0</td>
<td>5 (25)</td>
</tr>
</tbody>
</table>

* Exposures not mutually exclusive; occurred any time after onset of patient’s symptoms.
† Without direct, skin-to-skin contact.
‡ Cumulative total time spent in room with patient; may have occurred over multiple interactions.

**Risk Classification and Monitoring of Contacts**

Standardized questionnaires on the nature and duration of potential exposures were administered to contacts to stratify them into exposure risk groups termed “high risk,” “some risk,” or “no known exposure” (Table 1). These groups were defined according to the extant CDC classification criteria, which have since been revised (15). The “no known exposure” category encompassed contacts without recognized unprotected exposures to Ebola, including HCP who used recommended
personal protective equipment when caring for patients with Ebola. After confirmation of patient 2’s Ebola diagnosis, additional subclassifications (“higher risk,” “lower risk,” and “least risk”) were created to further stratify risk levels within the “no known exposure” group and help guide heightened monitoring and movement restrictions (Table 1).

All contacts received instruction about symptom monitoring and procedures to follow in the event of illness onset. Monitoring entailed twice-daily oral temperature measurement and checking for symptoms compatible with Ebola for 21 days from the date of last exposure. Contacts in the “high risk” and “some risk” groups underwent direct active monitoring, with at least 1 of their twice-daily symptom checks directly observed by a member of the investigation team at their place of lodging, and the second reported by phone.

In accordance with the extant national guidance, twice-daily self-monitoring for fever and symptoms was instructed to contacts in the “no known exposure” risk group. After patient 2’s Ebola diagnosis, all HCP contacts in the “no known exposure” category were transitioned to direct active monitoring, with at least 1 in-person check daily onsite at the hospital. From 1 to 7 November, the last week of monitoring in Dallas County, alternatives, such as video chat, were used when in-person checks were not feasible.

Data from EPI-Info 7 (CDC) was reentered into Microsoft Access 2010 (Microsoft Corp.) and later into Maven (Consilience Software) databases and analyzed using SAS software, version 9.3 (SAS Institute). Because this investigation was part of a public health response, it was determined to be nonresearch by the CDC and therefore was not subject to CDC institutional review board review.

Movement Restrictions

Movement restrictions were recommended to prevent possible spread should a contact become symptomatic. Contacts with “high risk” and “some risk” exposure levels were instructed to avoid travel by commercial conveyances and public transportation during their monitoring period (15). According to the extant CDC guidance for monitoring and movement of persons with Ebola exposures, contacts in the “no known exposure” risk category were not initially subject to movement restrictions; however, after patient 2’s Ebola diagnosis, directives for controlled movement were also applied to this risk group. On 16 October, all contacts in the “no known exposure” category who had ever entered the index patient’s room were additionally restricted from direct care activities of other patients and from public gatherings. Public health control orders for quarantine were implemented whenever vol-

Table 3. Contacts of Patients With Ebola, by Exposure Risk Classification and Setting—Dallas, Texas, 2014

<table>
<thead>
<tr>
<th>Risk</th>
<th>Community/ Household</th>
<th>ED</th>
<th>MICU</th>
<th>Laboratory</th>
<th>EVS</th>
<th>EMS Staff</th>
<th>EMS Patients</th>
<th>Total</th>
<th>Community/ Household</th>
<th>ED</th>
<th>MICU</th>
<th>Lab</th>
<th>EVS</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High risk</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Some risk</td>
<td>14</td>
<td>6</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>10</td>
<td>41</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>43</td>
</tr>
<tr>
<td>No known exposure</td>
<td>NA</td>
<td>7</td>
<td>50</td>
<td>22</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>88</td>
<td>NA</td>
<td>22</td>
<td>12</td>
<td>0</td>
<td>3</td>
<td>125</td>
</tr>
<tr>
<td>Higher risk</td>
<td>NA</td>
<td>1</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>37</td>
<td>NA</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>41</td>
</tr>
<tr>
<td>Lower risk</td>
<td>NA</td>
<td>4</td>
<td>11</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>18</td>
<td>NA</td>
<td>14</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>22</td>
<td>40</td>
</tr>
<tr>
<td>Least risk</td>
<td>NA</td>
<td>2</td>
<td>3</td>
<td>22</td>
<td>6</td>
<td>0</td>
<td>33</td>
<td>NA</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>11</td>
<td>44</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>18</td>
<td>52</td>
<td>29</td>
<td>10</td>
<td>3</td>
<td>10</td>
<td>139</td>
<td>3</td>
<td>22</td>
<td>12</td>
<td>0</td>
<td>3</td>
<td>179</td>
</tr>
</tbody>
</table>

ED = emergency department; EMS = emergency medical services; EVS = environmental services; MICU = medical intensive care unit; NA = not applicable.

* Includes all health care personnel who had contact with patient 1; 33 (29%) health care personnel also had contact with patient 2 or 3; 74 (66%) health care personnel had contact with patient 1 only.
† Includes health care personnel who had contact with patients 2 or 3 only.
‡ Two health care personnel self-reported inadvertent exposures while removing personal protective equipment during care of patient 1 in the MICU, resulting in classification in the “some risk” category.

Table 4. Movement and Work Restrictions for Contacts of Patients With Ebola

<table>
<thead>
<tr>
<th>Variable</th>
<th>Restriction From Travel by Commercial Conveyances*</th>
<th>Restriction From Public Gatherings Without Quarantine†</th>
<th>Restriction From Direct Patient Care‡</th>
<th>Work Exclusion‡</th>
<th>Control Order/Mandatory Quarantine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community contacts, n (%)</td>
<td>20 (100)</td>
<td>0</td>
<td>NA</td>
<td>8 (40)</td>
<td>5 (25)</td>
</tr>
<tr>
<td>Ambulance contacts, n (%)</td>
<td>10 (100)</td>
<td>0</td>
<td>NA</td>
<td>0</td>
<td>2 (15)</td>
</tr>
<tr>
<td>Health care personnel contacts, n (%)</td>
<td>149 (100)</td>
<td>68 (44)</td>
<td>57 (40)</td>
<td>78 (52)</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>179</td>
<td>68</td>
<td>57</td>
<td>86</td>
<td>7</td>
</tr>
</tbody>
</table>

NA = not applicable.

* Restrictions recommended by public health to all contacts in “high risk” and “some risk” exposure level categories on 1-3 October 2014; and subsequently extended to all contacts in “no known exposure” categories beginning 12-14 October 2014. Travel restrictions included placement on CDC Do Not Board lists for all “some risk” and “high risk” contacts. After 17 October, contacts in the “no known exposure” risk group were also placed on Do Not Board lists for the remainder of their monitoring periods, with the exception of persons in the “least risk” subgroup.
† Recommended by Texas Department of State Health Services on 16 October 2014 to all health care personnel who ever entered the room of patient 1.
‡ Reflects employer decisions to exclude contacts from work during any portion of a contact’s monitoring period.
RESULTS

obtained 72 hours or more after symptom onset.
symptoms for 24 hours or a negative Ebola test result
gible for discharge after improvement or resolution of
contacts with persistent symptoms and without an alter-
ated. If the result of an initial reverse-transcription
ssessed to determine whether Ebola testing was war-
muscle pain, diarrhea, vomiting, rash, or unexplained
* Initial test results following presentation to hospital.
† Multiplex real-time reverse transcriptase PCR for the detection of influenza A, influenza B, respiratory syncytial virus, adenovirus, parainfluenza virus 1, parainfluenza virus 2, parainfluenza virus 3, coronavirus, human metapneumovirus, human rhinovirus/enterovirus, Mycoplasma pneumoniae, Chlamydia pneumoniae, Bordetella pertussis.
‡ Reverse transcriptase PCR for Ebola virus disease.

Investigation of Symptomatic Contacts

Contacts of the 3 patients with Ebola reporting a
temperature of 100.4 °F (38 °C) or greater, or compat-
sible symptoms (severe headache, sore throat, malaise,
muscle pain, diarrhea, vomiting, rash, or unexplained
bleeding) were referred to the ED, isolated, and as-
essed to determine whether Ebola testing was war-
anted. If the result of an initial reverse-transcription
polymerase chain reaction test for Ebola was negative,
contacts with persistent symptoms and without an alter-
ative diagnosis underwent additional Ebola testing 72
hours or more after symptom onset. Patients were eli-
gible for discharge after improvement or resolution of
symptoms for 24 hours or a negative Ebola test result
obtained 72 hours or more after symptom onset.

Table 5. Clinical Characteristics and Exposure Risks of Symptomatic Contacts Evaluated for Ebola Virus Disease—Dallas, Texas, 2014

<table>
<thead>
<tr>
<th>PUI Number</th>
<th>Date of Symptom Onset</th>
<th>Symptoms Prompting Evaluation</th>
<th>Temperature ≥100.4°F (38°C) While in Hospital</th>
<th>Duration Potential Exposure, d</th>
<th>Description of Exposure</th>
<th>Risk Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10/7/14</td>
<td>Temperature 100.3°F (37.9°C), headache, loose stool</td>
<td>No</td>
<td>1</td>
<td>Transported in ambulance after patient 1</td>
<td>Some risk</td>
</tr>
<tr>
<td>2</td>
<td>10/8/14</td>
<td>Diarrhea, nausea, headache</td>
<td>No</td>
<td>2</td>
<td>HCP, cared for patient 1 in MICU</td>
<td>No known exposure: higher risk</td>
</tr>
<tr>
<td>3</td>
<td>10/8/14</td>
<td>Temperature 101.0°F (38.3°C), headache, sore throat, myalgias</td>
<td>No</td>
<td>1</td>
<td>HCP, transported patient 1 from ED to MICU</td>
<td>No known exposure: higher risk</td>
</tr>
<tr>
<td>4</td>
<td>10/10/14</td>
<td>Temperature 100.6°F (38.1°C), sore throat, headache</td>
<td>Yes</td>
<td>3</td>
<td>HCP, cared for patient 1 in MICU</td>
<td>No known exposure: higher risk</td>
</tr>
<tr>
<td>5</td>
<td>10/11/14</td>
<td>Abdominal pain, headache</td>
<td>No</td>
<td>1</td>
<td>Household contact of patient 2</td>
<td>High risk</td>
</tr>
<tr>
<td>6</td>
<td>10/12/14</td>
<td>Temperature 100.7°F (38.2°C), rhinorrhea, sore throat, malaise</td>
<td>No</td>
<td>3</td>
<td>HCP, assisted with patient 1 dialysis</td>
<td>No known exposure: higher risk</td>
</tr>
<tr>
<td>7</td>
<td>10/13/14</td>
<td>Temperature 100.7°F (38.2°C)</td>
<td>No</td>
<td>2</td>
<td>HCP, cared for patient 1 in MICU</td>
<td>No known exposure: higher risk</td>
</tr>
<tr>
<td>8</td>
<td>10/14/14</td>
<td>Temperature 100.5°F (38.1°C), fatigue, decreased appetite</td>
<td>Yes</td>
<td>5</td>
<td>HCP, cared for patient 1 in MICU for 3 shifts</td>
<td>No known exposure: higher risk</td>
</tr>
<tr>
<td>9</td>
<td>10/14/14</td>
<td>Temperature 99.1°F (37.2°C), nausea</td>
<td>No</td>
<td>3</td>
<td>HCP, cared for patient 1 in MICU</td>
<td>No known exposure: higher risk</td>
</tr>
<tr>
<td>10</td>
<td>10/15/14</td>
<td>Temperature 101.0°F (38.3°C), headache, sore throat</td>
<td>No</td>
<td>1</td>
<td>HCP, positioned patient 1</td>
<td>Some risk</td>
</tr>
<tr>
<td>11</td>
<td>10/16/14</td>
<td>Temperature 99.2°F (37.3°C), diarrhea</td>
<td>No</td>
<td>5</td>
<td>HCP, provided respiratory care for patient 1 in MICU</td>
<td>No known exposure: higher risk</td>
</tr>
<tr>
<td>12</td>
<td>10/18/14</td>
<td>Temperature 100.0°F (38.8°C), nausea, vomiting, headache</td>
<td>No</td>
<td>1</td>
<td>Transported in ambulance after patient 1</td>
<td>Some risk</td>
</tr>
<tr>
<td>13</td>
<td>10/26/14</td>
<td>Temperature 101.4°F (38.6°C), headache, abdominal pain, fatigue</td>
<td>Yes</td>
<td>1</td>
<td>HCP, removed waste from patient 2’s anteroom</td>
<td>No known exposure: least risk</td>
</tr>
<tr>
<td>14</td>
<td>10/29/14</td>
<td>Vomiting, diarrhea</td>
<td>No</td>
<td>2</td>
<td>HCP, runner in anteroom for patient 3 in ED</td>
<td>No known exposure: lower risk</td>
</tr>
</tbody>
</table>

AST = aspartate aminotransferase; ED = emergency department; HCP = health care personnel; MICU = medical intensive care unit; NA = not applicable; ND = not done; PCR = polymerase chain reaction; PUI = person under investigation for Ebola.

were investigated, of whom 179 were confirmed
as contacts and monitored (Figure). Patient 1 had 139
contacts (17 community contacts and 122 health care
contacts, 2 of whom became patients 2 and 3). Patients
2 and 3 had 73 contacts (3 community and 70 HCP
contacts); 33 of their HCP contacts were also contacts
of patient 1. Among the 3 patients who were part of
this investigation, patient 1 had the longest period of
symptoms before hospital admission (5 days; 24–28
September) and the longest hospital stay (11 days;
28 September–8 October). Patients 2 and 3 were each
symptomatic for less than 24 hours in the Dallas com-

Community Contacts

Community contacts (n = 20) (Table 2) ranged in
age from 2 to 58 years; 53% were female. Seven were
household contacts of patients with Ebola; the remain-
ing 13 visited patient 1’s household after his first ED
Four contacts met criteria for “high-risk” exposure (Table 3): Patient 1’s domestic partner, who served as his primary caregiver from symptom onset until his hospital admission (including after the onset of diarrhea on 27 September); 2 community members who had direct skin-to-skin contact with patient 1; and 1 contact who had direct skin-to-skin contact with patient 2. Three contacts shared a bed with a symptomatic patient with Ebola. Most (80%) community contacts were in the “some risk” category, primarily from having spent an hour or more in the same room as a symptomatic patient with Ebola.

Because all identified community contacts had exposures of “high risk” or “some risk” levels, all were restricted from travel by commercial conveyances (Table 4). After initiation of direct active monitoring, 2 community contacts missed an in-person symptom check during their monitoring period. Five community contacts were quarantined to ensure adherence to direct active monitoring and movement restrictions.

Health Care Contacts

No patients in the ED were contacts of patient 1 during his first or second ED visit. Because not all medical equipment in the ambulance that transported patient 1 to his second ED visit had undergone complete disinfection, 10 patients transported in the ambulance after him were classified in the “some risk” group; 2 of these were quarantined.

The HCP contacts from all 3 patients (n = 149) included staff from ambulance (n = 3) and hospital settings (n = 146) (Table 3). The HCP contacts most frequently worked in the medical intensive care unit (43%), the ED (27%), and laboratory (19%). Twenty percent (22 of 112) of HCP contacts of the index case had known unprotected exposures classified as “high risk” (n = 7) or “some risk” (n = 15). All of these exposures occurred during patient 1’s first ED visit or during emergency medical service transport. At the first ED visit and during ambulance transport to the second visit, the patient experienced no episodes of diarrhea or vomiting. No known unprotected exposures of HCP occurred among contacts of patients 2 or 3.

Among the 125 HCP without recognized unprotected exposures who had been classified in the “no known exposure” group (Tables 1 and 3), 41 (33%) were differentiated as being in the “high-risk” group because they had entered the room of a patient with Ebola on more than 1 day or had substantial interaction.
with the patient or contaminated items or surfaces. This group comprised mostly medical intensive care unit personnel (93%). Another subset of 44 (35%) HCP within the “no known exposure” group were differentiated as having “least risk” because of activities outside of active patient care areas, such as laboratory and environmental services personnel (Tables 1 and 3).

Movement restrictions for HCP contacts were expanded after 12 October (Table 4), prohibiting all but the “least risk” subgroup of the “no known exposure” group from traveling by commercial conveyances. On 16 October, the Texas Department of State Health Services also issued directives restricting use of public transportation and attendance at public gatherings for all contacts who had ever been in patient 1’s room. More than 30 HCP voluntarily undertook self-quarantine, which entailed staying in a home alone or in a designated facility; none required public health orders for quarantine. The hospital provided food and accommodation in the hospital’s hotel wing for 11 HCP contacts who chose to self-quarantine at this location, as well as wage compensation for HCP placed on administrative leave.

Among the 62% (91 of 147) of health care contacts residing in Dallas, none had more than 1 day elapse without in-person or telephone monitoring while under direct active surveillance. Complete monitoring records were not available for the 38% of health care contacts residing outside of Dallas. Adherence to direct active monitoring checks conducted at contacts’ places of lodging was high, with no missed in-person checks for the “high risk” or “some risk” health care contacts residing in Dallas. Lower completion rates for in-person checks were noted among the “no known exposure” HCP contacts for whom direct active monitoring was conducted on-site at the hospital. For HCP who were requested to drive themselves to the hospital for their daily checks, 34% (24 of 70) missed at least one in-person check during their active monitoring period. Adherence to phone monitoring was higher; 6% (4 of 70) of HCP missed 1 or more phone checks.

**Evaluation of Symptomatic Contacts**

Fourteen contacts were hospitalized for Ebola evaluation during their monitoring period, including 11 contacts of patient 1 (including patients 2 and 3), 2 contacts of patient 2, and 1 contact of patient 3 (Table 5). Most (n = 11) were HCP, 2 were ambulance patient contacts, and 1 was a community contact. Fever with temperature of greater than 100.4 °F (38 °C) was documented in 7 of the 14 contacts; symptoms of headache, abdominal pain, nausea, vomiting, or diarrhea were reported in the 7 who did not have fever. Eleven of these 14 contacts recognized and reported their symptoms promptly. The 3 with delays were HCP. One contact who experienced fever while self-monitoring did not report symptoms until 4 days after onset because of attributing the fever to a recent dental procedure. Another contact experienced several days of fatigue and low appetite before admission; these symptoms occurred during the transition period from self-monitoring to active monitoring and were not among the specified symptoms for which contacts were self-monitoring at the time. A third contact under direct active monitoring, who was admitted for documented fever at an in-person check, disclosed that a self-measured fever had been unreported and a scheduled telephone check had been missed because of oversleeping the prior evening. The median duration of hospitalization for contacts who tested negative for Ebola virus was 2.5 days (range, 1-5 days). Patients 2 and 3 were the only contacts who tested positive for Ebola virus, each within their first day of hospitalization.

**DISCUSSION**

This report identifies key experiences from our implementation of contact tracing and monitoring that may assist ongoing preparedness efforts for Ebola. Although contact tracing is a well-established cornerstone of communicable disease control in public health, the intensity and scale of particular aspects of contact tracing for Ebola were unprecedented in the United States for any acute communicable disease. The need to comprehensively identify possibly exposed persons emphasized that hospital preparedness for such highly infectious and lethal pathogens must include systems for identifying and expeditiously reaching all HCP who had contact with a patient who had Ebola. A particular challenge for Ebola hospitalizations is the establishment of accurate prospective tracking mechanisms and data management for the duration of accrual and monitoring of HCP contacts (16). Preparedness activities should also predesignate a limited cadre of health care staff to interact with possible Ebola patients to minimize the total number of HCP contacts. The ED and ambulance health care contacts of the index patient also emphasize the importance of plans that include emergency medical service and ED preparedness—particularly for patients who are not under active monitoring and may not report a history of possible Ebola exposure (17).

Our experience also illustrates the challenges of applying specific monitoring approaches and movement restrictions when these measures are predicated upon assignment of exposure risk categories; as new risks are recognized, reevaluation of risk assignment criteria becomes essential. Although the specific exposure mechanisms that led to the Ebola infections of the 2 HCP remain unknown (Kuhar DT, Chung W, Kallen AJ, Hunter JC, Epstein L, Schrag S, et al. Transmission of Ebola virus in a U.S. hospital—Dallas, Texas. Unpublished data), these transmissions to HCP within the “no known exposure” category prompted revision of the risk classifications of HCP in this exposure group. Rapid expansion of associated monitoring and movement recommendations based on new evidence was found necessary during this response, and further adaptations may be required in future investigations. On 29 October, the CDC updated guidance on Ebola movement and monitoring to reflect our experience that Ebola may develop in HCP with unrecognized exposures dur-
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ing patient care in the United States (15). Of note, health care contacts in the United States without known unprotected exposure should be categorized as low (but not zero) risk for Ebola and actively monitored.

Community contacts, particularly those whose contact occurred during the first days of illness, may have a lower risk for infection than HCP caring for hospitalized patients with Ebola. None of patient 1’s community contacts became infected, despite some “high-risk” exposures. One of his contacts served as his primary caregiver, an identified risk factor in African Ebola outbreaks (18, 19). This is consistent with studies in Africa indicating that Ebola is not necessarily highly transmissible in the first days of symptom onset and that HCP can be at increased risk for Ebola compared with community contacts (20–23). Studies of household Ebola transmission in Africa have reported transmission rates of 10% to 20% among household contacts, with lower risk among children and higher risk among those with physical contact late in the clinical course (18, 19). Although our investigation included only 7 household contacts, the lack of observed transmission may be consistent with these rates. Other differences between Africa and the United States, such as almost universal access to running water and flush toilets in the United States, may reduce the risk for transmission to U.S. community contacts.

Maintaining a direct active surveillance program for large numbers of contacts provided an additional measure of assurance that contacts with possible symptoms of Ebola would be recognized and referred for evaluation promptly, rather than relying predominantly on contacts to self-monitor and report symptoms. The public health burden of in-person active monitoring was substantial for this Dallas cluster, however, and required additional surge support resources that should be considered in planning for future responses. Our experience did not allow for assessment of whether in-person direct active monitoring is superior to active monitoring by telephone for early detection of symptomatic contacts. Overall adherence to active monitoring was high among our contacts, some of whom voluntarily self-quarantined. Public health control orders were implemented for only a small subset of contacts.

Our experience with large-scale application of movement restrictions illustrates the critical importance of meeting social and economic needs of contacts under active monitoring in order to facilitate their adherence to monitoring stipulations and movement restrictions (24, 25). Many contacts were excluded from the workplace by their employers (Table 4); school-age contacts were excluded from schools; decontamination of patients’ residences left household contacts without a place of residence; some contacts could not meet daily living needs; and most contacts experienced anxiety, stigma, or social isolation because of their possible Ebola exposures. Public health emergency preparedness for Ebola should therefore include engagement with community, charity, and faith-based organizations and mental health resources in planning to provide for nonclinical needs, such as housing, transportation, education, food, and household supplies.

Because some contacts under monitoring (7% during our experience) can be expected to develop symptoms possibly consistent with Ebola, public health agencies must ensure capacity to support frontline clinicians in decisions about when to admit and test contacts. Facilities with domestically diagnosed patients with Ebola should prepare for referrals of potentially large numbers of exposed health care and community contacts who may develop symptoms requiring medical evaluation. Clearly established protocols should be communicated to contacts to minimize further transmission in case they become ill, including procedures to notify public health agencies and designated health care facilities before presenting for care, along with transportation protocols using designated emergency medical services.

Additional Ebola introductions into the United States will remain possible while the epidemic in western Africa continues. Maintaining flexibility in adapting principles of contact tracing and monitoring to the introduction of Ebola in new settings (in our case, a metropolitan setting in the United States) and to account for the evolving understanding of risks of unrecognized HCP transmissions may help to limit the size of any future clusters.

As a high-consequence communicable disease new to the United States, Ebola propelled to the forefront core challenges associated with effective contact tracing for such diseases, including heightened urgency of comprehensive contact identification and interview, implementation of direct active monitoring of large numbers of contacts, large-scale application and enforcement of movement restrictions, and mobilization of humanitarian services to meet nonclinical needs and to protect the dignity and privacy of contacts under monitoring and quarantine (24). Planning for such anticipated challenges will strengthen collective preparedness for emerging diseases, such as Ebola, and for resurgences of more familiar diseases, such as measles and tuberculosis.

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