Ebola: coming to a hospital near you?

Infection prevention and control challenges

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‘This animal carries a deadly virus...and the greatest medical crisis in the world is about to happen.’

- Transmission routes (“it’s airborne”)
- Role of quarantine
- Animal reservoirs
- PPE
- Lab safety

Ebola virus disease (EVD), formerly known as Ebola haemorrhagic fever (Ebola HF), is a type of viral haemorrhagic fever (VHF) associated with a high rate of mortality.\textsuperscript{1,2}

- EVD was first reported near the Ebola river in the Democratic Republic of Congo in 1976.
- Ebola is an enveloped RNA virus from the \textit{Filoviridae} family.\textsuperscript{1-3}
- It is classified as Biosafety Level / Containment Level 4.

Image: Photo courtesy CDC/Cynthia Goldsmith.
Ebola: clinical

- EVD is a viral haemorrhagic fever (VHF), characterised sudden onset of fever, intense weakness, muscle pain, headache and sore throat.
- This is often followed by vomiting, diarrhoea, and sometimes internal and external bleeding.
- Initial symptoms are generic and can be misdiagnosed (esp. malaria).
- The incubation period is 2-21 days.
- There is no effective treatment or vaccine for Ebola.

Bioquell Ebola microbiology page.
# Ebola: mortality

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Ebola sp.</th>
<th>Cases</th>
<th>Deaths</th>
<th>Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Democratic Republic of Congo</td>
<td>Bundibugyo</td>
<td>57</td>
<td>29</td>
<td>51%</td>
</tr>
<tr>
<td>2012</td>
<td>Uganda</td>
<td>Sudan</td>
<td>7</td>
<td>4</td>
<td>57%</td>
</tr>
<tr>
<td>2012</td>
<td>Uganda</td>
<td>Sudan</td>
<td>24</td>
<td>17</td>
<td>71%</td>
</tr>
<tr>
<td>2011</td>
<td>Uganda</td>
<td>Sudan</td>
<td>1</td>
<td>1</td>
<td>100%</td>
</tr>
<tr>
<td>2008</td>
<td>Democratic Republic of Congo</td>
<td>Zaire</td>
<td>32</td>
<td>14</td>
<td>44%</td>
</tr>
<tr>
<td>2007</td>
<td>Uganda</td>
<td>Bundibugyo</td>
<td>149</td>
<td>37</td>
<td>25%</td>
</tr>
<tr>
<td>2007</td>
<td>Democratic Republic of Congo</td>
<td>Zaire</td>
<td>264</td>
<td>187</td>
<td>71%</td>
</tr>
<tr>
<td>2005</td>
<td>Congo</td>
<td>Zaire</td>
<td>12</td>
<td>10</td>
<td>83%</td>
</tr>
<tr>
<td>2004</td>
<td>Sudan</td>
<td>Sudan</td>
<td>17</td>
<td>7</td>
<td>41%</td>
</tr>
<tr>
<td>2003 (Nov-Dec)</td>
<td>Congo</td>
<td>Zaire</td>
<td>35</td>
<td>29</td>
<td>83%</td>
</tr>
<tr>
<td>2003 (Jan-Apr)</td>
<td>Congo</td>
<td>Zaire</td>
<td>143</td>
<td>128</td>
<td>90%</td>
</tr>
<tr>
<td>2001-2002</td>
<td>Congo</td>
<td>Zaire</td>
<td>59</td>
<td>44</td>
<td>75%</td>
</tr>
<tr>
<td>2001-2002</td>
<td>Gabon</td>
<td>Zaire</td>
<td>65</td>
<td>53</td>
<td>82%</td>
</tr>
<tr>
<td>2000</td>
<td>Uganda</td>
<td>Sudan</td>
<td>425</td>
<td>224</td>
<td>53%</td>
</tr>
<tr>
<td>1996</td>
<td>South Africa (ex-Gabon)</td>
<td>Zaire</td>
<td>1</td>
<td>1</td>
<td>100%</td>
</tr>
<tr>
<td>1996 (Jul-Dec)</td>
<td>Gabon</td>
<td>Zaire</td>
<td>60</td>
<td>45</td>
<td>75%</td>
</tr>
<tr>
<td>1996 (Jan-Apr)</td>
<td>Gabon</td>
<td>Zaire</td>
<td>31</td>
<td>21</td>
<td>68%</td>
</tr>
<tr>
<td>1995</td>
<td>Democratic Republic of Congo</td>
<td>Zaire</td>
<td>315</td>
<td>254</td>
<td>81%</td>
</tr>
<tr>
<td>1994</td>
<td>Cote d'Ivoire</td>
<td>Taï Forest</td>
<td>1</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>1994</td>
<td>Gabon</td>
<td>Zaire</td>
<td>52</td>
<td>31</td>
<td>60%</td>
</tr>
<tr>
<td>1979</td>
<td>Sudan</td>
<td>Sudan</td>
<td>34</td>
<td>22</td>
<td>65%</td>
</tr>
<tr>
<td>1977</td>
<td>Democratic Republic of Congo</td>
<td>Zaire</td>
<td>1</td>
<td>1</td>
<td>100%</td>
</tr>
<tr>
<td>1976</td>
<td>Sudan</td>
<td>Sudan</td>
<td>284</td>
<td>151</td>
<td>53%</td>
</tr>
<tr>
<td>1976</td>
<td>Democratic Republic of Congo</td>
<td>Zaire</td>
<td>318</td>
<td>280</td>
<td>88%</td>
</tr>
</tbody>
</table>

**Consolidated total** 2387 1590 67%

Source: [World Health Organisation](https://www.who.int)
Ebola: challenges

- High mortality
- No treatment / vaccine
- Diagnosis
- Human-to-human spread
- Animal reservoir

Ebola: transmission routes

Direct contact with blood or body fluids incl. droplet sprays (through broken skin or mucous membranes)$^{1,2}$

Indirect contact with contaminated environments$^{1-3}$

Ebola: outbreak in West Africa

Prior to current outbreak:
2,387 cases
Mortality 67%

Current outbreak:
3,069 cases
Mortality 51%

Source: World Health Organisation & VDU blog, as of 28 Aug 2014
Ebola: outbreak in West Africa (not a happy epi curve)

Source: VDU blog, as of 28 Aug 2014
### Ebola: healthcare worker risk

<table>
<thead>
<tr>
<th></th>
<th>Infected</th>
<th>Died</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-HCW</td>
<td>2375</td>
<td>1318</td>
</tr>
<tr>
<td>HCW</td>
<td>240</td>
<td>120</td>
</tr>
</tbody>
</table>

Source: [World Health Organisation](http://www.who.int), 25 August 2014
Ebola: global spread

Final Destinations of Airline Travelers Departing from Guinea, Liberia, and Sierra Leone
By WHO region during the month of August

- Europe: 29.6% (10,241 travelers)
- Eastern Mediterranean: 6.5% (2,249 travelers)
- Africa: 55.2% (19,073 travelers)
- Western Pacific: 3.1% (1,058 travelers)
- South-East Asia: 1.1% (385 travelers)

Data source: IATA, 2012

Source: healthmap.org
Ebola: is anywhere safe?

- Aug 2, Dr Kent Brantley, first reported US case.
  - Emory Hospital, Atlanta, Georgia, USA
  - Liberia -> Atlanta

- Aug 5, Nancy Writebol, second reported US case.
  - Emory Hospital, Atlanta, Georgia, USA
  - Liberia -> Atlanta

- Aug 25, William Pooley, first reported UK case.
  - Royal Free Hospital, London, UK

- EVD patients have also been repatriated to Spain and Germany. All are healthcare workers.
Ebola: infection prevention and control

A number of public health agencies including the US CDC and UK Department of Health have issued guidelines for preventing and controlling EVD in hospitalised patients. Although there are some differences in the recommended strategies, the following principles are common:

- Place suspected or confirmed EVD patients in single room isolation, ideally in a specialised containment facility.
- PPE for direct and indirect patient contact: gloves, gown, eye protection and a face mask (+/- leg coverings / overshoes).
- Record and monitor all HCW contact with EVD patients, especially those who have unprotected contact.
Ebola: patient isolation

- EVD patients should be transferred to a specialist containment facility where possible.
- Otherwise, suspected and confirmed patients should be placed in single room isolation with an en suite or dedicate commode.
- Bioquell Pod may be useful for pre-emptive isolation in emergency departments lacking single rooms, or for suspected Ebola patients where side rooms occupied by higher priority patients.
## Ebola: PPE – ‘to CDC or not to CDC’

<table>
<thead>
<tr>
<th>PPE</th>
<th>CDC for suspected or confirmed cases*</th>
<th>UK DH for suspected cases</th>
<th>UK DH for confirmed cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gloves</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>Fluid repellent gown**</td>
<td>✓</td>
<td>✓ if copious secretions</td>
<td>✓</td>
</tr>
<tr>
<td>Face shield</td>
<td>✓ or goggles</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Goggles</td>
<td>✓ or face shield</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>Surgical mask</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>N95 / FFP3</td>
<td>✓ if AGP***</td>
<td>✓ if AGP / splash</td>
<td>✓</td>
</tr>
<tr>
<td>Double gloving</td>
<td>✓ if copious secretions</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Leg coverings / overshoes</td>
<td>✓ if copious secretions</td>
<td>x</td>
<td>✓/x</td>
</tr>
<tr>
<td>Plastic apron</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

* standard, droplet and contact precautions, with some exceptions  
** gown or suit specified in the UK only  
*** AGP = aerosol generating procedures

Source: [US CDC](https://www.cdc.gov) and [UK Department of Health](https://www.gov.uk)
Ebola: PPE supply and training

Having the right PPE policy is only part of the solution – you also need to ensure PPE supply and that staff know how to don and doff safely.\textsuperscript{1,2}

The MSF ‘Buddy’ system has been designed for field settings, and may be useful in acute settings.\textsuperscript{1,2}

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Image source: Controversies in HAI blog
Ebola: surface contamination risk

- Despite being an enveloped virus, Ebola can survive for days when dried onto surfaces.\(^1\)
  - \(<1\) log reduction per day.
  - \(6\) days for a \(4\)-log reduction.
- Epidemiological data support the possibility of indirect Ebola acquisition through contact with contaminated environments.\(^3-6\)
- Therefore, careful attention should be given to cleaning and disinfection of hospital rooms.

Surface survival: viruses with pandemic potential

<table>
<thead>
<tr>
<th>Virus</th>
<th>Survival time</th>
</tr>
</thead>
<tbody>
<tr>
<td>SARS-CoV</td>
<td>Days to weeks(^1,2)</td>
</tr>
<tr>
<td>MERS-CoV</td>
<td>More than 2 days(^3)</td>
</tr>
<tr>
<td>Influenza</td>
<td>Hours to days(^1,4)</td>
</tr>
<tr>
<td>Ebola</td>
<td>More than 6 days(^5)</td>
</tr>
</tbody>
</table>

## Ebola: terminal disinfection of hospital rooms

<table>
<thead>
<tr>
<th></th>
<th><strong>CDC</strong></th>
<th><strong>UK DH</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PPE for cleaners</strong></td>
<td>As for HCW with direct patient contact</td>
<td>As for HCW with direct patient contact</td>
</tr>
<tr>
<td><strong>Disinfectant</strong></td>
<td>EPA registered disinfectant effective against non-enveloped virus</td>
<td>Standard methods where no blood contamination, 10,000ppm bleach where blood contamination evident</td>
</tr>
<tr>
<td><strong>Fumigation</strong></td>
<td>Not mentioned</td>
<td>Recommended</td>
</tr>
</tbody>
</table>

Source: [US CDC](https://www.cdc.gov) and [UK Department of Health](https://www.gov.uk)
Fumigation via automated room disinfection

- Ebola is an enveloped virus, so will be susceptible to a range of disinfectants *in vitro*, including alcohol, QAC, bleach and other disinfectants.
- However, studies with other organisms have demonstrated that conventional methods consistently fail to eliminate contamination with pathogens that can survive on surfaces such as *C. difficile*, MRSA and norovirus.
- Hydrogen peroxide vapor (HPV) is effective *in vitro* for the inactivation of enveloped and non-enveloped viruses (see table below) and eliminates pathogens from hospital surfaces.
- Formaldehyde and chlorine dioxide would also be effective, but it would be difficult to apply these safely and without material damage in hospitals.
- The lower level of efficacy in general and especially out of direct line of sight makes aerosolised hydrogen peroxide (AHP) and UV systems unsuitable for terminal decontamination following EVD cases.

<table>
<thead>
<tr>
<th>Virus (strain)</th>
<th>Log$<em>{10}$ reduction in virus titer (TCID$</em>{50}$) ± (SD) after HPV Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 mL*</td>
</tr>
<tr>
<td>TGEV</td>
<td>&gt;5.05 (0.19)</td>
</tr>
<tr>
<td>Avian influenza virus (H9N9)</td>
<td>&gt;4.08 (0.58)</td>
</tr>
</tbody>
</table>

Data from Goyal et al. 4

Terminal room disinfection: case study

A patient with Lassa fever (VHF virus) died in an ICU room on the day of admission to UCLH in London.

The body was removed and the ICU room was quarantined, still containing clinical waste.

Following removal of clinical waste, the 40m$^3$ negative pressure ICU isolation room was decontaminated using Bioquell HPV.

Mobile medical equipment was left inside the room.

6-log *G. stearotherophilus* biological indicators were used to verify cycle efficacy.

The authors comment: "HPV decontamination was integrated successfully into our decontamination plan and provided an extra level of assurance than manual cleaning alone."

PPE:
- Full Tyvek suit
- Double overshoes
- Double gloves
- Face mask
- FFP3 (N95) respirator

Otter et al. *J Hosp Infect* 2010;75:335-337.

And my personal view...
Integrated HPV: BSL-4 isolation facility, Norway

- HPV selected by a Norwegian hospital to decontaminate their Biosafety Level 4 patient care facility.
- The technology has been fully integrated into the unit to provide rapid, efficient HPV decontamination.
- Two Bioquell HPV generators are situated in the plant room above the facility, linked to the building management system for safe and efficient ‘push button’ decontamination cycles.
- A pipe matrix has been installed for vapour supply and return, which serves all patient rooms, wash rooms and filter systems.
- Each area is fitted with inflatable seal doors for effective isolation. Discreet ceiling mounted nozzles are used for effective vapour distribution.
Ebola: key questions

- How will mortality look for patients cared for in US / UK?
- Is there an under-reporting of low-grade / asymptomatic cases, and could these be a risk for transmission?
- What is the relative importance of air and surface contamination in transmission?
- Are the CDC recommended PPE and environmental recommendations stringent enough to prevent in-hospital transmission?
- Will an effective treatment or vaccine come to market?
Why there’s not Ebola treatment or vaccine

Source: http://blogs.plos.org/publichealth/2014/08/01/still-dont-know-ebola/
Ebola: summary

1. The current outbreak of EVD centred in West Africa is the largest ever reported.
2. Imported cases are likely to increase in frequency and prevention of in-hospital spread is paramount.
3. Guidelines recommend placing patients with suspected or confirmed EVD in single rooms, and the use of PPE including gloves, gowns, eye and respiratory protection.
4. Ebola virus can survive on dry surfaces for days, so consider using HPV for terminal disinfection of rooms used to care for patients with EVD.
Other sources for information

- WHO fact sheet
- CDC Ebola pages
- CDC recommendations for infection prevention and control
- UK Department of Health / Health Protection Agency guidelines for management of viral haemorrhagic fever
- Health Protection Agency Ebola pages
- Bioquell Ebola resources
- Virology Down Under blog (images used with permission of Dr Ian Mackay)
- Controversies in HAI blog
Ebola: coming to a hospital near you?

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