Research Priorities to Inform Public Health and Medical Practice for Ebola Virus Disease: Workshop in Brief

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The 2014 epidemic of Ebola Virus Disease (EVD), caused by a filovirus, has affected multiple countries worldwide,[1] becoming the worst EVD outbreak since its discovery in 1976. Until 2014, previous outbreaks have been confined to smaller geographic areas and often only affected a few hundred people. Dr. Daniel Bausch, associate professor in the Department of Tropical Medicine and Section of Infectious Diseases at the Tulane University Health Sciences Center, added that previously to date, there have only been 24 documented human outbreaks and 2,400 cases.[2] Confirmed and suspected cases of EVD have now occurred in the United States through human-to-human transmission, requiring the U.S. medical and public health systems to prepare for and respond to domestic cases of EVD. The heightened awareness and attention to the disease in the United States has also led to questions from affected communities on specific characteristics of the virus, how the virus behaves, and personal protective equipment (PPE) and personal protective behaviors that can be used to prevent its spread and reduce exposure.

While the Ebola viruses have typically been studied in laboratory settings, said Dr. Lynn Goldman, workshop chair and dean of the George Washington University Milken Institute School of Public Health, conducting additional biomedical and public health research performed in or collected from real world settings (e.g., outside the laboratory) can best prepare the United States to safeguard the public and at-risk workers. Improving the knowledge about the viruses' characteristics and how they relate to human exposure and infection could lead to improved medical and public health guidance and measures, said Goldman, and could help provide public health officials and the general public with accurate information about health risks and appropriate public health and medical interventions. At the request of the Office of the Assistant Secretary for Preparedness and Response (ASPR), the National Institutes of Health (NIH), and the Centers for Disease Control and Prevention (CDC), the Institute of Medicine (IOM), in collaboration with the National Research Council, convened a workshop on November 3, 2014, with key stakeholders and experts to discuss the research priorities that could guide medical and public health practice. Discussions included the degree of transmission and biopersistence of the Ebola virus under a range of conditions and on a variety of materials, as well as issues of handling potentially infected materials, decontamination, and the training and PPE usage of traditional and nontraditional workers involved in the full spectrum of this response.

Goldman grounded the workshop focus areas in real case studies and current data. She highlighted the consideration of other hosts or vectors as transmission risks (for example, companion animals) and the uncertainty of potential risk. Goldman also discussed a recent article in the *New England Journal of Medicine*[3] documenting EVD patient histories in Sierra Leone and the varying signs and symptoms, supporting the need to explore multiple routes of exposure in relation to clinical symptoms. Further, Dr. Victor J. Dzau, president of the IOM, commented

[1] As of November 7, 2014, the World Health Organization reported a total of 13 268 confirmed, probable, and suspected cases of Ebola virus disease (EVD) in six currently affected countries (Guinea, Liberia, Mali, Sierra Leone, Spain, and the United States of America) and two previously affected countries (Nigeria, Senegal) up to the end of November 4, 2014. There have been 4960 reported deaths. See more at http://apps.who.int/iris/bitstream/10665/137592/1/roadmapsitrep_7Nov2014_eng.pdf?ua=1 (accessed November 12, 2014).

[2] http://www.who.int/mediacentre/factsheets/fs103/en (accessed November 10, 2014).

[3] http://www.nejm.org/doi/pdf/10.1056/NEJMoa1411680 (accessed November 10, 2014).

BOX 1
Statement of Task

An ad hoc committee, under the auspices of the Institute of Medicine in collaboration with the National Research Council will organize a one-day workshop that will explore potential research priorities arising as a result of the emergence of Ebola Virus Disease (EVD), a hemorrhagic disease caused by a filovirus, in the United States. The workshop will focus primarily on basic science and environmental health research issues of specific concern to affected and potentially affected U.S. communities. The workshop will help inform future research that could be conducted under real-world conditions (i.e., during an event) that would provide public health officials and the general public with additional accurate information about virus transmission, mitigation of health risks, and appropriate measures to prevent the spread of disease. Specific topics that may be discussed include:

- Routes of transmission and persistence of the virus to inform public health practice.
  - Examine characteristics and properties of the virus that influence the stability and viability of EVD in order to continue to inform public health efforts, handling of potentially infectious materials, and protection of at-risk responders.
  - Assess methods of viral inactivation and alternative solutions for effective disinfection of contaminated surfaces.
  - Explore considerations regarding the real-world use of personal protective equipment (PPE) among non-traditional workers or others that may be exposed to infected individuals or contaminated materials, including real-time training and education.
- Strategies to address issues of concern to healthcare workers and the general public, including the use of PPE and personal protective behaviors to prevent spread and reduce exposure.

The committee will develop the agenda for the workshop session, select and invite speakers and discussants, and moderate the discussions. An individually authored brief workshop summary based on the presentations and discussions held during the workshop will be prepared by a designated rapporteur in accordance with institutional guidelines.

that the recent emergence of EVD in the United States has been a wake-up call to the importance of having a robust and coordinated emergency preparedness public health and hospital system. He also stated that it is important to ensure that guidance and actions are based on up-to-date scientific evidence, and that transient opportunities to collect scientific data should be leveraged to enable ongoing and planned research.

In her charge to workshop participants, Assistant Secretary for Preparedness and Response Dr. Nicole Lurie noted the need for conducting research during catastrophic events that can inform and improve responses in real time and for future disasters. Lurie said it is essential to avoid being in the same situation repeatedly and wait for After-Action Reports that are generally released months following the end of an event. She added that disaster science should be done in a timely manner while also not affecting the response in progress. In this context, she charged participants to explore and prioritize research questions to address and identify data that need to be collected in real time to best inform the current medical and public health response as well as informing and improving future responses (see Box 1 for full statement of task).[4]

Current Knowledge of Ebola and the 2014 EVD Outbreak

Existing Knowledge Base and Uncertainty

Dr. James LeDuc, director of the Galveston National Laboratory in Texas, reviewed the current knowledge of the Ebola virus characteristics. He explored what has been learned about the virus from cases in Africa and the United

[4] This summary represents the viewpoints of the speakers and does not necessarily represent the views of all workshop participants, the planning committee, or the National Academies.

States, acknowledging that virus behavior appears consistent with that of past outbreaks. Currently, available data confirm that viral shedding starts with the onset of clinical symptoms, with the viral load increasing in severity as the disease progresses, and peaking upon patient death. However, he said there is no current scientific evidence to suggest that transmission is possible before the onset of symptoms.[5] Adding to these remarks, CJ Peters, director for biodefense at the Center for Biodefense and Emerging Infectious Diseases, University of Texas Medical Branch, explained that the incubation period for EVD is a distribution rather than a single number, and that distribution can differ based on a variety of inputs. Because of this, Peters said, he expects that a small percentage of people could fall outside of the distribution, with some surpassing the 21-day incubation period (Eichner et al., 2011). It will be important to continue to assess how the virus is transmitted, especially within the tail ends of the distribution, to ensure safe practice.

LeDuc highlighted a number of important overarching research questions where further data are needed:

- What is the impact of unprecedented numbers of human-to-human transmission generations?
- How clean is clean? What are appropriate strategies to disinfect locations where infected patients have been (e.g. households, ambulances)?
- What is the duration of Ebola infectivity in bodily fluids?
- Is there a risk of domestic companion animals becoming hosts for Ebola?
- What opportunities are there to develop new diagnostics that can identify infected patients prior to the clinical onset of symptoms?
- What risks exist and what mitigation efforts are needed when using modern medical interventions on confirmed and suspected Ebola patients?
- What strategies can best be used for risk communications, and what effect do these strategies have on minimizing virus transmission?

Observations and Lessons from West Africa

Bausch discussed challenges observed during the current EVD outbreak across affected countries in West Africa and the impact these challenges may have on performing research. Highlighting labor, infrastructure, and PPE as some of the top issues, he also commented that there are ethical and logistical considerations when introducing research in this type of emergency response. Pulling the already strained number of health care workers away from their patient-care duties to instead conduct research would be difficult. Simply finding a labor force to assist in the overall response remains an ongoing challenge internationally.

While acknowledging that it is not impossible, Bausch also discussed the need to be realistic about the infrastructure available to perform research in a resource-constrained response environment such as the affected countries in West Africa. Laboratory staff and capacity, PPE availability, and data collection for research are also issues that would need to be addressed if and when a study is begun, he said. Given the desire for collected data to be standardized and accessible to encourage diverse and multiple research projects, he said it is important to consider the information technology limitations in some of the treatment centers and facilities and the corresponding impact they may have on gathering data. Some electronic equipment (e.g., diagnostic) did not perform properly, due to the more austere conditions presented in West Africa, including excess heat. Further, because technology is sparse, special attention should also be given when transferring paper materials from inside infected areas. Bausch finally highlighted the need for social and behavioral considerations and understanding the context of research in countries in West Africa, whose populations are ready for therapeutics and may not understand the need for clinical trials and may also be concerned about research conducted by outsiders. However, these challenges notwithstanding, collecting and categorizing samples now that may eventually be used in research could greatly augment future studies that are mobilized after the event has declined.

[5] Some studies have suggested that limited transmission can occur in asymptomatic individuals or prior to individuals becoming symptomatic (WHO, 1978; Dowell et al., 1999; Leroy et al., 2000). Other studies also reference the genetic mutations in this outbreak that could contribute to changes in viral adaptation (Gire et al, 2014). These are also research questions that were highlighted during the workshop warranting more study, see Box 2.

Research Priority Areas: Environmental Characteristics of the Ebola Virus and Personal Protective Equipment

Individual workshop participants discussed research questions in the following four focus areas: transmission of the virus, survival and infectivity, personal protective equipment and behaviors, and waste handling and management.

Transmission and Routes of Entry and Shedding of the Virus

Many of the current risks, quarantine policies, and public health mitigation measures could be better informed and more effective if the means and potential routes for transmission were more thoroughly characterized. The transmission discussion covered types of bodily fluids and subclinical infection, potential for aerosolized spread, inclusion of other hosts or vectors, and potential co-factors that could have an impact on susceptibility. Gary Kobinger, chief of special pathogens at The Public Health Agency of Canada, emphasized the need to further optimize animal transmission models to better mimic human infections. He also touched on the need to establish standardized methods of viral load detection to find correlates of transmission and promote early diagnosis. During his own comments, Vincent Muster, chief of the Virus Ecology Unit at the National Institute of Allergy and Infectious Disease of NIH, said that further studies regarding the generation of the Ebola virus in the respiratory tract and the stability of the virus in droplets and on surfaces could help define all routes of infection and improve infection control policies. A recurring question was mentioned by a couple of participants about quantifying the viral load during different phases of EVD across all types of bodily fluids. Additionally, information about how the virus is maintained in these bodily fluids could be useful, as well as whether there are any surrogates for transmission that could be tracked in bodily fluids. A few participants also noted that virus detection is based on the presence of viral nucleic acid material and that transmission epidemiology could be improved by the ability to perform actual virus titration. Separately, a participant proposed a question of fatality management on whether embalming in formalin could make a body safe for handling, and what long distance transport considerations are needed for a deceased EVD patient or biological samples.

Regarding susceptibility, a few participants raised questions about co-factors such as immune function, pregnancy, age, homelessness, or mental health status that would be important to better understand who might be more likely to contract EVD and if some are more susceptible to low levels of inoculum. Discussion leaders Andy Pavia, Eric Toner, and Thomas Ksiazek[6] presented research questions that should be addressed now (see Box 2).

Survival and Infectivity

How infectious are bodily fluids and how long are they infectious were two questions offered by Joseph Fair, adviser at Foundation Mérieux and founder and former vice president of Metabiota, Inc. He also added that research studies about the survivability of the virus on fomites should be revisited, as well as survivability during human burials; most of the current information has been extrapolated from animal studies, and further study would be helpful. Regarding questions of virus survivability on a dry countertop, Fair explained that to survive more than 60-120 seconds, like other viruses of this type, there needs to be moisture for the virus structure to be maintained. It is a "poorly protected virus"—an enveloped virus—but when other bodily fluids or media are paired with the virus, it could survive longer.

With some of these points as context, Trish Perl, professor in the Department of Medicine, Infectious Diseases at The Johns Hopkins University School of Medicine, outlined two immediate questions that she believes need more data. In addition to assessing the time the virus is infective in different tissues, she commented that the incubation period for Ebola is very long and could be refined using newer modeling approaches. Fair added that these data from the field historically have been very sparse and challenging to collect, but assessing how the patient

[6] Andrew Pavia, M.D., FAAP, FIDSA, is the George and Esther Gross Presidential Professor and Chief of the Division of Division of Pediatric Infectious Diseases at the University of Utah and Director of Hospital Epidemiology at Primary Children's Medical Center. Eric Toner, M.D., is a senior associate with the UPMC Center for Health Security. Thomas Ksiazek, D.V.M., Ph.D., is professor at the University of Texas Medical Branch's Seely Center for Vaccine Development and director of High Containment the Galveston National Laboratory.

BOX 2
Research Questions Related to Transmission[a]

Presented by Andy Pavia, Eric Toner, and Thomas Ksiazek

1. Is there transmission that is subclinical (asymptomatic transmission)?
2. What happens in the first day or two of being symptomatic?
    - What is the viral load during different phases of EVD?
3. Detailed studies of potential household transmission
    - Environment and behavior?
    - Detailed case study of domestic cases?
    - What can be learned from epidemiological data from West Africa; natural history studies of viral shedding?
    - What are surrogates of transmission that can be traced through bodily fluids to detect infection prior to presenting symptoms?
4. Modes of transmission: Is EVD an aerosol spread disease?
    - What is the potential for the virus to be aerosolized?
    - Does the potential for aerosol transmission vary depending on the viral load and how the viral load may have changed in comparison to previous outbreaks?
    - What potential does genetic modification of the virus have on the potential for aerosol transmission?
    - What is the difference in risk to a patient if exposed to airborne particles versus aerosol droplets versus fomites?
5. What is appropriate handling of deceased bodies?
6. Maintenance of virus in bodily fluids
    - What are the surrogates for transmission through bodily fluids?
7. Introduction into intermediate hosts or vectors for transmission
    - Can agricultural animals (e.g., pigs and their bedding) act as an intermediate host and vector of transmission?
    - Companion animals: What are the data on acting as a host?
        - Can dogs and cats act as fomites or intermediate hosts, harboring virus on, or within, their fur that might be transmitted to other individuals who come in contact with those animals?
        - How long would the virus survive on the external surface of a dog or cat?
8. What are co-factors that could impact transmissibility or susceptibility of populations?
    - Are all contacts equally likely to lead to transmission?
        - Could immune function affect the shedding rate or susceptibility (HIV and other co-infections)?
        - Can subpopulations (e.g., mentally ill, homeless) and their behaviors impact transmission rates?
    - Are the dynamics of transmission different in pregnant women and children?
        - What is the role of the placenta, in utero infection?

[a] These questions reflect points made by individual speakers and participants and do not reflect consensus among workshop participants.

became infected and at what stage could really help in informing incubation data.[7] Jeff Duchin[8] highlighted other questions that arose during discussion that related to the specific topics of survival and infectivity of the virus and that may warrant additional research (see Box 3 on next page).

[7] Some recent studies suggest that 21 days is not long enough for 100 percent of patients to become ill. See more at http://currents.plos.org/outbreaks/article/on-the-quarantine-period-for-ebola-virus (accessed November 7, 2014).

[8] Jeff Duchin, M.D., is chief of the Communicable Disease Epidemiology & Immunization Section for Public Health–Seattle & King County, Washington, and professor of medicine, Division of Infectious Diseases and Adjunct Professor in the School of Public Health and Community Medicine at the University of Washington.

BOX 3
Research Questions Related to Survival and Infectivity of the Ebola Virus[a]

Presented by Jeff Duchin

1. Define the relationship between symptoms, viral load, and infectivity (spectrum of illness).
2. What is the level of virus in different body fluids/tissues over time?
3. Does the virus contaminate the environment and/or spread by fomites?
    - Laboratory equipment
    - PPE
    - Household surfaces
    - Wastewater
    - Hospital and other clinical points of entry
4. What is the efficiency/limitation of current sampling methods?
    - Sensitivity and specificity
    - How clean is clean?
5. What is the definitive incubation period?
    - Does it vary with infectious dose and/or route and/or tissue source of exposure?
6. How can the Ebola virus be rendered noninfectious?

[a] These questions reflect points made by individual speakers and participants and do not reflect consensus among workshop participants.

Personal Protective Equipment and Behaviors

Protecting health care workers was a concept that was brought up throughout the workshop discussion, beginning with perspectives from the Occupational Safety and Health Administration (OSHA) and the CDC's National Institute for Occupational Safety and Health (NIOSH), and continuing with Emory University Hospital's paradigm shift from "patient-centered care" to "provider-centered care" to keep their entire team healthy and protect other patients and contacts. John Howard, director of NIOSH, offered eight different research priorities related to PPE, pertaining both to equipment and knowledge about virus behavior. Building on other discussions on virus inactivation, Howard identified questions surrounding types of disinfectants and contact times, as well as the best sampling methods to determine virus viability on varying surfaces to help match appropriate PPE levels. He noted that some current PPE recommendations are not associated with a standard, and better test methods are needed to determine whether specific PPE will protect workers from a hazard. Michael Hodgson, chief medical officer for OSHA, expanded on this topic, noting that questions still remain around the appropriate use of surgical masks and respirators. Hodgson also suggested including front-line health care workers in these types of research and decisions, adding that *Medecins Sans Frontieres* has managed Ebola outbreaks successfully for many years and has very specific guidance that was created using a nonhierarchical team approach to health care worker protection and leadership commitment.

Lisa Brosseau, professor in the Division of Environmental and Occupational Health Sciences at the University of Illinois at Chicago, echoed this as well, stating that public health policies for PPE should involve collaborative and inclusive decision making and that the next round of federal government guidance related to Ebola should reflect that. Additionally, she said, the current response related to PPE has been very prescriptive and overlooks important risk assessments that each organization should be doing to make thoughtful decisions about matching of PPE to exposure. Donna Gallagher, co-director of the Office of Global Health at the University of Massachusetts Medical School, voiced that understanding how PPE elements work and interact with one another will require more research as well. Better information on the PPE ensemble can help to inform more accurate

donning and doffing strategies. Melissa McDiarmid and Bill Kojola[9] presented the highlighted questions emerging from their discussions (see Box 4).

BOX 4
Research Questions Related to Personal Protective Equipment and Behaviors[a]

Presented by Melissa McDiarmid and Bill Kojola

1. Approach to evaluating system in which personal protective equipment and behaviors are embedded (e.g., training, competency assessment, hazard analysis, debriefing, medical)
    - Identify innovative approaches to the hierarchy of controls[b]
    - What is the best way to optimize the PPE supply chain in real time?
        - How can predictive modeling assist in resource allocation?
    - How can methods of evaluating PPE needs be improved based on risk stratification?
    - Studies of work processes and practice
        - What design changes can be made to identify or develop PPE that is usable and effective in a range of temperatures or that is specifically designed to meet the needs of one temperature extreme, such as high temperature climates?
        - What are the data on health care worker fatigue (physical, mental, and social)?
    - What are the testing methods for products originally designed and approved to be used separately but that in practice are used in combination as an ensemble?
    - What is the transparency level of the evidence base for PPE effectiveness?
2. Personal protective equipment and behavior effectiveness and tolerability
    - Assess PPE design—what are the appropriate standards for apparel and equipment considering safety, performance, and usability?
        - Can participatory research involving end users and designers/manufacturers be used in assessment?
        - What is the sustainability and ease of use over time?
        - What is the user compliance level?
3. Targeted and risk-based training
    - Identify and evaluate the training needs of health care workers and others
        - How much training/education? What training, for what staff, with what risk, and how often?
    - Identify effective educational methods
        - What are the best ways to train people effectively and evaluate sustainability of training?

[a] These questions reflect points made by individual speakers and participants and do not reflect consensus among workshop participants.

[b] For more on hierarchy of controls, see http://www.cdc.gov/niosh/topics/engcontrols (accessed November 10, 2014).

Waste Handling and Management

Although not always included in discussions related to public health emergencies, issues and concerns surrounding handling of infected materials and waste management have received much attention during this outbreak, partially due to the lack of knowledge regarding survival on different surfaces and in different types of media. Patricia Olinger, director of the Environment, Health and Safety Office at Emory University, and John Lowe, associate director of Research, Nebraska Biocontainment Unit, presented their experiences after treating Ebola patients at their facilities and the challenges and information needed to inform better waste management practices.

[9] Melissa McDiarmid, M.D., M.P.H., is professor of Medicine, Epidemiology and Public Health and director of the University of Maryland School of Medicine's Division of Occupational and Environmental Medicine. Bill Kojola, B.S., M.S., was the industrial hygienist for the AFL-CIO.

Lowe noted that currently the standard operating procedures at hospitals for health care workers is to use bleach wipes to wipe down potentially infected staff. Debra Sharpe, president of SSI and a biosafety and biosecurity specialist representing the American Biological Safety Association, highlighted that this process creates unnecessary exposures for employees by using their hands to come in contact with the pathogen, and a fine mist spray that covers more surface area should be used instead.

Both Lowe and Olinger agreed that treatment of EVD patients generated far more waste than many realize, with Lowe stating that a 3-week stay for one patient generated more than 1,000 pounds of waste requiring special treatment and disposal. During his remarks, Paul Lemieux from the Environmental Protection Agency (EPA) clarified that EVD-contaminated waste is generated at 30-40 times the rate of regular medical waste and is extremely expensive to manage at more than $1,000 per barrel. He also noted that thermal treatment (autoclaving) is typically analogous to disinfection; however, in the case of Ebola viruses, there are no available data on thermal treatment to directly evaluate. Because there is a limited capacity in the United States to handle EVD-contaminated waste, said Lemieux, more data are needed on effective methods of treatment and disposal. Sharpe added that it will be important to also protect the health and safety of workers who will be performing these processes.

Many questions on managing EVD-contaminated waste arose, especially relating to sectors such as waste management personnel, funeral directors, and hospital maintenance staff. Standardized, evidence-based training was requested by several participants on best practices of decontamination, as currently each state or organization

BOX 5
Research Questions Related to Waste Handling and Management[a]

Presented by Dan Hanfling

1. Safe decontamination practices
    - Is there a methodology that can be applied for performance of consistent sampling and analysis?
        - How clean is clean; how can safety be assured?
    - What alternative disinfectants are available for use, and what decontamination solution type (liquid, foam, or gas) is best?
    - Studies of work processes and practice
        - What is the optimized amount of contact time?
        - What is the occupational health exposure for those performing the decontamination process, and is it safe?
2. Validation of virus inactivation
    - What is a surrogate that can be used to study effectiveness of decontamination?
    - What are the effects of decontamination on other products in a facility, especially PPE?
3. Fatality and cadaver management
    - How infectious are dead bodies, and what is the persistence of the virus?
    - How can impermeable body bags be developed at a low cost?
4. Training to an operational level of competence
    - How can we evaluate effectiveness of existing training, content, and modalities for different occupational settings?
    - To manage an Ebola patient in a community, what role does a process tool play in improving response?
        - Could a standard tool help guide communities so responses both inside and outside the hospital are fair and equitable to all affected?

[a] These questions reflect points made by individual speakers and participants and do not reflect consensus among workshop participants.

may decontaminate differently. A few participants called for a model for hospital waste management—and for other settings such as airport screening areas, individual homes, schools, and others. A participant noted that for one or two patients, the current practices for disinfection and decontamination are possible to implement, but if there were more patients at one time, it would not be efficient or economically feasible. In response to this, Lemieux called for more research on natural attenuation as a means of decontamination and more data on the effectiveness of decontamination on porous materials. Although speakers from University of Nebraska and Emory hospitals detailed intensive steps to decontaminate patient waste and their communication with water authorities in their respective jurisdictions, Lemieux confirmed that the EPA currently does not have wastewater guidelines for Ebola. Assisting as a discussion leader, Dan Hanfling[10] presented research questions related to waste handling and management (see Box 5 on previous page).

Cross-Cutting Focus Areas

Although some questions offered were limited to the parameters of the focus areas, a few questions and data collection needs were identified that apply to multiple focus areas that were relevant to many different stakeholders. Goldman, workshop chair, highlighted the need for a surrogate virus, as much of the research discussed on this Ebola virus would need to be performed in a Biosafety Level (BSL)-4 laboratory, making it difficult for most researchers and organizations to perform. Identifying a surrogate virus, categorized at or below BSL-2, would allow many more studies to be done, informing a variety of concerns. The issue of training needs was identified by multiple groups, with training requested related to proper PPE donning and doffing, as well as data needs on evidence-based ways of handling infected materials and waste in a sustainable and environmentally acceptable way. (For example, one consideration is the fact that incinerating bleach-soaked materials releases dioxins.) The infectivity level of decedents was noted by several groups as well, as this information could affect funeral homes, wastewater treatment facilities, those handling bodies, and other stakeholders. The need for a risk assessment was brought forward by a participant from the National Science Foundation (NSF), especially related to viability in water and wastewater and corresponding needs for disinfection and decontamination. Another participant also identified the need to address, from a public policy standpoint, waste disposal facilities' reluctance to accept decontaminated EVD waste, related to research about the viability of the virus on a variety of substrates and surfaces and determining its environmental stability. She stated this as an important concern for hospitals trying to transport the waste once it has been autoclaved or chemically disinfected. Finally, the concept of a systems approach was highlighted in a variety of discussions throughout the day, especially related to PPE and procedures surrounding hierarchy of controls.[11]

In addition to the focus areas, several workshop participants also highlighted a number of topics that were of importance outside of the four targeted areas of the workshop. One concept that many participants highlighted during this time was risk communication, encompassing a broad spectrum that includes multi-level communication through hospitals, public health, and other involved sectors. A participant called for research on the best ways of communicating to young people and the public to reduce fear messages from the media and encourage learning sessions about the disease to avoid stigma. Hodgson also added that we want to create an organizational culture of safety that encourages workers in relevant sectors to come to work, or the problem may only worsen. Peters described what he thought would be important research issues of therapeutic modalities and treatment options. He was also interested in the benefit of understanding why some treatment options work better than others, and if they can truly be tied to higher survival rates. Other important points brought up by various participants throughout the different discussions included the creation of a culture of preparedness in our society; integration

[10] Dan Hanfling, M.D., is a contributing scholar at the UPMC Center for Health Security and a clinical professor for the Department of Medicine at George Washington University.

[11] Controlling exposures to occupational hazards is the fundamental method of protecting workers. Traditionally, a hierarchy of controls has been used as a means of determining how to implement feasible and effective controls. For more on hierarchy of controls, see http://www.cdc.gov/niosh/topics/engcontrols (accessed November 10, 2014).

of the operational and research portions of the response; issues of funding responsibility for this type of research; and the important intersection of policy, research, and communications. Finally, Pavia emphasized that for the research to be most valuable it will be necessary for the various federal funding agencies to be fully coordinated, including ASPR, CDC, the Department of Defense, EPA, NIH, and NSF.

Goldman summarized that this outbreak demonstrates the need for an infrastructure of disaster science. She highlighted the following issues that require attention prior to a disaster, which were addressed in a previous IOM workshop on how to perform research during disasters and public health emergencies;[12] considerations of rapid funding mechanisms, data collection methods, rapid institutional review board and biosafety research approval processes; and integration of research into an operational response. Such an approach could lead to much more coordinated and improved research outcomes than current ad hoc approaches. In closing, Dzau reiterated the need for establishing effective mechanisms to integrate science into the response. Further, he noted that for this research to be maximally effective, methodologies are required to facilitate data sharing, access, and standardization. Finally, he highlighted the need for engaging the greater global health network and interfacing with organizations such as the World Health Organization, World Bank, and others to fully coordinate efforts and future activities to mitigate the impact of EVD and future public health emergencies.

[12] For more on previous IOM work on disaster science, see www.iom.edu/disasterscienceworkshopsummary (accessed November 14, 2014).

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REVIEWERS: To ensure that it meets institutional standards for quality and objectivity, this workshop in brief was reviewed by **Mike Osterholm,** Center for Infectious Disease Research and Policy; **Debra Sharpe,** Sharpe Solutions International, LLC; **Scott Mugno,** FedEx Ground; **David Sundwall,** University of Utah School of Medicine; **Mark Kortepeter,** Uniformed Services University of the Health Sciences; **Kristine Gebbie,** Flinders University School of Nursing; and **James Johnson,** JSJ and Associates. **Steve Fienberg,** Carnegie Mellon University, served as review monitor.

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