



U.S. Medical Examiner/Coroner capability to handle highly infectious decedents

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Abstract

In the United States of America, Medical Examiners and Coroners (ME/Cs) investigate approximately 20% of all deaths. Unexpected deaths, such as those occurring due to a deceased person under investigation for a highly infectious disease, are likely to fall under ME/C jurisdiction, thereby placing the ME/C and other morgue personnel at increased risk of contracting an occupationally acquired infection. This survey of U.S. ME/Cs' capabilities to address highly infectious decedents aimed to determine opportunities for improvement at ME/C facilities serving a state or metropolitan area. Data for this study was gathered via an electronic survey. Of the 177 electronic surveys that were distributed, the overall response rate was $N = 108$ (61%), with 99 of those 108 respondents completing all the questions within the survey. At least one ME/C responded from 47 of 50 states, and the District of Columbia. Select results were: less than half of respondents (44%) stated that their office had been involved in handling a suspected or confirmed highly infectious remains case and responses indicated medical examiners. Additionally, ME/C altered their personal protective equipment based on suspected versus confirmed highly infectious remains rather than taking an all-hazards approach. Standard operating procedures or guidelines should be updated to take an all-hazards approach, best-practices on handling highly infectious remains could be integrated into a standardized education, and evidence-based information on appropriate personal protective equipment selection could be incorporated into a widely disseminated learning module for addressing suspected or confirmed highly infectious remains, as those areas were revealed to be currently lacking.

Keywords Coroners · Medical examiners · Highly infectious diseases · Autopsy · Personal protective equipment · Forensic pathology

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Background

Increased international travel and exchange are factors that escalate the risk for rapid transmission of emerging and re-emerging infectious diseases, and highly infectious diseases (HIDs). While neither the Centers for Disease Control and Prevention (CDC) nor the World Health Organization (WHO) has formally published a current standard list of pathogens deemed to be highly infectious, multiple ‘priority’ pathogens (e.g. coronaviruses, viral hemorrhagic fever viruses, *Bacillus anthracis*, *Yersinia pestis*) are frequently cited as requiring advanced resources, protocols, and training to minimize risk of disease transmission and mortality [1–3]. The 2014–2016 West Africa Ebola virus disease (EVD) outbreak, for example, challenged the capabilities, capacities, and efficacy of healthcare facilities in caring for patients with a highly infectious pathogen both abroad and in the United States [4–12]. In addition to the direct clinical care provided to patients with confirmed and suspected EVD, public health departments and other affiliated sectors including emergency management, clinical and research laboratories, medical waste management, and mortuary services collaborated with medical providers to optimize and support patient care while reducing the risks to environmental and public safety [13–17].

Due to the highly infectious nature of EVD, comprehensive aspects of infection prevention—including appropriate handling of highly infectious remains—had to be carefully considered and planned to contain disease spread. Careful handling of highly infectious remains was particularly imperative given that viral loads were found to be high immediately after an EVD-infected individual died, thereby posing hazardous to pathology and mortuary personnel [16, 18, 19]. The risk of infection for death care sector workers posed by HIDs was exemplified by the 2016 infection of a German mortuary worker with Lassa fever following the processing of remains previously unknown to be infected with Lassa virus [20]. At the height of the 2014–2016 outbreak, the CDC published guidelines for handling EVD-infected human remains informed by evidence-based best practices to address the transmission risk posed to workers [18]; however, a recent gap analysis survey of the U.S. death care sector—specifically of funeral homes and crematories—revealed that most were unaware of these guidelines. Overall, the study found a lack of up-to-date education, training and resources provided to this industry to safely manage potential or confirmed highly infectious remains scenarios [21]. As EVD is now re-emerging in other regions of Africa [22] and incidence and mortality of other infectious diseases is globally on the rise, the concerns raised in this study remain ever relevant. Thus, it is imperative for those working with potentially infected human remains to receive the requisite training and resources to enable effective disease containment and prevent secondary transmission.

In the United States of America (U.S.), Medical Examiners and Coroners (ME/Cs) investigate approximately 20% of all deaths. Typically, MEs are physicians, usually pathologists specializing in forensic pathology, who are appointed government officials. They are charged with investigating unexpected, suspicious, and unnatural deaths in order to determine cause and manner of death and perform autopsies as needed. Coroners, conversely, could be non-physicians or non-pathologist physicians who are elected or appointed at the county level; they look into deaths similar to those investigated by MEs. Coroners largely rely upon pathologists to perform the autopsies. Unexpected deaths, such as those occurring due to a deceased person under investigation (PUI) for a HID, are likely to fall under ME/C jurisdiction, thereby placing the ME/C and other morgue personnel at increased risk of contracting an occupationally acquired infection [23, 24].

Historically, ME/Cs have often been among the first to encounter infectious disease outbreaks. For instance, ME/C offices were instrumental in recognizing outbreaks of diseases such as Hantavirus pulmonary syndrome, West Nile encephalitis, and novel severe acute respiratory syndrome coronavirus (SARS-CoV) [25–27]. While the CDC recommends that no autopsy be performed for a confirmed patient with Ebola virus disease, it is likely that if a patient were to die from an unidentified HID that an autopsy would be conducted [18]. Additionally, ME/C offices play a critical role in discovering the pathogenesis of infectious diseases as well as providing a means of disease surveillance on a global level [28, 29]. In Puerto Rico, ME/C autopsy samples have been used to track Dengue virus fatalities, while in South Asia they have diagnosed deaths due to emergent Nipah virus. ME/C offices have also helped demonstrate the lethality of pediatric influenza and confirmed deaths due to Creutzfeldt-Jakob disease (CJD) [30–32].

Despite the essential role ME/C offices play in public health, there have been multiple published reports of considerable obstacles to effective infectious disease and mortality surveillance including the following: inadequate morgue bio-safety infrastructure, lack of appropriate staff training/educational updates, and critical shortages in the numbers of forensic pathologists [31–33]. Uncertainties persist on the capabilities of ME/C offices to address increasing baseline case volumes, of which the majority are lower risk infectious disease scenarios. Disease containment, in this setting, including prevention of secondary transmission, is critical for the benefit of public health, emergency management, medicine, and the general public. Given the critical role ME/Cs play in this endeavor, and the apparent lack of resources dedicated to this sector of the workforce to protect themselves from potential occupational exposures, this study was conducted to evaluate what protocols are in place for suspected or confirmed highly infectious remains, as well as determining levels of training among U.S. ME/Cs to handle highly infectious remains.

Methods

Total population purposive sampling was utilized for this non-experimental design, as each state has its own unique death investigation system [34]. A contact list of ME/C offices serving populations of 300,000 or greater was compiled for each state by the National Association of Medical Examiners (NAME) Ad Hoc Committee for Bioterrorism and Infectious Disease. This minimum population limit was selected in an effort to avoid duplication of survey results, as geographic areas with smaller populations often outsource to larger ME/C offices. An electronic survey with questions created by the authors was distributed via Qualtrics® (Software Version 2016.17, Provo, UT) through a link in an email solicitation (Indiana University Institutional Review Board exemption protocol #1711094822). Survey questions included: demographic information (e.g. title, population served, state), personal protective equipment (PPE) worn in different infectious scenarios, procedures performed in different infectious scenarios, duration of training received, biosafety level (BSL) capabilities, and jurisdictional handling of highly infectious remains.

The NAME Ad Hoc Committee for Bioterrorism and Infectious Disease sent email solicitations from December 5, 2017 to February 6, 2018 to encourage responses from ME/C offices nationwide, ensuring a comprehensive view of U.S. ME/C practices. The survey was closed after 9 weeks. Data from Qualtrics® was exported and data was analyzed utilizing SAS Version 9.4 (Copyright (c) 2002–2012 by SAS Institute Inc., Cary, NC, US). Frequencies and percentages were used to summarize question responses and chi-square tests were performed to investigate associations between variables; only significant findings were reported and individual states were not named to protect the identity of the State ME/C. All responses to questions were voluntary so response rates between questions varied.

Results

Demographics

Of the 177 electronic surveys that were distributed, the overall response rate was $N = 108$ (61%), with 99 of those 108 completing all the questions within the survey. At least one ME/C responded from 47 of 50 states, and the District of Columbia; three states were excluded because their largest ME/C office did not serve a population size of 300,000 or greater. Medical examiners represented the majority of respondents (68%), followed by Coroners (18%) and ‘Other’ titles (14%) (e.g. Forensic Pathologist, Deputy Coroner, Sheriff-Coroner). There appeared to be a difference in distribution of professions

across the region, with MEs being more evenly distributed than other titles.

Each U.S. region, as delineated by the Department of Health and Human Services, had at least 3 medical examiners, while several regions had zero or one respondent who selected ‘Coroner’ or ‘Other’. For coroners, 35% were from the Midwest (IL, IN, MI, MN, OH, and WI) and 40% of those who selected ‘Other’ were from the west coast (AZ, CA, HI, and NV) [35]. Twenty-five percent of respondents worked in an office that served a population size between 300,000–500,000; 16% served 500,001–750,000; 15% served 750,001 up to 1 million and 44% of respondents came from an office that served a population greater than 1 million people. When asked which entity was responsible for their office’s oversight, 60% stated a government agency, 16% public safety or law enforcement, 13% ‘other’ (academic medical center or university, city or county health department, political subdivision, or self), 8% state health department, and 3% a forensic laboratory.

Personal protective equipment (PPE)

Respondents were asked to select all PPE worn when performing standard duties, i.e. when no known infectious disease outbreak was occurring locally or regionally or was reported to the ME/C (Table 1). ‘Other’ optional items of PPE listed were: a plastic apron over the surgical gown ($n = 6$), waterproof sleeve covers ($n = 5$), hair nets/bonnets ($n = 2$), dedicated autopsy socks ($n = 1$), and one respondent noted use of a Tyvek suit for standard duties. For comparison, respondents were asked to select what PPE they would wear when performing duties on suspected or confirmed highly infectious remains (Table 1). ‘Other’ optional items of PPE listed were: disposable apron ($n = 7$), waterproof sleeves ($n = 5$), hair net/bonnet ($n = 2$), self-contained breathing apparatus (SCBA) ($n = 1$), Hazardous Waste and Emergency Response standard (HAZWOPER) gear ($n = 1$), Tyvek suit ($n = 1$), and two layers of clothes (cloth and plastic) ($n = 1$). Four respondents stated their office would not perform autopsies on such cases.

Slightly more than half of respondents (56%; 61/108) stated their office staff had received training on donning and doffing PPE in suspected or confirmed cases of highly infectious remains; nearly one-third (32%) (18/56) reported the amount of cumulative training in hours per person, on average per year, was 1 h or less while 29% (16/56) spent between 1 and 2 h of training. The entity that provided the PPE training varied widely among respondents. Common responses included: in-house staff ($n = 16$), state or local health department ($n = 7$), an affiliated university ($n = 6$), occupational health or a safety and compliance coordinator external to the ME/C office ($n = 6$), online-based training ($n = 3$), risk or emergency management ($n = 3$), an infectious disease or infection control

Table 1 Personal protective equipment (PPE) for standard duties vs. PPE for suspected or confirmed highly infectious remains

Personal protective equipment item	Standard duties percentage	Suspected or confirmed percentage
Gloves, outer, chemical-resistant	91% (<i>n</i> = 98)	85% (<i>n</i> = 92)
Gloves, inner, chemical-resistant	58% (<i>n</i> = 63)	64% (<i>n</i> = 69)
Gloves, cut-resistant	51% (<i>n</i> = 55)	58% (<i>n</i> = 63)
Face shield	59% (<i>n</i> = 64)	76% (<i>n</i> = 82)
Eye protection (e.g., safety glasses, chemical splash goggles)	70% (<i>n</i> = 76)	66% (<i>n</i> = 71)
Boot/shoe covers	80% (<i>n</i> = 86)	87% (<i>n</i> = 94)
Dedicated, easily disinfected footwear for autopsy	53% (<i>n</i> = 57)	56% (<i>n</i> = 60)
N95 particulate disposable respirator mask	52% (<i>n</i> = 56)	68% (<i>n</i> = 73)
Surgical/procedure mask (i.e., non-N95)	35% (<i>n</i> = 38)	6% (<i>n</i> = 7)
Powered air purifying respirator (PAPR)	4% (<i>n</i> = 4)	36% (<i>n</i> = 39)
Coveralls or disposable gown	94% (<i>n</i> = 101)	87% (<i>n</i> = 94)
Dedicated clothing not worn outside the workplace (i.e., scrubs)	82% (<i>n</i> = 89)	82% (<i>n</i> = 89)
Other	11% (<i>n</i> = 12)	15% (<i>n</i> = 16)

^a Percentages add up to more than 100% because this question was multiple-select

specialist (*n* = 3), or individuals highly trained in hazardous materials (HAZMAT) external to the ME/C office (*n* = 2).

Permissible procedures

In the event of suspected highly infectious remains, respondents were asked what procedures would be permissible and performed by their office (Table 2). The most frequent responses for ‘Other’ were: dependent on a case-by-case basis/contingent upon suspected pathogen (*n* = 16), sending the remains to the appropriate biocontainment facility (*n* = 3), and one noted a written policy for handling highly infectious remains does not exist and would require discussion with multiple stakeholders, including the safety committee to evaluate risk.

For comparison, respondents were asked which procedures or tasks would be performed in the event of confirmed highly infectious remains (Table 2). ‘Other’ responses echoed those

in a suspected case where it was dependent on the circumstances and suspected pathogen, or only as required by the CDC or local health department (*n* = 16). One respondent stated they would decline jurisdiction if no circumstance beyond the confirmed infectious disease made it reportable.

Highly infectious remains experience and capabilities

Less than half of respondents (44%; 44/101) stated that their office had been involved in handling a suspected or confirmed highly infectious remains case. The most commonly encountered highly infectious pathogens were: CJD and unclassified prions (*n* = 21); forms of tuberculosis (including extremely drug-resistant [XDR-TB] and multiple drug resistant [MDR-TB]) (*n* = 13); forms of meningitis (*Streptococcus pneumoniae*, meningococcal) (*n* = 9); anthrax (*Bacillus anthracis*) (*n* = 6); suspected cases of Ebola and other hemorrhagic fevers (*n* = 4); human immunodeficiency virus (HIV)

Table 2 Procedures conducted with suspected highly infectious remains vs. confirmed highly infectious remains

Procedure	Suspected percentage	Confirmed percentage
Complete autopsy	49% (<i>n</i> = 53)	22% (<i>n</i> = 24)
Limited autopsy (e.g., biopsy or culture for diagnosis)	55% (<i>n</i> = 59)	31% (<i>n</i> = 34)
Washing or cleaning of the body	41% (<i>n</i> = 44)	24% (<i>n</i> = 26)
Removal of inserted medical equipment or devices	33% (<i>n</i> = 36)	17% (<i>n</i> = 18)
Thermal sealer bag for remains	19% (<i>n</i> = 20)	14% (<i>n</i> = 15)
Multiple body bags	53% (<i>n</i> = 57)	39% (<i>n</i> = 42)
Body storage in freezer	65% (<i>n</i> = 70)	45% (<i>n</i> = 49)
Bypass office and have body directly transported to funeral home/crematory	30% (<i>n</i> = 32)	51% (<i>n</i> = 55)
Other	23% (<i>n</i> = 25)	31% (<i>n</i> = 23)

^a Percentages add up to more than 100% because this question was multiple-select

($n = 3$); H1N1 influenza (swine strain) ($n = 3$); and SARS ($n = 2$). While just under half of the respondents stated their office had been involved in handling such remains (44%; 44/101), those cases do not appear equally distributed across regions. No respondents from upper west coast states (AL, ID, OR, WA) reported office involvement, while all respondents from east coast states (CT, ME, MA, NH, RI, VT) reported office involvement. Other regions had between 22% to 60% of respondents reporting office involvement.

Eighty-one percent (81/100) of respondents did not have a Biosafety Level 3 (BSL-3) facility within their office to conduct examinations in suspected highly infectious cases; some did have BSL-1 capabilities (40%; 31/77) and BSL-2 capabilities (60%; 46/77). Table 3 provides definitions of the BSL levels [36]. In regard to the location at which autopsies were performed in a suspected highly infectious remains case, 58% (47/81) stated there was a separate autopsy area where no other autopsies were being performed at the same time; 20% (16/81) stated they do not examine suspected highly infectious remains at their facility; and 22% indicated ‘other’, which include not having a separate room/in the regular autopsy area

($n = 4$), altering protocol to limit staff and only have that single case autopsied at the time if there was not a separate room available ($n = 3$), performing autopsy in a negative pressure disaster portable morgue unit ($n = 1$), and that autopsy was contingent on the case load and space available ($n = 1$). One open-ended comment emphasized that it was case dependent, and that “TB gets autopsied, Ebola straight to the funeral home”. This statement raises concern as the study by Le et al. that surveyed the level of education and training received by U.S. funeral home and crematory personnel on highly infectious disease mitigation and management revealed large gaps in knowledge, including incorrectly marking routes of exposure for EVD [21].

More than half (62%; 62/100) indicated that their staff was not trained to carry out specialized decontamination procedures following autopsy of suspected or confirmed highly infectious remains. Of those who had been trained on decontamination procedures, the most frequent response for the average cumulative length of training in hours per year per person was 1 h or less (20%; 7/35), followed by 2 h (17%; 6/35). Additionally, a little over one-third of respondents (34%; 33/

Table 3 Definitions and specifications of biosafety levels 1, 2, and 3

	Definition
Biosafety Level-1 (BSL-1)	This level is appropriate for working with defined and characterized strains of microorganisms not known to consistently cause disease in healthy adult humans. Standard microbiological practices are followed and work can be performed on an open bench or table; work surfaces should be decontaminated daily. Personal protective equipment (PPE) (i.e. coats, gloves, eye protection) should be worn as needed. The facility should have a sink for handwashing, sharps containers, biohazard signs, and have doors separating the working space from the rest of the facility. An example of an organism appropriate for use in a BSL-1 laboratory is non-pathogenic <i>E. coli</i> .
Biosafety Level-2 (BSL-2)	BSL-2 builds upon BSL-1 but includes additional precautions and facility features which are appropriate for work with moderate-risk microorganisms that are associated with human disease of varying severity. Laboratory access is restricted when work is conducted. Enhanced engineering controls and personal protection is needed. PPE typically includes lab coats and gloves; eye protection and face shields as needed. In addition to the sink for handwashing, there should also be an eyewash station. All aerosol or splash-generating procedures should be performed in a biological safety cabinet (BSC). There must be an autoclave or alternate method of decontamination for proper waste disposal, and the facility must have self-closing, lockable doors. An example of an organism appropriate for use in a BSL-2 laboratory is human immunodeficiency virus (HIV).
Biosafety Level-3 (BSL-3)	BSL-3 builds upon the requirements of BSL-2 but includes additional precautions and facility features which are appropriate for work with microorganisms which cause serious or potentially fatal disease through respiratory transmission. Access to the facility is restricted and controlled at all times. In addition to all the aforementioned PPE, respirators may be worn and are required when experimentally infected animals are present. All microorganisms must be handled within a BSC. A hands-free sink and eyewash station must be available near an exit, exhaust air cannot be recirculated and the facility must have sustained directional airflow from clean areas to more contaminated areas. Lastly, entrance into the facility is through two sets of self-closing, locking doors. An example of an organism appropriate for use in a BSL-3 laboratory is Severe Acute Respiratory Syndrome (SARS) coronavirus.

^a These definitions are paraphrased from those provided by the Centers for Disease Control and Prevention [36]

97) indicated staff were trained to handle and transport (i.e. package and ship) specimens for suspected highly infectious cases. If staff were trained, specimens were sent most frequently to one or two of the following locations: the CDC ($n = 14$), state reference laboratory ($n = 13$), the National Prion Disease Pathology Surveillance Center (NPDPS) at Case Western Reserve University for prion diseases ($n = 4$), or an academic medical center/hospital laboratory ($n = 3$). Of those that had received training on handling and transporting specimens, the most frequent response for the average cumulative length of training in hours per year per person was 1 h (41%; 11/27), followed by less than 1 h (11%; 3/27). There was a statistically significant relationship determined between those answering “No” to their office being involved in handling highly infectious remains and those answering “No” to receiving training to safely handle/transport the specimens. For those who answered “No” to involvement, 78% had no training for transporting specimens and 21% did; however, for those who answered “Yes” to office involvement, only 51% had training for transporting specimens and 49% did not. When asked what their jurisdiction permitted for highly infectious remains, 13% (16/124) stated embalming was permitted, 15% (18/124) traditional burial practices, 25% (31/124) cremation and 47% (58/124) were unsure.¹

Survey respondents also had the opportunity to provide open-ended comments at the end of the survey; 26 respondents did. Comments included: a desire for formalized or more frequent training in the area of handling highly infectious remains ($n = 7$); a need for more resources or a lack of preparedness or appropriate facilities to address highly infectious remains ($n = 7$); the difficulty of answering questions pertaining to newly emerging and re-emerging highly infectious diseases because policies had not been written or revised ($n = 4$); a need to formalize and update protocols ($n = 3$); and a need for better funding to attract more prospective forensic pathologists to practice and to purchase greater stocks of PPE since what was available was expired or on back-order ($n = 1$). Select direct quotations and themes included that the, “national infrastructure for autopsy biosafety is woefully inadequate” and a perception of being overlooked/neglected in infection control training but still an office “they hand bodies off to” without regard for the limited training and resources.

Discussion

As sudden unexpected deaths fall under Medical Examiner/Coroner jurisdiction, they may play a fundamental role in the response to infectious disease deaths. If communication between various health sectors is unclear or protocols have not been established by the local health department, there is a risk

for occupational exposure for all parties involved, and the potential for a ME/C to be exposed to a highly infectious death that has yet to be confirmed. The logistical challenges associated with the response to highly infectious pathogens is demanding for public health sectors focused on the treatment and management of living patients. The role of the death care sector in effective disease surveillance and containment of infectious diseases is often overlooked; including the fundamental role of ME/Cs. ME/Cs frequently investigate deaths with little clinical information on the circumstances preceding death. Hence, it is crucial to for ME/Cs to have robust, up-to-date education and training in potential highly infectious remains handling, PPE donning and doffing, and clear protocols used when handling human remains that stress universal precautions. To determine what training areas are insufficient or need to be supplemented, this survey evaluated current ME/C office capability to handle highly infectious remains.

This survey provided a national view of the handling of highly infectious remains by capturing a sample of ME/Cs from nearly every state and Washington D.C. Medical examiners comprised the majority of the survey respondents and were more evenly geographically distributed than coroners. Nearly half of the respondents served large counties or metropolitan areas with populations of greater than one million people, highlighting the large populations that may be covered by a single ME/C office. Additionally, most ME/C offices, including the body storage areas (morgues), are under government oversight.

In order to gauge circumstance-dependent PPE use among ME/Cs, respondents were asked for standard PPE ensembles worn during routine autopsies and those worn for autopsies on suspected or confirmed highly infectious remains (Table 1). Slightly more than half (52%) reported wearing an N95 respirator during routine autopsies and this increased to only 68% for autopsies on suspected or confirmed highly infectious remains. Other higher level PPE such as a powered-air purifying respirator (increased by over 30%), Tyvek suit, HAZWOPER gear and SCBA also showed an increase. A surgical mask was worn by 35% in standard autopsies and by 6% of ME/Cs for a suspected or confirmed highly infectious case. Typically, at minimum an N95 is recommended for protection against aerosolized particles arising such as TB, Monkeypox, SARS and others, rather than a surgical mask [37]. Additionally, an autopsy is inherently an aerosol-generating procedure, even organisms that might normally require only large droplet precautions (i.e. surgical mask) can be aerosolized at autopsy due to oscillating saws, aspirating hoses, etc. and thus require added respiratory precautions (i.e. N95 respirator or PAPR) [33, 38, 39]. Use of a face shield rather than glasses/goggles also has been shown to reduce contamination of respirators by particles but only 59% of ME/C respondents routinely wear them [40].

The following PPE changes occurred for suspected or highly infectious remains: the use of inner gloves, a face shield,

¹ Respondents were able to select multiple options.

and boot/shoe cover wear increased by 6%, 17%, and 7%, respectively, while donning eye protection decreased by 4%. Usage of a N95 respirator increased by more than 15% and the use of a powered-air purifying respirator notably increased by nearly 30%. Higher level PPE, such as a Tyvek suit, HAZWOPER gear and SCBA also were used when autopsies were performed on suspected or confirmed highly infectious remains. Of concern, these results indicate ME/C alter their PPE based on suspected versus confirmed highly infectious remains rather than taking an all-hazards approach. Despite some improvements in more protective ensembles in the suspected increased risk cases, the amount of training received by respondents was lacking. Little more than half (56%) of respondents had received training on donning and doffing PPE in such scenarios, with the 61% of those who did have PPE training having spent an average of only 2 h or less per person per year on the topic.

Additionally, the entity that provided PPE training widely varied (e.g. in-house staff, affiliated university, safety and compliance departments), and no information was collected on the survey on the expertise level of those delivering trainings. The lack of reproducible training time and variability of training entity suggest that more standardized training might be of benefit. Designating a knowledgeable public organization to offer standardized training modules could lead to the following: (1) standardization of the organizational source of training; (2) content of training materials and modules based on reproducible, evidence-based best practices commonly found in the ME/C field; and (3) subscription to online training as it will likely be the most cost-effective and convenient means of training, as was proven successful in healthcare [41].

Moreover, best practices and evidence-based studies have demonstrated that regular training for donning and doffing high level PPE in highly infectious scenarios provide substantially better occupational safety and health outcomes for the employee [6].

In the event of suspected or confirmed highly infectious remains, most ME/C offices stated that the situation was handled on a case-by-case basis, depending on the pathogen that was suspected and required detailed conversations with all stakeholders. As shown in Table 2, procedures did vary between what would be performed with a suspected highly infectious body versus a confirmed infectious body. In a confirmed case, all but one of the listed procedures as decreased compared to a suspected case (e.g. complete autopsy [27% decrease], washing or cleaning of the body [17% decrease], body storage in freezer [20% decrease]). The only increase was, “bypass office and have body directly transported to funeral home/crematorium” by 21% which, as previously mentioned, may result in funeral home and crematory personnel being placed at risk.

Fewer than 50% of ME/C offices having been involved with handling a suspected or confirmed case, demonstrating a lack experience in handling highly infectious remains. When asked which suspected or confirmed pathogens were encountered, however, many noted Category A or B pathogens (Table 4) [1, 2] that require specific deactivation and decontamination procedures—of which only approximately one-third (38%) of respondents had received training in. It is possible that after such an event that the ME/C office would hire an appropriate contractor to conduct the appropriate deactivation and decontamination; however, the possibility remains

Table 4 Category A vs. Category B agents/pathogens

	Category A	Category B
Definition	These highest priority pathogens because pose a severe threat to national security and public health. Category A pathogens are easily disseminated or transmitted from one individual to another, have high mortality rates, may result in public panic and require special planning and action for public health preparedness and response.	These second to highest priority agents are moderately easy to disseminate, have moderate morbidity and low mortality rates, and require enhanced surveillance and diagnostic capabilities.
Select Examples	<ul style="list-style-type: none"> • <i>Bacillus anthracis</i> (anthrax) • <i>Clostridium botulinum</i> toxin (botulism) • <i>Yersenia pestis</i> (plague) • <i>Francisella tularensis</i> (tularemia) • Smallpox • Filoviruses (i.e. Ebola, Marburg) • Arenaviruses (i.e. Junin, Machupo) • Flaviviruses (i.e. Dengue) 	<ul style="list-style-type: none"> • <i>Brucella</i> species (brucellosis) • <i>Salmonella</i> • <i>Escherichia coli</i> O157:H7 • Q fever • Staphylococcal enterotoxin B • Viral encephalitis (i.e. equine) • <i>Vibrio cholerae</i> • Hepatitis A • Zika virus • West Nile virus

^a These definitions are verbatim as those provided by the National Institute of Allergy and Infectious Diseases, and World Health Organization Classifications [1, 2]

that the task could go to individuals within the ME/C offices without proper training.

While most offices did not have a BSL-3 facility, nearly two-thirds (60%) of those without a BSL-3 did have BSL-2 capabilities. However, if 40% have only BSL-1 capability, then these morgues would essentially be considered appropriate for work only with agents not known to consistently cause disease in healthy human adults per CDC guidelines [42]. In essence, a sizeable percentage of morgues in the U.S. are not equipped to safely perform autopsies on human remains with a large number of infections, especially those highly infectious disease autopsies. In addition to improved training, more investment in morgue infrastructure would be necessary to enhance their capabilities. Anecdotally, some larger ME/C offices have a computerized tomography (CT) scanner in which triple bagged sealed infectious remains can undergo virtual autopsy. These bags can be constructed with portals to collect needed specimens for microbiologic/virologic studies. The triple bagging prevents leaks and contamination and the remains can safely be sent to funeral home. It would also be beneficial to have list of pathologists and support personnel in each ME/C office who could volunteer to take vaccines to handle certain cases with suspected contagious diseases (i.e. smallpox, etc.).

Approximately 20% of respondents reported that they did not examine suspected or confirmed highly infectious remains at their facility. Given the lack of proper BSL facilities, this would be appropriate. Slightly more than 20% noted the lack of space and/or a lack of staff in their offices as a limitation for being able to perform autopsies of suspected or confirmed highly infectious remains in a separate room or alone. For biosafety, it is recommended that autopsy facilities should have a minimum of 12 air exchanges per hour, be negatively pressurized relative to surrounding office spaces, and exhaust air outside of the facility and away from areas of high pedestrian traffic. Morgue laminar air flow should travel from clean to progressively less clean areas with downdraft table ventilation to decrease personnel exposure to aerosolized pathogens [32, 39]. It is likely that significant financial investment would be required to retrofit many existing morgues to meet these standards. Another option would be to have jurisdictional planning to transport suspected or confirmed cases to known centers that currently have the necessary BSL capability; again, body transportation would incur costs but likely lower costs than that associated with retrofitting many existing morgues. In addition to improved morgue biosafety, it would also benefit ME/C facilities to have better publicized, easily accessed, and clearly laid-out protocols for various infectious scenarios in which limited autopsy (e.g. brain-only in suspected CJD cases) or no autopsy (e.g. EVD cases) is currently recommended.

When asked about level of training to handle and transport specimens for suspected highly infectious cases, only one-third of respondents had received this training with 20% spending on average less than 1 h per year per person on the

topic. Nearly half of respondents (47%) were unsure of what their jurisdiction permitted in the case of highly infectious remains for ultimate disposal, and alarmingly, 13% of respondents stated their jurisdiction permitted embalming and 15% traditional burial. For EVD, for example, the recommended procedure is cremation to ensure complete deactivation of the virus in order to prevent spread to workers and the environment; those who were killed by the disease will have high viral loads present in their body post-mortem [43]. While needs for funding, resources, supplies and appropriate capabilities may be universal across the death care sector, this survey's results strongly suggest that it would benefit state or regional-specific ME/Cs to have standardized education and training throughout the U.S [24]. Likewise, open-ended comments from respondents indicated a need for augmented up-to-date formalized trainings, as well as revised written policies and procedures, and enhanced resources (including facilities and funding). There were general perceptions of unpreparedness to address highly infectious remains, budgetary constraints and a weak national structure regarding autopsy biosafety, and a lack of incorporation of ME/C offices into infection control planning despite ME/C office involvement with highly infectious remains.

There were limitations to this study. Because of the study's exploratory nature, the survey was not validated beyond subject matter expert vetting. Additionally, the survey only included ME/C offices that served larger populations; smaller offices may still encounter HID cases if they do not outsource larger nearby offices. Therefore, this study may not be generalizable to smaller offices (i.e. those serving populations <300,000). Also, the survey instrument was designed to allow respondents to check multiple boxes when asked about the use of PPE. The results, therefore, were not clear whether the respondent meant the PPE would be used simultaneously or one instead of the other. For example, a face shield and respirator may be used simultaneously or a face shield may be used instead of a respirator. Additionally, a limitation related to potential response bias may exist. Although this study was not funded, there could have been sponsor bias on behalf of the respondents, as the survey was distributed by members of NAME, thereby potentially affecting the candidness of their responses. Lastly, non-responses may have arisen because it would not appeal to prospective participants to take a survey about a topic for which they are not trained out of concern their answers may not be "correct." Nevertheless, this study addresses a critical gap about what is known and unknown about U.S. ME/C capabilities to handle highly infectious remains.

In conclusion, this survey of U.S. medical examiners and coroners' capabilities to address highly infectious decedents presents opportunities for improvement at ME/C facilities serving their state or metropolitan area. Standard operating procedures or guidelines (SOPs or SOGs) should be updated

to take an all-hazards approach, best-practices on handling highly infectious remains could be integrated into a standardized education, evidence-based information on appropriate PPE selection could be integrated into a widely disseminated learning module, and existing relationships with the local health department, funeral homes and crematories could be bolstered to develop a multi-sectoral concept of operations for addressing suspected highly infectious remains. While some issues will require greater capital and resources to address—such as retrofitting facilities to meet better biosafety recommendations, or more financial resources to enhance operation—the hope is that this study will draw attention to these more systemic issues and stimulate a call to action from the appropriate entities.

Key points

1. U.S. Medical Examiners/Coroners play a critical role in death investigation, yet their capabilities to address highly infectious remains are unknown.
2. Medical Examiners/Coroners are at greater risk for an occupationally-acquired infection.
3. This survey, with respondents from nearly every U.S. state, revealed current levels of Medical Examiner/Coroner training and education to address suspected or confirmed highly infectious remains.
4. Questions, and thereby results, focus on permissible autopsy procedures, personal protective equipment, and biosafety-level facility capabilities.
5. Medical Examiners/Coroners could benefit from updates to standard operating procedures and standardized education on handling suspected or highly infectious remains that taken an all-hazards approach.

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Compliance with ethical standards

Conflict of interest None of the authors have any conflicts of interest to disclose.

Ethical approval This study was deemed exempt by Indiana University Institutional Review Board (Protocol #1711094822).

Informed consent Survey participants were informed of potential risks and benefits prior to taking the voluntary survey. This informed consent survey was reviewed by the Institutional Review Board and approved as part of the exemption in the aforementioned protocol number.

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