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Melanie L. Yarbrough
Washington University School of Medicine in St. Louis

Jennie H. Kwon
Washington University School of Medicine in St. Louis

Meghan A. Wallace
Washington University School of Medicine in St. Louis

Tiffany Hink
Washington University School of Medicine in St. Louis

Angela Shupe
Washington University School of Medicine in St. Louis

See next page for additional authors

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Authors

Melanie L. Yarbrough, Jennie H. Kwon, Meghan A. Wallace, Tiffany Hink, Angela Shupe, Victoria J. Fraser, Erik R. Dubberke, Carey-Ann D. Burnham, and CDC Prevention Epicenters Program

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VIROLOGY

Frequency of Instrument, Environment, and Laboratory Technologist Contamination during Routine Diagnostic Testing of Infectious Specimens

Melanie L. Yarbrough,[a] Jennie H. Kwon,[b] Meghan A. Wallace,[a] Tiffany Hink,[b] Angela Shupe,[a] Victoria J. Fraser,[b] Erik R. Dubberke,[b] Carey-Ann D. Burnham,[a] for the CDC Prevention Epicenters Program

[a]Department of Pathology and Immunology, Washington University School of Medicine, St. Louis, Missouri, USA

[b]Department of Medicine, Washington University School of Medicine, St. Louis, Missouri, USA

ABSTRACT Laboratory testing to support the care of patients with highly infectious diseases may pose a risk for laboratory workers. However, data on the risk of virus transmission during routine laboratory testing conducted using standard personal protective equipment (PPE) are sparse. Our objective was to measure laboratory contamination during routine analysis of patient specimens. Remnant specimens were spiked with the nonpathogenic bacteriophage MS2 at 1.0×10^7 PFU/ml, and contamination was assessed using reverse transcriptase PCR (RT-PCR) for MS2. Specimen containers were exteriorly coated with a fluorescent powder to enable the visualization of gross contamination using UV light. Testing was performed by two experienced laboratory technologists using standard laboratory PPE and sample-to-answer instrumentation. Fluorescence was noted on the gloves, bare hands, and laboratory coat cuffs of the laboratory technologist in 36/36 (100%), 13/36 (36%), and 4/36 (11%) tests performed, respectively. Fluorescence was observed in the biosafety cabinet (BSC) in 8/36 (22%) tests, on test cartridges/devices in 14/32 (44%) tests, and on testing accessory items in 29/32 (91%) tests. Fluorescence was not observed on or in laboratory instrumentation or adjacent surfaces. In contrast to fluorescence detection, MS2 detection was infrequent (3/286 instances [1%]) and occurred during test setup for the FilmArray instrument and on FilmArray accessory equipment. The information from this study may provide opportunities for the improvement of clinical laboratory safety practices so as to reduce the risk of pathogen transmission to laboratory workers.

KEYWORDS Ebola virus, laboratory-acquired infection, sample-to-answer testing, contamination, risk assessment

Clinical laboratories in the United States employ about 500,000 workers, many of whom routinely perform testing on potentially infectious biological specimens (1). It is difficult to determine the true incidence of laboratory-acquired infections (LAIs), since no systematic reporting system exists. However, the national surveillance system for health care workers (HCWs) estimated that about 4% of blood and body fluid exposures in health care occur in laboratory workers (2), and the most common route of exposure is percutaneous injury. To reduce the risk of exposure, standard precautions are recommended for laboratory workers, and all specimens should be treated as though they are potentially infectious (3). Historically, the most common viral LAI agent is hepatitis B virus (HBV), which is present at titers of $\leq 10^9$ viral particles per ml in the blood of infected patients (4). However, the incidence of hepatitis B infection acquired through occupational exposure of HCWs has declined in recent years, likely due to universal vaccination programs (5). The recent emphasis on laboratory biosafety, including the use of biosafety cabinets (BSCs) and personal protective equipment (PPE), has likely reduced the incidence of the most common

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Address correspondence to Carey-Ann D. Burnham, cburnham@wustl.edu.

causes of LAIs (6). However, the threat of emerging infectious diseases is a significant concern, and in the early stages of an epidemic with a new infectious disease, very little is usually known about the transmission dynamics or microbiological characteristics of these pathogens, posing further risks to laboratory workers who may come into contact with infectious specimens during laboratory testing.

From 2014 to 2015, an Ebola virus epidemic spread across western Africa, leading to a massive humanitarian effort to contain the spread of this disease. During this time, several patients were treated for and/or suspected to have Ebola virus disease (EVD) in the United States. While no LAIs were recorded in the United States, two HCWs were treated for hospital-acquired EVD (7, 8).

The care of patients with EVD in the United States typically took place at high-containment facilities, where the management of patients was supported with routine laboratory testing. In addition, persons under investigation for EVD require diagnostic testing to rule in or rule out EVD, in addition to routine testing to support their care and rule out other infectious etiologies (9–11). Much of this testing was performed using sample-to-answer, near-patient assays. At the time, guidance for laboratories from professional societies and device manufacturers regarding safe practices for clinical testing, from processing through decontamination, was incomplete and, at times, contradictory. Due to the lack of standardized protocols, clinical laboratories that performed testing for persons under investigation for EVD risked voiding manufacturer equipment warranties or even rendering the instrument unusable if it became contaminated (12).

While many causes of LAI have been documented, there is very little evidence detailing the risks of testing specimens from highly infectious patients in the clinical laboratory. One recent study addressed the contamination of central laboratory equipment through the interrogation of automated instrumentation for the presence of contamination with HBV and HCV at baseline and after the processing of specimens containing high titers of HCV (13). However, little is known about the major points of risk when one is using sample-to-answer or manual laboratory methods. Because HCV and HBV are commonly encountered in clinical specimens, it may be difficult to dissect the timing and nature of a contamination event using these viruses.

Fluorescent markers are commonly used to monitor the contamination of PPE used by HCWs (14–16). While easily visualized, fluorescence is not necessarily a sensitive or specific marker of viral particle dispersal during specimen processing, but it could be used as a marker of gross contamination. MS2 is a nonpathogenic bacteriophage that has been used as a surrogate to model the dynamics of virus transmission, explore mechanisms of environmental and HCW contamination, and evaluate the efficacy of disinfection protocols (15, 17–19). The use of MS2 as a biomarker of contamination permits the detection of *de novo* contamination events, since this marker should not be present at baseline in biological specimens such as blood or body fluids or on laboratory equipment.

Our objective was to assess the potential for contamination of instrumentation, laboratory surfaces, and the laboratory worker during test setup and the analysis of blood, urine, fecal, and nasopharyngeal swab specimens by use of fluorescence and MS2 as markers of contamination.

MATERIALS AND METHODS

Preparation of test specimens. This investigation was reviewed and deemed non-human subject research by the Institutional Review Board of Washington University in St. Louis, MO. Deidentified remnant specimens consisting of nasopharyngeal swabs in Universal Transport Medium, feces, urine, EDTA whole blood, EDTA plasma, and positive blood culture broth were obtained from the clinical laboratory. Specimens of each matrix type were pooled and were spiked with a commercially available preparation of bacteriophage MS2 (ZeptoMetrix, Buffalo, NY), a nonpathogenic (biosafety level 1) single-stranded RNA virus. Stock MS2 solution (at a concentration of 1×10^9 PFU/ml) was diluted 1:100 into each specimen matrix for a final concentration of 1×10^7 PFU/ml, a concentration that can be present in blood and body fluids during many viral infections, including Ebola virus infection (20). Specimens were aliquoted into new containers appropriate for the specimen type and were frozen at −80°C until testing. Each specimen type, along with the associated testing and instrumentation, is detailed in Table 1.

TABLE 1 Instrumentation platforms, assays, and sample types evaluated

Instrument/device	Assay	Specimen[a]
BioFire FilmArray	BioThreat-E panel	Whole blood (EDTA)
	Respiratory panel	Nasopharyngeal swab in UTM
	Gastrointestinal panel	Feces
	Blood Culture Identification	Positive blood culture broth[b]
Gene Xpert	Flu/RSV[c]	Nasopharyngeal swab in UTM
Piccolo Xpress	Comprehensive metabolic panel	Plasma (EDTA)
Urinalysis test strips	Dipstick urinalysis	Unpreserved urine
Alere BinaxNOW	Malaria antigen	Whole blood (EDTA)

[a]UTM, Universal Transport Medium (Copan Diagnostics, Murrieta, CA).
[b]VersaTREK Redox 1 medium (Thermo Fisher Scientific).
[c]Influenza/respiratory syncytial virus.

Test setup and operation. Prior to testing, specimens were thawed at room temperature. The exterior of each specimen container was coated with a fine application of Glo Germ powder using a Glo-Brush applicator (both from Glo Germ, Moab, UT). Specimen containers appeared unaltered in visible light, but fluorescence was easily visualized using a UV flashlight (see Fig. S1 in the supplemental material). Testing for each specimen type was set up in a biosafety cabinet (class II, type A2; NuAire, Plymouth, MN) and was performed using manufacturer-recommended protocols. Each test was performed twice by each of two experienced medical laboratory technologists (one with 9 years of experience and one with 14 years of experience) on different days. The only exception was comprehensive metabolic panel (CMP) testing on the Piccolo instrument, which was performed four times by each technologist using standard PPE and twice by each technologist using double gloves (two pairs of the same type of glove) in addition to standard PPE. Standard PPE worn by the technologists included nitrile gloves (Fisherbrand; Fisher Scientific, Waltham, MA), a laboratory coat, and goggles.

Assays evaluated. The assays evaluated included the FilmArray BioThreat-E, Gastrointestinal, Respiratory, and Blood Culture Identification panels (all from BioFire, Salt Lake City, UT), the Xpert Flu/RSV assay (Cepheid, Sunnyvale, CA), a urine dipstick (Multistix 10 SG; Siemens, Tarrytown, NY), the BinaxNOW malaria antigen test (Alere, Scarborough, ME), and a Piccolo comprehensive metabolic panel (Abaxis, Union City, CA).

Fluorescence detection. Before each test was set up, the laboratory worker, surfaces, and instrumentation were checked for baseline fluorescence by use of a UV light. If any fluorescence was noted, the area was cleaned with bleach, water, and 70% ethanol (surfaces) or soap and water (technologists). After test setup, each designated area was checked for fluorescence using a UV flashlight (TT-FL002; TaoTronics, Fremont, CA). The laboratory worker was monitored for fluorescence prior to and after the removal of PPE. Between rounds of testing, the biosafety cabinet and laboratory surfaces adjacent to the instrumentation were cleaned as described above. A disposable laboratory coat (Fisher Scientific, Hampton, NH) and disposable gloves were used one time for test setup to permit the assessment of contamination for each test assessed.

MS2 detection. Prior to test setup, baseline MS2 contamination was assessed by swabbing the biosafety cabinet, biohazard container, instruments, and laboratory surfaces adjacent to the instrumentation with flocked swabs in Universal Transport Medium (Copan Diagnostics, Murrieta, CA). After the setup of each test, each designated area was swabbed using premoistened flocked swabs in Universal Transport Medium. Sampling was targeted at areas commonly touched during test setup (the space bar and "enter" key of the keyboard, mouse buttons, touchscreen, instrument buttons, etc.). For benchtop and floor surfaces, an area of approximately 4 by 4 in was sampled with a premoistened swab. The bare skin of technologists was assessed after the removal of PPE. To assess for PCR inhibition associated with different specimen matrices (blood, urine, etc.) and as a positive control, a direct swab of the MS2-spiked specimen was obtained for each specimen type. All swabs were frozen at −80°C until nucleic acid was extracted. MS2 RNA was extracted using a QIAamp viral RNA minikit (Qiagen, Valencia, CA). MS2 was detected using quantitative reverse transcriptase PCR (RT-PCR) with previously described primers (21) and a QuantiTect Probe RT-PCR kit (Qiagen, Valencia, CA) on a SmartCycler system (Cepheid, Sunnyvale, CA), as described previously (15). Additionally, a positive control consisting of MS2 RNA and a negative control consisting of PCR water were included in each run. The cycle thresholds for all positive results were recorded.

RESULTS

Fluorescence transfer to the laboratory worker and environment during testing and test setup. Specimens in fluorescent containers were subjected to laboratory testing that encompassed a variety of instrumentation and specimen matrices (Table 1). As expected, the gloves of the technologists were fluorescent after test setup in 36 of 36 (100%) instances, since touching the specimen container (coated with a fluorescent marker) was a requirement for test setup (Table 2). The bare hands of technologists were fluorescent in 13 of 36 (36%) rounds of testing. The majority of the bare-hand contamination events occurred during the setup of 7 of 8 comprehensive metabolic panels on the Piccolo instrument (Table 2; Fig. 1). Fluorescence was noted on laboratory

TABLE 2 Assessment of fluorescence on laboratory workers and surfaces following laboratory testing[a]

Surface	No. of instances in which fluorescence was detected by:								No. of fluorescent samples/total no.	% of samples that were fluorescent
	Biofire				Piccolo (CMP)[b]	Gene Xpert (Flu/RSV)	Malaria antigen	Urinalysis		
	Biothreat	GI	BCID	RP						
Laboratory technologist										
Gloves	4	4	4	4	8	4	4	4	36/36	100
Hands	1	1	0	2	8	0	1	0	13/36	36
Laboratory coat cuffs	0	1	0	0	1	0	1	1	4/36	11
Wrists	0	0	0	0	0	0	0	0	0/36	0
Face	0	0	0	0	0	0	0	0	0/36	0
Laboratory surfaces										
Accessory equipment[c]	3	4	3	4	8	0	4	3	29/32	91
Test cartridge/device	0	0	2	2	7	1	2	0	14/32	44
Biosafety cabinet	1	2	0	2	0	1	0	2	8/36	22
Benchtop near instrument	0	0	0	0	0	0	0	0	0/36	0
Instrument (exterior)	0	0	0	0	0	0	0	0	0/28	0
Instrument (interior)	0	0	0	0	0	0	0	0	0/28	0
Hardware[d]	0	0	0	0	0	0	0	0	0/20	0

[a]GI, Gastrointestinal panel; BCID, blood culture identification panel; RP, respiratory panel; CMP, comprehensive metabolic panel; Flu/RSV, influenza/respiratory syncytial virus.
[b]CMP testing was performed 8 times, while all other tests were performed 4 times.
[c]Includes Biofire pouch station, pipettes, and reagent bottles used during test setup.
[d]Includes computer, mouse, and/or keyboard.

coat cuffs in 4 of 36 (11%) tests performed. Importantly, no instances of fluorescence were recorded on the wrists or face of the technologist.

Assessment of laboratory surfaces indicated that fluorescent contamination of the biosafety cabinet occurred in 8 of 36 (22%) rounds of testing (Table 2). No fluorescence was observed on the other laboratory surfaces evaluated, such as the interior or exterior surfaces of the instruments, associated hardware, and the floor and benchtop immediately surrounding the instrumentation. Contamination with the fluorescent marker was noted on accessory equipment, such as the FilmArray pouch station, pipettes, and

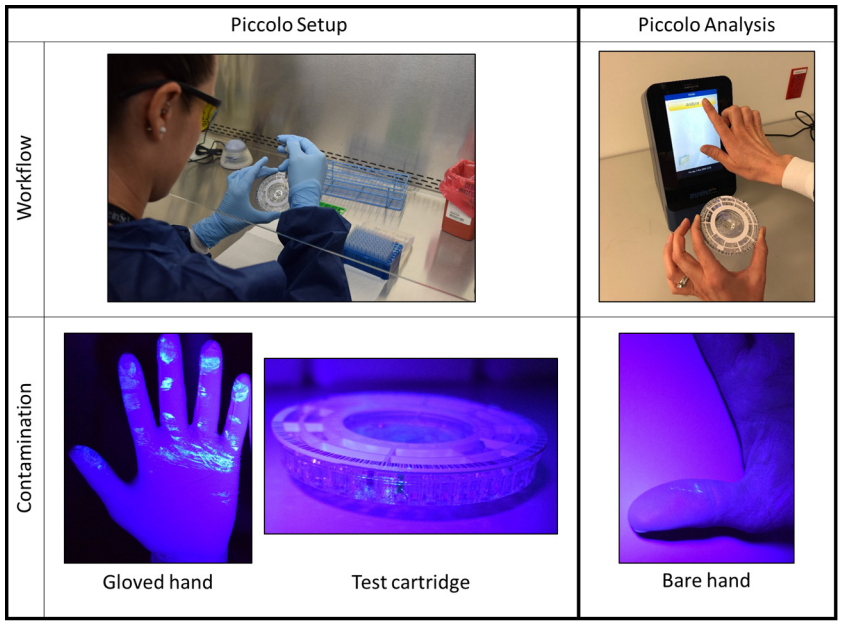

FIG 1 Workflow for the comprehensive metabolic panel test setup on the Piccolo instrument. The glove previously contaminated by the specimen container holds the test cartridge during the pipetting of plasma into the cartridge. The instrument features a touchscreen for instrument operation. Bare hands become contaminated as the test cartridge is being loaded into the instrument.

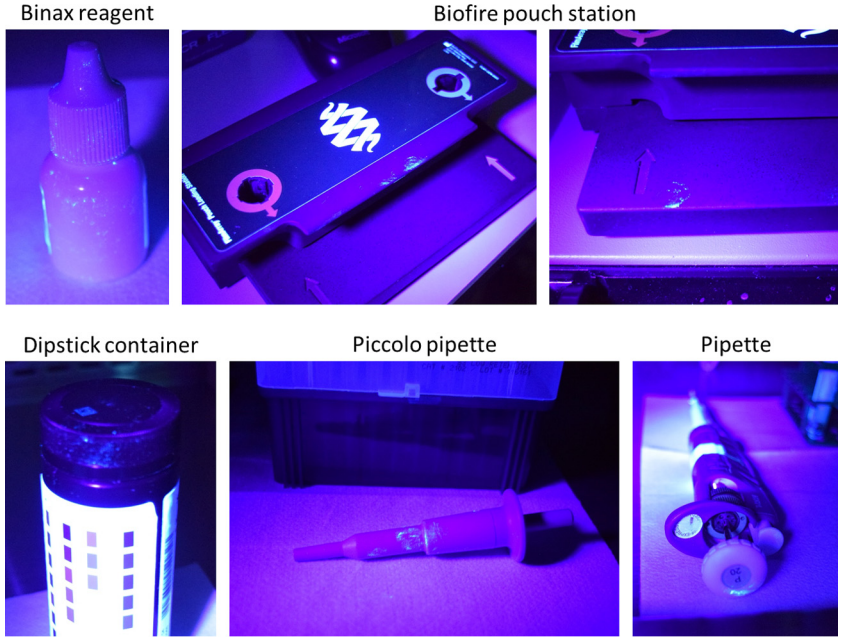

FIG 2 Examples of reagent bottles and accessory equipment contaminated during test setup.

reagent bottles used during test setup, in 29 of 32 (91%) tests (Table 2; Fig. 2). Fluorescence contamination was demonstrated on the pouch station in 14 of 16 (88%) rounds of testing and on the pipette used during CMP setup in 8 of 8 (100%) tests (Table 2). Reagent containers from the BinaxNOW malaria test and dipstick urinalysis exhibited fluorescence contamination in 4 of 4 and 3 of 4 tests, respectively. Fluorescence was observed on 14 of 32 (34%) test cartridges. Half of the contaminated test cartridges or devices (7 of 14) were Piccolo cartridges for CMP testing (Table 2; Fig. 1).

Frequency of MS2 contamination events during test setup. Every specimen used during testing was spiked with the noninfectious bacteriophage MS2 to model the potential for virus transmission during testing of high-titer infectious specimens. All laboratory surfaces tested at baseline were negative for the presence of the MS2 virus, and MS2 was detected in all positive-control samples obtained directly from spiked specimens. Surfaces swabbed after test setup were positive for MS2 in 3 of 286 (1%) samples obtained (Table 3). A sample from the biosafety cabinet was positive after setup of the FilmArray biothreat panel, and MS2 was detected on the accessory pouch station and test cartridge after setup of the FilmArray blood culture identification panel. No MS2 was detected on the laboratory workers, instrumentation, and hardware, or on surrounding laboratory surfaces (Table 3).

To obviate the high frequency of fluorescence contamination events on the bare hands of the laboratory worker that occurred during transport of the test cartridge from the BSC to the instrument in the initial round of CMP testing on the Piccolo instrument, a modification of the protocol that incorporated a double set of the same type of gloves was instituted for a second round of testing. The outer pair of gloves was removed after addition of the specimen to the test cartridge and prior to the loading of the cartridge onto the instrument. When this procedure was used, the interior pair of gloves was fluorescent in 4 of 8 (50%) rounds of testing, while no fluorescence was observed on bare hands (Table 4). Fluorescence was observed on the wrists of a technologist in 1 of 8 (13%) test setups using double gloves. All posttest swabs of the laboratory worker and surfaces were negative for MS2 (Table 4).

DISCUSSION

Low-level contamination of automated laboratory equipment has been demonstrated previously (13). However, patients with EVD and other highly transmissible

TABLE 3 Frequency of contamination of laboratory workers and surfaces with MS2 following laboratory testing

Surface	No. of instances in which MS2 was detected/total	Test[a] (instrument) associated with contamination event
Technologist		
Bare hands	0/32	
Wrists	0/32	
Face	0/32	
Laboratory surfaces		
Biosafety cabinet	1/32	FilmArray Biothreat-E (BioFire)
Floor/bench near instrument	0/32	
Instrumentation and equipment		
Accessory equipment	1/24	FilmArray BCID (BioFire)
Test cartridge/device	1/28	FilmArray BCID (BioFire)
Hardware (computer, mouse, keyboard)	0/20	
Instrument (exterior)	0/24	
Instrument (interior)	0/24	
Total	3/286	

[a]BCID, blood culture identification panel.

diseases are often managed in specialized or separate patient care units with dedicated testing facilities that use near-patient testing rather than automated central laboratory instrumentation (10, 11, 20, 22, 23). A recent survey of designated EVD treatment centers indicated that 94% intend to provide clinical laboratory testing for patient care (23). Indeed, access to laboratory testing is a critical factor in facilitating the proper management of patients with EVD (24). In addition, it may be desirable to perform testing on these specimens outside the central laboratory facility, since a spill could result in a shutdown of routine testing for decontamination, which could have a negative impact on all of the patients in the health care facility. Thus, the goal of this study was to investigate the risks of testing high-titer infectious specimens using sample-to-answer instrumentation and manual testing methods.

Our findings highlight potential contamination risk points when technologists perform laboratory tests using sample-to-answer benchtop instruments and manual testing methods while wearing standard PPE. The instrumentation and test menu used in this study were designed to mirror those used for persons under investigation for EVD but would be broadly applicable to the clinical workup of a febrile returning traveler (25). The use of a fluorescent powder to measure transmission dynamics permitted the monitoring of surfaces for areas at high risk of contamination without affecting specimen processing. The frequent contamination of gloves worn as part of standard PPE and of testing accessories

TABLE 4 Frequency of contamination events after the use of double gloves for Piccolo analysis

Surface	No. (%) of events	
	Fluorescence transfer	MS2 detection
Laboratory technologist		
Gloved hands (exterior pair)	8/8 (100)	0/8 (0)
Gloved hands (interior pair)	4/8 (50)	0/8 (0)
Bare hands	0/8 (0)	0/8 (0)
Wrists	1/8 (13)	0/8 (0)
Laboratory surfaces		
Cartridge	6/8 (75)	0/8 (0)
Biosafety cabinet	0/8 (0)	0/8 (0)
Benchtop near instrument	0/8 (0)	0/8 (0)
Instrument (exterior)	0/8 (0)	0/8 (0)
Instrument (interior)	0/8 (0)	0/8 (0)

highlights the importance of thorough decontamination protocols that include cleaning auxiliary items used during test setup. In standard laboratory protocols, these items might be overlooked for cleaning each time testing is performed.

Perhaps more concerning was the contamination of bare hands with fluorescent markers after the setup of some of the testing in this study. Most of the contamination events occurred following glove removal during the transport of the test cartridge out of the BSC to the Piccolo instrument. While the use of double gloves during the Piccolo procedure ameliorated the fluorescence contamination of bare hands, the removal of the gloves resulted in an instance of contamination of the wrists of the technologist. The additional doffing step led to more chances for contamination. Indeed, self-contamination and difficulty in doffing multiple pairs of gloves have been reported previously (15, 26). A recent evaluation of protocol deviations during the donning and doffing of PPE found that contamination events occurred with the use of both standard and enhanced EVD PPE (15). However, the median number of contamination events was higher with EVD PPE, and self-contamination was a common occurrence during the removal of the shoe covers required with EVD PPE. Because contact with patient specimens poses a lower risk than contact with an actual EVD patient, it is likely that the use of enhanced EVD PPE represents an unnecessary burden to laboratory workers and may increase self-contamination episodes. In addition, standard PPE is more likely to be utilized in routine clinical practice. Thus, we evaluated the use of standard PPE in this study. It should be noted that regardless of the use of standard PPE with a single pair or double pairs of gloves, contamination was not perpetuated throughout the testing process to downstream surfaces, such as the instruments or associated hardware.

While the fluorescent marker is useful for approximating transmission that can occur secondary to gross contamination of laboratory specimens, the MS2 contained in the specimen may be a more accurate predictor of viral transmission during laboratory testing, and MS2 has been used in a number of studies previously as a surrogate for viral transmission dynamics (15, 17, 18). Detection of this marker was uncommon in our study. While it is possible that some contaminated surfaces were not sampled during our investigation, three positive samples were detected, all of which were from the setup of FilmArray assays. The workflow for FilmArray samples includes the use of a pouch station and syringes for rehydration of reagents and the addition of the test specimen to the test cartridge (27, 28). It is likely that contamination with microdroplets of the specimen that were not visible to the technologist occurred during this process. In four instances of test setup on BioFire instrumentation, visible drops were noted during the addition of the specimen to the cartridge. All occurrences of visible contamination were immediately cleaned with an ethanol wipe prior to MS2 sampling, and MS2 sampling was negative after each instance. The infectious dose for Ebola virus is estimated to be approximately 10 viral particles, while concentrations in blood specimens may be as high as 10^8 PFU/ml (20). Thus, less than a nanoliter of blood could contain enough viral particles to transmit infection. The limit of detection of the quantitative MS2 PCR was about 1,000 viral particles/ml, so a positive result suggests a potentially infectious event, although infectivity and/or viral viability was not assessed in this study. These results further highlight the need to immediately clean any visible drops that occur during test setup and to include accessories such as the pouch station in regular decontamination procedures.

There is a dearth of published evidence on mitigating the risk of testing highly infectious specimens in a clinical laboratory. Identification of surfaces and processes commonly contaminated during testing will facilitate an informed risk assessment. A study by Wang et al. analyzed the presence of human rhinovirus (HRV) nucleic acid on laboratory surfaces after the processing of HRV specimens and found that the biosafety cabinet, gloves, and laboratory coat cuffs were the most frequently contaminated laboratory surfaces (29), results consistent with those of our study. Wang et al. also noted frequent contamination of the centrifuge used for sample processing. While no centrifuge was used to process samples in our study, this result highlights another possible high-risk location for contamination and may represent a potential area for further investigation.

Bryan et al. identified high-risk areas of automated laboratory equipment that include parts where samples are heavily manipulated, such as the decapper and adjacent exposed areas (13). This is supported by the results of our study, in which the few instances of MS2 detection occurred after setup of the tests that required the most manipulation with accessory equipment (the BioFire pouch station). The study by Bryan et al. underscores the frequency with which laboratory workers come into contact with infectious specimens with high viral titers (13). In spite of this, LAIs are infrequent, further highlighting the role of universal precautions in preventing exposures and infection.

The strengths of this study include the evaluation of a variety of specimen matrices, container types, and instrument platforms that would be utilized for the diagnosis and management of EVD and other infectious diseases. Additionally, contamination was evaluated using multiple methods. The use of MS2, a model virus that would not be present in routine human clinical specimens, permitted specific monitoring of contamination events that occurred in our study and precluded the detection of low-level background contamination that may occur with other, more common viral pathogens (13).

A potential limitation of our study is the fact that laboratory testing was performed by highly experienced and skilled medical technologists. This feature may not be reflective of a routine testing scenario, where some of the testing may be performed by point-of care and/or less-experienced staff with different risk factors for self- and instrument contamination. Another limitation of our study is that while molecular detection of MS2 nucleic acid was used as a surrogate for viral transmission, our study design does not distinguish between the detection of infectious and noninfectious viral particles. Finally, while MS2 is a single-stranded small RNA virus that has been utilized previously as a nonpathogenic surrogate for the highly pathogenic Ebola virus, the actual dynamics using Ebola virus may differ from our findings (15, 17, 18).

While clinical laboratories routinely test high numbers of samples each day, many of which may contain a blood-borne pathogen, LAIs are infrequent. The data in our study are tantalizing and support the idea that the use of standard PPE may be adequate for protecting the laboratory worker against samples containing pathogens that are infective via direct contamination of skin and/or mucous membranes. However, as a result of the limitations of our study, additional investigations are necessary to further address the frequency of contamination events using different laboratory workflows, with additional types of instrumentation, and involving laboratory workers with a wide spectrum of educational and skill levels.

Fear of testing potentially high risk specimens may lead to delays in diagnosis and life-saving treatment, as it did recently when malaria testing was delayed for a person under investigation for EVD (30). The findings from our study suggest that standard PPE is sufficient to protect the laboratory worker from self-contamination with infectious particles, as long as adherence to the use of standard precautions and PPE is maintained. Our investigation suggests that rigorous decontamination protocols are needed for accessory equipment required for test setup, and these data may inform evidence-based guidelines for laboratories that perform testing on samples containing highly infectious pathogens. In conclusion, while laboratory surfaces may become contaminated with blood-borne viruses during routine clinical laboratory testing, adherence to the use of standard PPE and universal precautions protected the laboratory worker and instrumentation.

SUPPLEMENTAL MATERIAL

Supplemental material for this article may be found at https://doi.org/10.1128/JCM.00225-18.

SUPPLEMENTAL FILE 1, PDF file, 0.1 MB.

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