devices for killing of methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococcus (VRE), or *Clostridium difficile* spores.[1] The caveat of our findings is that the 2 devices utilized an equivalent light source (low-pressure mercury gas bulbs) and power supply, and they delivered an equivalent radiant dose. However, not all UV devices deliver similar wavelengths of light or the same strength of radiant dose.

UV radiation has peak germicidal effectiveness in the wavelength range from 240 to 280 nm.[2–5] Most UV devices use low-pressure mercury gas bulbs that primarily emit UV-C at 254 nm, but recently pulsed xenon flash bulbs have also been incorporated into disinfection systems. Xenon gas bulbs produce a broad spectrum of radiation that encompasses the UV (100–280 nm) and visible (380–700 nm) spectra.[6–8] In a subsequent study, we evaluated the efficacy of a pulsed-xenon device for reducing hospital-acquired pathogens on surfaces in hospital rooms.[9] While the pulsed-xenon device did significantly reduce recovery of *C. difficile*, VRE, and MRSA from frequently touched surfaces, it was significantly less effective than a low-pressure mercury device in reducing pathogen recovery on glass slides with equivalent exposure time, inoculum, organic load, distance from device, etc.[9] These findings suggest that not all UV devices are equally effective.

Clearly, there is a need for direct comparisons of devices, but the cornerstone to comparing UV-C devices is standardized methodology. We recently demonstrated that variation in test methods could significantly impact the performance of UV-C devices.[10] Factors such as increasing the surface area of inoculum spread, orientation of the carriers, and changes in the formulation of organic load greatly impacted the level of killing achieved (in some cases by >2 $\log_{10}$ CFU, or 99%).[10] These findings have significant implications for the consumers of UV technologies. Without uniform testing methods, there is no baseline for the interpretation of percent or log reduction of pathogens. These examples reiterate the need for a universal set of testing guidelines to be developed by the EPA.

The efficacy of UV-C irradiation for killing pathogens is not in question, nor is the importance of testing these types of technology for reducing pathogens on hospital surfaces. However, due to the speed with which new UV-C devices are entering the market, peer-reviewed studies and standardized guidelines have fallen behind. We agree with Cowan that there is a need for uniform standards for testing the efficacy of UV-C devices. This deficiency should be addressed by regulatory agencies and the scientific community. Finally, there is a need for high-quality studies to determine whether use of UV-C devices reduces healthcare-associated infections. Currently, no published randomized trials have demonstrated that UV-C disinfection is beneficial as an adjunct to standard cleaning and disinfection.

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A Validation Protocol: Assessing the Accuracy of Hand Hygiene Monitoring Technology

To the Editor—A number of hand hygiene monitoring technology (HHMT) options have become commercially

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available with varying degrees of capability, reflecting a growing market without clear evidence of the impact these systems have on hand hygiene (HH). A systematic review including 42 articles mentioning automated measurement found that fewer than 20% of studies identified calculations for accuracy; among them, the level of rigor was highly variable.[1] Manufacturers' accuracy assessments are often inadequate and vary with physical location. Given increasing pressure from accreditation bodies to measure HH,[2] a methodology is needed to assess HHMT efficacy in a standardized way, allowing for comparison both with the gold standard, direct observation, and with each other. Validation of HHMT must be tested in actual clinical practice to avoid overestimation or underestimation of accuracy.[3] We propose a rigorous method for validation of HHMT in a medical setting.

HH compliance can be measured in a number of ways. A patient-encounter–based approach measures compliance from just before room entry to just after room exit. This approach requires the observation of the entire patient encounter, which may prove valuable for detection of healthcare worker (HCW) patterns. Alternatively, an independent-event approach treats room entry and exit as separate events, maximizing observer efforts. For HHMT validation, we recommend an extremely independent-event–based approach: each room entry, exit, soap dispenser actuation, and alcohol-based hand rub (ABHR) dispenser actuation should be treated as independent events. This method allows for real-time identification of inaccuracies.

HHMT requires significant investment of resources in proper calibration. Many systems use room "zones" that must be properly calibrated to capture room entries and exits while distinguishing a person walking in a hallway from room activity. In the most sophisticated systems, the interaction between an individual's identification device and the entry/exit sensor adds additional complexity. Once calibration and structural assessment are deemed acceptable, the basic functionality of the system should be tested using a planned path.

A planned path is a route created throughout a clinical area that allows for systematic validation of HHMT through purposeful activation of every device. In this approach, a planned path is developed for each area, accounting for all soap dispensers, ABHR dispensers, and monitored rooms (Figure 1a). An investigator follows the planned path, activating each device while documenting deviations from the path. Detailed notes are essential for comparison of performed activity with system data. For example, if a room is skipped, it should be noted. Thus, investigators must consider each device activation as a unique encounter.

After executing the planned path, data are pulled from the HHMT in the most raw format available. Devices often have a unique identifier, allowing for the association of each event with a specific device or location. Each device encounter recorded by direct observation is compared to data recorded by the system. This approach is valuable for both aggregate and individualized HHMT because it accurately quantifies both activity and attributes of that activity for comparison with performed behavior. For example, a system capable of monitoring individual behavior is assessed for its ability to both document room activity and attribute that activity to the correct individual. There are likely to be inaccuracies identified that require repositioning of devices. After these adjustments, devices can be assessed again using the planned path.

While the planned path quantifies a system's accuracy in detecting purposeful behavior, behavioral validation quantifies a system's ability to accurately detect real-world behaviors, which can be chaotic and unpredictable (Figure 1b). Behavioral validation requires trained observers to document all room activity, dispenser actuations, and, for individualized systems, the individual performing each behavior. Observers document unusual behaviors (eg, a patient requiring immediate resuscitative measures) or those that pose difficulty for the technology. For instance, many HHMT observers struggle to accurately distinguish multiple, simultaneous room entries/exits. Thus, when groups enter a patient room, it should be documented.

Once investigators have reached the behavioral validation step of this protocol, basic functionality of the system has been deemed acceptable through the planned path. This allows flexibility in observing natural behavior, with the goal of observing a representative sample of HCWs, locations, and time of day. However, this step should be purposefully planned and systematically executed, ensuring standardization of observations and documentation. Each device activation is again considered a unique encounter with observed behaviors compared to system data.

Accuracy of HHMT can be calculated using fundamental epidemiologic approaches. Sensitivity of HHMT is calculated using direct observation as the accurate data source. This allows identification of true-positive events (those both captured through direct observation and counted by HHMT), false-positive events (events that are not observed but are counted by HHMT), and false-negative events (those which are observed but are not captured by HHMT). Because it would not be feasible to quantify the number of nonevents (ie, how many times a person did not walk into a room or did not perform HH), true-negative events are not captured in this approach. Sensitivity and positive predictive value are then calculated as the measures of system accuracy.

A standardized approach to validating HHMT is the next logical step to establishing standards that allow for comparison of available technologies by the healthcare industry. We recommend the following steps: (1) manufacturers should share the burden of performing validation steps with hospitals; (2) hospitals should require transparency of any accuracy data provided by manufacturers; and (3) either the hospital or a third party should be actively involved in assessing accuracy of HHMT in each physical location where it is installed. The protocol described above provides a method for moving toward these recommendations.

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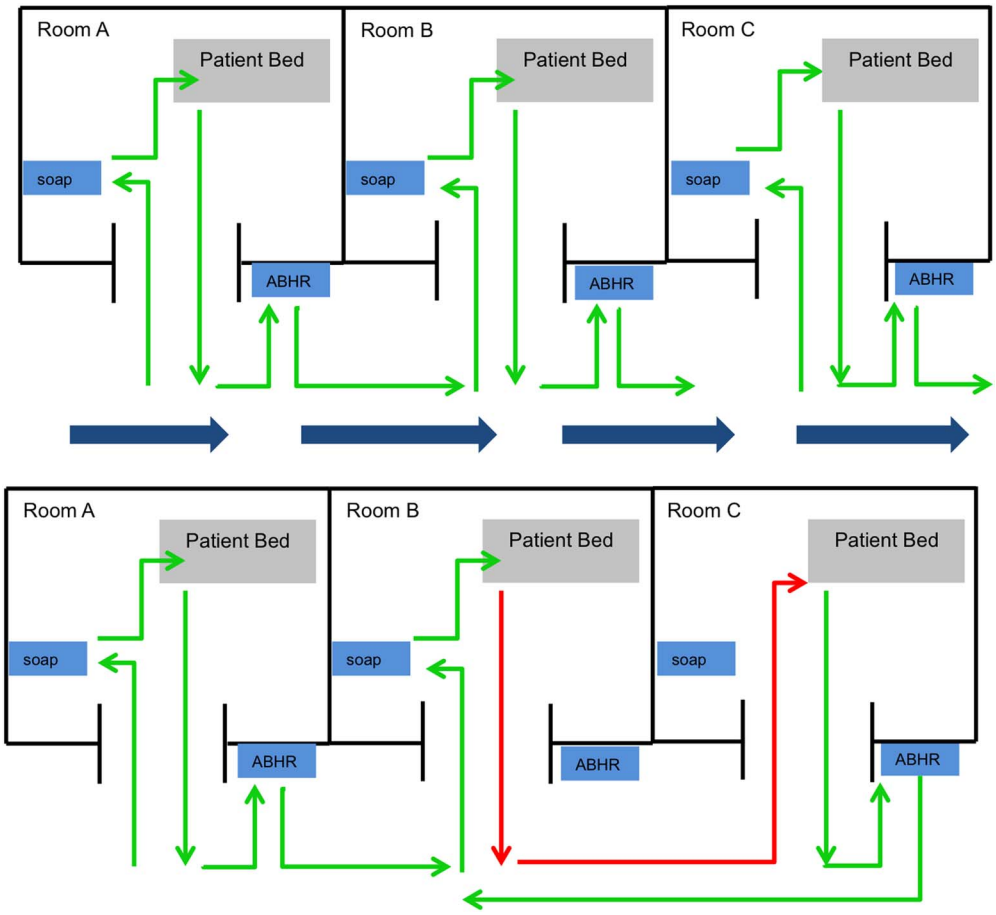

FIGURE 1. Comparison of a planned path to natural healthcare provider behavior.

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