CLEAR: A Novel Approach to Ultrasound Equipment Homeostasis

Michael I. Prats, MD, Bret P. Nelson, MD, Delia L. Gold, MD, Lauren D. Branditz, MD, Creagh T. Boulger, MD, David P. Bahner, MD

Protocols for the sanitation and maintenance of point-of-care ultrasound (US) equipment are lacking. This study introduces the CLEAR protocol (clean, locate, energize, augment supplies, and remove patient identifiers) as a tool to improve the readiness of US equipment, termed US equipment homeostasis. The state of US equipment homeostasis in the emergency department of a single academic center was investigated before and after implementing this protocol, with an improvement in outcomes. These findings demonstrate that the CLEAR protocol can improve US homeostasis. CLEAR can function as a teaching tool to promote homeostasis as well as a checklist to assess compliance.

Key Words—education; equipment maintenance; point-of-care ultrasound; safety

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Address correspondence to Michael I. Prats, MD, Department of Emergency Medicine, The Ohio State University Wexner Medical Center, 757 Prior Hall, 376 W 10th Ave, Columbus, OH 43210 USA.

E-mail: michael.prats@osumc.edu

Abbreviations

ACEP, American College of Emergency of Physicians; AIUM, American Institute of Ultrasound in Medicine; CLEAR, clean, locate, energize, augment supplies, and remove patient identifiers; ED, emergency department; EM, emergency medicine; US, ultrasound

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Point-of-care ultrasound (US) has become commonplace in many emergency departments (EDs) and clinical care settings. This situation is partially due to an increased emphasis on point-of-care US training, which is now a mandatory component of emergency medicine (EM) training in North America.[1] With improved training, point-of-care US has been shown to reduce health care costs and imaging requiring radiation, as well as improve throughput and patient satisfaction in the ED.[2] Although point-of-care US has improved the quality of patient care and outcomes, the potential risks associated with the more heterogeneous and widespread use of US equipment in the ED and other point-of-care environments may not be fully understood.[1,2] In comprehensive US examinations, a single sonographer will often use the same equipment for a given work period, during which he or she is responsible for and directly benefits from the cleanliness and function of the equipment. In contrast, point-of-care US practitioners are simultaneously clinicians, generally using the equipment for a single examination before returning to other clinical duties. The same equipment is then shared by multiple users over a short period. This system introduces the potential for a lack of responsibility for the equipment and therefore increases the risk of poor equipment maintenance.

Multiple studies have demonstrated contamination of US equipment, including transducers and conductive gel, with potentially infectious organisms.[3–7] There is considerable variability in the disinfection protocols across institutions, especially for point-of-care equipment.[8] Multiple national and international organizations have

guidelines that apply to the maintenance and cleaning process of US equipment.[9–16] The American Institute of Ultrasound in Medicine (AIUM), the American College of Emergency of Physicians (ACEP), and the European Society of Radiology Ultrasound Working Group specifically address US equipment cleanliness, safety, and maintenance.[9–11] The United States Food and Drug Administration and Centers for Disease Control and Prevention also provide guidelines for medical equipment disinfection.[12,13] We have termed this combination of necessary operations for US equipment homeostasis, as it reflects maintenance of the equipment in a perpetual state of readiness to ensure proper functioning for the next use. According to the ACEP, ED US equipment should undergo regular transducer cleaning and care, stocking of supplies, and maintenance by an engineering team. Similarly, the AIUM guidelines provide specific tasks related to US equipment safety and cleanliness for users, engineering staff, and environmental services. The Joint Commission also offers general guidelines for instrument reprocessing, which apply to point-of-care US equipment.[14,15] Despite these various recommendations, it is unclear whether many EDs have developed standardized protocols based on these guidelines for the cleanliness, safety, and maintenance of US equipment and have determined the ideal personnel responsible for this upkeep. The absence of protocols can result in noncompliance and can be detrimental to patient safety and the ED work flow.[17–19]

At our institutions, US is used in the ED for a wide array of clinical scenarios, including educational, diagnostic, and procedural guidance. The CLEAR protocol was developed to improve US equipment homeostasis within our ED and provide a practical approach for the implementation of the guidelines provided by the ACEP and AIUM. CLEAR stands for clean equipment, locate equipment, energize, augment supplies, and remove patient identifiers. Completing the CLEAR protocol ensures that US equipment is properly disinfected, easy to find, connected to a power source for battery charging, and stocked with appropriate supplies and does not have identifiable patient information from a prior study. Overall, this protocol results in equipment that is adequately prepared for use by the next provider. The primary objective of this study was to introduce the CLEAR protocol as one way to standardize guidelines for US equipment cleanliness, safety, and maintenance. In addition, we performed a pilot analysis of US homeostasis at a single institution before and after implementing the CLEAR protocol.

Materials and Methods

CLEAR Protocol

The CLEAR protocol was developed by a panel of point-of-care US experts to standardize the work flow of preparing US equipment for subsequent users in the ED. CLEAR can serve as both a mnemonic and a checklist: (1) clean equipment; (2) locate equipment; (3) energize the US machine by connecting to an electricity source to charge the battery; (4) augment supplies; and (5) remove patient identifiers (Table 1). Each feature of the CLEAR model plays an important role in sustaining the ACEP and AIUM guidelines for US cleanliness, safety, and maintenance.

Data Collection

To determine whether the CLEAR protocol had the potential to improve US equipment homeostasis, prospective observational data were collected in 2 phases at a single institution: before and after educating ED faculty and residents on the CLEAR protocol. All data were collected over a 4-week period from January 3, 2017, to January 31, 2017, in 2 EDs at a single institution, one an academic quaternary referral center and the other a university-affiliated community hospital.

Baseline data were collected for a 2-week period before introducing the CLEAR model. Two EM attending physicians (M.I.P. and C.T.B.) collected observational data before their clinical or educational shifts in either ED during the study period. Data collected were as follows: date and time of the

Table 1. CLEAR Protocol for Ultrasound Homeostasis

Feature	Question Asked
Clean equipment	Are the transducers and machines disinfected?
Locate equipment	Are the US machines in their appropriate location?
Energize	Are the machines plugged into an electrical source?
Augment supplies	Are the US gel and other supplies restocked for the next user?
Remove patient identifiers	Are the patient identifiers cleared from the screen?

encounter, specific machine assessed, whether the US machine and transducers were found clean, whether the US machine was in its specified location, whether the US machine was actively charging, whether there was adequate US gel for a subsequent US examination, and whether the previous patient's data had been removed from the screen by ending the examination (Table 1). These data were documented for each US machine encountered. We defined a US encounter to be "CLEAR" only if all of the criteria were met.

After the period of data collection, ED faculty and staff were educated on how to implement the CLEAR model. The CLEAR protocol was presented to the department of EM residents and faculty who were present on a single morning grand rounds conference. The presentation was approximately 5 minutes in duration and explained the specifics of each of the 5 components of US equipment homeostasis. This presentation was followed by an e-mail to all ED faculty and residents relaying this method of remembering the components of US equipment homeostasis. There was no mention made of the study or that data would be collected. After this education, data were collected for an additional 2 weeks.

Statistical Analysis

Microsoft Excel (Microsoft Corporation, Redmond, WA) and VassarStats (Vassar College, Poughkeepsie, NY) were used for the statistical analysis. Categorical data were transformed into binary dummy variables. Data were expressed as proportions.

Results

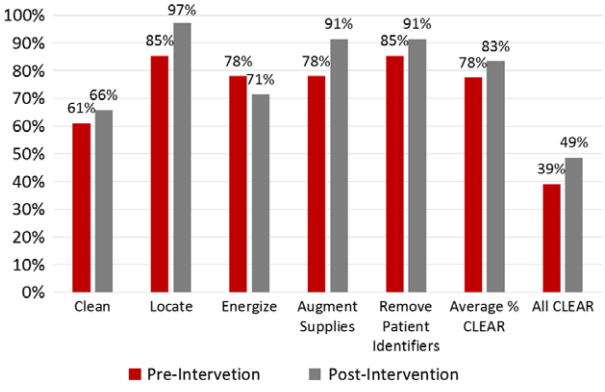
There were 76 US equipment encounters assessed. Of these encounters, 84.2% occurred at the quaternary care center ED, and 15.8% occurred at the community hospital ED. In addition, 40.8% of the CLEAR encounters were recorded during morning times, whereas 59.2% were recorded during afternoon or evening hours. There were significantly more morning encounters in the baseline encounters compared to the postintervention encounters (53.7% versus 25.7%; $P = .01$).

During the initial 2-week period before implementing the CLEAR method, observational baseline data were collected on 41 US machine encounters. The average proportion of CLEAR criterion met across all encounters was 78%. Only 39% of encounters fulfilled all criteria and were considered CLEAR. After the CLEAR education intervention, observational data were collected on an additional 35 US machine encounters. The average proportion of CLEAR criteria met across all encounters improved to 83%. The proportion of encounters that met all of the CLEAR criteria also increased to 49%. Figure 1 compares the baseline and postintervention assessments of each of the CLEAR protocol criteria.

Discussion

Machine homeostasis should be a core component of point-of-care US programs. Prior studies have focused primarily on a single component of homeostasis: namely, the cleanliness of the equipment as it pertains to infectious risk.[3–7,18–21] It is our belief that all 5 components are integral to the ongoing functionality of a point-of-care US program. As the field of point-of-care US has grown, there are many aspects that compromise the homeostasis of the equipment. First, there are multiple US machines being used in a single clinical environment by multiple operators with varying levels of experience. Furthermore, in contrast

Figure 1. Comparison of baseline and postintervention US equipment homeostasis. The figure illustrates the proportion of encounters in which the presence of each of the 5 components of the CLEAR protocol was recorded both during the baseline data collection and after the intervention. The average percentage of CLEAR reflects the combined mean of all encounters for all 5 components. The percentage of All CLEAR represents the number of encounters meeting all 5 criteria of the total number of encounters.



to many sonographer-performed examinations, the equipment goes to the bedside of the patient. As such, there are substantial challenges regarding maintaining cleanliness, determining the location of the machine, and monitoring the battery life. With multiple operators using any given US machine, there is a need to keep the equipment in good working condition. Key to the concept of US machine homeostasis is remembering that the last user of the US machine is "connected" to the next user of the machine. Thus, if the last operator neglected to plug in the machine, when the next operator requires the US for a critically ill patient, the machine might not be ready for use. A lack of US equipment homeostasis can lead to delays in care and potentially harm patients. This situation can occur because of the inability to perform a timely examination or by transmitted infection. For this reason, US equipment maintenance has become a focus of governing bodies such as the ACEP, AIUM, and Joint Commission. It is conceivable that the maintenance and sanitation of US equipment may be linked to health care reimbursement. Regardless of the incentive, the point-of-care US community has the responsibility to implement standards and regulations to uphold patient safety.

The purpose of recognizing and codifying US equipment homeostasis is to promote a concept that can be incorporated into the US community. In the many clinical settings where point-of-care US examinations are performed, there are multiple nontraditional imaging specialists using the US devices. We sought to develop a mnemonic that captures the essential components of equipment homeostasis such that it can be easily remembered and used as a checklist to improve compliance. After our simple intervention of introducing the concept and the CLEAR acronym, there was overall improvement in US homeostasis at our institution.

All of the individual components of CLEAR showed improvement after the intervention, with the exception of "energize." It is unclear why this particular factor was unaffected while the others showed improvement. Perhaps further attention to previously ignored components led to neglect of the more basic principles of homeostasis. The "clean" aspect of homeostasis was found to have the lowest compliance both before and after the intervention. In a busy ED, where the appropriate type of cleaning supplies may not always be at hand, it is easy to forget to sanitize the equipment thoroughly; however, this lack of sanitization is unacceptable. Not only can an inappropriately cleaned machine be a vector for disease, but it also may affect patients' perceptions of professionalism and sanitation. Several protocols for machine sanitation using various sterilizing chemicals have been reported.[3,20,22,23] It is key to recognize that alcohol can lead to transducer damage.[24] A solution to poor compliance in this component of homeostasis is to keep cleaning supplies well stocked and readily available, either on the machine itself or in a consistent and predetermined space near the machine. This method could also be used to ensure that US machines are well stocked with gel and other equipment, such as transducer covers and peripheral intravenous access equipment. Additionally, assigning a specific person the duty of assessing the machines can help combat the lack of individual ownership as a factor. A senior resident, ED technician, or zone nurse, for example, could be tasked with "CLEAR-ing" the machines in his or her care area at the start of each shift as part of the expected duties.

It can be dangerous for patients if health care providers cannot locate the US machine when an emergent examination is indicated. Fortunately, our study showed this area ("location") to have the highest degree of compliance. There are many ways in which to improve success in locating the machines. The most important component is to have designated areas for each piece of equipment. Designated space can be scarce in a busy ED; therefore, clear signage noting that the area is meant for US machine storage is critical. The space should have easy access to a power outlet and germicidal wipes if they are not stored on the machine itself. The machines can be labeled with a map of the department, including the proper location for that machine (Figure 2). Thus, users have a visual cue leading them to the proper placement for each US machine by simply matching the sign on the machine with the sign on the wall. This analog solution is a good first step, but many more robust solutions exist. Several vendors offer real-time asset tracking based on radiofrequency identification, Bluetooth, or triangulation of Wi-Fi signals to and from networked devices. Depending on the specific solution, users could track a specific tagged device based on a smartphone application, or by

viewing a map of the care area with assets such as the US machines displayed in real time. Considering that many hospital systems already have robust real-time asset tracking for infusion pumps, stretchers, electrocardiogram machines, and even patients, it may not be difficult to add US equipment to the list of tagged items. Asset tracking may become even more necessary with the growing popularity of handheld and mobile device–based US equipment.

The goal for all US equipment should be 100% homeostasis at all times. Even in a busy center with multiple users and multiple machines, we think that this goal is a reasonable expectation. In our study, even after the intervention, less than 50% of the encounters had all aspects of the CLEAR protocol completed. This result was likely due to the lack of education on the importance of the topic and the minimal educational intervention that was performed. Since faculty and residents were blinded to the study during data collection, no ongoing reminders or educational sessions were explicitly provided after the initial brief intervention. None of the 5 components take particular skill or time to complete. Therefore, the discrepancy between the goal and the observed compliance was likely due to a lack of effort or a failure to recognize the components necessary for complete homeostasis. We think that the CLEAR mnemonic is a method that can assist with branding the process of US homeostasis. For a program to maintain a culture of homeostasis, there must be ongoing reminders and emphasis on the importance of this concept. These steps can be done through regular communications or through postings on or near the US equipment. For these interventions, the CLEAR protocol can be used as a checklist to remind users to assess all of the components after each examination. Quality improvement operations can also use the CLEAR protocol to assess which aspects have the lowest compliance to direct educational initiatives appropriately. Future innovations might include tracking individual users of the equipment so that appropriate compliance can be rewarded and noncompliance be addressed with further education.

Figure 2. Signage for US machines and their respective "docking stations." Each care area can be clearly labeled and color coded for visual redundancy. The map on the machine instructs users to return the device to the proper location within the ED, and the machine and docking station signs match. The laminated signage on the wall is quite visible and marks the spot for US machine use and not for other equipment.

There were several limitations to this study. It included a convenience sample of data at a single institution with a limited number of total encounters. There was fairly low compliance before the intervention. In locations where compliance is close to optimal, the users may benefit from more targeted interventions instead of overall education about US homeostasis. Although most components of the CLEAR protocol did show an improvement in the percentage of compliance, it was not possible to determine the statistical significance of these differences. This limitation was due to the fact that multiple investigators were evaluating different unique machines that could not be differentiated during the data analysis. We also did not assess the inter-rater reliability of the homeostasis assessments. The simplicity of the CLEAR checklist and the prespecified requirements for each component were thought to be accurately reproducible between the 2 investigators who assessed the equipment. Last, these data were limited in their ability to determine the lasting effect of a single short intervention. It is possible that US homeostasis declined after the 2-week period of data collection. As discussed, any program interested in improving US homeostasis will need ongoing educational and instructive interventions for continual maintenance of equipment homeostasis.

As the point-of-care US community grows, it is up to leaders in the field to solve common problems. We believe the concept of machine homeostasis and the CLEAR acronym are helpful tools for addressing

infection control, machine maintenance, and overall readiness for the next user. Problems cannot be solved until they are identified, codified, and logistically operationalized toward a working solution. Additional challenges include the increase in point-of-care US users among nonphysicians such as nurses, advanced practice providers, and EM services. The growth of transesophageal echocardiography in the ED will require further education regarding the high-level disinfection and upkeep of these devices.[25] It is important for the principles of homeostasis to be carried forward wherever point-of-care US is taught.

More research and innovation will be needed to address these challenges as point-of-care US continues to expand. We plan to further investigate the CLEAR concept in a multicenter study of EDs from a variety of geographic locations and practice environments. We will assess the impact of simple signage on the machines and their locations in addition to establishing US homeostasis as a specific job role at least once per shift. Once this process is operationalized across a variety of care environments, we can assess any impact on patient-centered outcomes.

This study was meant to serve as an introduction of the concept of US equipment homeostasis and provide a helpful list of the key components. The CLEAR mnemonic (clean, locate, energize, augment supplies, and remove patient identifiers) is a simple protocol that can be used to promote this concept to users of point-of-care US and also functions as a checklist to assist with compliance. Our study demonstrates that merely introducing this concept can improve short-term homeostasis of US equipment in the ED.

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