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Effect of Interventional Program on the Utilization of PACS in Point-of-Care Ultrasound

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Abstract While the implementation of Picture Archiving and Communication Systems (PACS) has revolutionized the field of radiology, there has been considerably less utilization of PACS by emergency physicians with point-of-care ultrasound. Benefits of PACS archival of images include improved quality assurance, preservation of image quality, and accessibility of images. Our objective was to determine if a simple interventional program would influence the utilization of PACS in point-of-care ultrasound. A before-after study was conducted in an urban, academic emergency department. Data was collected during a 4-week baseline period, a 12-week intervention period, and a 12-week post-intervention period. The percentage of ultrasound studies archived to PACS was recorded during each week of the study. Interventions were designed to encourage the utilization of PACS. A significant increase in the mean percentage of PACS studies was found between the baseline and intervention period (59.4 %; 95 % CI: 34.76–84.08 %; $p < 0.001$). Mean percentage of PACS studies at 1-month (74.3 %), 2-month (61.0 %), and 3-month (74.8 %) post-intervention periods remained elevated and were all significantly increased compared to baseline values ($p < 0.001$). Mean percentages of PACS studies at 1-month, 2-month, and 3-month post-intervention periods were not statistically significant from the intervention period ($p = 0.977$, $p = 0.849$, $p = 0.967$, respectively). A simple interventional program for emergency physicians can significantly increase and sustain the utilization of PACS for point-of-care ultrasound.

Keywords PACS · Emergency ultrasound · Point-of-care ultrasound · Imaging informatics

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Introduction

With the evolution of electronic health records (EHR), the integration of digital imaging into the EHR is critical for patient management and clinical decision-making. The Picture Archiving and Communication System (PACS) is an information system that enables the management, archiving, and distribution of digital images from a server. During the past three decades, the implementation of PACS has revolutionized the field of radiology and facilitated rapid access to images by clinicians [1]. The use of PACS has been associated with a reduction in the number of lost images, increased productivity, reduced costs, and improved patient care [2–4].

The adaptation of PACS for point-of-care (POC) ultrasound has not previously been discussed in the literature. While radiologists have successfully implemented digital archiving of sonographic images, there has been considerably less utilization of PACS by emergency medicine physicians performing POC ultrasound. In the emergency department (ED), providers routinely thermally print or store digital images to a local hard drive. However, similar to consultative ultrasound (i.e., those performed by radiology), POC ultrasound is subject to the same quality assurance and billing requirements for image archival and report generation. Printed POC ultrasound images are commonly of poor quality

or misplaced, and digital images on a local hard drive or non-PACs server may not be preserved for a prolonged period of time, thereby not meeting these requirements.

The objective of this study was to determine if a simple interventional program, consisting of reminders and incentives, would influence the utilization of PACS in POC ultrasound. We hypothesized that the interventions would result in a significant increase in the percentage of ultrasound studies archived on the PACS server. Additionally, we investigated whether such an effect could be maintained after removal of the interventions.

Materials and Methods

Study Design

A before-after study design was used. The study was performed from July 2014 to January 2015 and was conducted over 28 weeks. Data was collected during a 4-week baseline period, a 12-week intervention period, and a 12-week post-intervention period. The Colorado Multiple Institutional Review Board determined the study to be exempt.

Study Setting and Population

Denver Health Medical Center (DHMC) is a 477-bed, urban, academic, Level 1 trauma center with an annual adult ED census of approximately 60,000 patient visits. It is the primary site of a 4-year emergency medicine residency with 17 residents per year and a 1-year emergency ultrasound fellowship with approximately 2-4 fellows per year. There are over 25 full-time ED attendings at DHMC.

Approximately 2400 POC ultrasounds are performed each year in the ED. The majority of these studies are performed by residents under the direct supervision of an attending physician or fellow. There are four ultrasound machines in the department, each having linear, curvilinear, and phased-array transducers with endocavitary transducers available.

A convenience sample of ED residents, fellows, and attendings were included in the study. Senior and junior residents were equally distributed within each week throughout the study period. Subjects were blinded to the existence and purpose of the study.

Point-of-Care Ultrasound Workflow

POC ultrasound studies in the DHMC ED are archived either as printed thermal images or digital images stored on the PACS server. Historically, POC ultrasound studies have been predominantly recorded with printed images. Each ultrasound machine is connected locally to a printer, which prints static images. Our ED implemented PACS for POC ultrasound in 2011, 4 years prior to data collection associated with this study. Ultrasound studies are uploaded to the PACS server using a hospital intranet wireless connection.

The POC ultrasound workflow begins when the patient is registered and a physician places an order for an "ED Focused Ultrasound." The order is transmitted to the Radiology Modality Worklist, a function of the Radiology Information System (RIS), which creates a worklist with patient demographic information. The patient demographics are then wirelessly transmitted to the ultrasound machine, allowing the physician to select the patient from the worklist and begin the study. Digital images are then stored in a standard Digital Communication within Medicine (DICOM) file format that combines both uniquely identifying demographic information and the images. At the end of each ultrasound study, the DICOM file is transmitted wirelessly to the PACS server. There is an electronic reporting system for documenting ultrasound reports within the RIS system, which enables integration of reports with images within PACS in addition to the EHR. The electronic report form provides a structure to optimize billing and the ability to automatically export information into a quality assurance (QA) database.

Study Protocol

Data was collected from the ultrasound QA database, which indicated whether images were archived to PACS or thermally printed for each documented ultrasound study. The percentages of studies archived to PACS and thermally printed were recorded during each week of the study. There was a 4-week baseline period prior to implementation of the interventions. Interventions were then implemented for a period of 12 weeks and were designed to be simple and generalizable. The interventions consisted of bi-weekly emails by an ultrasound fellow, daily verbal reminders by senior residents during shift sign-out, and signage on the ultrasound machines, all encouraging the use of PACS to archive ultrasound studies. In addition, there was a bi-weekly departmental contest with a $20 gift card awarded to the physician who archived the most studies to PACS. During the post-intervention period, signage remained but verbal, email, and monetary interventions were removed and data was collected for an additional 12 weeks.

Outcome Measures

The primary outcome was the mean percentage of POC ultrasounds archived to PACS for each study period.

Data Analysis

A one-way analysis of variance (ANOVA) was used to compare mean percentage of PACS studies at baseline, intervention, and 1-month, 2-month, and 3-month post-intervention

periods. Significant results were explored post hoc using pairwise comparisons ($\alpha < 0.05$) with a Bonferroni adjustment. All calculations were performed using Stata 13/IC software (StataCorp. 2009. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP), and the a priori level of significance was set at $p \leq 0.05$.

Result

During the 28-week study period, 1088 POC ultrasounds were performed. The total number of studies varied during the study period (Fig. 1), with a peak in both the number of PACS and total number of ultrasound studies performed occurring at 14 weeks. A significant increase in the mean percentage of PACS studies was found between the baseline and intervention period ($p < 0.001$). At baseline, the mean percentage of PACS studies was 10.0 %. During the intervention period, the mean percentage of PACS studies rose to 69.4 %, a mean difference of 59.4 % (95 % CI: 34.76–84.08).

The mean percentage of PACS studies at 1-month (74.3 %), 2-month (61.0 %), and 3-month (74.8 %) post-intervention periods remained elevated and were all significantly increased compared to baseline values ($p < 0.001$). The distribution of the percentage of PACS studies across study periods is displayed in Fig. 2. The mean percentages of PACS studies at 1-month, 2-month, and 3-month post-intervention periods were not statistically significant from the intervention period ($p = 0.977$, $p = 0.849$, $p = 0.967$, respectively).

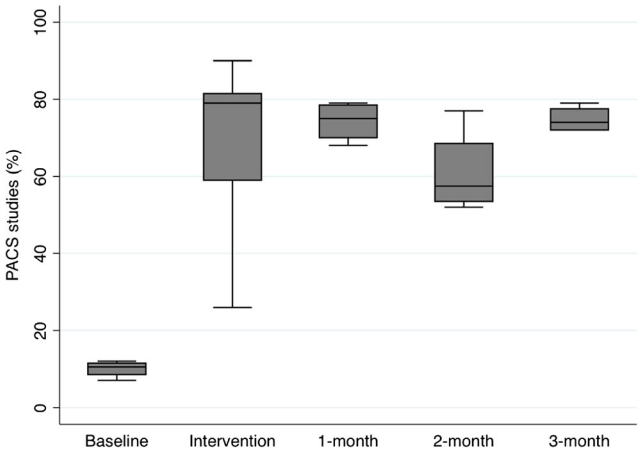

Fig. 2 Box-and-whisker plot of distribution of the percentage of PACS studies across baseline, intervention, and post-intervention periods

Discussion

To our knowledge, this is the first study to evaluate the utilization of PACS in POC ultrasound. We found that a simple interventional program, consisting of reminders and incentives, significantly increased the utilization of PACS for POC ultrasound. Although we anticipated attrition after removal of the interventions, the percentage of studies archived to PACS was sustained over time. Studies have demonstrated that interventions, such as educational initiatives to enhance patient safety and improve sepsis guideline compliance, can result in a change in practice and improved patient care [5, 6]. A similar change in departmental culture was observed with our interventional program for POC ultrasound, which we

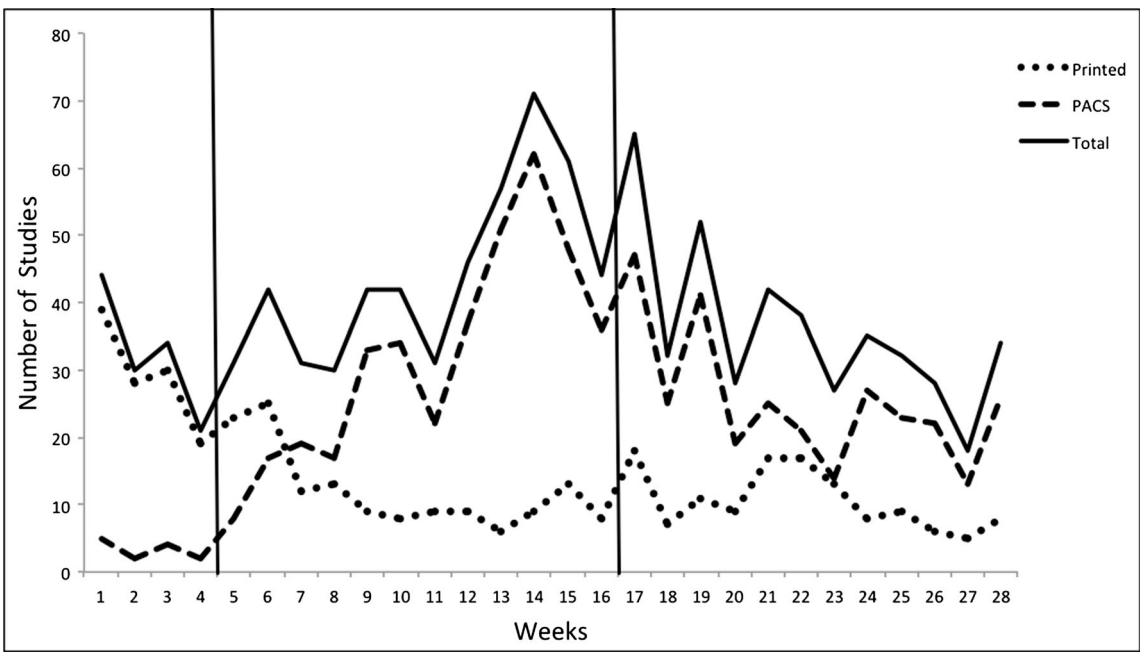

Fig. 1 Ultrasound studies performed in the emergency department over 28-week study period. The 12-week intervention period is displayed between the *vertical black lines*, from the beginning of week 5 through the end of week 16

believe is generalizable to other EDs and can help sustain a robust digital ultrasound program with PACS connectivity.

In addition to an increase in the percentage of PACS studies, there was an increase in the total number of POC studies during the interventional period of the study. The most likely explanation for this effect is that the interventions served as reminders to utilize POC ultrasound in general, in addition to archiving images to PACS, and therefore resulted in an increase in number of total studies performed. Another possible explanation is that the interventions encouraged physician documentation, and that there were ultrasound studies being acquired prior to the interventions that were not optimally documented and recorded. Future research is needed to examine whether implementation of PACS for POC ultrasound is associated with increased revenue and productivity for emergency physicians and departments.

There are many advantages of PACS archival of ultrasound images in the ED. These benefits include improved quality assurance resulting in better patient care and physician education and preservation of image quality for billing requirements. Additionally, one of the most important advantages is the accessibility of POC images to consultants, resulting in improved patient care, decreased duplicate studies, and therefore decreased imaging costs. For example, in a patient with an ectopic pregnancy, the obstetrics and gynecology service can view POC ultrasound images on PACS and emergently take the patient to the operating room rather than repeating the study with a consultative ultrasound.

The adoption of PACS archiving for POC ultrasound in the ED is not as widespread as for consultative radiology-based ultrasound. A difference in workflow process likely explains this slow adoption, with the foundation of ultrasound technology being built around the radiology workflow. POC ultrasound is focused, physician-performed, interpreted in real-time, and meant to answer one or more emergent clinical questions. In contrast, consultative ultrasound is often comprehensive, technician-performed, interpreted afterwards, and meant to answer one non-emergent specific clinical question [7]. Current industry technology requires a patient to be registered and an ultrasound order to be entered in order to generate a DICOM file with patient demographics, which can then be sent to the PACS server [8]. If images are collected without linking demographics, they cannot be merged easily without manual PACS administrator intervention. This multistep process can be an obstacle in an emergency situation and thus encourages the use of an immediate storage solution: thermally printed images or digital images to a hard drive. One potential solution to improve PACS archival of ultrasound images requires patient registration to occur near instantaneous with automatic order entry for POC ultrasounds in critically ill medical and trauma patients. This allows immediate generation of a DICOM file with temporary patient identification information, which is forwarded to the worklist on the ultrasound machine to initiate the study, and then reconciled at a later time.

While current POC ultrasound equipment is capable of automatically uploading images directly to PACS, this is not a common practice in emergency departments. Instead, even with PACS connectivity, departments choose to manually upload images to PACS. Given the nature of POC ultrasound workflow, there are many barriers that interfere with automatically sending studies to PACS. First, as described above, many critically ill patients are not registered at the point the emergency ultrasound exam is done, and therefore, the study cannot be automatically uploaded to PACS without patient identifiers. Therefore, these studies are frequently archived to a storage solution outside of PACS, such as a hard drive or non-PACS server. Second, due to patient care demands competing for time to acquire images or variations in technical skill in performing POC ultrasound, there are studies performed which can be incomplete or of poor quality. It is important that these studies are not automatically sent to the PACS server. Third, there are many POC ultrasound studies in academic emergency departments which are done by residents and students under the supervision of ultrasound faculty which are educational in nature rather than for clinical decision-making. These exams cannot be automatically uploaded to the PACS server as they do not play a role in patient care and cannot be billed. Instead, these educational studies are archived to a hard drive or non-PACS server for review and quality assurance with the trainees. Finally, there can be technical issues with connecting to the PACS server within the emergency department, preventing a workflow solution where all POC ultrasound studies are automatically sent to PACS. In these situations, these clinically important studies must still be archived to a storage solution outside of the PACS server. Despite these obstacles, our interventions were effective in increasing the utilization of PACS.

There are several limitations to this study. First, this was a single institutional study in an urban academic ED with an ultrasound fellowship program; thus, our findings may not be generalizable to community settings. However, the interventions were designed to be simple and generalizable to both academic and non-academic settings. Second, this was an uncontrolled before-after study, which can be biased by regression to the mean and confounded by changes in the sample population. Senior and junior residents were equally distributed within each week throughout the study period, although it is possible that certain individuals were more proactive with ultrasound in different study cohorts. Finally, wireless connectivity and ultrasound machine malfunction during the study could have affected our data, which emphasizes the need for a healthy information technology infrastructure. Particularly, we were aware of network connectivity problems during weeks 21–23 of the post-intervention period, which may explain the transient decrease in PACS utilization during that time.

Conclusion

A simple interventional program for emergency physicians, consisting of reminders and incentives, can significantly increase and sustain the utilization of PACS for POC ultrasound. Benefits of PACS archival of images include improved quality assurance, preservation of image quality for billing requirements, decreased duplicate studies and imaging costs, and accessibility of images to consultants resulting in improved patient care.

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Compliance with Ethical Standards

Conflicts of Interest The authors declare that they have no conflict of interest.

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