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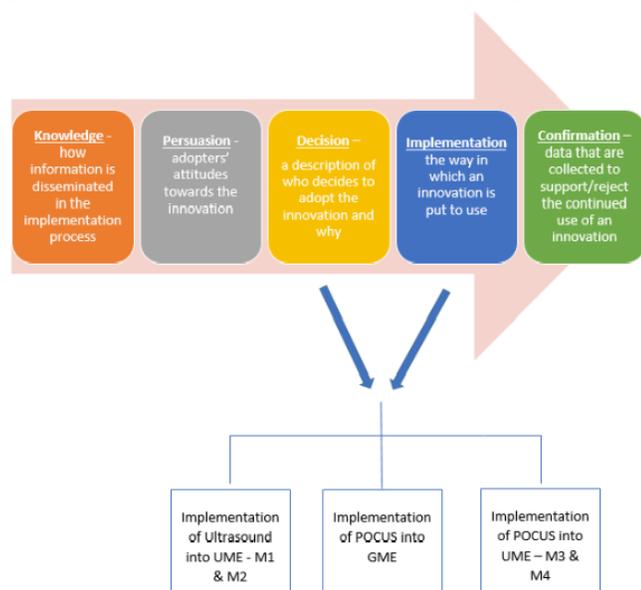
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Abstract

Educational research that describes the curricular development and implementation of point-of-care ultrasound (POCUS) has expanded exponentially in the last ten years as medical schools design and deliver ultrasound curricula.¹ However, much of the published literature in this area describes the design and delivery process within centralized U.S. medical schools, leaving regional campuses guessing on how best to approach their efforts. In an attempt to build capacity for POCUS in schools with regional campuses, this article describes the Medical College of Georgia's (MCG) two-year effort to implement and disseminate a POCUS curriculum across three regional campuses and a partnership campus in Athens. Although there are several studies that have described the implementation of POCUS elsewhere,²⁻⁵ previous descriptions of similar efforts have not had the challenges of incorporating regional campuses into their efforts. Innovation dissemination brings its own set of issues regardless of the educational context, however the inclusion of regional campuses raised the complexity of our effort.

In this article, we offer our insights on how to implement POCUS across all four years of students' undergraduate medical education (UME) as a way to assist other medical schools interested in the same effort. Our goal is to help other schools plan for and address potential challenges that can make implementation difficult. To frame our process, we utilize a Diffusion of Innovations Theory,⁶ a well-established framework often used in a variety of fields to describe how new ideas and innovations are spread across a system. A Diffusion of Innovations framework can be applied to both educational⁷ and clinical settings⁸ as a way to understand how individual and institutional change is achieved. Specifically, the framework is useful in describing our process provides a systematic way to understand *why* and *how* the innovation was successful. See Figure 1 for an overview of the Diffusion of Innovations framework and where we will be focusing our description.

Figure 1. Diffusion of Innovations Framework Stages

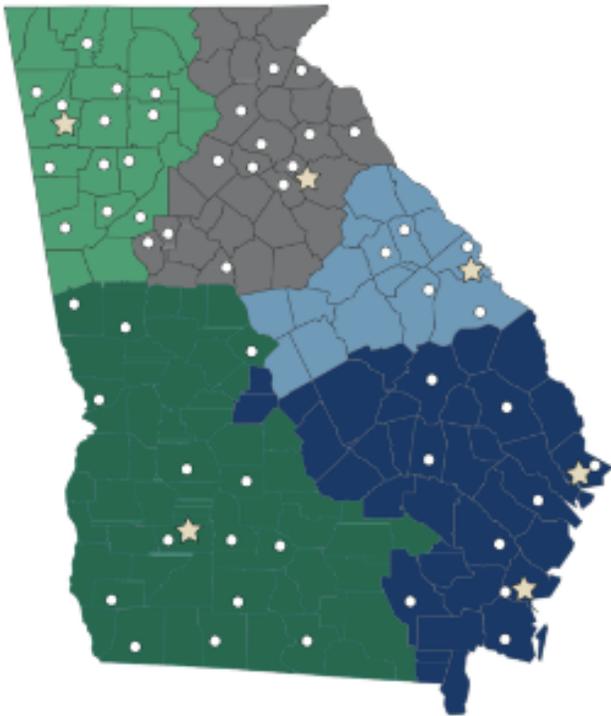


Implementation Overview

Founded in 1828, MCG is the 13th oldest and the 8th largest medical school in the U.S. with approximately 230 UME students enrolling per year. Located in Augusta, Georgia, MCG is an integrated health system with shared leadership between the medical school and hospital. Given MCG's large class size, our institution collaborates with hospitals and clinical care sites across the state of Georgia to ensure all students have adequate training for their clerkships and have access to a variety of patient populations. In total, there are 200 sites across the state where 3rd and 4th-year students are placed on their rotations. Although MCG is comprised of a main campus in Augusta, three regional campuses and a 4-year partnership campus in Athens, the clerkship coordinators in Augusta are responsible for ensuring all students meet standardized clerkship requirements. See Figure 2 for an graphic overview of MCG's regional campuses and clinical sites across the state.

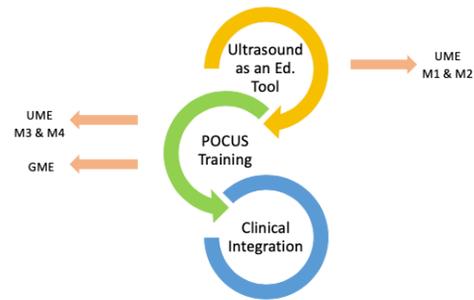
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Figure 2. Map of MCG's Distributed Campuses and Clinical Sites



Implementing ultrasound education into MCG consisted of multiple challenges given the distance between each of the dispersed clinical sites and the main campus in Augusta. For simplicity, we describe our implementation process as occurring in three distinct phases: Medical School Year 1 & 2 (M1/M2), Residency, Medical School Year 3 & 4 (M3/M4). The clinical integration in M3/M4 was by far the most challenging given that this is when students are distributed across the state for their clinical clerkship rotations. Successful implementation of POCUS into MCG's residency programs was critical for achieving the final stage, therefore we describe our process at the graduate medical education (GME) level, too. The following sections describe MCG's efforts, with attention paid to both our initial iterations of adoption and final programmatic details. Figure 3 provides an overview of our educational process.

Figure 3 Overview of MCG's Ultrasound/POCUS Training



Undergraduate Medical Education (UME) - M1 & M2

With changes in ultrasound technology and the development of smaller hand-held devices, our institution was interested in integrating POCUS into UME. The first phase of POCUS integration was to implement ultrasound training in the undergraduate medical curriculum (M1-M2) where students spend two years learning basic science concepts. The overarching goal at this point was to allow ultrasound to serve as an adjunct to students' courses, as a way to help them retain classroom material. It was also intended to enable readiness to incorporate ultrasound into later clinical practice when students would start their clerkships. The majority of this phase occurred in 2013-2015.

To accomplish this goal, one of MCG's ultrasound educators was given responsibility for identifying curricular opportunities where ultrasound could be incorporated into the M1 & M2 curriculum. However, the first challenge was realized because faculty could not be persuaded to implement ultrasound in the midst of LCME re-accreditation. From the faculty perspective, ultrasound was not an LCME requirement, and faculty members were hesitant to make substantial curricular changes prior to re-accreditation. POCUS was also perceived as having high complexity, and difficult for faculty members to use. A task force was convened and recommended that the first year of ultrasound training occur in M1 and M2 ultrasound labs (2014-2015) where students scanned each other during a one-hour session. M1 students learned to identify structures in the musculoskeletal system, cardiopulmonary system, abdomen, and pelvis.

The M2 labs were more advanced and included scanning of the abdomen, vascular system, and the cardiopulmonary system. In both M1 and M2 labs, students received tailored feedback by an experienced faculty member who commented on students' image quality, and identification of organs and other markers. Eventually, several more labs were added to each section, totaling six for the M1s and six for the M2s. These labs became the core ultrasound courses for students, which continue to serve as a curricular foundation for ultrasound learning in the M1 and M2 years.

Looking forward, future implementation for M1 and M2 learning includes integrating POCUS into MCG's physical diagnosis (PD) as a supplement to students' PD skills. In these sessions, students will advance their ultrasound skills and practice using the POCUS equipment in ways they will be expected to use it in the clinic. For example, students will take a blood pressure reading using a cuff and then watch the artery close off to better understand what is happening in the body when a blood pressure reading is taken. Other examples include students percussing the liver and then verifying its size against ultrasound images. See Table 2 for a complete description of the student labs. In all cases, students use either Philips Sparq or Lumify handheld ultrasound devices.

Table 2. Description of Student Labs

Graduate Medical Education (GME) – Emergency Medicine

M1 Ultrasound Labs	M2 Ultrasound Labs
Introduction to Ultrasound – Physics and Artifacts	Refresher on Ultrasound – Physics and Artifacts
Musculoskeletal Knee	Musculoskeletal Shoulder
Cardiac (Subcostal four chamber heart & Perasternal long axis)	Cardiac (Apical four chamber heart & Perasternal short axis)
Abdomen (Liver, Right Kidney, Gall Bladder)	Abdomen (Spleen, Left Kidney, Aorta, Inferior Vena Cava)
Pelvis (Endovaginal and 1 st trimester Obstetrics)	Pelvis (2 nd trimester Obstetrics)

The second phase of dissemination occurred in GME after students' ultrasound education was established in M1 and M2 years. POCUS training had initially been established in 2013 within the Emergency Medicine department because it was a requirement in Emergency Medicine for the Accreditation Council for Graduate Medical Education (ACGME). Soon after, other residencies were interested in POCUS training, but implementation was immediately halted because there was no centralized training equipment for residents to use. Everything the hospital owned belonged to individual departments. Additionally, it was difficult to coordinate the residents' schedules given their clinical duties, and when they were able to come, residents frequently missed their time slot when their clinical duties ran over. Recognizing that individualized residency training sessions were not building capacity at the institution, stage two of the implementation process officially began in 2016 with the creation of the Center for Ultrasound Education. At this time, RE and ML, the second and third authors, were brought together to conserve institutional resources, and build capacity for ultrasound within the institution. Unrelated, but around that same time, Phillips Alliance approached MCG with the agreement that would allow physicians to use their equipment in the hospital, which provided the Center for Ultrasound Education with an opportunity to begin developing more robust training. This agreement with Phillips Alliance moved ultrasound equipment privileges from departments to the hospital, thus creating accessibility.

With the equipment accessible to everyone in the hospital, continuous training could be provided to all residents, which quickly became a hospital priority. Several adverse events in the hospital at the time highlighted the need for residents to be trained in POCUS. The third author, who is an Emergency Medicine physician, was asked to create a system-wide GME training program around ultrasound-guided central line training in response to these adverse events. The program he created was designed as a GME wide quality improvement intervention that included both a didactic component with standardized ultrasound-guided vascular access training. Additionally, a competency testing component was developed using a cadaveric model and a standardized grading rubric.

Blocks of time were set aside for residents to come to the Center for Ultrasound Education and learn how to conduct POCUS. Initially, there were many different opinions concerning which exams and the type of training should be included in the curricula, but eventually a unified approach was constructed where all of the residencies would learn the same exam during each calendar month. The agreed upon curriculum for GME is outlined in Table 3. This unified approach increased the visibility of POCUS in the hospital, which continued to entice other residencies to adopt the technology. Since then, Central Line Associated Blood Stream Infections (CLABSI) associated with resident insertions was reduced from 3.75 infections per quarter to 0 in the last 6 quarters.⁹ Additionally, major mechanical complications have been reduced from 4 infections per year in the preceding 12 months to 0 infections.

The adoption of POCUS in GME was the missing link for integration of POCUS into the student clerkships. Initially, clerkship directors struggled to articulate how to integrate it into the clinical years given MCG's dispersed medical campus and clinical sites. It was not until the residency directors influenced the clerkship directors to implement POCUS into M3 and M4 that they were able to creatively problem-solve and implement POCUS into the clinical sites across the state. Residency directors made the argument that if POCUS was integrated throughout UME and GME, MCG would be better positioned to recruit higher-quality students and residents, thus increasing the public profile of its institution. Therefore, the integration of POCUS in residency laid the foundation for ultrasound integration into M3 & M4.

Table 3. Ultrasound Training for Residents

Month	Ultrasound Lab
July	Orientation to / limitations of POCUS, Knobology, Care of the US machine, FAST
August	Aorta, Abdominal Vasculature, Kidneys
September	Procedures: US Guided Central Venous Access, Peripheral Venous Access, Thora / Parecentesis, Arterial Access
October	Cardiac
November	Gallbladder
December	Soft Tissue/Lymph Nodes
January	Shock
February	Lower Extremity Venous, Ocular
March	Breast / Pelvis
April	Lung, Thyroid
May	Pediatric
June	Review for US Practicum

Undergraduate Medical Education (UME) – M3 & M4

The final stage of implementation occurred in MCG's clerkships, which are distributed in clinical sites across the state of Georgia. One of the difficulties in having a distributed campus model is that it makes it challenging to ensure standardized POCUS experiences. To assess the feasibility of disseminating POCUS into the clerkships, a pilot year was conducted within the Emergency Medicine clerkship. In 2016-2017, students were required to do one Focused Assessment with Sonography in Trauma (FAST) exam and submit their images back to Augusta's Emergency Medicine clerkship director for feedback. FAST exams are rapid bedside ultrasound exams typically performed by surgeons, emergency physicians and some paramedics as a screening test for internal bleeding. However, given that the equipment quality varied by site, students were asked to take pictures of their de-identified images using their smartphones and then upload the images to Box, a cloud-based management, and file sharing service that MCG uses.

By all accounts, the pilot was successful, and in 2017, a POCUS requirement was added to two other clerkships, Family Medicine and OB/GYN. OB/GYN was chosen as one of the next clerkships because, in ways similar to Emergency Medicine, ultrasound technology is commonly used in each clinical site allowing the student to have access to ultrasound equipment in order to complete the assignment. The Family Medicine clerkship was chosen due to the strong state-wide network of clinical sites, being the longest established clinical clerkship with students at remote clinical sites. To support the Family Medicine clerkship rotations, Philips Lumify transducers and Android-based tablets were used. Beginning in 2018, the Center for Ultrasound Education expanded

POCUS into two other clerkships, Surgery and Internal Medicine using the model developed with the Family Medicine clerkship.

The challenge at this phase, however, was that MCG's 230 students were placed in 200 clinical sites across the state of Georgia, in which only students in the Emergency Medicine and OB/GYN clerkships had access to POCUS equipment. The other students in the 25 Family Medicine clerkships, did not have equipment, nor did they have access to someone to provide feedback on their images. Again, it was the geographic distribution and placement of MCG's students that made POCUS implementation into the clinical years difficult, particularly given the need to standardize students' learning experiences and the curriculum. Complicating the issue was that many of the Family Medicine preceptors had not been exposed to POCUS and were hesitant in having students use it on their patients or in their clinics where they had no ability to supervise or assist students with making sense of the images. Additionally, community preceptors experienced a reduction in patient flow as students scanned patients, which many Family Medicine preceptors found frustrating.

To solve these problems, an additional sonographer was hired at MCG's Center for Ultrasound Education to assist with reading and providing feedback on students' POCUS images. Students in all three clerkships were required to scan five patients, then upload their de-identified images to MCG's learning management system (Desire2Learn; D2L) where they were assessed by the trained sonographer. When students completed their five scans, the sonographer provided each student and their clerkship director with feedback on student performance. Additionally, the Center for Ultrasound Education secured 20 Lumify transducers and distributed them to each of the 20 different Family Medicine clinical sites for students to use during their rotation. Rather than giving each student their own equipment, it continues to be shared across students at each site.

In clinics where community preceptors are concerned about students scanning patients, patients sign an electronic consent form indicating that the patient knows that the ultrasound exam is for non-diagnostic, educational purposes and the information will not be included in the patient's medical record. In some cases, students were allowed to scan their family members and friends, rather than patients, which is primarily the case in centers for primary care, where liability concerns are the highest.

Conclusion

Innovation dissemination always has its challenges, however when issues of standardization must be met across regional campuses, medical educators are faced with an extra layer of complexity. As we reflect on aspects that made our effort successful, we recognize that MCG's leadership was

helpful in identifying curricular openings and convincing faculty members to be flexible with the curriculum. We also had the advantage of an expert in ultrasound technology who could teach ultrasound in M1 and M2 years.

In addition to ensuring the right personnel, we also have several suggestions for other institutions interested in implementing POCUS into their own medical education curricula. We would suggest that ultrasound not be taught as a separate and distinct skill, but rather a tool for teaching medical students at the UME level. The value of POCUS is in the ability to integrate it into procedures, which helps to solidify knowledge and ensure ultrasound will be used in the clinic. We suggest finding ways to integrate into the current curriculum and assist students to see its value within both the pre-clinical and clinical environment. We also suggest working backward by starting the implementation process with where there is ultrasound experience and then moving into specialties where ultrasound is fairly new. Our efforts suggest beginning the adoption process in this order: Emergency Medicine, OB/GYN, Surgery, Internal Medicine, Family Medicine, and Pediatrics because we have had remarkable success in the uptake of ultrasound by appealing first to those specialties who already have exposure and experience with the technology. And finally, we suggest that instead of beginning with ultrasound implementation in UME, as we did, start by convincing the residency directors of its value and then move to clerkship directors. Working in this direction helps sell the residency to potential applicants and recruit better residents, all the while working to create an institutional climate that supports the use of ultrasound in the clinic.

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