Innovations in Fellowship Education

2024 Highlights Book

ATS 2024

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The following programs were selected by the ATS Training Committee as the standout programs in educational excellence this year.

The ATS would like to showcase the additional institutions who submitted an abstract to the 2024 Innovations in Fellowship Education program.

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PROGRAM DETAILS

The American Thoracic Society greatly values a strong fellowship program as a means of academic and clinical success. To recognize programs that implement exceptional practices, the ATS Training Committee developed the Innovations in Fellowship Education program. All pulmonary, critical care, sleep, and allergy fellowship programs (adult and pediatric) are invited to submit abstracts showcasing a novel and innovative best practice.

Abstracts are reviewed and ranked based on the following criteria:

- Innovation: How unique is the educational program? What is new and different?
- Implementation/Sustainability: How was the program implemented and how effective was such implementation? Is this program sustainable?
- Transferability: How easily might this educational program be adopted by other fellowship programs?
- Outcomes: Are there reported outcomes or plans to measure them?

The goal of this program is to recognize fellowship programs that demonstrate educational excellence and to share these best practices with other programs.

There is a focus on fellowship innovations addressing racial/ethnic disparities or improving diversity, equity, or inclusion.

This award focuses on projects related to fellowship education and curricula.

The following program was selected by the ATS Training Committee as the standout program in educational excellence this year:

Temple University Hospital
TextBytes for Smarter Practice: Revolutionizing Tobacco Use Disorder Treatment Education for Physicians

University of Colorado
Impact of a Virtual Reality Anatomy Trainer on Endobronchial Ultrasound Performance

Temple University Hospital

Educational Excellence

TextBytes for Smarter Practice: Revolutionizing Tobacco Use Disorder Treatment Education for Physicians

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INTRODUCTION

Tobacco use is a leading cause of preventable deaths worldwide and in the U.S. Healthcare systems and individual clinicians are crucial in reducing these harms through tobacco use disorder treatment (TUDT). A recent study revealed that training in TUDT for most clinicians is limited, lacks competency assessment, and receives minimal evaluation in certification exams, despite its essential nature in medical training. We conducted a survey at Temple University Hospital that revealed that, on average, 70% of providers in Internal Medicine, Pulmonary and Critical Care, and Family Medicine felt comfortable treating tobacco use disorder and around 85% counseled patients on smoking cessation. However, despite their self-reported comfort levels, notable gaps in knowledge were discernible, particularly concerning the accurate prescription of pharmacotherapy dosing and duration. Continuing medical education for physicians is hindered by challenges such as time constraints, work-life balance, and the need to stay updated in a rapidly evolving medical field. In response to the informational voids uncovered by the survey, innovative methodologies for the dissemination of readily comprehensible knowledge were explored. Among the promising approaches, text message-based learning has exhibited efficacy across various healthcare and educational domains..

METHOD

We designed a 13-day text series aimed at educating internal medicine residents and pulmonary/critical care fellows and attendings on Tobacco Use Disorder Treatment (TUDT) through succinct messages. Each message included reference links for the information provided. We evaluated physicians' confidence in TUDT before and after the series using a self-reported 1 to 100 scale. The text series operated on an opt-in basis, allowing participants to subscribe voluntarily and providing them the option to unsubscribe at any time..

RESULTS

A total of 34 individuals were recruited, with 22 completing the questionnaire regarding their initial confidence in TUDT and subsequently enrolling in the series. The distribution of participants based on their level of training is presented in Table 1. Prior to intervention, the overall level of confidence in TUDT across all training levels was 59.3. All enrolled participants completed the series and no participants unsubscribed. Upon the series' conclusion, we received responses on confidence level from 18 participants, along with comments and feedback. Notably, 4 participants did not respond to the follow-up message. The average confidence level at the series' conclusion increased to 85. Reference links provided in the messages were accessed 67% of the time, indicating engagement with additional resources. A selection of the comments received can be found in Figure 1.

DISCUSSION

Participating in ongoing medical education as a physician can be quite challenging, especially when time and training constraints loom large. Thus, it is imperative to seek out innovative teaching and learning approaches to keep pace with the demands of a rapidly evolving healthcare environment. Microlearning, a method that dissects educational content into easily digestible units, has proven to be a successful approach in enhancing learning retention and engagement. Our utilization of microlearning to educate physicians on the vital yet often overlooked topic of TUDT yielded remarkably positive results. This approach was well-received by both trainees and attending physicians, emphasizing the significance of innovative learning tools that seamlessly integrate into the demanding lives of busy learners.

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TABLE 1: INDIVIDUAL BREAKDOWN OF PARTICIPANTS

SUBJECT	DEPARTMENT	LEVEL OF TRAINING	PRE CONFINDENCE	POST CONFIDENCE
1	IM	1	50	70
2	PCCM	4	50	70
3	PCCM	4	40	75
4	IM	2	30	No response
5	PCCM	5	80	100
6	IM	1	25	75
7	PCCM	5	40	80
8	PCCM	5	83	100
9	PCCM	6	60	85
10	PCCM	6	75	90
11	PCCM	4	50	85
12	IM	3	65	No response
13	IM	2	70	No response
14	IM	2	60	90
15	PCCM	6	55	90
16	PCCM	4	60	85
17	IM	3	75	No response
18	PCCM	Attending	47	70
19	PCCM	6	75	90
20	PCCM	Attending	80	90
21	PCCM	Attending	60	90
22	PCCM	Attending	75	95

FIGURE 1: PARTICIPANT FEEDBACK

Text based format made it easy to learn in an efficient manner
This series absolutely increased my comfort level with treating tobacco use disorder. I found the text messages simple and focused and a great learning platform. I pinned the text chain and each day a text came in I was excited to read it. I even went back to it when I had a question. Loved it.
The texts are awesome. Very informative short and to the point.
Definitely feel more comfortable after the series and will incorporate this to my practice. Add visual aids next time! Not sure if that would be possible but otherwise no critique!
I found the concise, synthesized recommendations especially helpful!
Made me realize I was not using the correct dosing for nicotine! Thanks for teaching, I keep going back to it.
This is so innovative! Don't stop, do some other topic next!!
I have been opening the text thread in clinic instead of hunting through uptodate for answers! Thank you!

Oregon Health & Science University

Implementation and Evaluation of a Patient Safety Curriculum for Pulmonary and Critical Care Medicine Fellows

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RATIONALE

Morbidity and mortality (M&M) conference is a common model used for patient safety (PS) education. However, integration of PS principles into M&Ms can be challenging when faculty and fellow trainees lack PS expertise. To address these issues within our pulmonary critical care medicine (PCCM) and critical care medicine (CCM) fellowships, we used expertise from hospital medicine faculty, local fellowship leadership and fellow input to co-develop a PCCM/CCM fellowship PS curriculum and systems-based M&M.

METHODS

A hospital medicine systems science expert and PCCM faculty member with quality improvement (QI) interest were paired to co-develop a PS and M&M curriculum within the PCCM/CCM fellowship. Fellows interested in systems leadership also joined the team. With support from the PCCM and CCM fellowship and divisional leadership, the curriculum was created to address goals of fellows, target topics of interest and incorporate the curriculum within the existing fellow education framework. A needs assessment was conducted by the design team along with fellowship leadership to address Accreditation Council for Graduate Medicine Education fellowship common core requirements for PS and QI including knowledge on root cause analyses and how to report patient safety incidents (PSI). Selected didactic topics included error identification and reporting, apparent-cause analysis, data gathering, intro to QI and cognitive biases. In addition to didactic time, goals were established around teaching fellows on effective error reporting and restructuring the monthly divisional fellow-run M&M conference.

RESULTS

The PS team developed a multi-modal programmatic structure that included 1) a new PS didactic curriculum outlined in figure 1, 2) a revised M&M format, and 3) education and new requirements for tracked error reporting for PCCM/CCM fellows.

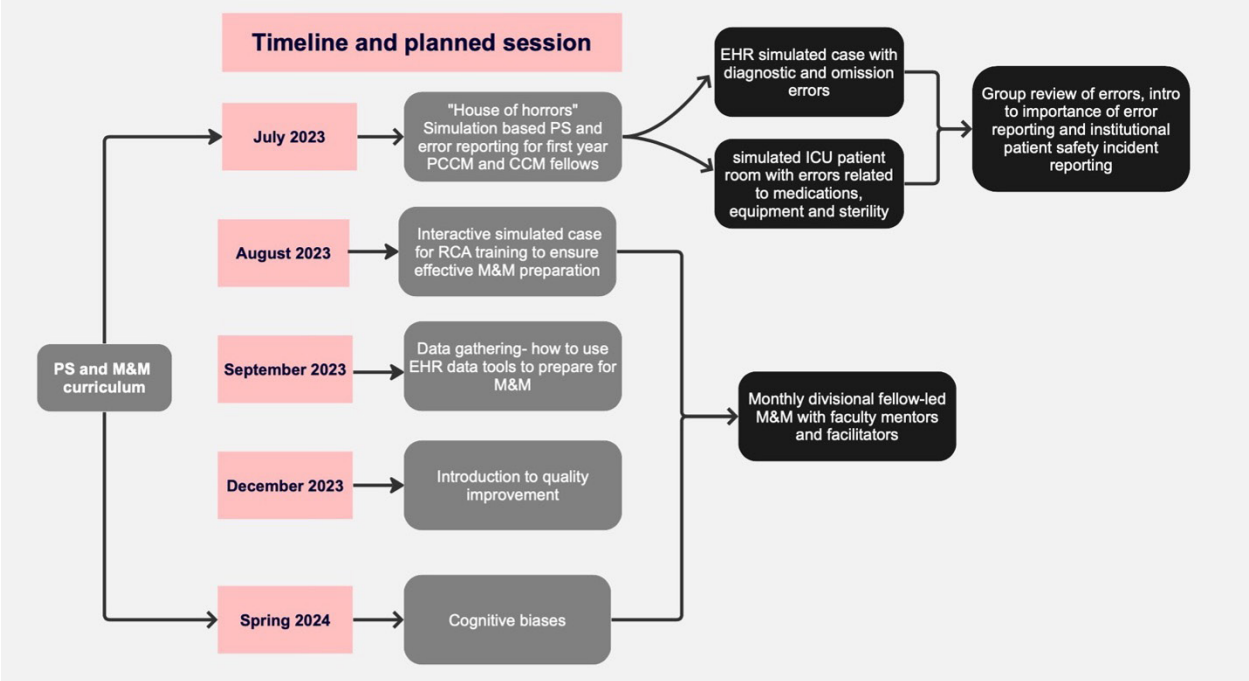
The PS curriculum included a 3-hour interactive simulation on error identification and PSI reporting. First year fellows were provided one hour to identify 1) errors related to medication administration, patient positioning, equipment, ventilator settings and sterility during procedures in a training room configured to be identical to an ICU room and 2) diagnostic and omission errors in an Electronic Health Record (EHR) based simulation exercise using specifically designed EHR charts. The remaining session was focused on debriefing identified errors, review of the error reporting system at our institution and discussion on importance of error reporting. An additional requirement for error reporting was instituted asking each fellow to report at least one PSI per two week MICU block to practice error reporting skills. To ensure the additional PSI requirement did not result in low quality reports, a PSI grading rubric was also created to track quality of PSI's.

For M&M conference, a 1-hour interactive session inviting fellows to participate in a stimulated case was conducted to model use of apparent cause analysis to create a M&M. In addition, a standardized M&M PowerPoint template including formatting, outline and common questions was developed and provided to the fellows. The cases for fellow M&M were assigned at least 8-weeks in advance with a QI trained faculty mentor to help guide M&M development and facilitate the session. To track M&M presentation quality, a standardized M&M evaluation tool was developed based off a modified SBAR (Situation, Background, Assessment & Analysis, Review of Literature, Recommendations) demonstrated in figure 2.

CONCLUSIONS

Teaming between divisions and fellows was used to create an innovative PS curriculum and revamped M&M conference for our fellows. Our novel approach overcame limitations in faculty time and expertise and created the infrastructure for fellows to develop robust M&M conferences. We are tracking M&M and PS reporting quality pre-post implementations. Our programmatic structure, and SBAR tool used for grading M&Ms and PSI quality, may be applied and/or tailored to other programs' unique needs.

FIGURE 2. MODIFIED SBAR (SITUATION, BACKGROUND, ASSESSMENT & ANALYSIS, REVIEW OF LITERATURE, RECOMMENDATIONS) FOR FELLOW M&M EVALUATION



Situation	**Neither clear nor concise**			**Clear and concise**	
Statement of adverse outcome or problem being presented	1	2	3	4	5
Background	**Lacking relevant detail**			**Succinct and precise**	
Relevant patient history presented	1	2	3	4	5
Relevant systems information pertinent to understanding assessment and analysis	1	2	3	4	5
States how and when the error/near miss was recognized	1	2	3	4	5
Clearly describes outcomes from the error/near miss	1	2	3	4	5
Includes error reporting	1	2	3	4	5
Includes disclosure information	1	2	3	4	5
Assessment & Analysis	**Poorly described or not discussed**			**Accurate and detailed**	
Chronological description of events leading to the error/near miss	1	2	3	4	5
Evaluation of what happened and why it happened (error analysis)	1	2	3	4	5
Includes perspectives from involved persons or stakeholders	1	2	3	4	5
Description of potential contributing factors 1. Systemic errors 2. Cognitive biases	1	2	3	4	5
Free from blaming or identifying individuals involved in the error	1	2	3	4	5
Review of literature	**Not relevant to conclusion**			**Strong and relevant**	
Pertains to error being discussed or possible action plans	1	2	3	4	5
Recommendations	**Vague or unclear**			**Specific and detailed**	
Proposed actions to prevent future similar problem	1	2	3	4	5
Actions focus on system wide change					
Identifies learning points from case					
Identifies how problem could have been prevented or better managed					

Ohio State University Wexner Medical Center

Emotional Intelligence Coaching at the Beginning of Fellowship

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INTRODUCTION

Physician coaching is an increasingly utilized resource in medical education. Coaching in medical education aligns along four archetypes: academic coaching, skills-building, developmental coaching, and at-risk/remediation. Certified (executive) coaches offer skills development for both faculty and trainees in multiple domains, including interpersonal communication, leadership, navigating career transitions, and emotional intelligence (EI). EI reflects the ability to understand and manage one's own emotions to resolve conflict, reduce stress, empathize with others, and communicate effectively. In graduate medical education contexts, EI contributes to the interpersonal and communication skills competency. While executive EI coaching offers opportunities to understand and regulate one's emotions, programs do not routinely offer this resource to residents and fellows outside of remediation. Instead, published professional development coaching interventions have mostly focused on academic faculty. We believe that EI coaching during periods of career transition, such as the beginning of a training program, is an underutilized resource to help new fellows build emotional resilience, navigate transitions in training, and foster positive adaptive behaviors.

ABSTRACT PRESENTATION

In July 2022, we implemented an EI coaching program focused on helping new Pulmonary and Critical Care Medicine fellows manage transitioning to their new role. Each new fellow met for one hour during their orientation with a certified executive physician coach, discussing EI and ways to manage stressors and well-being. The fellows received brief preparatory reflective work to complete ahead of time, focused on identifying their dreams for an ideal future, and discussed those reflections during the coaching session. The coach helped each fellow identify activities and strategies to manage chronic stress, such as paying attention to what brings them joy and inspiration and expressing gratitude on a routine basis. Fellows could establish a longitudinal relationship with the coach if they desired. A second cohort of fellows participated in the coaching intervention in July 2023. We surveyed the first two classes of participating first-year fellows, 14 fellows in total. Fellows entering our program in July 2022 were surveyed in January 2023, six months after the coaching intervention; fellows entering our program in July 2023 were surveyed in August 2023, one month after the coaching intervention. We queried whether fellows had utilized strategies covered in the coaching session; in what ways EI coaching at a time of transition may have benefited them early in fellowship; in what ways the coaching experience could have been improved; and whether they intend to engage in executive coaching in the future. Five fellows responded to the survey (four in 2022, one in 2023). All five fellows reported a positive experience with their EI coaching session, and all fellows indicated an interest in receiving executive coaching in the future. Each fellow's responses to questions about positive renewal strategies learned in the coaching sessions, and how executive coaching was beneficial to them, are summarized in the accompanying Table.

DISCUSSION

Based on our experience, we believe that EI coaching at times of transition has the potential for substantial benefits for graduate medical education trainees. Primarily, it demonstrates via a positive "hidden curriculum" that the program expects that trainees will have and/or cultivate high levels of emotional intelligence. It also offers trainees an opportunity for deliberate self-reflection, followed by tangible strategies and resources provided by the coach to manage their emotions, build adaptive and healthy habits, and thrive professionally during a time of transition. Finally, the fellows can establish longitudinal relationships with an executive coach during their training, if desired.

CONCLUSION

Pulmonary and Critical Care Medicine Program Directors should consider implementing executive EI coaching for new fellows, if available at their institutions.

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TABLE

Fellow respondent (year)	What positive renewal strategies have you implemented since your coaching session?	In what ways was executive coaching beneficial to you early in fellowship?
1 (2022)	Increased exercise	Nice to be intentional about renewal strategies rather than trying to come up with something on the fly
2 (2022)	Music, meditation, exercise, spending time with loved ones	It gave me some tools to use to recharge when I am feeling burned out. It allowed me to reflect on priorities in my life and what makes me happy. It gave me strategies to live a more balanced life
3 (2022)	Exercise	It was nice to create a plan
4 (2022)	Taking walks, being intentional at home to focus on living outside of work. Expressing gratitude at the dinner table. Sharing in other's successes	Having the meeting forced a self-reflection both before and after the meeting
5 (2023)	Connecting with the humanity of my patients, finding time to thank my residents and nurses, dancing, daily gratitude practice, living authentically without hiding the parts that don't fit the image of a pulm-crit fellow (uncertainty, grief)	Reinforced my existing strategies

University of Colorado

Educational Excellence

Impact of a Virtual Reality Anatomy Trainer on Endobronchial Ultrasound Performance

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RATIONALE

Endobronchial ultrasound (EBUS) requires operators to identify lymph node stations relative to mediastinal vascular structures, an aspect of the procedure that is challenging to teach novice learners. We hypothesized that using an immersive virtual reality (VR) anatomy trainer to demonstrate mediastinal anatomy would be a preferable and more effective way of learning than two-dimensional (2D) anatomy images or a three-dimensional (3D) physical model.

METHODS

Fellows and residents at three institutions were recruited to participate in this mixed-methods study. Participants were randomized to independently learning EBUS-related anatomy with 2D, 3D or VR versions of the same anatomic model. They underwent pre- and post-learning assessment of their EBUS performance during a simulated procedure. Components of the validated EBUS skills and tasks assessment (EBUS-STAT) addressing vascular and lymph node identification were the assessment tool (scored 0-35; higher score indicates better performance). During a second learning episode, subjects in 2D and 3D learning groups crossed over to VR and those in the VR group were randomized to 2D or 3D learning, followed by a second post-learning EBUS performance assessment. Participants completed pre- and post-session Likert-scale surveys of knowledge, confidence and learning preferences. All participants were interviewed regarding their experience.

RESULTS

Sixty-eight participants enrolled in the study, including 53 fellows and 15 residents. Most participants were novices with 84% having participated in 15 or fewer EBUS procedures. Compared with pre-learning EBUS performance, all groups had statistically significant improvements in their performance after the first learning episode (2D: pre median score 18 (IQR 16.5) vs post 26 (13), Wilcoxon signed-rank p=0.002; 3D: 12 (17) vs 22 (16), p=0.008; VR: 14 (19.2) vs 18.5 (12.2), p=0.005) (Figure 1). No group had evidence of additional improvement after the second learning episode. Score improvements were similar across learning modalities. Participants' self-reported knowledge and confidence in vascular anatomy and lymph node station identification improved (p<0.0001) after learning for all comparisons. After the session, 64 (96%) participants indicated their learning modality preference was VR. Qualitative data confirmed this learning preference and explored the application of learning with VR to procedure performance, with many participants citing the additional challenge of ultrasound interpretation limiting their translation of the anatomy learned with VR into improved procedural performance.

CONCLUSIONS

Anatomy learning resulted in EBUS performance improvement, and VR was preferred by most learners. Translation of anatomy learning into procedure performance was challenged by the ultrasound view, which can be built into future VR programs.

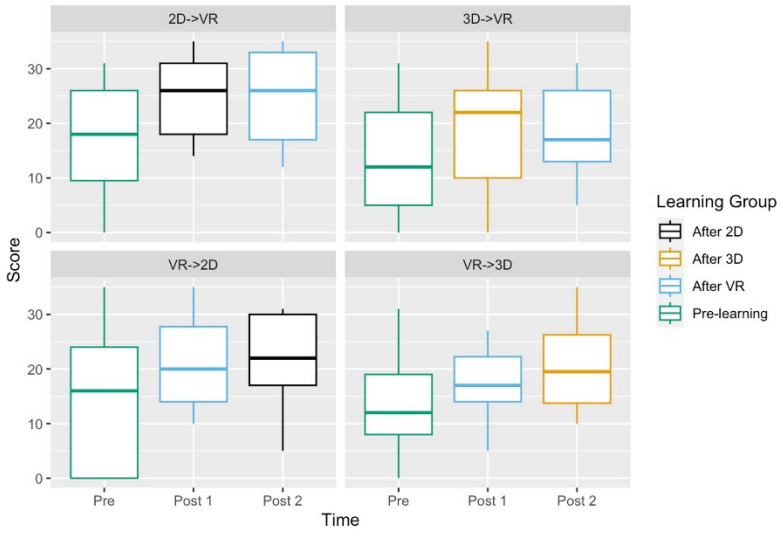

Figure 1. Scores by session and learning group. Box plots of EBUS performance scores pre- and post-learning episodes by learning group with median (bold midline), interquartile range (box) and score range (line) displayed.

Icahn School of Medicine at Mount Sinai

A Novel, Technology-Driven Health Professions Education Pathway for Cross-Disciplinary Fellows

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INTRODUCTION

Most Health Professions Education (HPE) Pathways target single-specialty resident learners and rely on in-person education. Fellows who aspire to HPE careers may struggle to find community to support their education practice and scholarship. We leveraged technology and systemwide Clinician Educators (CE) Faculty to implement an HPE Pathway for cross-disciplinary fellows in the Mount Sinai Health System (MSHS).

ABSTRACT PRESENTATION

MSHS is an eight-hospital system with the largest graduate medical education (GME) footprint in the nation spread over three New York City boroughs. In 2020-2021, the authors partnered with systemwide cross-disciplinary CEs to design a Teaching Scholars Curriculum (TSC) for Pulmonary & Critical Care Medicine (PCCM) fellows. Fourteen interactive modules were developed on curriculum design, adult education theory, educator skills, and career advancement. Course delivery over 12 months was 75% asynchronous and 25% synchronous online. Feedback from four PCCM pilot fellows was collated by Kirkpatrick Level1 : coursework was engaging and amenable to self-pacing (1, 2a, 2b); teaching and self-reflection skills were readily applied and evaluated (2b, 3); learners partnered with new cross-disciplinary mentors, and course faculty gained digital education skills (4b). In 2022-2023, the TSC served as the foundational coursework for an enhanced HPE pathway including: a formalized Selections Committee; parallel implementation of a medical education scholarship program; biannual networking events with systemwide CE faculty; a multi-tiered mentorship structure (Fig 1); and biannual advisory review.

Eight fellows representing six fellowship programs (PCCM, Infectious Diseases, Gastroenterology, Hematology-Oncology, Cardiology, Nephrology) from five hospitals were admitted. In their exit survey (five-point Likert scale), the learners would recommend that others participate in the TSC (mean 4.875) and felt that the TSC increased their CE skills (mean 4.875) and knowledge (mean 4.875). Overall learner opinions for each module relative to various domains are relayed in a heatmap (Fig 2). All eight learners presented scholarship in a rapid-fire abstract session and secured CE faculty appointments; three were retained in the MSHS. 70% of course faculty generated new, interactive teaching modules suitable for standalone or in-course education.

DISCUSSION

HPE Pathways aim to develop a pipeline of future CEs with experience in designing novel curricula, innovative pedagogies, and education scholarship.2 Learners perceive advantages from remote learning structures including time saved on travel, access to external educators, and self-paced learning.3 We describe the successful implementation of a technology-driven HPE Pathway that engaged crossdisciplinary fellows and faculty. The blended learning model allowed for the flexible participation of time-constrained, geographically distanced learners. Digital education technologies may improve instructor efficiency, self-directed learning, and knowledge/skill retention.4 Learners whose home programs lacked a breadth of CE faculty developed an Educator Community. Increased frequency of inperson networking would further strengthen opportunities for professional identity formation. The Pathway provided learners with a structure for generating education scholarship; however, the 12- month duration was insufficient time for further dissemination. Learners secured desired CE faculty positions. Course faculty developed comfort with digital education skills; the majority added this new element to their career advancement portfolios. The HPE Pathway's technology-driven structure is sustainable, scalable, and resilient in the face of unplanned education disruptors. Future directions may include improved program evaluation via the American College for GME CE Milestones and evolving curricular modules to address newer technologies (i.e., artificial intelligence in medical education).

CONCLUSION

This innovative HPE Pathway — anchored by a predominantly asynchronous TSC — attracted cross-disciplinary fellows who gained expertise in the method and practice of teaching healthcare providers, devised novel education scholarship, and built a systemwide Educator Community. PCCM fellowships who lack a breadth of divisional CE faculty or scholarship mentors may especially benefit from such a cross-disciplinary and technology-driven design.

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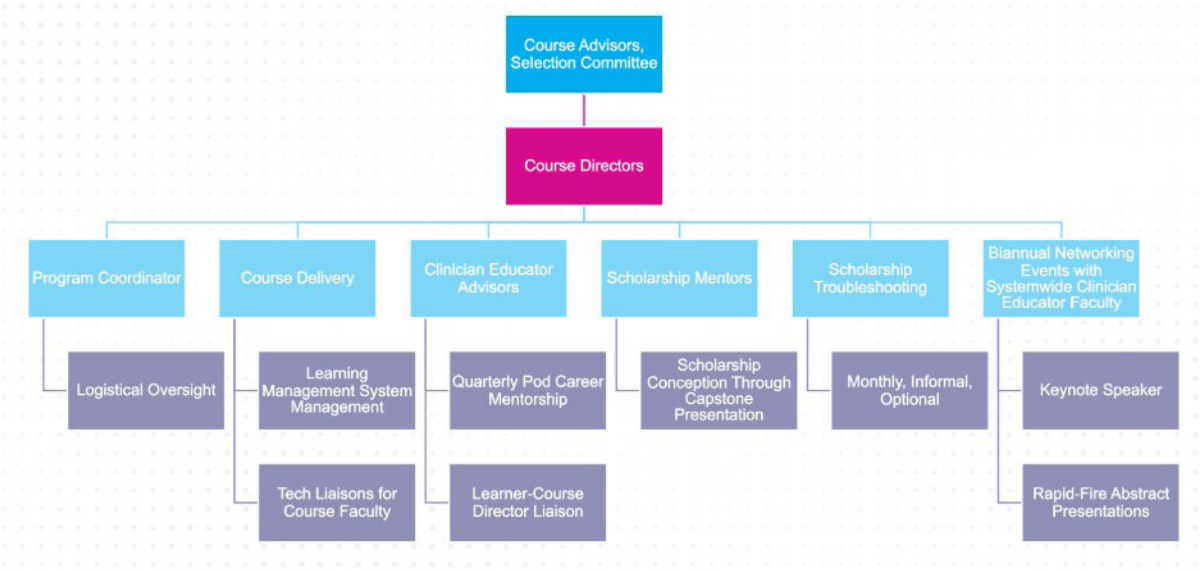

Figure 1. Health Professions Education Pathway multi-tiered organizational and mentorship structure.

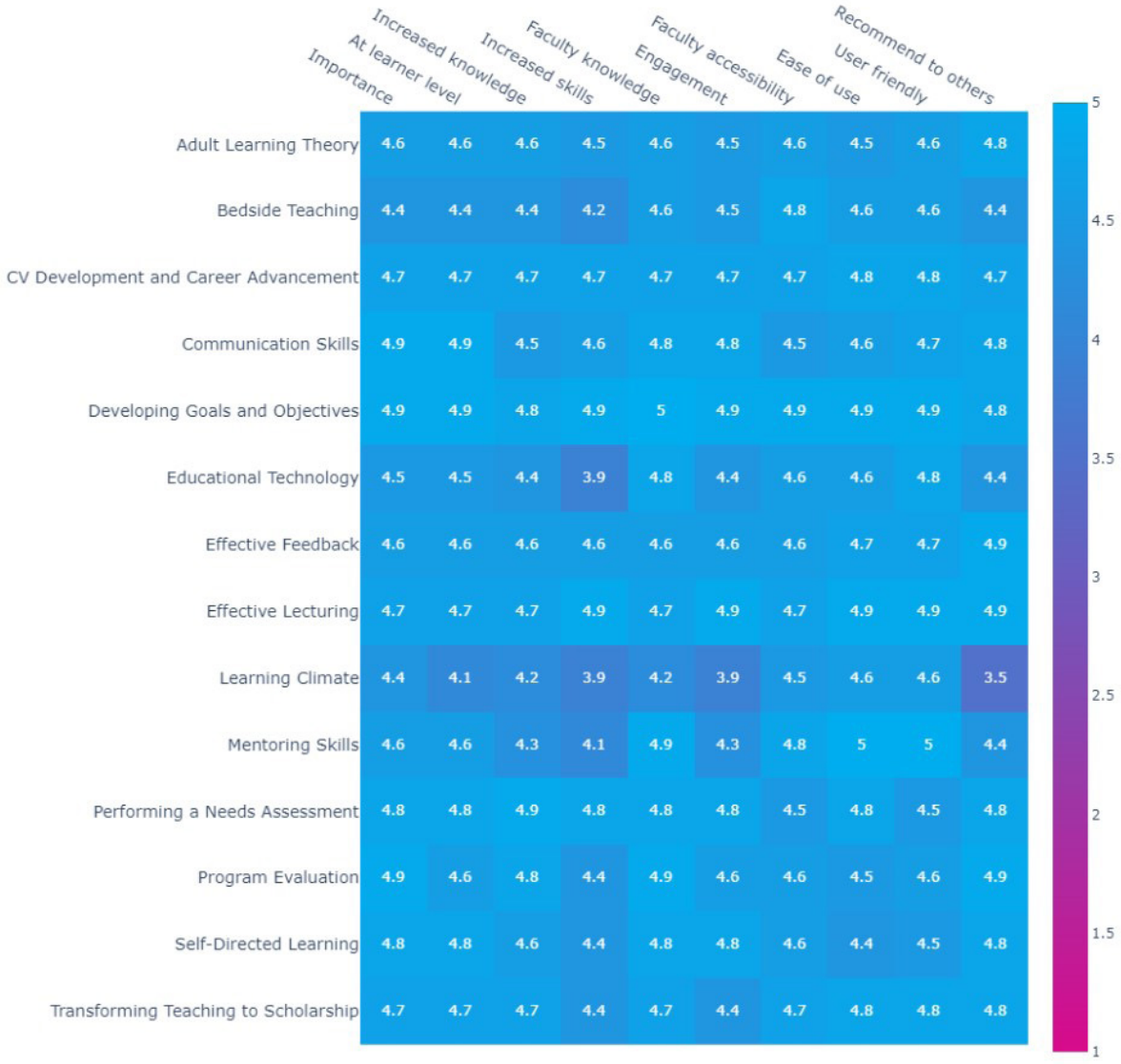

Figure 2. Survey results for each module cross-referenced to captured domains in the survey.

Baylor College of Medicine/ Texas Children's Hospital

Pivot in Pediatric Pulmonology Instruction at a Time of Exponential Growth in Medical Knowledge; Process Oriented Guided Inquiry Learning (POGIL)

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RATIONALE

It is estimated that the doubling time of medical knowledge in 1950 was 50 years; in 1980, 7 years; in 2010, 3.5 years, and in 2020, just 73 days. Due to the constant advances in the field of medicine, physicians must commit to lifelong learning to provide their patients with exemplary care. It is important to cultivate cognitive process skills to keep up with rapid advances in medical knowledge. Our pediatric pulmonary fellowship curriculum was outdated with traditional didactic lectures that didn't allow opportunity for higher order learning.

The current literature on adult learning emphasizes the improvement of higher order thinking through active learning methodologies. Process oriented guided inquiry learning (POGIL) is an instructional strategy involving discussions generated by carefully crafted questions. Students move through three phases: exploration, concept formation and application. POGIL can enhance retention, content mastery and process skills. Our objective was to pivot from traditional instruction and integrate POGIL in fellows' curriculum to see if we could enhance key cognitive skills.

METHODS

Using educational design research, we conducted a systematic approach to rebuild the curriculum. We performed needs assessment surveys to obtain perspectives of fellows and faculty. Informed by this data, we designed a pilot Pulmonary "201" Series consisting of advanced high-yield topics. Working with a core group of faculty, we introduced POGIL and ways to implement it successfully. Figure 1 below includes the application of POGIL to a new topic entitled Asthma 201: Biologic Therapy.

Critical thinking, problem solving, and metacognition were selected as the process skill outcomes to study. We used validated rubrics from the ELIPSS project (Enhancing Learning by Improving Process Skills in STEM) in our evaluation surveys and reviewed the meaning of the questions with select fellows for response process validity.

RESULTS

There were eight unique sessions offered with POGIL (n=40). We collected data from the participants on problem solving (5 items), critical thinking (6 items) and metacognition (4 items). The median scores on all items of each domain were 4 with interquartile range from (4-4), (4-4.5) and (3-5) respectively, where 1= minimally able and 5= completely able to perform the skill. 93% enjoyed the learning format and 95% were either satisfied or extremely satisfied with the learning sessions. 93% scored the quality of instruction as either "very good' or "excellent". Faculty who implemented POGIL provided feedback that the preparation was labor intensive, but the interactive format was enjoyable. They advised a narrow topic would be more successful, which helped guide selection of conference topics to use POGIL.

CONCLUSION

This curriculum rebuild emphasizes the importance of rethinking how we educate young physicians. Based on our data, POGIL has shown to be feasible for faculty, enjoyable for fellows and a new way to educate in this era of rapid advances. Future directions for the project may include comparing POGIL lectures to traditional (non-POGIL) lectures.

FIGURE 1

PHASE of POGIL	Proposed Examples to Faculty	Asthma 201: Biologic Therapy
EXPLORATION	Send relevant article(s) to fellows “Warm- up” simple patient case to introduce material	Read article on own before session
CONCEPT FORMATION	• Brief didactic • Pose a few critical thinking questions to guide discussion	Open ended questions to reinforce the most important points from the article
CONCEPT APPLICATION	• Provide new and more complex patient cases • Have the fellows work through the cases in small groups • Come back together in large group discussion	• 5 patient scenarios- Fellows worked in groups to determine first and second choices for biologic agent for each patient and why • Results reviewed as a large group

Mayo Clinic

Identifying Lung Transplant Knowledge Requirements for Pulmonary and Critical Care Medicine Fellows: A Delphi Survey Study

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INTRODUCTION

According to the Scientific Registry of Transplant Recipients (SRTR) data, there are currently 75 lung and 53 heart-lung transplant centers in the United States with a growing number of lung transplants performed each year. Given that nearly 33% of transplanted patients are surviving up to 10 years post transplant, a greater number of transplant and general pulmonologists may be needed to care for these patients. In the United States, the training pipeline often begins in a combined Pulmonary and Critical Care Medicine (PCCM) fellowship, however fellowships across the country do not universally require their fellows to complete a rotation in lung transplantation or have dedicated lung transplant curriculum. Furthermore, a survey of the Association of Pulmonary and Critical Care Medicine Program Directors (APCCMPD) in 2016 showed a large educational gap when comparing fellowships based in transplant centers versus those not: transplant curriculum was offered in 94% of fellowships based in transplant centers compared to 41% of fellowships not based in transplant centers. Currently, there is no standardized lung transplant curriculum. Here, we describe an outline for such curriculum development achieved through electronic Delphi methodology.

METHODS

We developed expert consensus on “Must know” lung transplant topics and sub-topics (“items”) for a graduating PCCM fellow through three rounds of electronic Delphi methodology from July 2023-October 2023. Experts were self-identified after a recruitment email was sent to the American College of Chest Physicians Transplant Network (ACCP) list-serv and to a separate group of International Society for Heart Lung Transplantation (ISHLT) network members interested in lung transplant education. Experts were asked to rank items as “Must know”, “Nice to know” or “Not necessary to know”. Panelists were also allowed to submit new items for ranking in round one which were reviewed by the authors for duplication, uniqueness to transplant medicine, and relevance to learner level before being included in subsequent rounds for ranking. “Must-know” consensus was defined as >50% “Must-know” responses. If an item had a tied response that included “Must-know”, it was included in subsequent rounds for re-ranking. Closing criteria a priori was decided to be three rounds or when consensus had been reached on all items. Weekly reminder emails were sent during each round.

RESULTS

A total of 33 panelists were sent questionnaire links in each round. Survey response and completion rates across rounds were 58%–70% and 96%–100% respectively. Of the 22 respondents to the item on educational leadership role, 17 identified as core faculty members of a PCCM fellowship, 6 identified as program directors of a lung transplant fellowship and 4 identified as medical directors of a lung transplant program.

In round one, panelists were provided eight topics and 30 sub-topics for initial ranking. Six topics and 21 sub-topics achieved “Must-know consensus”. Panelists generated 82 new items in this round, of which 19 were included in round two for ranking along with one topic from round one that required re-ranking. In round two, that topic and 15/19 sub-topics achieved “Must-know” consensus. Only two items required re-ranking, and these items comprised round three. Neither achieved “Must-know consensus” in the last round.

CONCLUSION

Self-identified lung transplant experts were able to obtain consensus on seven “must know” topics and 36 sub-topics in lung transplant for graduating PCCM fellows. These topics are “transplant immunology”, “evaluation of a lung transplant candidate”, “surgical and peri/post operative management”, “rejection”, “immunosuppression”, “infections”, and “other complications”. Dissemination of this work is the first step in creating a standardized, curriculum for lung transplantation.

TABLE 1. PANELIST DEMOGRAPHICS. Panelists were allowed to select more than one clinical role. Of the 22 panelists that responded to the item, 9/22 had >1 clinical role, 8/9 included core faculty as one of their roles. OPO = organ procurement organization.

Panelist Demographics	
Delphi Response Rates	Number (%)
Number of Delphi rounds	3
Number of invited participants each round	33
Round one response rate	23 (70)
Completion rate	22 (96)
Round two response rate	22 (67)
Completion rate	22 (100)
Round three response rate	19 (58)
Completion rate	19 (100)
Leadership Role	
Core faculty	17
Surgical director of a lung transplant program	1
Medical director of a lung transplant program	4
Program director of a lung transplant fellowship	6
Program director of adult cystic fibrosis program	1
Assistant program director of a lung transplant fellowship	1
Assistant program director of a pulmonary and critical care fellowship	1
Number of Panelists by Geographic Distribution	
United States (by OPO region)	20
Region 2	2
Region 4	2
Region 5	4
Region 7	2
Region 8	1
Region 9	1
Region 10	8
Europe	3

TABLE 2. LIST OF "MUST-KNOW" TOPICS AND SUB-TOPICS ACHIEVED AFTER THREE SURVEY ROUNDS. CMV = Cytomegalovirus, EBV= Epstein Barr virus, COPD = chronic obstructive lung disease, ILD = interstitial lung disease, PAH = pulmonary arterial hypertension, CF = cystic fibrosis, PFT = pulmonary function testing, HLA = human leukocyte antigen, ECMO = extracorporeal membrane oxygenation.

Must-Know Topics and Sub-Topics	"Must-know" Percentage (%)
Infections	**100.0**
CMV infection (viremia, organ manifestations, prophylaxis, resistance)	90.9
Fungal infections	86.4
Infections < 1 year post-transplant	81.8
Prophylaxis (anti-fungal, viral, bacterial prophylaxis)	77.3
EBV and CMV serostatus	72.7
Infections > 1 year post-transplant	68.2
Donor derived infections	59.1
Immunosuppression	**90.9**
Classes of medications (including dosing schedule)	95.5
Side effects	86.4
Drug interactions	72.7
Induction	54.6
Rejection	**86.4**
Chronic lung allograft dysfunction	81.8
Acute cellular rejection	77.3
Antibody mediated rejection	68.2
Hyperacute rejection	63.6
Evaluation of a transplant candidate	**81.2**
Timing of referral for specific disease states (COPD, ILD, PAH, CF)	95.5
Contraindications and risk factors for transplant	77.3
Management of patients awaiting transplant (periodic status assessment, PFTs, rehab)	77.3
Evaluation process (testing, financial approval)	68.2
Ethics, gender, and racial inequities surrounding selection	63.6
Frailty	59.1
Indications for re-transplant	54.6
Timing of listing	50.0
Transplant immunology	**68.2**
Innate (cellular) immune response	63.6
Adaptive (humoral) immune response	59.0
HLA system and highly HLA sensitized patients	50.0
Mechanism of pre-transplant cross-match	50.0
Other complications	**63.6**
Airway (stenosis, malacia, dehiscence)	68.2
Pulmonary vein thrombosis	54.6
Cardiovascular and vascular	50.0
Hyperammonemia syndrome	50.0
Malignancy (skin, solid organ)	50.0
Surgical and peri/post-operative management	**59.1**
Bridge to transplant (including ECMO indications)	90.9
Mechanical ventilation strategies in immediate post-op period	72.7
Primary graft dysfunction	68.2
Overview of immediate post-operative management	59.1

University of Washington

Anatomy-based chest CT interpretation curriculum for pulmonary fellows

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INTRODUCTION

Chest computed tomography (CT) interpretation is a key competency for pulmonary fellows. There are many resources intended for radiologists, but very few for pulmonary fellows. We created a high-yield resource to connect CT patterns of disease to underlying pulmonary anatomy and provide algorithms to develop differential diagnoses.

INNOVATION

We assembled a team of two pulmonologists, one radiologist, and a fellow with computer drafting software experience. We reviewed available chest CT interpretation teaching materials, outlined the content, and developed learning objectives. We collected original CT images exemplifying key patterns of disease, created illustrations of the key anatomy and patterns of disease, and outlined an approach to identify chest CT patterns and build differential diagnoses. We presented the material to three classes of first year pulmonary and critical care medicine (PCCM) fellows at our institution. The first year this was as a 1.5-hour interactive power point presentation. For subsequent years, we created a series of five short videos and 18 practice cases with answer keys, to be reviewed asynchronously, with a one-hour in-person review session facilitated by a chest radiologist. We created a survey to assess learner comfort before and after reviewing the material, knowledge after reviewing the material, and solicit feedback.

OUTCOMES/IMPACT

Eighteen fellows in three cohorts reviewed the curriculum. Verbal feedback described the material as the best CT teaching they had experienced.

Eight fellows completed the survey. There was a significant improvement in comfort with mean difference + 1.27-points, p-value <0.05. Seven of eight fellows agreed the videos alone were enough to gain confidence in their understanding. All fellows reported that practice cases and the session contributed to their learning.

The webpage hosting the curriculum has been viewed over 680 times from February of 2022 to August 2023. Despite fellows being assigned to complete the curriculum during their lightest clinical rotation, they did not all study the asynchronous material before the review session and very few completed the survey.

CONCLUSIONS

This self-guided interactive curriculum provides a structured approach connecting key lung anatomy to patterns of disease. Fellows who completed the whole curriculum reported finding it very helpful. Nonetheless, in order to complete it, fellows needed regular reminders.

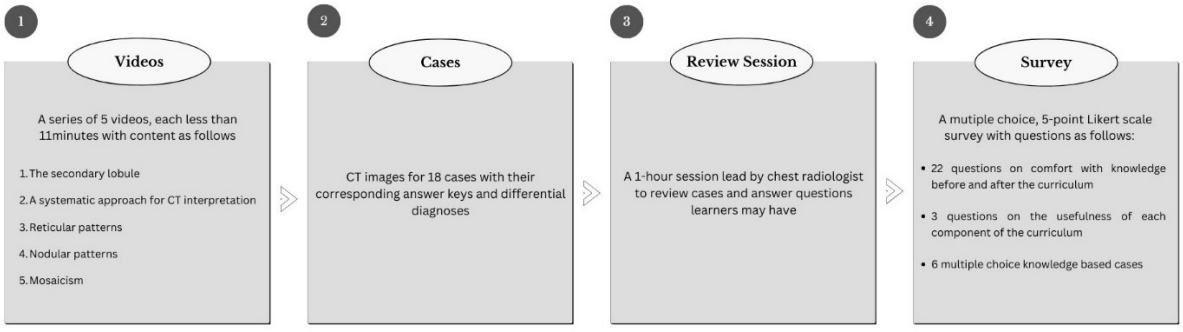

Figure 1. Components of the curriculum with overview of the content of each

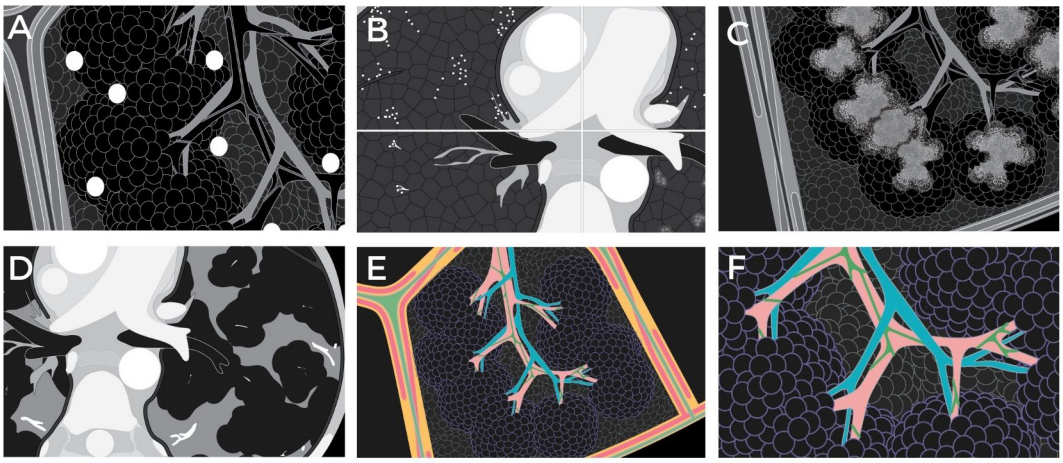

Figure 2. A compilation of illustrations of anatomy and key disease processes produced as part of the curriculum. a) random nodules b) comparison of nodular patterns c) centrilobular nodules d) mosaicism due to air trapping e) secondary lobule f) central artery, bronchi and acini

Ohio State Wexner Medical Center

Building a Groundwork for Change: A Sustainable Diversity, Equity, and Inclusion (DEI) Fellowship Curriculum in Pulmonary and Critical Care

INTRODUCTION

Patients with pulmonary disease often face systemic barriers to care, yet trainees do not feel trained to manage these barriers. Our program perceived a need to increase Pulmonary and Critical Care Medicine (PCCM) Fellows' knowledge of structural causes of inequity and improve their ability to effectively care for historically disadvantaged patients.

METHODS

A needs assessment surveyed fellows' opinions on race and disparities. Based on these results and clinical needs, we created a 3-year curriculum to address PCCM topics through a lens of health equity. After the first programmatic year, the fellows completed a follow up survey.

RESULTS

In the initial needs assessment, 17/18 (94.4%) fellows believed race to be a significant contributor to disparities in healthcare. 16/18 (88.9%) agreed that racial bias contributes to inequities specific to PCCM.

In the 2022 – 2023 academic year, we created and delivered three workshops: "Person First Healthcare," "Race and Spirometry" and "Reframing Pulmonary Disease using a Health Equity Framework." While the initial plan was to focus on racial disparities, ongoing conversations and clinical exposures prompted us to expand the topics. In 2023 – 2024, we will present workshops: "The Rural/Urban Divide in Critical Care" and "Pulmonary Care for Incarcerated Patients." For 2024 –2025, planned workshops are "Disparities in Lung Transplant" and "Care of the Patient with Sickle Cell Disease." We aim to revise and repeat these sessions in a three-year cycle, to take advantage of the three-year fellowship curriculum.

After our first programmatic year, fellows were again surveyed, and 9 of 11 (82%) fellows agreed that a patient's ethnic and racial identity can affect their pulmonary testing and treatment. 10 of 11 (91%) fellows agreed that PCCM fellowship should provide them with the tools to provide high quality care to patients from historically underprivileged groups. 7 of 10 (70%) were engaged in efforts to reduce health disparities outside of fellowship.

CONCLUSIONS

Equity and inclusion in PCCM remains an aspirational idea. However, based on our experience, providing trainees exposure to DEI topics can impact their perceptions and create a change-minded culture. Our most recent survey highlights that fellows acknowledge race is a factor in healthcare and that fellowship programs have an obligation to provide meaningful education on this topic. Ongoing assessment of curricular efficacy will help to continue to refine this longitudinal PCCM curriculum.

Hospital of the University of Pennsylvania

Multimodal interdisciplinary mechanical ventilation education for critical care trainees: A pilot curriculum

INTRODUCTION

Management of mechanical ventilation (MV) is a core competency in critical care (CC) training. Over half of CC trainees are dissatisfied with their mechanical ventilation education and perform poorly on related assessments. We implemented a longitudinal, multimodal MV curriculum for pulmonary and CC trainees and assessed its impact on trainee confidence, knowledge, and skills in managing MV.

METHODS

Informed by a pre-curriculum needs assessment of our learners, CC faculty educators compiled goals, learning objectives, and a skills checklist. A yearlong MV curriculum was implemented from 2022-2023 and included lectures on MV principles, bedside MV clinical skills sessions with faculty, and weekly online ventilator waveform quizzes. Skills taught included maneuvers for respiratory mechanics, adjusting peak pressure alarms, and performing a positive-end-expiratory pressure titration. Fellows additionally participated in an immersive one-on-one session with an intensive care unit-based respiratory therapist (RT), and a case-based ventilator simulation session with CC faculty and an RT educator. Trainees completed post-curriculum surveys at the end of the academic year, which queried their comfort in MV skills and assessed MV knowledge (six questions). Faculty intensivists were surveyed to validate the questionnaire. Faculty responses were compared to fellow responses.

We performed descriptive statistics on all surveys. Pre- and post-curriculum trainee surveys were analyzed with paired, two-tailed t-tests with an alpha level of 0.05 for significant differences. Quantitative data analysis was performed with StataCorp 17.

RESULTS

Twenty fellows (67%) completed the pre-curriculum survey, 18 fellows (60%) completed the post-curriculum survey, 13 fellows (43%) completed the RT immersive session, and 10 CC faculty (37% of those queried) completed the validation survey. Fellows were least confident in waveform interpretation and connecting ventilator mechanics to pathophysiology. Following the longitudinal curriculum, confidence improved for all skills queried. The greatest change was seen in comfort with waveform interpretation. First year fellows had relatively less comfort with all skills queried compared to senior fellows (*Table 1*).

There were statistically significant improvements for the eight fellows whose pre- and post-curriculum surveys could be linked in MV terminology ($p=0.03$) and pressure control waveform interpretation ($p=0.01$). They had an improvement in mean pre- versus post-curriculum survey knowledge questions answered correctly (average correct responses: 3 vs. 4.75, $p<0.01$).

The RT immersive session improved comfort with basic skills (e.g., checking respiratory mechanics, performing in-line suctioning) and advanced skills (e.g., performing positive end-expiratory pressure titration or performing and interpreting a cuff leak test).

Faculty performed better than the fellows with the knowledge questions, but similarly performed poorest on the questions about pressure control ventilation and airway pressure release ventilation (*Figure 1*).

Trainees were satisfied with the curriculum overall, citing the skills sessions with faculty, simulations, and weekly waveforms as most helpful after direct patient care.

CONCLUSIONS

Our multimodal, interdisciplinary, longitudinal MV curriculum improved pulmonary and critical care fellow confidence and proficiency in MV management skills and knowledge of MV principles. RT involvement in fellow MV training strengthens fellow comfort with specific MV skills.

Figure 1. Pre-curriculum needs assessment graphical representation of proportion of mechanical ventilation knowledge questions answered correctly in each group of participants.

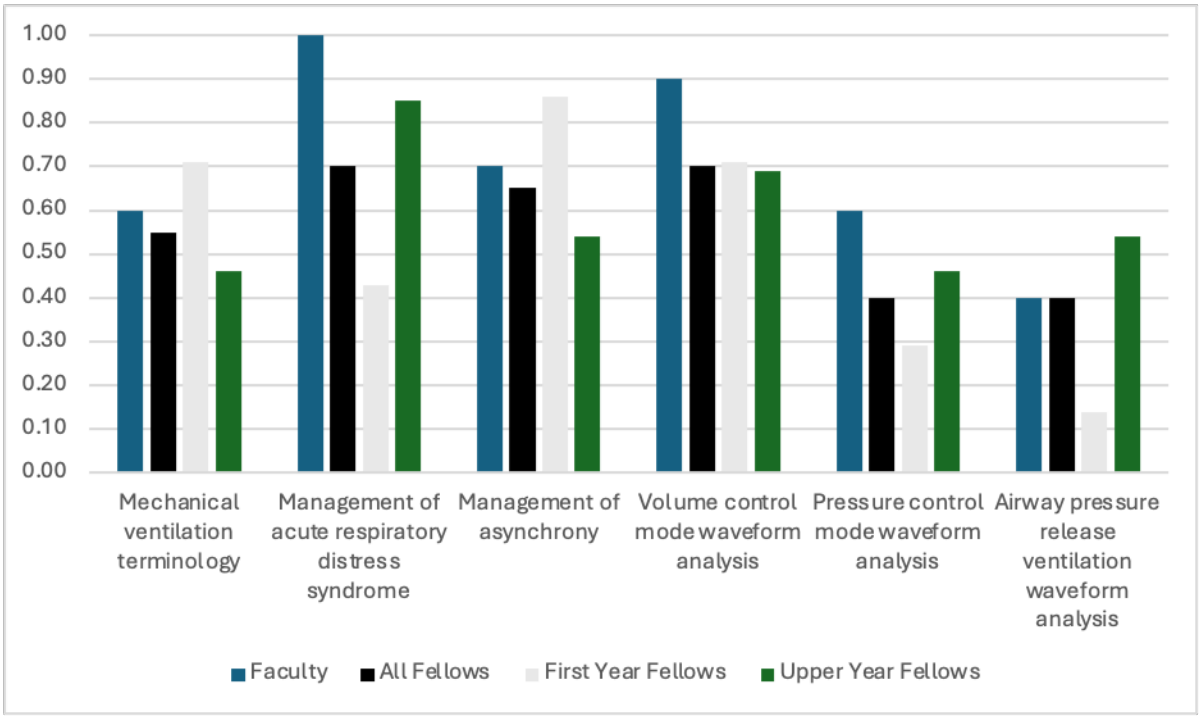

Table 1. Pre- and post-curriculum responses to skills checklist questions rating comfort with each skill on a Likert scale. For the pre-curriculum survey, 5 is extremely comfortable, 4 is somewhat comfortable, 3 is neither comfortable nor uncomfortable [same level of comfort as previously], 2 is somewhat uncomfortable, and 1 is extremely uncomfortable. For the post-curriculum survey, questions were worded as comfort with each skill compared to the beginning of the academic year. The Likert scale was the same, but as compared to the beginning of the academic year, therefore 5 is much more comfortable, 4 is somewhat more comfortable, 3 is comfort level unchanged, 2 is somewhat more uncomfortable, 1 is much more uncomfortable.

Skill queried	First Year Fellows		Upper Year Fellows		All Fellows		After RT Immersion
	Pre (n=7)	**Post** (n=4)	**Pre** (n=13)	**Post** (n=8)	**Pre** (n=20)	**Post** (n=12)	(n=10)
Required							
Perform maneuvers for respiratory mechanics.	3.7	3.5	4.7	3.8	4.4	3.7	4.9
Perform in-line suctioning.	2.9	4.3	4	3.8	3.6	3.9	4.8
Perform a synchronous spontaneous awakening trial (SAT) and spontaneous breathing trial (SBT).	3	4	3.9	4	3.6	4	4.6
Adjust peak pressure alarm to allow for breath delivery in emergencies.	2.6	4.8	4.3	3.9	3.7	4.2	4.6
Address common asynchronies (e.g., double stacking, flow hunger, dynamic hyperinflation).	1.9	4.5	3	4.9	2.6	4.8	3.8
Set up ventilator in different modes: ACVC, ACPC, and PSV.	2	4.8	3.3	4.4	2.9	4.5	4
Manipulate the following ventilator settings based on patient physiology and comfort: trigger, i-time, and E-sens.	2.4	4.5	3.3	4.8	3	4.7	4
Perform positive end-expiratory pressure titration.	3.3	4	4.9	3.5	4.4	3.7	4.8
Optional							
Adjust endotracheal tube (ETT) position.	2.1	3.8	3.6	3.5	3.1	3.6	3.8
Perform and interpret a cuff leak test.	2.1	4	3.5	3.8	3.1	3.8	4.2
Perform a recruitment maneuver.	2.1	3	3.5	3.4	3	3.3	3.5
Additional							
Identify and trouble shoot patient intolerance to non-invasive positive pressure ventilation (including mask fit, pressure settings, rise time).	2	3.8	2.7	4.4	2.5	4.2	N/A
Participate in choosing and evaluating settings for CPAP or BPAP.	3.3	4	3.4	4.1	3.4	4.1	3.8

RT: respiratory therapy; **ACVC**: assist-control volume control; **ACPC**: assist-control pressure control; **PSV**: pressure support ventilation; **CPAP**: continuous positive airway pressure; **BPAP**: bilevel positive airway pressure; **AVAPS**: average volume-assured pressure support; **N/A**: not assessed in this survey.

Wayne State University School of Medicine

Pulmonary Hypertension Curriculum for Pulmonary & Critical Care and Cardiology Fellows: A Case Based and Flipped Classroom Model

INTRODUCTION

Pulmonary hypertension (PH) is a complex disease which if left untreated, progresses to right heart failure and death. There is often a delay in early recognition and management of these patients1. In one cross-sectional study of referrals to a PH center, almost a quarter of patients were misclassified, and a significant portion started on medications contrary to published guidelines2 . Pulmonologists and cardiologists will frequently encounter PH throughout their careers and yet there is a dearth of curriculum guided towards the early recognition and appropriate diagnostic workup of PH during fellowship training. Our objective was to design a multidisciplinary standardized case-based curriculum to initiate appropriate diagnosis of PH for cardiology and pulmonary & critical care (PCCM) fellows.

ABSTRACT PRESENTATION

The curriculum was presented to PCCM and cardiology fellows across all levels of training (N=25). A baseline knowledge assessment was performed including Likert scales to assess confidence in interpreting pulmonary artery catheter (PAC) waveforms and initiating a diagnostic workup. Two pre-recorded videos were created using an internet-based educational editing and viewing platform, Edpuzzle.com. One video provided an overview of how to interpret PAC waveforms with a simulated model and embedded quizzes (10:21 minutes long). The second video provided an overview of the pathology of PH and updated definitions, as well as a detailed look into a diagnostic algorithm and echocardiographic findings of PH (14:53 minutes long). The use of the videos allowed the curriculum to be structured in a “flipped classroom” model wherein classroom didactic time was reserved for case-based learning and small group discussion. After viewing the videos, the fellows gathered for a 1-hour case-based discussion where 5 unique patient cases were reviewed, representing idiopathic pulmonary arterial hypertension, heart failure, interstitial lung disease, chronic thromboembolic PH, and acute right heart failure. The fellows worked through the undifferentiated patient cases together following a structured rubric. Finally, fellows participated in a second 1-hr lecture reviewing echocardiographic findings in real patients with PH as well as a literature review of treatment and risk assessment tools. A post-training knowledge assessment and confidence survey was conducted 4 weeks later.

DISCUSSION

In August 2023, 25 PCCM and cardiology fellows participated in the curriculum. The total duration of the curriculum (including the pre-recorded videos) was 2 hours and 25 minutes. The mean score on the pre-test was 8.8 (53.6%) ± 4.3 across all levels of training. The mean score on the post-test was 13.4 (84.2%) ± 2.1 with a p-value of 0.0001 showing a significant improvement in knowledge (figure 1). There was a significant improvement in the Likert assessment of PAC waveform analysis confidence and ability to initiate a diagnostic workup for PH (see Table 1). In a subgroup analysis stratified by post-graduate year (PGY), each level showed improvement in knowledge but only the PGY-4 year showed a significant benefit (p = 0.01).

CONCLUSION

This standardized case-based curriculum improved the medical knowledge and confidence of PCCM and cardiology fellows in the accurate diagnosis PH. The curriculum used asynchronous hybrid computerized and flipped class learning methods giving opportunities for learners with limited flexibility and busy training schedules with limited classroom time. The curriculum allowed fellows to learn in multidisciplinary teams which is essential in real-life patient care. The significant improvement

in knowledge and confidence in the appropriate diagnosis of PH using this novel curriculum among PCCM and cardiology fellows is promising and requires further validation for generalizability and effectiveness in improving patient outcomes.

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	Pre-training Mean ± SD	Post-training Mean ± SD
Likert PAC Waveform Analysis Confidence Score	2.3 ± 1.1	3.3 ± 0.8 *
Likert Initiate PH Diagnostic Workup Confidence Score	2.9 ± 1.2	3.9 ± 0.8 *
Knowledge Assessment Score Means (Percentages)		
PGY-4 (N = 9)	7.6 (42.7) ± 3.9	12.7 (79.2) ± 2.5*
PGY-5 (N = 9)	9.0 (56.3) ± 4.1	13.3 (82.8) ± 2.5
PGY-6 (N = 6)	9.8 (61.5) ± 5.5	14.7 (91.7) ± 7.2

Table 1. Mean and standard deviation of pre- and post-training survey using 5-point Likert scale, with 5 as 'extremely confident' in listed domains. Subgroup analysis of mean and standard deviation of knowledge assessment score pre- and post-training. * = p<0.05, PGY = post-graduate year. N = number of participants on sign-in sheet, one participant did not list their PGY level.

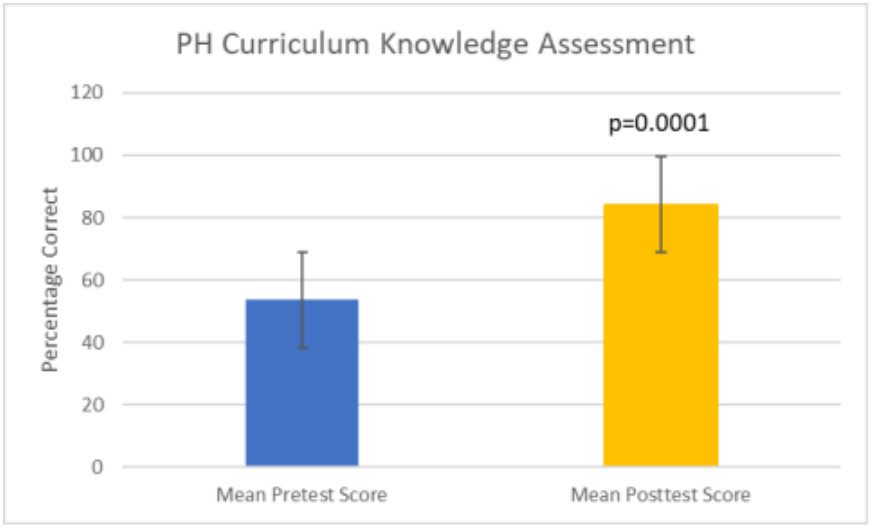


Figure 1. Mean and standard deviation of pre- and post-training knowledge assessment scores of pulmonary and critical care and cardiology fellows who participated in the pulmonary hypertension curriculum.

University of California - San Francisco

3D Printing the Pleura: A novel solution to the pleural procedure simulation problem

ILANA ROBERTS KRUMM MD, SCOTT DRAPEAU MA, YARON GESTHALTER MD, LEKSHMI SANTHOSH MD MAED

RATIONALE

The tides are shifting from the traditional “see one, do one, teach one” apprenticeship model of procedural education to a “graduated autonomy” approach with a focus on simulation-based mastery and maintenance. Simulation-based learning has been demonstrated to improve knowledge, skills, behaviors, and patient-related outcomes through hands-on, repeated practice, standardization, exposure to rare or complex situations, and assessment in a safe, zero-risk environment.

Despite the advantages of simulation, options for pleural procedure simulations are extremely limited. Simple thoracentesis task trainers cost up to $6000 and require frequent replacement parts. Despite the cost, the commercially available versions are poor fidelity proxies for the pleural space, using hard plastics that feel different from human tissue. Even at the national level, pleural procedural teaching is limited due to poor fidelity of high-cost pleural task trainers, with few alternatives to commercial task trainers. Some institutions use cadaveric-based simulation; however, these sessions are costly and not amenable to just-in-time training. Others recommend a half rack of pork ribs for simulation, which, while delicious to some, is unappetizing to others, and is overall not suitable for just-in-time implementation and has significant durability and storage limitations.

METHODS

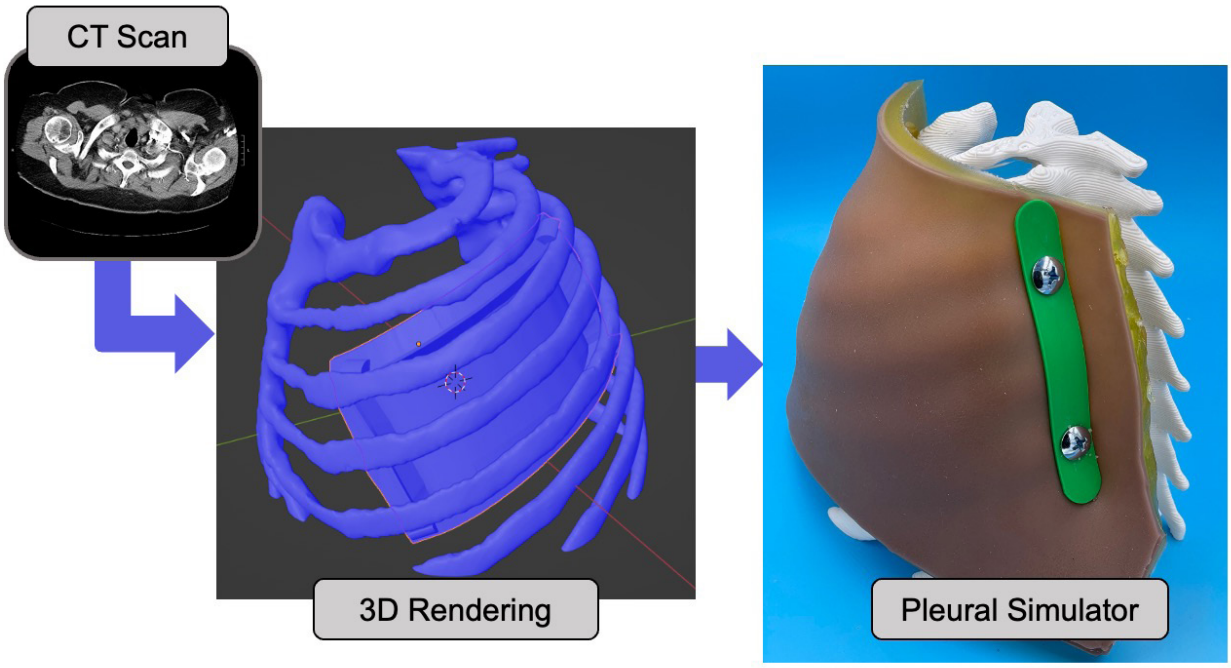
In conjunction with the UCSF Maker’s Lab, a model ribcage was printed from CT scan imaging using 3D Slicer (http://www.slicer.org), and then edited using Blender (Stichting Blender Foundation, Amsterdam; 2018). Next, the ribcage was fitted with silicone skin. Utilizing Design-Based-Research methodology the model was iteratively refined with pilot test groups to develop a pleural fluid pocket and ensure realistic haptic feedback.

RESULTS

A 3D-printed pleural procedure model was manufactured and piloted with internal medicine residents, pulmonary fellows and faculty, demonstrating realistic tactile feedback and successful thoracentesis training for learners. The model was iteratively designed with version 4.0 in production to facilitate modifiable soft tissue thickness and increased complexity of the pleural fluid pocket, costing less than $100 per simulator.

CONCLUSIONS

To our knowledge, this represents the first 3D-printed hemithorax for pleural procedural simulation, successfully created for a fraction of the cost of commercial simulators. These models are currently being employed in further studies of procedural teaching and simulation sessions with trainees, and utilized as a tool for pulmonary fellows to both learn and teach pleural procedures. Next steps will include national dissemination and expansion to chest tube and pleuroscopy simulation. With continued development, this work will radically improve pleural procedural education, adding capability for high-fidelity, low-cost, just-in-time simulation.


CT Scan
3D Rendering
Pleural Simulator