



Determination of Priorities for Lung Transplant Education for Pulmonary and Critical Care Medicine Fellows

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ABSTRACT

Background: In the United States, a growing number of lung transplants are performed each year, necessitating an increased number of general and transplant pulmonologists skilled in the care of these complex patients. However, pulmonary and critical care medicine (PCCM) fellowships across the country do not universally have dedicated lung transplantation curricula, and there is scarce literature in this area. We describe the generation of a content outline for curriculum development created through modified electronic Delphi methodology.

Objective: To identify “must know” topics in lung transplantation for a graduating PCCM fellows.

Methods: We developed expert consensus on “must know” lung transplant topics and subtopics (“items”) for a graduating fellow through three survey rounds from July 2023 to October 2023. Thirty-three panelists were asked to rank author-provided items as “must know,” “nice to know,” or “not necessary to know” and to generate new items in round 1 to be submitted for ranking in subsequent rounds. “Must know consensus” was defined as $\geq 50\%$ must know responses.

Results: Survey response and completion rates across rounds were 58–70% and 96–100%, respectively. In round 1, panelists were provided eight topics and 30 subtopics for initial ranking. Panelists generated 82 new items in this round, of which 19 were included in round 2 for ranking after author review, together with one item from round 1 that required

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Author Contributions: All authors were involved in study design, data collection, analysis, and manuscript preparation.

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reranking. From round 2, only two items required reranking, and these items comprised round 3. Seven topics were identified as “must know”: transplant immunology, evaluation of a lung transplant candidate, surgical and peri/postoperative management, rejection, immunosuppression, infections, and other complications, together with 36 subtopics.

Conclusion: Self-identified lung transplantation experts obtained consensus on seven “must know” topics and 36 subtopics in lung transplantation for graduating PCCM fellows. The findings serve as a starting point for future curriculum development.

Keywords:

education; Delphi; transplant; curriculum

According to annual Scientific Registry of Transplant Recipients and Organ Procurement and Transplantation Network data, more adult lung transplants are being performed annually in the United States now than a decade prior; in 2013, 1,877 adult lung transplants were performed (1) compared with 2,743 in 2022 (2). Given that nearly 33% of transplanted patients are now surviving up to 10 years after transplant (2), a greater number of transplant and general pulmonologists may be needed to care for these patients. General pulmonologists are often the source of referral, the candidate advocate, the first point of contact for a long-term survivor living at a distance from his or her transplant center, and the responsible physician for any acute issues or local testing or follow-up needed. In addition, they must have a high index of suspicion for rejection and infection, avoid drug interactions, and be aware of when to contact the transplant center (3).

These expectations of general pulmonologists align with the Accreditation Council of Graduate Medical Education (ACGME) core competencies for pulmonary and critical care medicine (PCCM) fellows, which are to understand the indications, complications, and outcomes of lung transplant (4). Specific training in patient selection, general and pulmonary

complications, and post-transplant outcomes is also highlighted in the American Board of Internal Medicine (ABIM) blueprint for pulmonary medicine board certification (5).

However, despite the growing patient population, transplant is not a mandatory rotation in PCCM fellowship, and there is a large educational gap in this area when comparing fellowships based in transplant and nontransplant centers (6). A national survey of PCCM program directors reported that in programs based in nontransplant centers, only 41% had a transplant curriculum (defined as the presence of reading material, large- or small-group lectures, institutional handbooks, or online modules), and only 49% had the ability for trainees to rotate either internally or externally. This was in comparison with 96% of fellowships based in transplant centers having a curriculum and the average duration of a transplant rotation being 8 weeks. Program directors at nontransplant centers identified limitations in faculty training, program resources, and patient contact as barriers.

A shared curriculum will help address this educational gap; however, very little has been published in this area. In 2013, Hayes and colleagues published a single-center description of a transplant curriculum that

listed fellow rotation duties and educational objectives but lacked a detailed content outline of reported video topics and reading lists (7). In 2022, Kassutto and colleagues described case-based teaching scripts that did have detailed content outlines but covered only three transplant-related topics (8). Although lung transplant occupies a small portion (2%) of the ABIM pulmonary board certification examination, we believe it is important to train a future workforce based on changing patient population trends while addressing known educational gaps. A current, comprehensive content outline for curriculum development in lung transplant for PCCM fellows is not available. Herein, we describe a study using modified electronic Delphi methodology to create such an outline for future curriculum development.

METHODS

Study Design

We developed expert consensus on lung transplantation topics and subtopics (“items”) for a graduating PCCM fellow through modified electronic Delphi methodology from July 2023 to October 2023. The modified electronic Delphi methodology was chosen because it is a systematic way to elicit expert consensus in an area without clear data (9). Our study conforms to the Delphi reporting guidelines as outlined by the CREDES (Conducting and Reporting of Delphi Studies) tool (10). This study was deemed exempt by the Mayo Clinic Institutional Review Board.

Panelist Selection

Our panelists were a group of transplant pulmonologists from academic medical centers with an interest in medical education from the United States and Europe. Panelists were self-identified after

a recruitment e-mail was sent to the American College of Chest Physicians Transplant Network listserv and to a separate group of International Society for Heart Lung Transplantation network members interested in lung transplant education. Panelists received personalized questionnaire links for each Delphi round. Preserving anonymity was not always possible, because several panelists included other interested colleagues in their reply to our recruitment e-mail.

The information provided to the panelists at the time of recruitment was a brief description of the study and learner level (“for a graduating PCCM fellow, not lung transplant fellow”), intended plans for the data generated, and expectations for participation. Panelists were expected to complete up to three survey rounds, review feedback between rounds, and provide information about their clinical roles.

Survey Design and Iterative Feedback

We used Qualtrics to survey our panelists. Panelists were asked to rank items as “must know” (MK), “nice to know” (NK), or “not necessary to know” (NN) for a graduating PCCM fellow. Consensus was defined as having $\geq 50\%$ of responses as MK. If an item had tied responses that included MK, it was submitted for reranking in the subsequent round. Closing criteria *a priori* was decided to be three rounds. Weekly reminder e-mails were sent during each round.

For round 1, we created a list of items based on senior author expertise (one lung transplantation fellowship-trained PCCM physician/associate program director of a lung transplantation fellowship/3 yr in practice; one PCCM physician/associate program director of a PCCM fellowship/7 yr in practice), and the ABIM/ACGME core competencies. Panelists were also

given the opportunity to suggest new items in this round only.

Between the first and second rounds, panelists were provided e-mail feedback on 1) round 1 response rate, 2) items that did not achieve consensus, and 3) transplantation-related ABIM and ACGME competencies for PCCM fellows. Summary statistics for how the group ranked items in this round were not provided. All new items generated were reviewed by the authors for duplication, relevance to learner level, clarity, and uniqueness to transplantation medicine before being considered for ranking in round 2. This additional step was taken by the authors as a quality control measure outside of usual Delphi practice to streamline the survey experience.

In round 2, panelists were asked to rerank any items from round 1 that had tied MK responses and those new items after author review. Between the second and third rounds, panelists were provided e-mail feedback on 1) round 2 response rate and 2) items that did not achieve consensus. Summary statistics for how the group ranked items in this round were not provided. In round 3, panelists were asked to rerank items that had tied MK responses in round 2.

Response rate was defined as having opened the questionnaire link and/or a partially completed questionnaire. Completion rate was defined as 100% completion of the questionnaire.

RESULTS

Panelists

A total of 33 panelists were sent questionnaire links in each round, and there were 25 unique panelists who participated in one or more rounds. The 23 panelists from round 1 responded

to the item on location of practice. Panelists represented 12 unique institutions in the United States and 3 from Europe. Of the 22 respondents to the item on educational leadership role, 17 (77%) identified as core faculty members and 1 identified as an assistant program director of a PCCM fellowship (Table 1).

Round 1

In round 1, the response rate was 70% ($n = 23$), and the completion rate was 96% ($n = 22$). The initial eight topics and 30 subtopics are provided in Appendix E1 in the online supplement.

All topics achieved “must know” consensus in this round except “transplant immunology” (50% MK, 50% NK), which was submitted for reranking, and “allograft donation and procurement” (59% NK, 27% NN), which was discarded. Three subtopics had tied MK responses: “response to allograft” (50% MK, 50% NK), “type of listing (41% MK, 41% NK), and “recurrence of native disease” (41% MK, 41% NK). “Response to allograft” was intentionally discarded from reranking because of vagueness of the term in relation to the new items suggested under transplant immunology. The other two subtopics were inadvertently omitted from the round 2 questionnaire. Five subtopics had majority responses that were not MK and were also discarded (“highly HLA sensitized patients,” “donor evaluation and types,” “*ex vivo* lung perfusion,” “overview of surgical techniques,” and “lymphoproliferative disorders”). Last, one subtopic that did achieve “must know” consensus (“normal immune response”) was intentionally discarded because of vagueness of the term in relation to the new items suggested under transplant immunology (Figure 1).

Table 1. Panelist demographics

	<i>n (%)</i>
Delphi response rates	
Number of Delphi rounds	3
Number of invited participants each round	33
Round 1 response rate (%)	23 (70)
Completion rate	22 (96)
Round 2 response rate (%)	22 (67)
Completion rate	22 (100)
Round 3 response rate (%)	19 (58)
Completion rate	19 (100)
Leadership role	
Core faculty	17
Program director of a lung transplantation fellowship	6
Medical director of a lung transplantation program	4
Surgical director of a lung transplantation program	1
Program director of adult cystic fibrosis program	1
Assistant program director of a lung transplantation 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

Definition of abbreviation: OPO = Organ Procurement Organization.

Panelists were allowed to select more than one clinical role. Of the 22 panelists who responded to the item, 9 had at least one clinical role, and 8 included core faculty as one of their roles.

In this first round, a total of 82 new items (22 items) and evaluation of a lung were suggested (Appendix E2), with most transplant candidate (10 items). After under the topics of transplant immunology author review, 19 new subtopics were

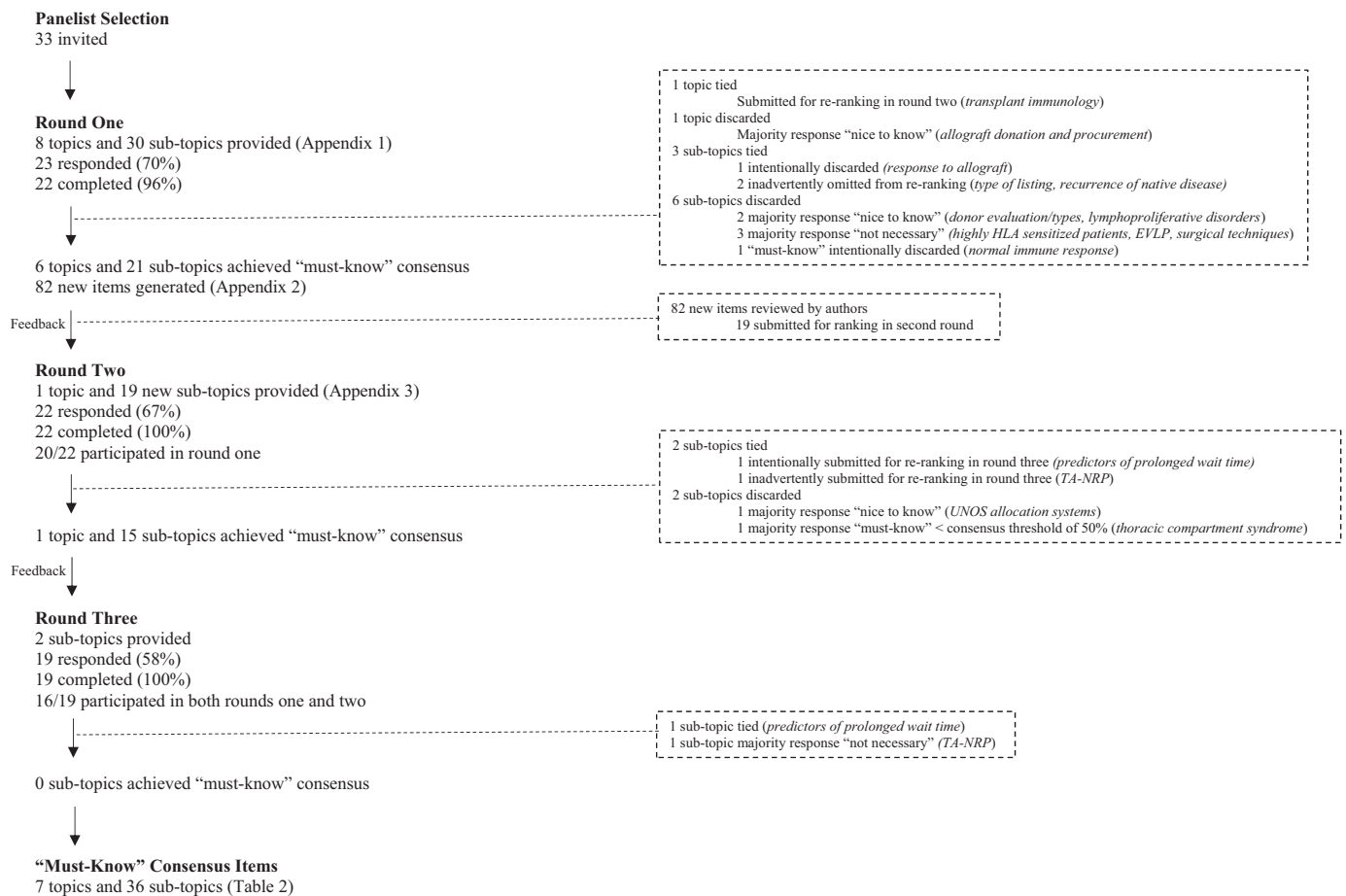


Figure 1. Delphi study flowchart. EVLP = *ex vivo* lung perfusion; HLA = human leukocyte antigen; TA-NRP = thoracoabdominal normothermic regional perfusion.

selected for reranking after consolidation in addition to the previous topic of “transplant immunology” (Appendix E3). Examples of our consolidation included, under the topic of “complications,” “long-term complications” was suggested (too vague); “heart failure,” and “osteoporosis” were suggested but also span many areas of pulmonary medicine (uniqueness); and “CLAD” (chronic lung allograft dysfunction) and “chronic rejection” were suggested (duplication).

Round 2

In round 2, the response rate was 67% ($n = 22$), and the completion rate was 100%. Twenty of the panelists participated in

round 1. The topic of “transplant immunology” and 15 subtopics achieved MK consensus. Two subtopics had tied responses and were submitted for reranking: “predictors of prolonged wait time” (45% MK, 45% NK) and “thoracoabdominal normothermic regional perfusion (TA-NRP)” (45% NK, 45% NN). The latter was unintentionally included in reranking despite not having an MK tied response. Two subtopics were intentionally discarded: “UNOS [United Network for Organ Sharing] allocation system” (50% NK, 14% NN) and “thoracic compartment syndrome” (MK majority of 40.9% less than the prespecified consensus cutoff of 50%).

Round 3

In round 3, the response rate was 58% ($n = 19$), and the completion rate was 100%. Sixteen of the panelists had participated in both prior rounds. Of the two items in this round, neither achieved MK consensus; “predictors of prolonged wait time” had a tied response (47% MK, 47% NK), and “TA-NRP” had a 53% majority response of NN. The final list of 7 “must know” topics and 36 subtopics is shown in Table 2.

DISCUSSION

Through modified electronic Delphi methodology, we created a content outline of 7 “must know” topics and 36 subtopics in lung transplantation for graduating PCCM fellows that serves as a starting point for future curriculum development. This content outline is comprehensive, reflects current practice, and fulfills a gap in the sparse lung transplantation education literature (6–8).

Our results suggest that transplant pulmonologists expect graduating PCCM fellows to have a more nuanced understanding of transplantation topics than suggested by current ABIM/ACGME standards. When comparing our results with these current standards (Table 3), it is evident that our content outline clarifies important details. This clarification can cue PCCM educators to high-yield transplantation topics to add to their fellowship curriculum and can be particularly helpful in cases where no transplant curriculum exists in part because of lack of faculty training or resources (6). Most of the items not included in the final content outline (Appendix E4) pertain to details on listing, surgery, or rare complications that are appropriate exclusions, considering the scope of practice of a general pulmonologist. One notable exception is “lymphoproliferative

disorders,” which fits in the ABIM “neoplastic complications” category.

However, creating a new curriculum for as broad an outline as this is a time-intensive process, and it may not be feasible to deliver this within the scope of a balanced PCCM training program. Some may argue that a curricular footprint this broad in transplantation is not necessary, given small representation on the current board certification examination. Regarding the former, we suggest starting with a more condensed list of 4 topics and 11 subtopics (Table 3) for reasons described below. We argue regarding the latter that the growing patient population of surviving lung transplant recipients does warrant increased training during fellowship and that standardized examinations have limitations, including not always reflecting real-world practice.

Several aspects of our study design may have contributed to this broad outline. First, there were no general pulmonologists on our expert panel, which may have led to selection bias regarding the nature and difficulty of items ranked as “must know”; a content expert panel may be generally unfamiliar with the educational needs of less specialized learners.

Second, we used a percentage agreement cutoff of $\geq 50\%$ to define consensus. Although the range of percentage agreement cutoffs reported in a meta-analysis of consensus studies varied from 50% to 97%, the median was higher at 75% (11). Our choice of using a lower cutoff meant more items were included in the final outline than if a higher threshold had been used. If we were to apply a threshold of 75% on the final outline, this would result in a list of 4 topics and 11 subtopics (Table 3). The advantage of this is a more realistic starting point for curriculum development, but it does result in deviation from standard Delphi methodology.

Table 2. Must know topics and subtopics

	"Must Know" Percentage (%)
Infections	100.0
CMV infection (viremia, organ manifestations, prophylaxis, resistance)	90.9
Fungal infections	86.4
Infections <1 yr post-transplant	81.8
Prophylaxis (antifungal, viral, bacterial prophylaxis)	77.3
EBV and CMV serostatus	72.7
Infections >1 yr 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, rehabilitation)	77.3
Evaluation process (testing, financial approval)	68.2
Ethics, sex, and racial inequities surrounding selection	63.6
Frailty	59.1
Indications for retransplant	54.6
Timing of listing	50.0
Transplant immunology	68.2
Innate (cellular) immune response	63.6

Table 2. Continued.

	"Must Know" Percentage (%)
Adaptive (humoral) immune response	59.0
HLA system and highly HLA-sensitized patients	50.0
Mechanism of pretransplant crossmatch	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/postoperative management	59.1
Bridge to transplant (including ECMO indications)	90.9
Mechanical ventilation strategies in immediate postoperative period	72.7
Primary graft dysfunction	68.2
Overview of immediate postoperative management	59.1

Definition of abbreviations: CF = cystic fibrosis; CMV = cytomegalovirus; COPD = chronic obstructive pulmonary disease; EBV = Epstein-Barr virus; ECMO = extracorporeal membrane oxygenation; HLA = human leukocyte antigen; ILD = interstitial lung disease; PAH = pulmonary arterial hypertension; PFT = pulmonary function testing.

Last, we did not provide complete summary statistics of how the group ranked items between rounds, so panelists were unaware of the extent of agreement on items. It is possible that had we provided this information and additional opportunity for feedback, fewer items would have been included in the final outline. Although this is a deviation from Delphi methodology, we believed that because most items achieved consensus in the first round, they did not need to be reconsidered, especially given that reconsideration of old items along with new items would have led to significant survey length and potentially lower completion rates.

Future Directions

More work is needed to determine optimal instructional design for lung transplantation topics. Given that only 8% of PCCM program directors reported use of online modules for lung transplantation (6), we believe that this avenue should be explored further. Online self-paced modules may solve the problem of limited protected didactic time to cover a broad content outline. Given the effort required to create new curriculum to address this, it is reasonable to consider sharing content with the caveat that transplantation medicine is highly institution specific (12).

Little is also known about trainee perspectives on lung transplantation

Table 3. Comparison of lung transplantation knowledge requirements

ACGME	ABIM	Delphi
Indications	Patient selection	Contraindications and risk factors for transplant Timing of referral for specific disease states (COPD, ILD, PAH, CF) Management of patients awaiting transplant (periodic status assessment, PFTs, rehab)
Complications	Complications of lung transplant	Acute cellular rejection Chronic lung allograft dysfunction
Outcomes	Transplant outcomes	
	Infections	CMV infection (viremia, organ manifestations, prophylaxis, resistance) Fungal infections Infections <1 yr post-transplant Prophylaxis (antifungal, viral, bacterial)
	Neoplastic complications	
	Other complications of organ transplantation (GVHD)	
		Immunosuppression Classes of medications and dosing schedule Side effects

Definition of abbreviations: ABIM = American Board of Internal Medicine; ACGME = Accreditation Council for Graduate Medical Education; CF = cystic fibrosis; CMV = cytomegalovirus; COPD = chronic obstructive pulmonary disease; ILD = interstitial lung disease; PAH = pulmonary arterial hypertension; PFT = pulmonary function testing; GVHD = graft versus host disease.

Comparison of lung transplant knowledge requirements between ACGME, ABIM, and Delphi results using *post hoc* $\geq 75\%$ cutoff. Delphi items were categorized under existing ABIM topics when possible.

education. The 2016 needs assessment was reflective of program directors' opinions only. Data regarding ILD education (13) show that there may be differences in how trainees rate their own ability levels relative to how program directors perceive trainees' ability levels.

Strengths

Our study has several strengths. It is the first, to our knowledge, to describe the creation of a lung transplantation content outline for PCCM fellows in a scholarly fashion, filling a gap in the literature. It has high survey response/completion rates with low attrition between rounds.

We had geographic diversity within our expert panel spanning 7 of 11 Organ Procurement Organization regions in the United States. Most panelists were also involved in trainee education in some capacity. Last, we report on most of the 13 elements considered to be "high quality" for a medical education Delphi study (Table 4) (9).

Limitations

In addition to the limitations described above regarding lack of general pulmonologists on the panel, a low percentage agreement cutoff, and the nature of feedback provided, we describe

Table 4. Delphi reporting quality

Characteristics	Present Article	Percentage of 257 Articles that Reported This Characteristic (9)
Literature review conducted	Yes	70.0
Background information provided to participants	Yes	27.2
Purpose is item generation or ranking or both	Yes	89.5
No. of participants indicated	Yes	83.7
No. of respondents for round 1 indicated	Yes	66.1
No. of respondents for round 2 indicated	Yes	50.2
Polling (mail, e-mail, or face to face) described	Yes	70.0
Private decisions collected (anonymity)	Yes	40.1
Formal feedback of group ratings	No	37.7
No. of rounds conducted ≥ 2	Yes	76.7
No. of rounds determined <i>a priori</i>	Yes	18.3
Predetermined definition of consensus	Yes	43.2
Consensus forced ("no" is favorable)	No	38.9

Comparison of our article's reporting quality with results from a scoping review of 257 medical education Delphi studies published in 2017.

a few others. There is overlap in multiple subtopics under the infections topic. We assume that the spirit of each subtopic is different, but more opportunities for panelists to provide feedback during the survey phase would have confirmed this. For example, for "EBV/CMV serostatus," we infer that it is important to know how this affects the risk of Epstein-Barr virus/cytomegalovirus infection or reactivation relative to "infections <1 year post-transplant," and we assume it is important to recognize that overall immunosuppression is greatest in the first year and that most opportunistic infections occur during this time.

Our panelists were self-identified, and our cohort included European providers who may have different opinions on knowledge requirements, given training pathways differing from those in the United States.

Last, because of clerical error, two subtopics that had tied MK responses were inadvertently excluded from reranking ("type of listing" and "recurrence of native disease") in the second round. Educator discretion should be used when considering these items in curriculum development.

Conclusion

We identified 7 topics and 36 subtopics in lung transplantation deemed to be "must know" topics for a graduating PCCM fellow through electronic modified Delphi methodology by a panel of self-identified lung transplantation experts. The findings serve as a starting point for future curriculum development.

Author disclosures are available with the text of this article at www.atsjournals.org.

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