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Original Article

Mixed-methods process evaluation of a respiratory-culture diagnostic stewardship intervention

Kathleen Chiotos MD, MSCE[1,2,3], Deanna Marshall MPH[4], Katherine Kellom AB[4], Jennifer Whittaker PhD[4], Heather Wolfe MD, MSHP[1,2], Charlotte Woods-Hill MD, MSHP[1,2,5], Hannah Stinson MD[1,2], Garrett Keim MD[1,2], Jennifer Blumenthal CRNP[1], Joseph Piccione DO, MS[2,6], Giyoung Lee MPH[3,7], Guy Sydney MD[8] and Jeffrey Gerber MD, PhD[2,3,9]

[1]Division of Critical Care Medicine and Anesthesiology, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania, [2]Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pennsylvania, [3]Center for Pediatric Clinical Effectiveness, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania, [4]PolicyLab, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania, [5]Leonard Davis Institute of Health Economics, University of Pennsylvania, Philadelphia, Pennsylvania, [6]Division of Pulmonary and Sleep Medicine, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania, [7]Department of Community Health and Prevention, Drexel University Dornsife School of Public Health, Philadelphia, Pennsylvania, [8]Department of Medicine, Southern Illinois University School of Medicine, Springfield, Illinois and [9]Division of Infectious Diseases, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania

Abstract

Objective: To conduct a process evaluation of a respiratory culture diagnostic stewardship intervention.

Design: Mixed-methods study.

Setting: Tertiary-care pediatric intensive care unit (PICU).

Participants: Critical care, infectious diseases, and pulmonary attending physicians and fellows; PICU nurse practitioners and hospitalist physicians; pediatric residents; and PICU nurses and respiratory therapists.

Methods: This mixed-methods study was conducted concurrently with a diagnostic stewardship intervention to reduce the inappropriate collection of respiratory cultures in mechanically ventilated children. We quantified baseline respiratory culture utilization and indications for ordering using quantitative methods. Semistructured interviews informed by these data and the Consolidated Framework for Implementation Research (CFIR) were then performed, recorded, transcribed, and coded to identify salient themes. Finally, themes identified in these interviews were used to create a cross-sectional survey.

Results: The number of cultures collected per day of service varied between attending physicians (range, 2.2–27 cultures per 100 days). In total, 14 interviews were performed, and 87 clinicians completed the survey (response rate, 47%) and 77 nurses or respiratory therapists completed the survey (response rate, 17%). Clinicians varied in their stated practices regarding culture ordering, and these differences both clustered by specialty and were associated with perceived utility of the respiratory culture. Furthermore, group "default" practices, fear, and hierarchy were drivers of culture orders. Barriers to standardization included fear of a missed diagnosis and tension between practice standardization and individual decision making.

Conclusions: We identified significant variation in utilization and perceptions of respiratory cultures as well as several key barriers to implementation of this diagnostic test stewardship intervention.

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Ventilator-associated infections (VAIs), including ventilator-associated tracheitis (VAT) and pneumonia (VAP), are among the most common indications for antibiotic use in the pediatric intensive care unit (PICU).[1,2] Although some of this antibiotic use is warranted, up to half of antibiotics prescribed for VAIs in children are inappropriate.[2] One driver of antibiotic overuse is the imprecision of respiratory cultures in differentiating bacterial colonization from infection; endotracheal and tracheostomy tubes are nearly universally colonized with potentially pathogenic bacteria soon after placement.[3–6] Therefore, a "positive" respiratory culture indicating colonization

Author for correspondence: Kathleen Chiotos, E-mail: chiotosk@chop.edu

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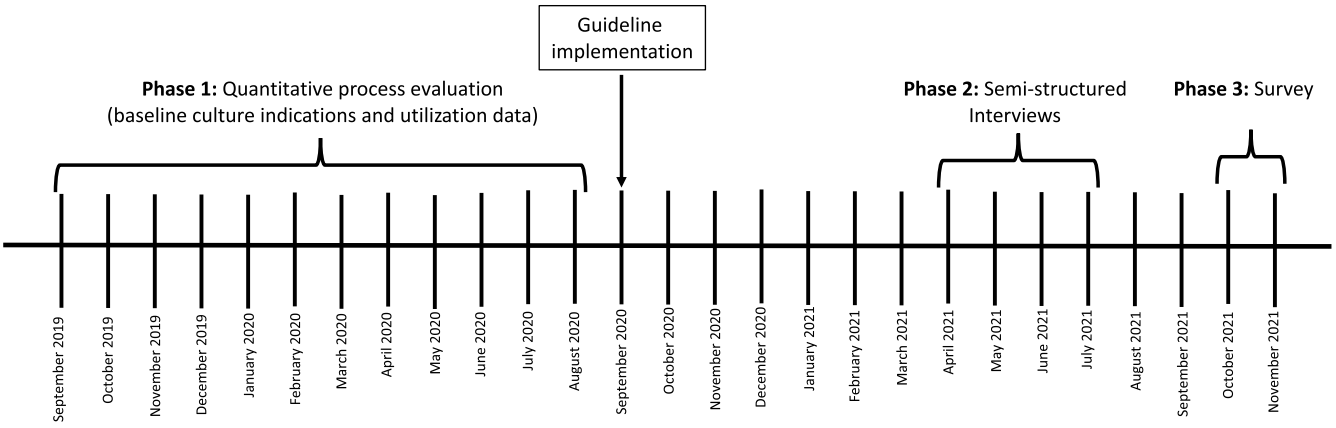

Fig. 1. Process evaluation timeline relative to diagnostic test stewardship intervention.

may be misinterpreted as evidence of infection, contributing to inappropriate antibiotic use in patients who do not have a VAI.

Microbiologic diagnostic test stewardship, in which the practice of ordering cultures is modified to reduce the number of cultures that are ordered absent evidence of infection, have consistently reduced culture utilization, with inconsistent reductions in antimicrobial use.[7–10] Several studies have evaluated the determinants of uptake of antimicrobial stewardship interventions, but few have focused on diagnostic test stewardship interventions, particularly in the PICU setting.[11–16] These data are fundamental to optimizing the implementation of diagnostic test stewardship interventions.[17,18] Therefore, we performed a mixed-methods process evaluation concurrent with a diagnostic-test stewardship intervention focused on reducing inappropriate respiratory-culture orders in our tertiary-care PICU.

Methods

Study design, sample, and recruitment

Our diagnostic-test stewardship intervention utilized a guideline defining indications for collecting a respiratory culture in our tertiary-care PICU, which was created using a multidisciplinary consensus-based process (Supplementary Fig. 1 online). In the first phase of the process evaluation, we used quantitative methods to characterize the indications for respiratory culture orders as well as variability in culture utilization across clinicians between September 2019 and August 2020. In the second phase, we conducted semistructured interviews of PICU clinicians between March and July 2021, including attending physicians, fellows, and nurse practitioners and hospitalists (Fig. 1). We utilized a purposive sampling strategy to sample PICU attending physicians in the highest and lowest quartile of respiratory culture utilization (Supplementary Fig. 2 online). Because we were not objectively able to quantify utilization among non–attending physicians, we randomly sampled these groups through a series of 3–4 e-mails. Recruitment stopped when thematic saturation was achieved.[19]

In the third phase of this study, we conducted a survey including PICU clinicians (attending physicians, fellows, nurse practitioners, and hospitalist physicians), infectious diseases (ID) clinicians (attending physicians and fellows), pulmonary clinicians (attending physicians and fellows), pediatric residents who completed their PICU rotation in the 4 months prior to conducting the survey, and PICU nurses and respiratory therapists. Completion of the survey was voluntary, and respondents were invited to participate via a series of 2 e-mails. The survey was administered using Research Electronic Database Capture (REDCap) software in October 2021 (Fig. 1). This study was classified as exempt research by the Chidren's Hospital of Philadelphia (CHOP) Institutional Review Board.

Data collection and instruments

In the first phase of our process evaluation, we quantified baseline variability in indications for respiratory culture collection by reviewing all respiratory cultures ordered in patients mechanically ventilated for >48 hours in the 1 year prior to the intervention. Presence of fever, hypothermia, change in secretion quality or quantity, chest radiograph infiltrate (determined by radiologist's interpretation), any change in positive end expiratory pressure (PEEP) or fraction of inspired oxygen (FiO_2), or combination of these findings were assessed in the 48 hours prior to culture collection by chart review. Variation in culture collection across attending physicians was assessed by measuring the number of cultures collected per day of clinical service worked.

We developed the interview guide for the semistructured interviews using a combination of our baseline quantitative data, questions derived from the Consolidated Framework for Implementation Research (CFIR), and themes from the published literature related to diagnostic test stewardship. The CFIR is a pragmatic meta-theoretical framework consisting of 5 domains, each with several constructs that influence effective implementation. Key CFIR domains include the following: characteristics of the individual (knowledge or beliefs and self-efficacy), intervention characteristics (evidence strength and quality and relative advantage), and inner setting (culture and implementation climate).[20] Interviews were conducted during the second phase of the process evaluation by trained study-team members experienced in conducting qualitative interviews (J.W. and D.M.). The interview guide was refined for clarity after a pilot interview. All interviews were recorded and transcribed prior to analysis with consent from participants.

Closed-ended survey questions were developed based on themes identified in the semistructured interviews and in the published literature. In addition, to classify individuals as higher or lower utilizers of respiratory cultures, we asked respondents to rate the likelihood of sending a respiratory culture in 3 controversial clinical scenarios. Respondents were then ranked into quartiles, with the lowest quartile including clinicians least likely to order respiratory cultures and the highest quartile including clinicians most likely to order respiratory cultures. The survey instrument

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Table 1. Indications for Respiratory Culture Orders

Indication	Total (N=625), No. (%)
Isolated fever or hypothermia	124 (20)
Three or more clinical signs/symptoms of a respiratory infection	86 (14)
Fever and any ventilator change	71 (11)
No symptoms of a respiratory infection	71 (11)
Any isolated ventilator change	67 (11)
Isolated secretion change	54 (9)
Secretion change and any ventilator change	44 (7)
Fever and secretion change	22 (4)
Any ventilator change and radiographic infiltrate	19 (3)
Fever and radiographic infiltrate	11 (2)
Other indication or combination of indications	56 (9)

was piloted by a group of 4 physicians, 4 nurses, and a respiratory therapist. Modifications were made after this pilot testing, and the final instrument, distributed in the third part of the process evaluation, contained 27 closed-ended questions with 4- or 5-point Likert scale responses and 2 open-ended questions (Supplementary Table 1 online).

Data analysis

Interview data and open-ended survey questions were analyzed using an inductive approach to thematic analysis. Beginning with familiarization, team members reviewed the interview (J.W. and D.M.) and survey data (K.C.), identified and applied codes emerging from data, and lastly, the full team (J.W., D.M., K.K., and K.C.) generated and refined the resultant, triangulated themes. Quantitative data were analyzed using descriptive statistics, including frequencies and percentages, using Stata statistical software (StataCorp, College Station, TX). For the purposes of analyzing data by groups, physician and nurse practitioner survey respondents were classified by primary specialty and by role, including attending physicians, trainees (including residents and fellows), and nurse practitioners and PICU hospitalists.

Results

Quantitative process evaluation

In total, 625 respiratory cultures were ordered in the 1 year prior to guideline implementation. Indications included the following: isolated fever or hypothermia (124 cultures, 20%), fever and any change in PEEP or FiO_2 (71 cultures, 11%), and isolated change in PEEP or FiO2 (67 cultures, 11%) (Table 1). The frequency of respiratory culture orders varied across critical-care attending physicians between 2.2 and 27 respiratory cultures per 100 clinical days (Supplementary Fig. 2 online).

Semistructured interviews

In total, 14 interviews were performed: 7 with attending physicians, 4 with fellows, and 3 with PICU nurse practitioners or hospitalists. Themes that emerged from these interviews included individual knowledge and beliefs about respiratory cultures, decision making about respiratory culture ordering, standardization of practices in the PICU, and the culture of implementation and impact of the intervention (Table 2).

Survey

In total, 87 clinicians (response rate, 47%) and 77 PICU nurses and respiratory therapists (response rate, 17%) completed the survey. Response rates were highest among critical care and infectious diseases attending physicians, followed by critical care and infectious diseases fellows (Table 3). Respondents were ranked into quartiles based on their stated likelihood of ordering a respiratory culture in response to 3 hypothetical scenarios according to a 4-point Likert scale (Supplementary Table 1 online). Most infectious diseases clinicians (76%) fell into the 2 quartiles least likely to order a respiratory culture, whereas most pulmonary clinicians fell into the 2 quartiles most likely to order a respiratory culture (91%).

Salient themes

Findings related to the key themes identified in the semistructured interviews and further explored in the survey (Supplementary Table 1 online), including individual knowledge and beliefs about respiratory cultures, decision making around culture ordering, standardization around respiratory culture ordering practices, and the culture of implementation, are summarized below.

Knowledge and beliefs about respiratory cultures (CFIR domain: characteristics of individuals)

Interview respondents noted significant variation in clinician practices regarding ordering and interpreting respiratory cultures. For example, fever alone was noted to be a sufficient trigger for ordering a culture for some clinicians whereas others questioned the value of sending a culture in this particular scenario. Uncertainty as to whether a positive culture should be interpreted as evidence of infection warranting antibiotic treatment was also noted as a challenge in utilizing the respiratory culture as a diagnostic test.

Moreover, 75% of attending physicians, 76% of trainees, and 80% of PICU nurse practitioners and hospitalists who responded to the survey felt that respiratory cultures were overutilized, whereas 20% of nurses and 29% of respiratory therapists felt that respiratory cultures were overutilized. Also, 80% of PICU clinicians and 100% of ID clinicians felt that respiratory cultures were overused, which was a much greater proportion than pulmonary clinicians (Table 4). Finally, clinicians who ranked in the quartile least likely to order a respiratory culture more often agreed that respiratory cultures were overutilized compared to those most likely to order a respiratory culture (96% vs 55%).

Consistent with the noted variability in interpretation of respiratory cultures, clinicians were divided as to whether a Gram-stain positive for moderate or many white blood cells indicated a bacterial infection: 41% strongly agreed or agreed, 59% disagreed or strongly disagreed. Similarly, opinions varied as to whether a culture positive for *Pseudomonas aeruginosa* in a patient with increased and thick respiratory secretions was suggestive of bacterial infection: 47% strongly agreed or agreed and 53% disagreed or strongly disagreed. When stratified across quartiles of utilization, individuals more likely to order a respiratory culture more often

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Table 2. Themes Identified in Semistructured Interviews and Sample Quotes

Theme	Subtheme	Quotes
Knowledge and beliefs about the respiratory culture test	Variability across individuals	"I think that there's definitely a spectrum. I think some people will . . . very rarely send them at all . . . Some people will be a lot more liberal and kind of send it, you know, almost as a default reaction to a patient's new fever . . . I've seen a whole variety of things." – *PICU fellow* "But I do feel like I walk in a lot . . . when I'm service and there's respiratory cultures that were sent because of some—my perceived— not severe symptoms or someone overnight . . . sends them as a screening in the work up of fever or tachycardia or something like that." – *PICU attending physician*
	Interpreting a positive respiratory culture	"I think I've become increasingly more hesitant to send them just because, especially [in patients with tracheostomies], I feel like I have yet to see a patient with a [tracheostomy] who does not have *Pseudomonas* and then you're always, you know, kind of stuck deciding whether to treat it or not." – *PICU fellow* "I feel like I personally am more cautious and conservative and do not send a tracheal culture and gram stain as often as others, especially [in patients with tracheostomies], just because I feel like the utility of it has not, in my experience, been shown to be useful and it really just leads to chronically infected children popping up positive and not knowing what to do with those results." – *PICU attending physician*
Decision making about sending respiratory cultures and treating with antibiotics	Default practices	"And so, if they have an indwelling catheter, we culture the urine, if they have an indwelling central line, we culture that line. And I think people loop in if we have an indwelling airway support source such as an endotracheal tube or a tracheostomy tube, that we culture it . . . and, again, like I said, the culture at CHOP for a long time has been if there's a fever, culture everything. And I think even when people try to change parts of that it's just, it's a hard thing to adjust." – *PICU attending physician*
	Fear of missing a diagnosis	"I think in general we send a lot of tests because we don't want to miss something. So I wouldn't separate respiratory cultures or infectious [tests] from something else, but, yes, I think that's the reason we culture lines all the time, I think that's the reason we send urinalyses and urine cultures all the time, even if the symptomatology doesn't fit with that. I think we have a huge culture of, I don't want to miss it." – *PICU attending physician*
	Perceptions of role and hierarchy in ordering	"It's always kind of like what [does], you know, the attending who's kind of supervising the team and has her name on the line, like are they somebody I think would want to get cultures because they're a little more conservative maybe or [are they] someone who's more skeptical about their utility, that'll probably affect whether I decide to order them in certain circumstances." – *PICU fellow* "Typical scenario is, usually, despite my will, the resident or [PICU NP/hospitalist] tends to send the respiratory culture . . . when the patient developed a fever or the increased oxygen requirement, or some questionable infiltrate, or new finding on a chest x-ray. Those are typical scenarios." – *PICU attending physician*
Standardizing practices in the PICU	Removal of autonomy in complex patient population	"I think that there are a lot of challenges to what can sometimes feel like a removal of autonomy and medical decision-making abilities if you're being told no, you always have to do this . . . So recognizing when it's appropriate to deviate from a standard can sometimes become a little more challenging for people to suss it out when it's appropriate. – *PICU NP/hospitalist* "I can certainly see the utility of pathways in an outpatient setting for a healthy child. The challenge for me is when I take care of these uniquely ill patients that we have in our ICU. Each one is very different with about 20 different comorbidities that are unique to them . . . And I worry that if I follow the pathway, I may end up missing a key factor that is important for this child. And oftentimes, [I] end up ordering the culture anyway and get my information . . . ." – *PICU attending physician*
	Fear of missing a diagnosis	"I mean, there's always going to be a tradeoff. You're going to miss certain kids that truly need to be treated [if you do the pathway], and the outcomes won't be good. Are we willing to accept that? On the other hand, by over treating, you're probably going to capture everybody, but then you're breeding resistance, and you're breeding a whole lot of other problems. So I don't think there's a good answer. And I think the answer is what is our threshold? What is our comfort level? What are we willing to accept as bad outcomes by not treating?" – *PICU NP/hospitalist* "I think people are worried that they're going to miss something and they're going to harm patients. And I think anything that's reassurance that we are not doing that is really what it comes from. I don't think people fear standardization. They fear missing something and having an impact on a patient." – *PICU nurse practitioner/hospitalist*

(*Continued*)

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Table 2. (*Continued*)

Theme	Subtheme	Quotes
Culture of implement-ation and impact	Culture of implementing respiratory culture guideline	"I think we definitely have a culture where people want to do the right thing and want to do what's best for the patient and not what's unnecessary. But I think there are a lot of required things that get in the way of even having the space to think about that other stuff . . . You're going to go to what the default is and the simplest part, anything that's going to . . . make you hope you didn't miss something." – *PICU attending physician*
	Impact of the respiratory culture guideline	"It was probably a good idea, just because there's so many cultures that I don't think are clinically useful that we get . . . I feel like the percentage of times it actually provides clinically useful information is pretty limited. So I thought that . . . it would make our lives less annoying probably to have some sort of guidelines recommending a more limited use." – *PICU fellow* "I think it prompts you to think a little bit more about whether you truly need that test, whether it's really going to change your management. And then I think any time you start thinking that way about one test, it makes you think that way about other tests. And so I think it just helps you be more judicious all around." – *PICU fellow*

Table 3. Survey Response Rate by Specialty and Role

Role	Response, No./Total (%)
Critical care medicine	
Attending	25/39 (64)
Fellow	10/19 (53)
Nurse practitioner/hospitalist physician	15/47 (32)
Nurse	55/306 (18)
Respiratory therapist	21/145 (14)
Infectious disease	
Attending	13/21 (62)
Fellow	4/7 (57)
Pulmonary	
Attending	5/15 (33)
Fellow	6/11 (55)
General pediatrics resident	9/25 (36)

interpreted both gram stains and cultures as suggestive of infection and were more likely to endorse that respiratory cultures had greater utility in the diagnosis and management of ventilator-associated infection (Table 5).

Decision making around ordering respiratory cultures (CFIR domains: characteristics of individuals, inner setting). Ordering respiratory cultures as a "default" practice was noted by several interview respondents, particularly in response to fever. In addition, a culture of "fear of missing something" was cited as influencing all practices in the PICU, including respiratory culture ordering. Finally, the actual or perceived opinions of the PICU attending physicians influenced the decision making of the PICU hospitalists, nurse practitioners, and fellows. Many respondents felt overruled by attending physicians in situations in which they did not feel that a respiratory culture was indicated. Responses from attending physicians regarding the role of hierarchy acknowledged that while decisions around whether a culture is ordered ultimately rest with the attending, most often this decision is made by non-attending clinicians. Several attending physicians also reported that cultures were collected in scenarios in which justification for ordering a culture was insufficient.

Using this survey, we explored drivers of individual decision making. Personal views of the value of a respiratory culture in a given scenario were most influential for attending physicians, trainees, nurses, and respiratory therapists. In contrast, expectations of attending physicians of one's own specialty was the most cited influence on culture ordering for nurse practitioners and hospitalists. Institutional guidelines, the focus of the concurrent diagnostic test stewardship project, were consistently influential across provider types, particularly trainees. Finally, clinicians were less often influenced by parental concerns regarding testing, whereas nurses and respiratory therapists were more likely to be influenced by parental concerns (Table 6).

Standardization of practices within the PICU (CFIR domain: inner setting, intervention characteristics). Many interview respondents reported a concern that standardization may remove clinician autonomy necessary to care for a medically complex patient population. Therefore, the need to recognize scenarios in which a clinician should deviate from a guideline recommendation was highlighted by many respondents. In addition, a concern that overreliance on standardized guidelines would lead to missed diagnoses was highlighted as a potential risk.

Across specialties and roles, physicians and nurse practitioners agreed that standardization of respiratory cultures was a priority and of benefit to both clinicians and patients, though few endorsed that standardization would be easy. In contrast, nurses were less likely to feel that standardization would be beneficial (Table 4). Salient themes cited as advantages to standardization included reducing inappropriate antibiotic use, consistency across members of the treatment team, reducing cost and/or resource utilization, improving efficiency around decision making, and improving the diagnosis of VAI. Disadvantages to standardization included limited individual decision making, fear of missing an infection, complexity of individual patients in the PICU, and concerns that standardizing practices may increase antibiotic use and/or prompt more cultures to be collected.

Culture of implementation and impact (CFIR constructs: inner setting, intervention characteristics). The local culture was generally felt to be receptive to changes in practice and implementation of this guideline, though several barriers were noted. First, multiple other guidelines and quality improvement projects were being

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Table 4. Knowledge and Beliefs About Respiratory Culture Ordering and Standardization

Survey Response[a]	Critical Care (N=50), No. (%)	Infectious Diseases (N=17), No. (%)	Pulmonary (N=11), No. (%)	Nurse (N=55), No. (%)	Respiratory Therapist (N=21), No. (%)
Bacterial respiratory cultures are overutilized (eg, collected too often) in the PICU.					
Agree	40 (80)	17 (100)	2 (18)	11 (20)	6 (29)
Neutral	9 (18)	0	6 (55)	20 (36)	7 (33)
Disagree	1 (2)	0	3 (27)	24 (44)	8 (38)
Standardizing practices surrounding collection of respiratory cultures in the PICU is a priority.					
Agree	40 (80)	16 (94)	8 (73)	33 (61)	16 (76)
Neutral	9 (18)	1 (6)	1 (9)	20 (37)	4 (19)
Disagree	1 (2)	0	2 (18)	1 (2)	1 (5)
No response	0	0	0	1 (2)	0
I have the skills to determine when it is appropriate to collect a respiratory culture.					
Agree	34 (68)	14 (82)	9 (82)	32 (49)	17 (67)
Neutral	13 (26)	2 (12)	1 (9)	19 (35)	4 (19)
Disagree	3 (6)	1 (6)	1 (9)	4 (7)	0 (0)
It is easy to standardize collection of respiratory cultures.					
Agree	13 (26)	1 (6)	1 (9)	26 (47)	11 (52)
Neutral	12 (24)	6 (35)	4 (36)	22 (40)	8 (38)
Disagree	25 (50)	10 (59)	6 (55)	7 (13)	2 (10)
Patients benefit from standardizing practices for respiratory culture collection in the PICU.					
Agree	43 (86)	17 (100)	8 (73)	45 (82)	19 (90)
Neutral	6 (1)	0 (0)	2 (18)	8 (15)	2 (10)
Disagree	1 (2)	0 (0)	1 (9)	2 (4)	0 (0)
Clinicians benefit from standardizing practices for respiratory culture collection in the PICU.					
Agree	44 (88)	16 (94)	8 (73)	46 (84)	18 (86)
Neutral	4 (8)	1 (6)	2 (18)	6 (11)	3 (14)
Disagree	2 (4)	0 (0)	1 (9)	3 (5)	0 (0)
Reducing inappropriate collection of respiratory cultures would help reduce inappropriate antibiotic use in the PICU.					
Agree	43 (86)	17 (100)	9 (82)	42 (76)	14 (48)
Neutral	7 (14)	0 (0)	1 (9)	6 (11)	5 (24)
Disagree	0 (0)	0 (0)	1 (9)	7 (13)	2 (10)

Note. PICU, pediatric intensive care unit.
[a]"Strongly agree" and "agree" were collapsed into "agree," and "disagree" and "strongly disagree" were conmbined into "disagree."

Table 5. Knowledge and Beliefs About Interpretation of Respiratory Cultures by Quartiles of Utilization

Survey Response	All Clinicians (N=87), No. (%)	Quartile 1 (N=24), No. (%)[a]	Quartile 2 (N=24), No. (%)	Quartile 3 (N=17), No. (%)	Quartile 4 (N=22), No. (%)[b]
A gram-stain with moderate or many WBC strongly supports a diagnosis of bacterial infection.					
Strongly agree	8 (9)	1 (4)	1 (4)	2 (12)	4 (18)
Agree	28 (32)	4 (17)	6 (25)	6 (35)	12 (55)
Disagree	44 (51)	17 (71)	13 (54)	8 (47)	6 (27)
Strongly disagree	7 (8)	2 (8)	4 (17)	1 (6)	0 (0)
A respiratory culture that is positive for heavy growth of *Pseudomonas aeruginosa* strongly supports a diagnosis of infection due to this organism, independent of clinical symptoms.					
Strongly agree	0 (0)	0	0	0	0
Agree	3 (3)	0	1 (4)	0	2 (9)
Disagree	44 (51)	10 (42)	8 (33)	12 (71)	14 (64)
Strongly disagree	40 (46)	14 (58)	15 63)	5 (29)	6 (27)
In a patient with increased and thicker secretions, a respiratory culture that is positive for heavy growth of *Pseudomonas aeruginosa* strongly supports a diagnosis of infection due to this organism.					
Strongly agree	5 (6)	0 (0)	1 (4)	1 (6)	3 (14)
Agree	36 (41)	9 (38)	6 (25)	9 (53)	12 (55)
Disagree	34 (39)	11 (46)	11 (46)	6 (35)	6 (27)
Strongly disagree	12 (14)	4 (17)	6 (25)	1 (6)	1 (5)
Respiratory cultures are not helpful in determining if bacterial infection is present or absent, but are helpful in determining what antibiotics should be given to treat a clinically diagnosed infection.					
Strongly agree	7 (8)	2 (8)	2 (8)	2 (12)	1 (5)
Agree	47 (54)	17 (71)	14 (58)	9 (53)	7 (32)
Disagree	30 (34)	5 (21)	7 (29)	5 (29)	13 (59)
Strongly disagree	3 (3)	0 (0)	1 (4)	1 (6)	1 (5)
Tracheal aspirate cultures have no value in the diagnosis or management of ventilator-associated pneumonia or ventilator-associated tracheitis.					
Strongly agree	3 (3)	3 (13)	0 (0)	0 (0)	0 (0)
Agree	5 (6)	3 (13)	1 (4)	1 (6)	0 (0)
Disagree	56 (64)	14 (58)	17 (71)	10 (59)	15 (68)
Strongly disagree	23 (26)	4 (17)	6 (25)	6 (35)	7 (32)

Note. WBC, white blood cell.
[a]Quartile 1 includes clinicians least likely to order a respiratory culture based on responses to hypothetical scenarios included in the survey.
[b]Quartile 4 includes clinicians most likely to order a respiratory culture based on responses to hypothetical scenarios included in the survey.

implemented simultaneously. Coupled with the baseline high workload in the PICU, prioritizing this intervention was a challenge. Second, given the practice variation regarding ordering respiratory cultures across clinicians at baseline, uptake of the

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Table 6. Drivers of Respiratory Culture Ordering by Role

Survey Response	Attending Physician (N=43), No. (%)	Trainee (N=29), No. (%)	NP or Hospitalist Physician (N=15), No. (%)	Nurse (N=55), No. (%)	Respiratory Therapist (N=21), No. (%)
Parental concern and desire for testing.					
Influential[a]	9 (21)	7 (24)	4 (27)	32 (58)	9 (43)
Not influential[b]	34 (79)	22 (76)	11 (73)	19 (35)	12 (57)
Would not make any suggestions to the provider team	NA	NA	NA	4 (7)	0 (0)
Nursing or respiratory therapy concern about clinical symptoms.					
Influential	17 (40)	20 (69)	8 (53)	NA	NA
Not influential	26 (60)	9 (31)	7 (47)	NA	NA
An attending or a colleague of my own specialty will expect this test to be sent.					
Influential	10 (23)	21 (72)	12 (80)	46 (84)	15 (71)
Not influential	33 (77)	8 (28)	3 (20)	6 (11)	6 (29)
Would not make any suggestions to the provider team	NA	NA	NA	3 (5)	0 (0)
An attending or colleague from a different specialty will expect this test to be sent.					
Influential	11 (26)	17 (59)	9 (60)	38 (69)	16 (76)
Not influential	32 (74)	12 (41)	6 (40)	13 (24)	5 (24)
Would not make any suggestions to the provider team	NA	NA	NA	4 (7)	0 (0)
Unit-specific/institutional guidelines for collecting respiratory cultures.					
Influential	31 (72)	25 (86)	11 (73)	NA	NA
Not influential	12 (28)	4 (14)	4 (27)	NA	NA
My own personal views on the value of a respiratory culture in a given clinical scenario					
Influential	40 (93)	27 (93)	11 (73)	47 (85)	17 (81)
Not influential	3 (7)	2 (7)	4 (27)	5 (15)	4 (19)
Would not make any suggestions to the provider team	NA	NA	NA	3 (5)	0 (0)

Note. NP, nurse practitioner; NA, not applicable.
[a]Strongly and moderately influences my decision was categorized as "influential."
[b]Mildly or no influence was classified as "not influential."

guideline was felt to be variable. Finally, as several clinicians discussed, although the specifics of the guideline were complex and may not be memorable, having the guideline in place prompted them to be more judicious and to consider how respiratory culture testing would change management. Clinicians also noted that fewer cultures to interpret might contribute to greater efficiency given the challenges in determining whether a respiratory culture reflected infection or colonization.

Discussion

We conducted a mixed-methods process evaluation concurrent with a diagnostic test stewardship intervention focused on reducing the overuse of respiratory cultures in a tertiary-care PICU. Quantitative data demonstrated variable perceptions of the utility of respiratory cultures as well as drivers of culture orders across clinicians, factors that may cluster by specialty or role. Qualitative data further highlighted that practice variation was perceived by individuals; that group "defaults," hierarchy, and fear influenced decision making; and that patient complexity and fear of missed diagnoses were challenges to standardization, despite broad agreement that standardizing respiratory-culture ordering practices would be beneficial for patients and clinicians. These findings support several key conclusions and expand upon the limited literature published to date related to antibiotic and diagnostic test stewardship in the PICU setting.

First, variable respiratory-culture ordering practices appear to be driven by both individual-level variation as well as variation across specialties. Absent evidence-based guidelines defining when a respiratory culture should or should not be sent, individual beliefs and specialty-specific culture may therefore be primary drivers of clinical practice.[21] Given that such guidelines are unlikely to be forthcoming, diagnostic-test stewardship interventions must acknowledge and define these multilevel influences on culture ordering practices. This acknowledgment is particularly important in the PICU practice setting, where medically complex patients are often cared for by a multispecialty and interprofessional teams.[22]

Second, our semistructured interviews demonstrated that cultural factors, including perceived "norms" or "default practices," as well as hierarchy within clinician group influence culture ordering practices. For example, ordering a culture in response to isolated fever was a common "default" practice, although several interview respondents acknowledged that this practice was often

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low yield. Similar findings were demonstrated in a study of blood-culture ordering practices in the PICU. This element of "testing etiquette" may influence PICU clinician behavior, similar to the more familiar phenomenon of antibiotic "prescribing etiquette," in which local culture defines expected practice.[12–14] However, and a novel finding of this study, is that there may be a mismatch between actual and perceived attending expectations, suggesting that attending support of diagnostic test stewardship interventions may facilitate uptake among non–attending physicians.

Third, fear of a missed diagnosis, both related to individual decision making and standardizing unit-wide practices, was a prominent theme, consistent with the limited published literature related to antibiotic and diagnostic test stewardship in the ICU setting.[13–15] However, in the case of respiratory cultures, this fear may be misplaced given that respiratory cultures perform poorly as a diagnostic test. Furthermore, actionable results from respiratory cultures are not available for 24–72 hours after the culture is ordered, such that clinicians must often make an initial diagnosis and take therapeutic action based on other clinical data. Future work should therefore explore the unique influences of fear on decision making regarding diagnostic tests, which are likely distinct from those driving treatment decisions.

Finally, while clinicians agreed that standardization of practices regarding ordering a respiratory culture is beneficial, barriers included concerns around a perceived loss of clinician autonomy and fear of missing a diagnosis. These findings are aligned with a qualitative study demonstrating unique barriers and facilitators to implementation of practice changes in the PICU, including the tension between standardization and clinician autonomy.[22] This issue may be exacerbated in the case of respiratory cultures, where the evidence base informing optimal criteria for testing is limited.

Our study had several limitations. First, the single-center design may limit generalizability and transferability, given that many local cultural and contextual factors were highlighted during this process evaluation. However, the consistency of our findings with related work strengthens our conclusions, which may generalize best to tertiary-care PICUs with multispecialty teams and trainees. Second, our semistructured interviews were limited to a small number of respondents, and only critical-care clinicians were included. We sought to overcome this limitation by including a multispecialty and multiprofessional population in our survey. Furthermore, we achieved thematic saturation despite our relatively small number of interviews, an observation supported by published data.[19] Third, assessments of individual culturing practices were based on stated, rather than observed, practices. This was unavoidable given our study design and the fact that only critical-care clinicians place orders in our PICU. Finally, our process evaluation took place several months after guideline implementation, so it is possible that the guideline itself influenced reported clinician views of the respiratory culture diagnostic test. However, because our goal was to simultaneously evaluate attitudes toward respiratory cultures as well as the guideline itself, this study timeline was necessary.

Overall, this process evaluation provides novel insights into clinician perceptions of respiratory cultures as well as a diagnostic test stewardship intervention to reduce inappropriate ordering of respiratory cultures. Based on our findings, attending physician support for stewardship interventions, engagement from subspecialty stakeholders, and implementation strategies focused on standardizing practice may facilitate uptake by promoting a culture of stewardship. Future studies should explore differences in determinants of ordering respiratory cultures across specialties and roles, the influence of fear and emotions on culture practices, and optimal strategies for promoting uptake of evidence-based practices related to ordering respiratory cultures.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2022.299

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