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Brief Report

Switching from expectorated to induced sputum cultures for tuberculosis diagnosis reduces cost without increasing risk

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Active pulmonary tuberculosis testing with 3 expectorated sputa can increase isolation days and expenditures compared with 1 induced sputum. Six-month retrospective and prospective chart reviews were conducted, and a screening algorithm was phased into 2 hospital sites. With induced sputum testing, isolation decreased from 7 to 4 days (interquartile range, 4-3, $P = .0135$), and there was a cost savings of $7,275 per case, with no added harm.

Typical pulmonary tuberculosis (TB) screening involves maintaining airborne isolation until all 3 expectorated or induced sputa smears are negative, an alternative diagnosis is made, and the patient has clinically improved.[1] Prolonged isolation associated with this can negatively affect the patient's mental well-being[2] and increase hospital expenditures.[3] The cumulative sensitivity of the third expectorated sputum is 63.2% (78.9%),[4] whereas a single induced sputum has been shown to have a sensitivity of 87% (96%)[5] (negative predictor values in parentheses). A 10-year retrospective study in Minnesota found that out of 246 culture-positive pulmonary TB patients, 120 had 3 or more sputum specimens collected, of which 95% were culture positive from the first or second specimen.[6] Therefore, the goal of this study is to show that a single induced sputum for pulmonary TB screening reduces isolation days and expenditures in the hospital setting without any added harm compared with 3 expectorated sputa.

METHODS

A 6-month retrospective and prospective study was conducted at 2 sites of a teaching hospital on general internal medicine (GIM) units that frequently receive patients with possible pulmonary TB. Site 1 had a 120-bed inpatient GIM unit (4 units in total), and site 2 had an 82-bed inpatient GIM unit (2 units in total). Specimens were usually ordered by the physician, collected by the primary registered nurse or respiratory therapist, and transported to an outside microbiology laboratory for processing, followed by analysis at the Public Health Ontario Laboratory.

The primary intervention was the implementation of a screening algorithm (Fig 1) for pulmonary TB that required only 1 induced sputum. This approach was based on literature, understanding of practices at both sites, and stakeholder consultation (respiratory therapy, GIM, infectious disease, and pulmonology leads). The algorithm was phased in at site 1 (May 10, 2017) and site 2 (November 1, 2017). Inclusion criteria were 3 expectorated sputum samples collected with or without an additional specimen (bronchoalveolar lavage, induced, or extrapulmonary) retrospectively and 1 induced sputum with or without an additional specimen (≤2 expectorated, bronchoalveolar lavage, or extrapulmonary) prospectively. Exclusion criteria were positive TB or *Mycobacterium avium* complex (MAC) patients identified on smears.

To determine the intervention effect, we reviewed the electronic medical record prior to (site 1, November 10, 2016, to May 10, 2017, and site 2, May 1, 2017, to November 1, 2017) and following (site 1, May 10, 2017, to November 10, 2017, and site 2, November 1, 2017, to April 1, 2018) implementation of the intervention.

For both phases, costs for maintaining isolation were calculated based on conversations with finance, hospital supply, microbiology,

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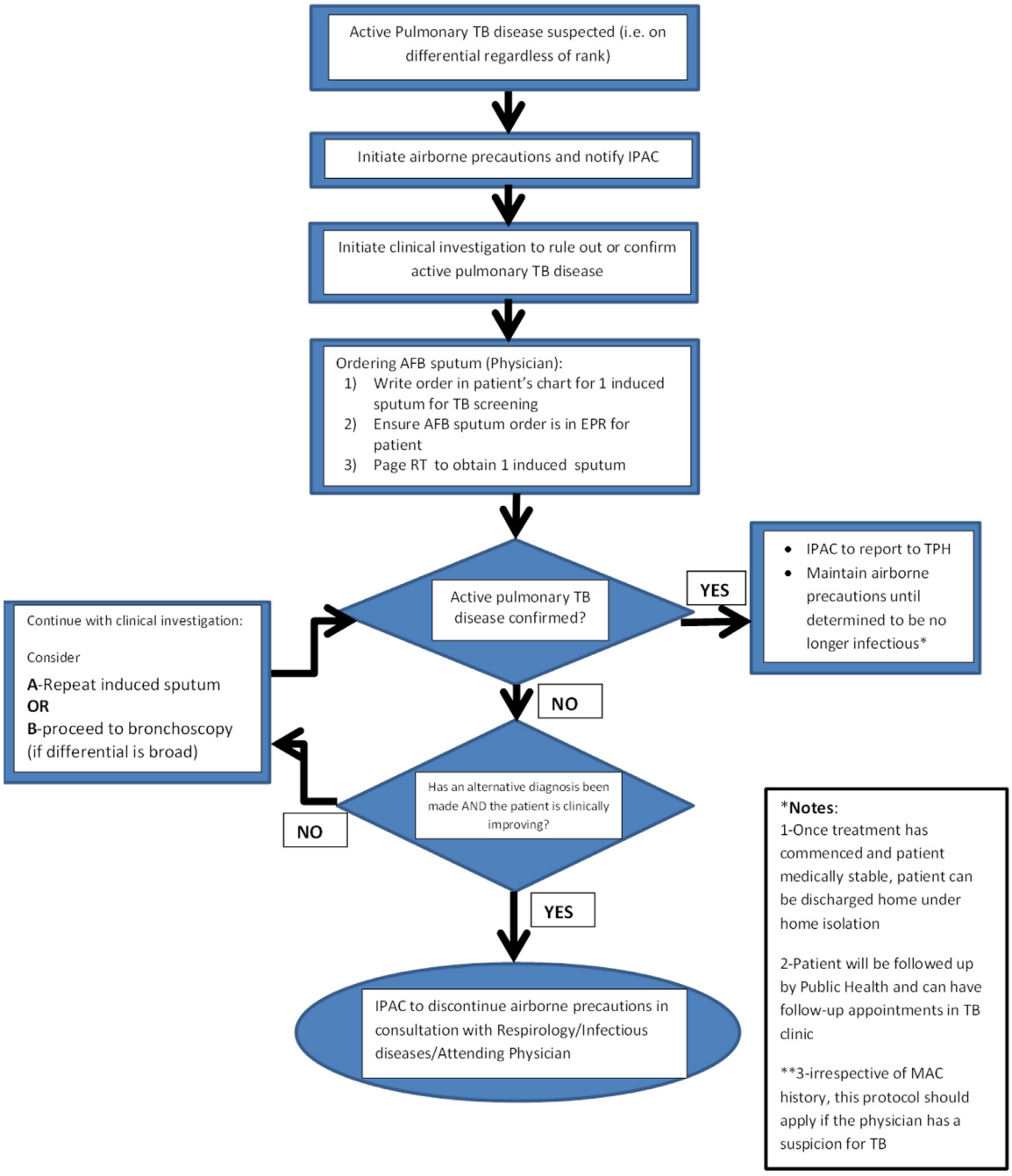

Fig 1. Suspected pulmonary TB isolation and diagnostic testing approach. Algorithm was modified from the the Public Health Agency of Canada Canadian TB standards.[1] *AFB*, acid-fast bacilli; *EMR*, electronic medical record; *EPR*, electronic patient record (hospital EMR); *IPC*, infection prevention and control; *MAC*, *Mycobacterium avium* complex; *RT*, respiratory therapist; *TB*, tuberculosis; *TPH*, Toronto Public Health.

Public Health Ontario Laboratory, and respiratory therapy. Isolation days were calculated based on isolation start and discontinuation dates, and duration of hospitalization was calculated based on hospital admission and discharge dates. Smear and culture results were collected for each patient meeting inclusion criteria to help determine harm. Descriptive statistics were used to summarize data, and Student t test was used to compare variables.

RESULTS

At the 2 sites, 113 patients had specimens collected for mycobacterial culture, of which 14 met inclusion criteria before and 20 after implementation of the intervention. Five patients with TB-positive smears and 1 with a MAC-positive smear were excluded from the retrospective review, and 5 patients with TB-positive smears and 3 with MAC-positive smears were excluded from the prospective review. The median ages were 73 years (57% women) retrospectively and 78 years (55% men) prospectively, with no differences in TB risk factors.

Fifty-two specimens were sent retrospectively and 33 prospectively. Expectorated sputum samples decreased (85% [44 of 52] vs 15% [5 of 33]), and induced sputum samples increased (2% [1 of 52] vs 64% [21 of 33]), with no change to bronchoscopy and extrapulmonary samples between the retrospective and prospective phases. Post-intervention, isolation days and average cost per case decreased, with

Table 1
Hospital length of stay, isolation duration, associated cost per case, and smear and culture results for prealgorithm and the postalgorithm groups for both hospital sites

	Prealgorithm (N = 14)	Postalgorithm (N = 20)	*P* value
Hospital length of stay (days)	9 (10)	7 (5)	.4510
Isolation duration (days)	7 (4)	4 (3)	.0135
Average cost per case (CDN)	$15,450	$8,175	
% smear results	93 (13/14) negative 7 (1/14) MAC positive	100 (20/20) negative	
% culture results	57 (8/14) negative 43 (6/14) MAC positive	80 (16/20) negative 20 (4/20) MAC positive	

NOTE. Hospital length of stay and isolation duration were calculated using the medians. Student t test was used to calculate the *P* value. Interquartile range included in parentheses. Average costs per case were calculated using average duration of isolation, bed maintenance costs per day, lost revenue resulting from an inability of the hospital to place a patient in a single room, material and labor costs, and costs incurred by PHOL for sputum processing.
CDN, Canadian; *MAC*, *Mycobacterium avium* complex; *PHOL*, Public Health Ontario Laboratory.

no effect on hospital duration and harm, as the majority of smear and culture results were negative (Table 1).

DISCUSSION

Screening with 1 induced sputum led to a significant decrease in isolation days and an average cost savings of $7,275 per case, without any added harm. This is in line with the Association for Professionals in Infection Control and Epidemiology's competency framework of performance improvement and implementation science,[7] as TB diagnoses reduce cost, safety is likely enhanced, and there is greater interdisciplinary clinical decision-making.

Post-intervention, 6 patients had an additional specimen collected, suggesting agreement with the literature that a single induced sputum is sufficiently sensitive to rule out TB in patients with lower suspicion; additional specimens can help increase case detection in those with a higher index of suspicion with airborne isolation maintained.[8] Those that met inclusion criteria and identified as TB or MAC positive on smears were excluded since isolation would have been maintained for those that were TB positive, thereby skewing isolation days. Those that were MAC positive would not have required isolation.

Strengths of this study were cost-effective design, use of an algorithm to guide physician testing and prompt isolation, and greater interdisciplinary involvement. Timely isolation and diagnosis are important,[9] as late ICU admissions, increased in-hospital mortality, and patient and staff exposures can otherwise occur.[10] Retrospectively, 4 of the 5 patients with TB-positive smears required exposure follow-up; no follow-up was required after the algorithm was introduced. Weaknesses of this study were small sample size and short study period, though results were similar to the literature. Credibility can be enhanced with a phenomenological study of patients in airborne isolation being screened for TB. Specific expertise and resources are required to perform the induced sputum; however, this is a value added cost impacting patient well-being and overall expenditures. The limitations in microbiology laboratory setup affected turnaround time of smear results; in-house testing would likely further decrease turnaround time and isolation duration. Some patients may not produce sputum on induction or physically or cognitively comply with directions; airborne precautions would be maintained, and a clinical management decision would be made among the interdisciplinary team.

CONCLUSIONS

Compared with 3 expectorated sputum samples, screening for pulmonary TB with 1 induced sputum reduces isolation days and expenditures in the hospital setting without any added harm.

Single induced sputum testing may be considered as a first line screening method for pulmonary TB in the inpatient setting.

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