Monaldi Archives for Chest Disease

eISSN 2532-5264 https://www.monaldi-archives.org/

Monaldi Arch Chest Dis 2025 [Online ahead of print]

To cite this Article:
Archana Baburao A, Ponnathota V, Mathew AM, et al. **Burden and impact of pertussis in patients with chronic obstructive pulmonary disease exacerbation.** *Monaldi Arch Chest Dis* doi: 10.4081/monaldi.2025.3421

Burden and impact of pertussis in patients with chronic obstructive pulmonary disease exacerbation

Archana Baburao,[1] Vindhya Ponnathota,[1] Aleena Mariam Mathew,[1]
Lakshminarayana Sura Anjanappa,[2] Parinita Suresh,[1] Thirthashree Kanabur[1]

[1]Department of Respiratory Medicine, Dr. M.G.R. Educational and Research Institute, Rajarajeswari Medical College and Hospital, Bangalore; [2]Department of Microbiology, Rajarajeswari Medical College and Hospital, Bangalore, India

Correspondence: Archana Baburao, Department of Respiratory Medicine, Dr. M.G.R. Educational and Research Institute, Rajarajeswari Medical College and Hospital, Bangalore 74, India. Tel.: 91 9741016606. E-mail: dr_archana82@yahoo.co.in

Contributions: AB, VP, AMM, design of the study; AB, VP, AMM, PS, TK, data acquisition; AB, LSA, AMM, data analysis; AB, LSA, VP, interpretation of data; AB, PS, AMM, drafting the manuscript; AB, VP, AMM, LSA, PS, TK, approval of the final version.

Conflict of interest: the authors declare no potential conflict of interest.

Ethics approval and consent to participate: the study was approved by the Institutional Ethical Committee (RRMCH-IEC/94/2021) and preregistered on clinicaltrials.gov, reference number CTRI/2023/03/050495.

Informed consent: written informed consent to participate was obtained from all study participants. The manuscript does not contain any person's data in any form

Patient consent for publication: written informed consent was taken from the study participants for publication.

Availability of data and materials: all data generated or analyzed during this study are included in this published article.

Funding: received seed grant from Dr. M.G.R. Educational and Research Institute

Abstract

Pertussis is highly prevalent in chronic obstructive pulmonary disease (COPD) patients, but it is underrecognized and underreported in India. This study aims to assess the burden and impact of pertussis in patients with COPD acute exacerbations and also evaluates the correlation between pertussis and COPD exacerbation. This is a prospective, observational, cross-sectional study enrolling 250 COPD patients admitted with moderate to severe exacerbation. Relevant investigations and oropharyngeal swabs for pertussis were collected from the study subjects. Among 250 patients with COPD acute exacerbation, a throat swab was positive for Bordetella pertussis in 40 (16.1%) of subjects. Among positive subjects, 45% had moderate and 55% had severe exacerbation. Pertussis-positive subjects had statistically significantly higher COPD assessment test scores (p=0.02), more exacerbations in the past year (p=0.03), associated coronary artery disease (p=0.007), pulmonary hypertension (p=0.001), significantly lower forced expiratory volume in 1 second values (p=0.04), exercise-induced desaturation (p=0.02), and belonged to group E GOLD category (p=0.01), compared to negative subjects with no significant difference in mortality. 55% of pertussis-positive patients required intensive care unit (ICU) admission compared to negative subjects (p=0.04). Further, within swab-positive patients, physiological indicators like peripheral oxygen saturation and diffusing capacity of the lung for carbon monoxide significantly predicted ICU need. This study demonstrates that COPD patients are potentially at increased risk of pertussis infection, and there is an association between pertussis infection and COPD severity. Vaccination coverage against pertussis among COPD patients is negligible. Large multicenter studies are required to establish the true burden of pertussis in COPD patients, including the healthcare costs.

Key words: pertussis, COPD, exacerbation, burden, vaccination.

Introduction

Chronic obstructive pulmonary disease (COPD) is the third leading cause of death worldwide, causing approximately 5% of all global deaths, and 90% of deaths occur in low and middle-income countries [1]. Chronic inflammation, which is a hallmark feature of COPD, contributes to lung damage, compromises innate and adaptive immune responses, and facilitates recurrent episodes of respiratory infection that further contribute to the pathological manifestations of the stable disease [2]. Exacerbations triggered by respiratory infections are responsible for accelerated decline in lung function, increased hospital admissions and mortality, and deteriorated quality of life [3,4]. However, evidence is scarce on the effect of pertussis in exacerbating these conditions.

Pertussis is a highly contagious respiratory illness mostly caused by a Gram-negative, pleomorphic, aerobic coccobacillus, Bordetella *pertussis*, which is transmitted directly from the infected to the susceptible subject [5]. Pertussis is well known to cause significant morbidity and mortality in young children [6-8]. In adults, the diagnosis is challenging as the clinical presentation is atypical, with less than half of them demonstrating whooping cough [9]. In a study conducted in the US, among adults hospitalized for pertussis, 18.8% had COPD (26.8% of those aged >65 years) [10], which was higher than the overall prevalence of COPD in the US (6.1% [11.9% of those aged > 65 years]) [11], and patients with COPD or asthma experienced a higher burden of pertussis and its complications compared with the general population [12]. Emerging data from countries like Europe and Italy have shown that not only COPD patients infected with pertussis could also experience exacerbation [13], but also underlying COPD increases the risk of a more severe presentation of pertussis [14].

Even though the Centers for Disease Control and Prevention-Advisory Committee on Immunization Practices (CDC-ACIP) recommended routine administration of Tdap booster for adolescents in 2005, the vaccine coverage remains low in the US, with only 56% of adolescents and 8.2% of adults vaccinated in 2012 [15,16]. The CDC recommends Tdap vaccination in adults with COPD who are not vaccinated in adolescence [17], and Tdap vaccination has been included in the non-pharmacological treatment of COPD in the GOLD 2021 guidelines onwards.

India has been employing whole-cell (wP/DTwP) vaccines in the national immunization program since 1978 [18]. Acellular (aP/DTaP) vaccines are mainly prescribed by the private sector, and coverage is still minuscule. Pertussis continues to be a serious public health problem, mainly among young children in India, and according to WHO, 4949 cases of pertussis were reported in 2023 [19]. There is no data on the coverage of Tdap in adolescents and adults in India since it is being used exclusively in the private health sector. As there are no Indian studies about the impact of pertussis in the COPD population, this study will be an

eye-opener of Indian data for pertussis in COPD patients and also emphasize the Tdap vaccination in COPD.

Materials and Methods

This prospective, cross-sectional observational study was conducted in the Department of Respiratory Medicine, Rajarajeswari Medical College and Hospital, Bangalore, affiliated to Dr. M.G.R. Educational and Research Institute, from March 2023 to September 2024. All the willing consecutive patients admitted to the department with the diagnosis of COPD acute exacerbation were enrolled in the study after screening for the inclusion and exclusion criteria. Written informed consent was taken from all the subjects, and ethical committee approval was taken from the Institutional Ethics Committee (RRMCH-IEC/94/2021), and the study was preregistered on clinicaltrials.gov, reference number CTRI/2023/03/050495.

Both male and female patients aged 40-75 years with a clinical diagnosis of COPD with moderate to severe exacerbation were included in the study. Moderate exacerbation was defined as an exacerbation without respiratory failure and treated with parenteral corticosteroids with or without antibiotics. Severe exacerbation – Type 1 / type 2 respiratory failure treated with parenteral corticosteroids and antibiotics. Patients with severe exacerbation requiring invasive/non-invasive ventilation were considered for ICU care. Patients with chronic lung diseases other than COPD, like lung cancer, and active tuberculosis, patients with life-threatening pulmonary embolism, patients who have undergone lung resection, and patients on immunosuppressive medications were excluded from the study.

The sample size was calculated as 250 patients using the formula:

$N = Z^2 pq/d^2$

N = minimum sample size required

Z = critical ratio of the confidence interval at 5% error, Z is 1.96

p = Prevalence of pertussis in COPD patients

q = 1-p

d = Allowable error on prevalence

Baseline data of all study subjects were collected, including demographics, duration of symptoms, smoking history, treatment history, occupational history, biomass exposure, number of exacerbations in the last year, underlying comorbidities, and medication history. All the subjects underwent a detailed physical examination and routine blood investigations, including complete blood count, renal function test, liver function test, serum electrolytes, ABG, chest x-ray, ECG, 2D echo, sputum gram stain and culture sensitivity, spirometry, DLCO, and six-minute walk test (6MWT) were done.

Oropharyngeal swab for B. Pertussis was collected from the study subjects after admission and was stored at - 80^0C until analyzed. DNA was extracted and tested for B. Pertussis by real-time PCR technique (HELINI Bordetella Pertussis Real-time PCR, G-LifeScience Solutions Pvt Ltd, Bangalore).

Statistical analysis

Statistical analysis was done using descriptive statistics to summarize the data and Inferential statistics. Chi-square was used to determine the association between attributes. The Z-test proportion and t-test were used to identify significant differences between groups using the Software MS Excel and SPSS V23. Multivariate logistic regression was used to predict ICU admission parameters. Receiver operating characteristic (ROC) curve analysis was performed to calculate AUC for ICU-related parameters. Rotated ROC curve was used to determine the cutoff for an ICU-related parameter using Youden's Index maximization, plotted using geometric means. All the statistical analysis was carried out at a 5% level of significance, and a p-value of < 0.05 was considered significant.

Results

Around 250 subjects were enrolled in the study after satisfying the inclusion and exclusion criteria. Table 1 demonstrates the demographic and laboratory data of the study subjects. The mean age of the study subjects was 66.45±7.16 years, with a BMI of 20.36±3.67. 75.6% were males. The mean CAT score was 18.58±6.44. About 62% of subjects had a previous history of exacerbation, and hypertension was the predominant comorbidity, followed by diabetes mellitus and coronary artery disease. Half of the enrolled subjects belonged to group E GOLD category, and 22.6% had associated pulmonary hypertension. 62% had moderate exacerbation and were admitted to the wards, and 38% had severe exacerbation requiring ICU admission. Sputum culture showed normal commensals in 75.2% of subjects with Klebsiella pneumonia, Pseudomonas aeruginosa, and Candida species accounting for 19.7%, 4.4%, and 0.7% respectively. Mean FEV1/FVC ratio was 0.59±0.1 with FEV1 of 47.61±15, and 45.3% of subjects demonstrating exercise-induced desaturation. The throat swab was positive for B. Pertussis in 40 (16.1%) of subjects. Among positive subjects, 45% had moderate and 55% had severe exacerbation. Mortality rate among admitted patients was 1.6%.

On comparing the pertussis-positive patients with the pertussis-negative patients (Table 2), there was no statistically significant difference in age, gender, and BMI. However, pertussis-positive subjects had higher CAT scores (p=0.02), more exacerbations in the past year (p=0.03), associated CAD (p=0.007), pulmonary hypertension (p=0.001), and belonged to group E GOLD category (p=0.01), which was statistically significant. 55% of pertussis-positive

patients required ICU admission as compared to 34.7% of negative subjects (p=0.04). Sputum culture grew a significant number of pathological bacteria (p=0.04) in positive subjects. Positive subjects had significantly lower FEV1 values (p=0.04), and exercise-induced desaturation (p=0.02) compared to negative subjects, with no significant difference in mortality.

The multivariate regression model (Table 3) identifies key physiological predictors of ICU admission among patients with swab-positive COPD. Baseline SpO_2 (OR-1.607, p<0.0001) was a strong predictor, followed by DLCO (OR-1.043, p=0.017). Higher probability predictors were considered for further ROC analysis. The AUC was highest for SpO_2 < 90% (0.884), followed by DLCO < 64% (0.668), and 6MWD% < 64% predicted (0.594) (Figures 1 and 2) among swab-positive COPD patients requiring ICU care.

Discussion

Several studies have shown a higher burden of pertussis and its complications in COPD patients compared with the general population [12,14,20,21]. The association between COPD and pertussis in clinical settings has not been investigated extensively, particularly in India. Also, the overall burden of pertussis in COPD patients is unclear in the Indian context.

This prospective cross-sectional study assessed the burden and impact of pertussis in patients with COPD acute exacerbation and also evaluated the correlation between pertussis and COPD exacerbation. In our study, the prevalence of pertussis by PCR technique among hospitalized patients with COPD exacerbation was 16.1%, which was similar to a recent seroprevalence study from England (13.8%) [20], suggesting that patients with COPD are at increased risk of pertussis. All the pertussis-positive patients were aged > 60 years (72% were aged >65 years), reflecting increased morbidity of pertussis in older adult COPD patients.

COPD is a chronic progressive inflammatory disease with structural modifications of the respiratory tract with hyper-production of mucus, defects in the ciliated epithelium, and a deficiency in innate and acquired immunity [21]. Respiratory system dysbiosis in patients with COPD increases the susceptibility to bacterial and viral infections that could trigger acute COPD exacerbations [21,22], which was evident in the present study.

Recent studies have shown B pertussis as an intracellular microorganism that is capable of proliferation within the cells of respiratory origin, such as alveolar macrophages and epithelial cells, causing chronic infections [21]. Different mechanisms like adhesion, secretion of different toxins effective on various cells, and antigenic changes have been found to facilitate the intracellular survival of B. pertussis. This compromised lung function and immune response caused by B pertussis make COPD patients more vulnerable to secondary bacterial infections, often leading to exacerbations. Furthermore, those who develop pertussis could experience

exacerbation of their pre-existing COPD and further susceptibility to other infections, resulting in a vicious cycle [14]. This was evident in our study, where secondary bacterial infections were more common among pertussis-positive COPD patients. Also, pertussis-positive patients had a significantly higher number of exacerbations in the past year.

A study from Iran demonstrated a statistically significant association between COPD and anti-pertussis toxin IgG seropositivity, indicative of past infection, although there was no association between B. pertussis seroprevalence and severity of COPD in the study [23]. However, in our study, we noted a significant association between pertussis and the severity of COPD in terms of the GOLD assessment tool, CAT score, significantly lower FEV1 values, exercise-induced desaturation, and severe pulmonary hypertension. Also significantly higher number of pertussis-positive patients had severe COPD exacerbation requiring ICU care. Further, within swab-positive patients, physiological indicators like SpO_2 and DLCO significantly predicted ICU need, emphasizing the fact that the progression of COPD may be promoted by pertussis, creating a vicious cycle for the patients. Significant eosinopenia among the positive patients may be attributed to higher doses of inhaled corticosteroid therapy, as the majority (67.5%) of these patients belonged to GOLD E category compared to negative patients.

Microbiological diagnosis of pertussis is challenging. Culture is regarded as the gold standard for diagnosis, exhibiting 100% specificity but only 20%–80% sensitivity, and it requires special media and extended incubation [24]. Conversely, molecular tests are rapid with excellent sensitivity. Additionally, PCR assays that include multiple target sequences enable speciation among B. species. Serology can be performed much later in the course of the disease compared to culture and PCR. The optimal timing for pertussis diagnostic testing, according to the CDC, is illustrated in Figure 3 [24]. In our study, we used a PCR assay for diagnosing pertussis, as there is no international threshold for seropositivity indicative of previous pertussis infection, and culture is cumbersome.

Pertussis continues to be a serious public health problem in India and continues mainly to be a problem of young children. DPT coverage in India among children is only 75%, and there is no data on the coverage of Tdap in adolescents and adults. In our country, there are various adult vaccination recommendations against B. Pertussis, but none have been nationally adopted [25]. Further, over 2/3 of Indian adults are not aware of adult vaccination [26]. This was evident in our study, as none of the study subjects had received the Tdap vaccination. Hence, there is an unmet need for Tdap vaccination in COPD patients in the Indian context.

Our study has a few limitations. There was no control group in the present study. We did not analyze the cost of healthcare utilization by these patients. Healthcare visits post-discharge

were not assessed, as studies have shown that all-cause hospitalization rates were higher in pertussis patients with COPD up to 6 months post-discharge [14].

Conclusions

Our results indicate that COPD patients are potentially at an increased risk of pertussis infection, and there is a correlation between pertussis infection and COPD severity. Vaccination coverage for pertussis among COPD patients is minimal. Large multicenter studies are necessary to determine the true burden and impact of pertussis in COPD patients, including healthcare costs, and to develop vaccination strategies for these at-risk groups.

References

1. GOLD. Global strategy for the diagnosis, management and prevention of COPD 2024 report. Available from: https://goldcopd.org/2024-gold-report/
2. Bhat TA, Panzica L, Kalathil SG, Thanavala Y. Immune dysfunction in patients with chronic obstructive pulmonary disease. Ann Am Thorac Soc 2015;12:S169-75.
3. Donaldson GC, Seemungal TA, Bhowmik A, Wedzicha JA. Relationship between exacerbation frequency and lung function decline in chronic obstructive pulmonary disease. Thorax 2002;57:847-52.
4. Papi A, Bellettato CM, Braccioni F, et al. Infections and airway inflammation in chronic obstructive pulmonary disease severe exacerbations. Am J Respir Crit Care Med 2006;173:1114-21.
5. Kilgore PE, Salim AM, Zervos MJ, Schmitt HJ. Pertussis: microbiology, disease, treatment, and prevention. Clin Microbiol Rev 2016;29:449-86.
6. Tan T, Trindade E, Skowronski D. Epidemiology of pertussis. Pediatr Infect Dis J 2005;24:S10-8.
7. Hartzell JD, Blaylock JM. Whooping cough in 2014 and beyond: an update and review. Chest 2014;146:205-14.
8. Moore A, Harnden A, Grant CC, et al. Clinically diagnosing pertussis-associated cough in adults and children: CHEST guideline and expert panel report. Chest 2019;155:147-54.
9. Lee GM, Lett S, Schauer S, et al. Societal costs and morbidity of pertussis in adolescents and adults. Clin Infect Dis 2004;39:1572-80.
10. Mbayei SA, Faulkner A, Miner C, et al. Severe pertussis infections in the United States, 2011-2015. Clin Infect Dis 2019;69:218-26.
11. Ward BW, Nugent CN, Blumberg SJ, Vahratian A. Measuring the prevalence of diagnosed chronic obstructive pulmonary disease in the United States using data from the 2012-2014 national health interview survey. Public Health Rep 2017;132:149-56.

12. Naeger S, Pool V, Macina D. Increased Burden of Pertussis Among Adolescents and Adults With Asthma or COPD in the United States, 2007 to 2019. Chest 2024;165:1352-61.
13. Jenkins VA, Savic M, Kandeil W. Pertussis in high-risk groups: an overview of the past quarter-century. Hum Vaccin Immunother 2020;16:2609-17.
14. Blasi F, Bonanni P, Braido F, et al. The unmet need for pertussis prevention in patients with chronic obstructive pulmonary disease in the Italian context. Hum Vaccin Immunother 2020;16:340-8.
15. Stokley S, Cohn A, Dorell C, et al. Adolescent vaccination-coverage levels in the United States: 2006-2009. Pediatrics 2011;128:1078-86.
16. Vashishtha VM, Bansal CP, Gupta SG. Pertussis vaccines: position paper of Indian Academy of Pediatrics (IAP). Indian Pediatr 2013;50:1001-9.
17. CDC. Use of tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccines: updated recommendations of the advisory committee on immunization practices — United States, 2019. Available from: https://www.cdc.gov/mmwr/volumes/69/wr/mm6903a5.htm
18. IAP Advisory Committee on Vaccines and Immunization Practices. Pertussis (whooping cough). Available from: https://acvip.org/parents/columns/pertussis.php
19. WHO. Pertussis reported cases and incidence. Available from: https://immunizationdata.who.int/global/wiise-detail-page/pertussis-reported-cases-and-incidence
20. Aris E, Harrington L, Bhavsar A, et al. Burden of pertussis in COPD: a retrospective database study in England. COPD 2021;18:157-69.
21. Sethi S. Infection as a comorbidity of COPD. Eur Respir J 2010;35:1209-15.
22. Hillas G, Perlikos F, Tsiligianni I, Tzanakis N. Managing comorbidities in COPD. Int J Chron Obstruct Pulmon Dis 2015;10:95-109.
23. Hashemi SH, Nadi E, Hajilooi M, et al. High seroprevalence of Bordetella pertussis in patients with chronic obstructive pulmonary disease: a case-control study. Tanaffos 2015;14:172-6.
24. CDC. Laboratory testing for pertussis. 2024. Available from: https://www.cdc.gov/pertussis/php/laboratories/index.html
25. Vora A, Di Pasquale A, Kolhapure S, et al. The need for vaccination in adults with chronic (noncommunicable) diseases in India - lessons from around the world. Hum Vaccin Immunother 2022;18:2052544.
26. Dash R, Agrawal A, Nagvekar V, et al. Towards adult vaccination in India: a narrative literature review. Hum Vaccin Immunother 2020;16:991-1001.

Table 1. Baseline characteristics of study subjects.

Variables	**n=250**
Age (years)	66.45±7.16
Gender (female/male), n (%)	61 (24.4) / 189(75.6)
BMI (kg/m^2)	20.36±3.67
CAT score	20.58±6.44
Exacerbation in past 1 year, n (%)	155 (62)
Comorbidities - Hypertension, n (%)	100(40.1)
Diabetes mellitus, n (%)	71 (28.5)
CAD, n (%)	27 (10.9)
GOLD assessment tool	
Group A, n (%)	31 (12.4)
Group B, n (%)	91 (36.5)
Group E, n (%)	128 (51.1)
Present exacerbation	
Moderate, n (%)	155 (62)
Severe, n (%)	95 (38)
Baseline saturation	90.43±8.17
Total count (cell/mm^3)	10.06±3.59
Neutrophils (%)	74.13±14.58
Eosinophils (%)	1.35±2.1
Pulmonary hypertension, n (%)	57 (22.6)
Sputum culture	
Normal commensal, n (%)	188 (75.2)
Klebsiella pneumoniae, n (%)	49 (19.7)
Pseudomonas aeruginosa, n (%)	11 (4.4)
Candida species, n (%)	2 (0.7)
FEV1/FVC (%)	0.59±0.1
FEV1 (%)	47.61±15
FVC (%)	56.39±13.49
BDR, n (%)	13 (5.1)
DLCO (%)	68.42±21.11
6MWD (m)	406.82±34.28
6MWT - desaturation, n (%)	113 (45.3)
Positive throat swab for pertussis, n (%)	40 (16.1)
Outcome (death), n (%)	4 (1.6)

Results are presented as mean ± standard deviation. CAT, COPD assessment tool; CAD, coronary artery disease; BDR, bronchodilator reversibility; DLCO, diffusing capacity of lung for carbon monoxide; 6MWD, 6-minute walk distance.

Table 2. Comparison between Pertussis positive and negative COPD patients

Variables	Pertussis positive (n=40)	Pertussis negative (n=210)	p
Age (years)	66.45±7.16	66.3±9.98	0.94
Gender (female/male)	15/25	46/164	0.14
BMI (kg/m2)	19.6±2.7	20.5±3.82	0.29
CAT score	18.31±6.63	19.95±5.31	0.02
Exacerbation in past 1 year, n (%)	26 (65)	129 (61.4)	0.03
Comorbidities - Hypertension, n (%)	18 (45)	82 (39)	0.57
Diabetes mellitus, n (%)	13 (32.5)	58 (27.6)	0.7
CAD, n (%)	11 (27.5)	16 (7.6)	0.007
GOLD assessment tool			
Group A, n (%)	2 (5)	29 (13.8)	0.01
Group B, n (%)	11(27.5)	80 (38.09)	
Group E, n (%)	27 (67.5)	101 (48.09)	
Present exacerbation			
Moderate, n (%)	18 (45)	137 (65.2)	0.04
Severe, n (%)	22 (55)	73 (34.7)	
Baseline saturation	90.5±5.17	90.42±8.64	0.95
Total count (cell/mm^3)	10.42±3.94	10±3.54	0.6
Neutrophils (%)	73.5±13.73	74.25±14.79	0.82
Eosinophils (%)	0.75±1.24	1.46±2.21	0.04
Pulmonary hypertension, n (%)	9 (22.5)	15 (7.14)	0.001
Sputum culture			
Normal commensal, n (%)	18 (45)	170 (80.9)	0.04
Klebsiella pneumoniae, n (%)	16(40)	33 (15.7)	
Pseudomonas aeruginosa, n (%)	4 (10)	7 (3.3)	
Candida species, n (%)	2 (5)	0	
FEV1/FVC (%)	0.58±0.08	0.59±0.1	0.65
FEV1 (%)	41.45±15.48	48.02±14.93	0.04
FVC (%)	55.68±16.78	56.52±12.85	0.7
BDR, n (%)	13 (5.1)	20 (9.52)	0.06
DLCO (%)	64.91±17.79	69.91±11.78	0.39
6MWD (m)	416.88±35.28	461.06±36.08	0.07
6MWT - desaturation, n (%)	27 (67.5)	86 (40.9)	0.02
Outcome, n (%)	2 (5)	2 (0.95)	0.06

Results are presented as mean ± standard deviation. CAT, COPD assessment tool; CAD, coronary artery disease; BDR, bronchodilator reversibility; DLCO, diffusing capacity of lung for carbon monoxide; 6MWD, 6-minute walk distance.

Table 3. Multivariate logistic regression output among pertussis-positive subjects requiring ICU admission.

Variables	B coefficient	Odds ratio (OR)	95% CI for OR	p
Baseline Spo_2	0.475	1.607	1.339-1.930	<0.0001
DLCO	0.042	1.043	1.008-1.079	0.017
6MWD%	0.046	1.047	0.996-1.101	0.074

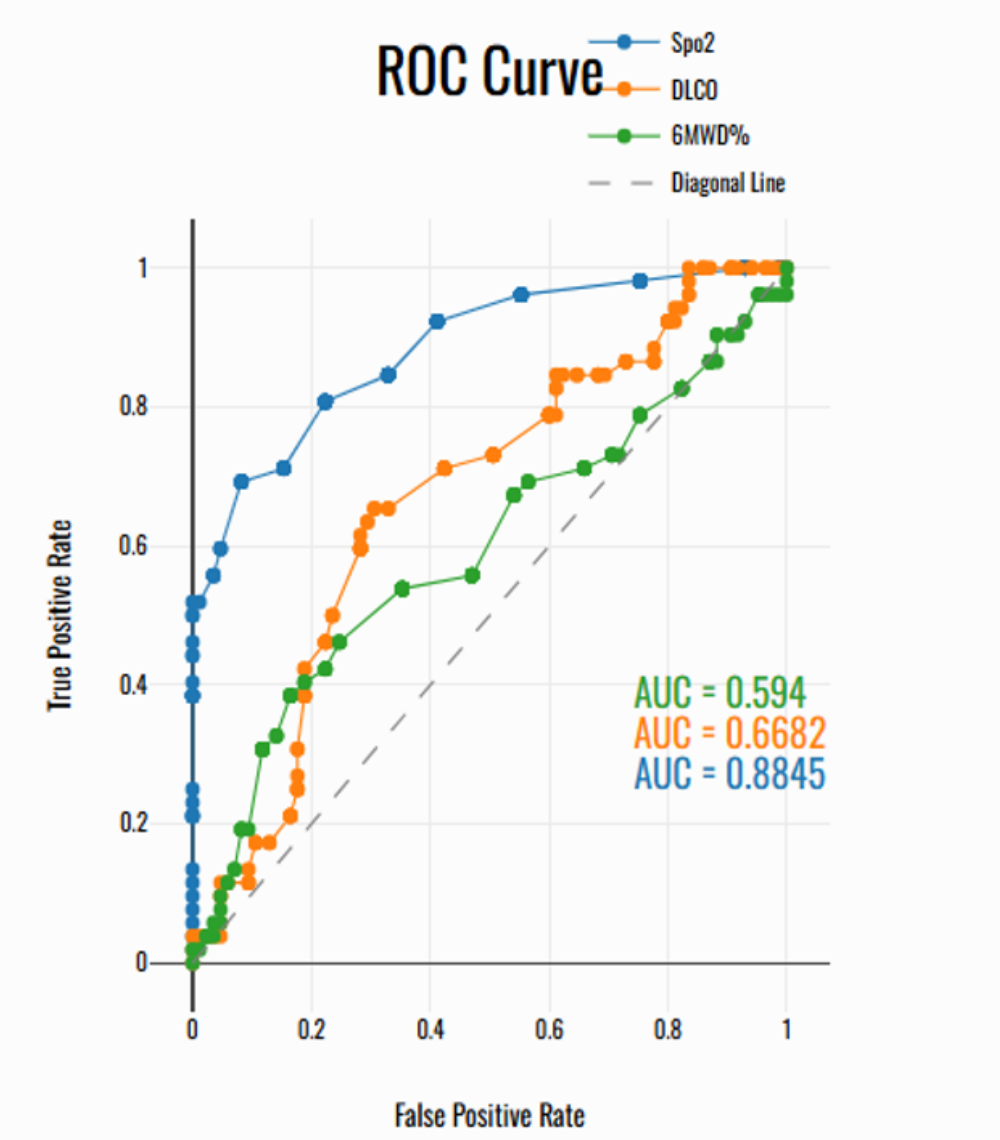

Figure 1. ROC curve from multivariate logistic model for predicting ICU admission among pertussis-positive subjects.

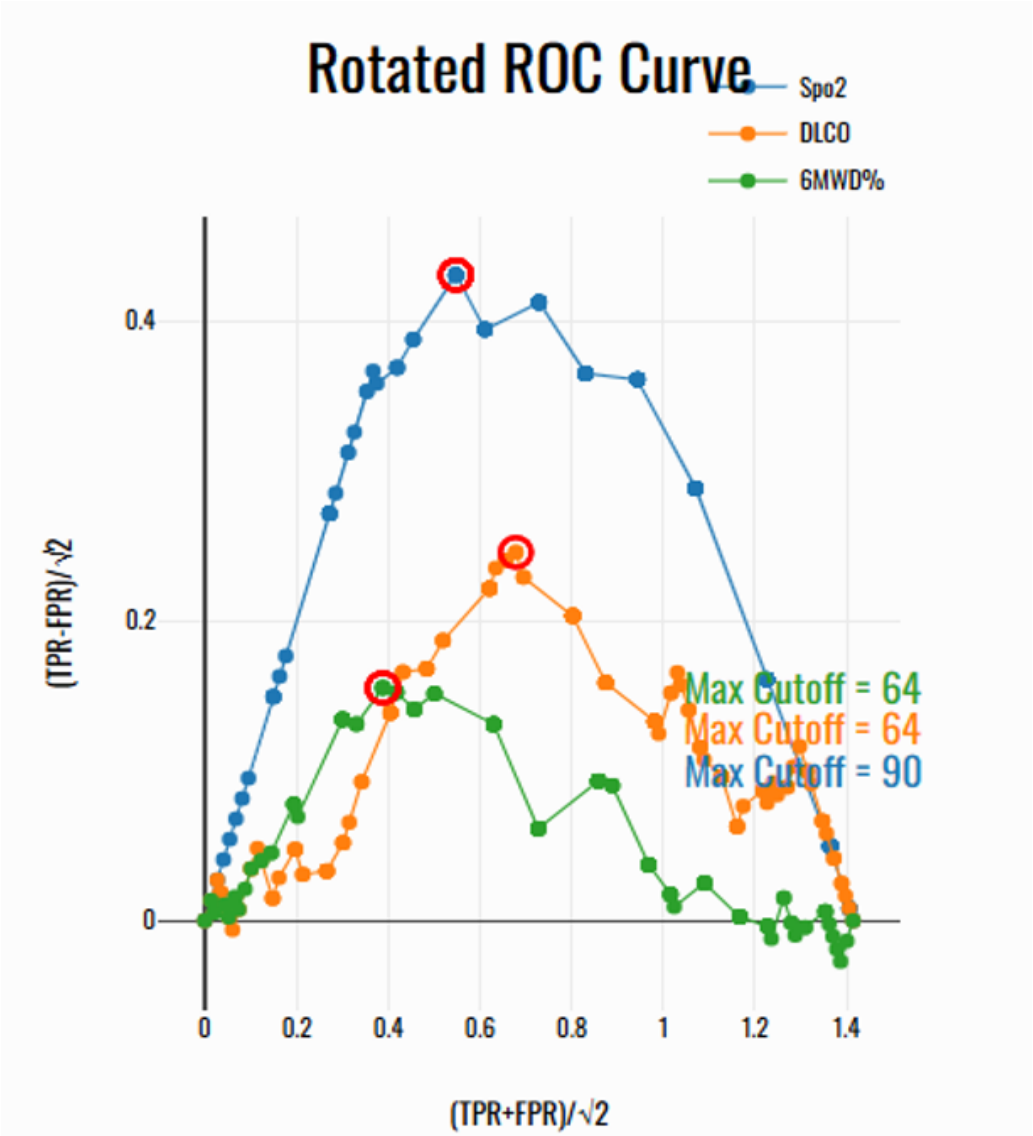

Figure 2. Rotated ROC curve showing the optimal cut-off points for predicting ICU admission among pertussis-positive subjects.

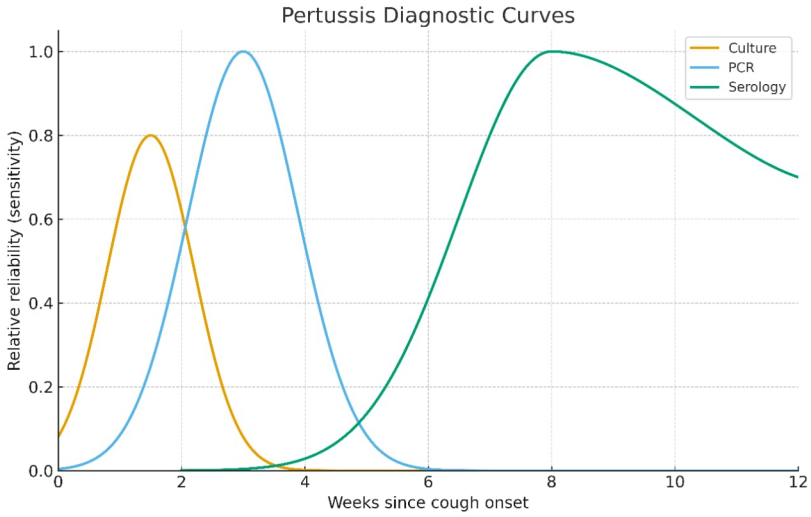

Figure 3. Optimal timing for pertussis diagnostic testing.