Effects of bronchial provocation test and bronchial dilation test for the diagnosis of lung diseases

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ABSTRACT

Aim: Present study was performed to explore the effects of bronchial provocation test (BPT) and bronchial dilation test (BDT) for the diagnosis of lung diseases.

Methods: BPT and BDT results were respectively detected by methacholine and albuterol in patients with different lung diseases and non-lung diseases. BPT and BDT indexes including exhaled nitric oxide (ENO), forced expiratory volume of first minute (FEV1), forced vital capacity (FVC), diffusion of carbon monoxide in the lungs (DLCO) and eosinophilia (EOS) were compared by t-test between different groups.

Results: Positive and negative BPT indexes were significantly different in lung diseases, similar results of BDT results were also discovered in patients with lung diseases (p < .001). Obvious differences of ENO, FEV1/FVC and EOS levels were discovered in different BPT degrees (p < .05). FEV1, FVC and FEV1/FVC levels were distinctly higher in I BDT degree than II and III BDT degrees (p < .05) in lung diseases. Significant differences of BPT and BDT indexes were discovered between different lung diseases (p < .05).

Conclusion: BPT and BDT may be employed as the tools for diagnosis of lung diseases. Moreover, the patients with different lung diseases show significantly different BPT and BDT indexes.

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Introduction

Asthma and chronic obstructive pulmonary disease (COPD) are chronic inflammatory diseases of the airways and lead to a major public health problem [1–3]. Asthma is a chronic inflammatory disease of the airways, usually starting in childhood, characterized by reversible airflow obstruction [4,5]. On the contrary, COPD is an acquired and preventable disease typically caused by tobacco smoking and featured by persistent obstruction [6,7]. The disease usually develops after the fourth decade of life, and it is characterized by shortness of breath, cough, and sputum production [7]. Obstruction is usually intermittent and reversible in asthma while the airflow limitations are classically progressive and irreversible in COPD [8,9]. Thus, asthma and COPD may overlap and converge, especially in older people [10].

Mounting studies have demonstrated that bronchial provocation test (BPT) played an important role in diagnosing asthma [11,12]. In clinical application, BPT is severed as the gold standard of asthma, especially cough variant asthma (CVA). At present, the positive standard of BPT is as follows: after inhaling bronchial activator (contractile), forced expiratory volume in the first second (FEV1) decreased ≥20% is considered to be positive, indicating airway hyperresponsiveness [13].

Pulmonary function testing is the gold standard of COPD [14]. It is a sensitive indicator for detecting the airflow limitations with small variability and good repeatability. Bronchial dilation test (BDT) is to dilate the narrow bronchi with a certain dose of β-receptor agonists and detect the magnitude of post-salbutamol forced expiratory volume in the first second (FEV1) change [15]. After inhaling bronchodilating agent, the FEV1 increased more than 12% and the absolute value increased more than 200 ml than prior to medication, and the BDT was positive. When FEV1/FVC (forced vital capacity) <70% was determined as incomplete reversible airflow limitation. In clinical practice, BDT was used for the diagnosis and differential diagnosis between asthma and COPD [16]. In BDT, FEV1 was used as a measure of evaluation [17].

In the present study, we explored the effects of BPT and BDT for detection of lung diseases, including asthma and COPD.

Materials and methods

Ethnic review

This study was approved by the Ethic Committee of Daping Hospital, Army Military Medical University and Written
Table 1. Positive BPT in patients with lung diseases and non-lung diseases.

| Case No. | ENO (mean ± SD, median, IQR) | FEV1 (mean ± SD, median, IQR) | FVC (mean ± SD, median, IQR) | FEV1/FVC (mean ± SD, median, IQR) | DLCO (mean ± SD, median, IQR) | EOS (mean ± SD, median, IQR) |
|----------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Lung disease | 320 | 54.97 ± 43.72 (35.50, 42.25) | 51.36 ± 17.79 (54.20, 27.47) | 76.09 ± 17.34 (75.50, 15.79) | 53.53 ± 10.43 (56.565, 24.375) | 71.09 ± 48.83 (69.60, 32.205) |
| Non-lung disease | 77 | 56.06 ± 20.14 (63.00, 24.25) | 77.91 ± 19.76 (80.95, 18.175) | 57.61 ± 11.52 (53.835, 17.00) | 78.54 ± 24.27 (84.60, 22.30) | 75.94 ± 19.46 (84.60, 22.30) |
| p        |     | .745                          | .235                         | .638                         | .839                         | .68                         |
BPT: Bronchial provocation test; ENO: Exhaled nitric oxide; FEV1: Forced expiratory volume of first minute; FVC: Forced vital capacity; DLCO: Diffusion of carbon monoxide in the lungs; EOS: Eosinophilia; SD: Standard deviation; IQR: Interquartile range.

Table 2. Positive BDT in patients with lung diseases and non-lung diseases.

| Case No. | ENO (mean ± SD, median, IQR) | FEV1 (mean ± SD, median, IQR) | FVC (mean ± SD, median, IQR) | FEV1/FVC (mean ± SD, median, IQR) | DLCO (mean ± SD, median, IQR) | EOS (mean ± SD, median, IQR) |
|----------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Lung disease | 320 | 64.72 ± 61.3 (33.00, 47.00) | 91.78 ± 52.09 (77.60, 53.0) | 99.18 ± 12.20 (97.40, 12.00) | 75.97 ± 9.50 (79.00, 27.71) | 77.07 ± 26.05 (79.35, 31.65) |
| Non-lung disease | 77 | 48.08 ± 44.79 (33.00, 19.75) | 98.02 ± 13.47 (97.17, 16.05) | 76.74 ± 9.37 (79.35, 31.65) | 75.94 ± 19.46 (79.35, 31.65) | 75.97 ± 9.50 (79.35, 31.65) |
| p        |     | .081                          | .569                         | .460                         | .422                         | .909                         |
BPT: Bronchial dilatation test; ENO: Exhaled nitric oxide; FEV1: Forced expiratory volume of first minute; FVC: Forced vital capacity; DLCO: Diffusion of carbon monoxide in the lungs; EOS: Eosinophilia; SD: Standard deviation; IQR: Interquartile range.

informed consent was signed by every subject before collecting samples.

Study subjects

The present study was a case-control study. Individuals who received bronchial provocation test (BPT) and bronchial dilatation test (BDT) were recruited into this study. BPT was detected by methacholine. BDT was detected by albuterol. These patients were respectively from outpatient department and in-patient department of Daping Hospital, Army Military Medical University. All the patients with lung diseases were diagnosed by physicians according to previous criteria [18–20]. While, the non-lung disease patients had no of the symptoms of lung diseases.

Inclusion and exclusion criteria

Inclusion criteria of the patients had lung diseases was as the following: had at least one of the diseases, such as bronchitis, asthma, cough, emphysema, chronic obstructive pulmonary disease (COPD), pneumoconiosis, lung cancer, asthma-COPD overlap syndrome (ACOS) or other lung diseases as cardinal symptom; had complete BPT and BDT examine results, including exhaled nitric oxide (ENO), FEV1, forced vital capacity (FVC), diffusion of carbon monoxide in the lungs (DLCO) and eosinophilia (EOS).

Statistical analysis

All of the clinical data were analyzed using PASW 18.0 (SPSS Inc., Chicago, IL, USA) Quantitative variables were shown as mean ± standard deviation (SD), median and interquartile range (IQR) and their distributions were detected using Kolmogorov–Smirnov test. If the data were in normal distribution, their comparisons between two groups were analyzed by student’s t-test, otherwise, Mann–Whitney U test was applied. p Value less than .05 predicted the statistical significance of the results.

Results

BPT and BDT results for the identification of lung diseases and diseases in other part

Six hundred eleven patients had positive BPT results, among them only 450 patients had complete examine data. We compared the BPT indexes between lung diseases and non-lung disease. Then, we found that no significant difference has been discovered in ENO, FEV1, FVC, FEV1/FVC, DLCO and EOS between lung diseases and non-lung diseases (Table 1, p > .05). Six hundred three patients had positive BDT results, whereas only 342 patients had complete data. Between lung diseases and non-lung diseases, ENO, FEV1, FVC, FEV1/FVC, DLCO and EOS had no significant difference (Table 2, p > .05). These results indicated that BPT and BDT indexes had no effects for the diagnosis of lung diseases from other diseases.

Differences of positive and negative BPT and BDT results in lung diseases

There were 1452 cases had negative BPT results and 373 cases had positive BPT results in patients with lung diseases. ENO, FEV1 and FEV1/FVC indexes were significantly higher in positive BPT patients than that in negative BPT patients with lung diseases (Table 3, p < .05). In patients with lung disease included 3414 negative BDT cases and 603 positive BDT cases. Significant differences have been discovered in ENO, FEV1, FVC and FEV1/FVC indexes. ENO and FEV1/FVC levels were significantly higher in positive BDT cases, FEV1 and FVC levels were significantly lower in negative BDT cases (Table 4, p < .05). Thus, we suggested that the difference of positive and negative BPT (or BDT) results had no significant influence.
in comparison with the second BPT degree, the third BPT
groups (Table 5). Then, we found that ENO level was dis-
pairwise comparison has been performed among these three
differences of BPT and BDT indexes in lung diseases
obvious difference.

Table 3. BPT Results in patients with lung diseases.

| Case No. | ENO (mean ± SD, median, IQR) | FEV1 (mean ± SD, median, IQR) | FVC (mean ± SD, median, IQR) | FEV1/FVC (mean ± SD, median, IQR) |
|----------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| BPT (−)  | 1452 26.07 ± 21.53 (20.05, 16.00) | 97.70 ± 26.82 (95.55, 18.25) | 100.23 ± 28.52 (82.70, 8.19) | 82.18 ± 7.65 (98.50, 17.30) |
| BPT (+)  | 373 64.72 ± 61.37 (44.00, 58.00) | 91.78 ± 52.09 (87.20, 16.00) | 99.18 ± 12.20 (97.40, 14.80) | 75.97 ± 9.50 (78.38, 11.98) |

BPT: Bronchial provocation test; ENO: Exhaled nitric oxide; FEV1: Forced expiratory volume of first minute; FVC: Forced vital capacity; DLCO: Diffusion of carbon monoxide in the lungs; EOS: Eosinophilia; SD: Standard deviation; IQR: Interquartile range.

Table 4. BDT Results in patients with lung diseases.

| Case No. | ENO (mean ± SD, median, IQR) | FEV1 (mean ± SD, median, IQR) | FVC (mean ± SD, median, IQR) | FEV1/FVC (mean ± SD, median, IQR) |
|----------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| BDT (−)  | 3414 31.54 ± 26.20 (24.00, 19.975) | 70.82 ± 41.61 (71.10, 44.50) | 84.60 ± 27.41 (86.00, 31.90) | 63.71 ± 15.81 (63.345, 26.03) |
| BDT (+)  | 603 51.19 ± 43.82 (36.00, 42.85) | 51.64 ± 17.94 (54.40, 27.40) | 76.76 ± 17.96 (76.00, 24.30) | 53.32 ± 10.70 (53.09, 16.64) |

BDT: Bronchial dilation test; ENO: Exhaled nitric oxide; FEV1: Forced expiratory volume of first minute; FVC: Forced vital capacity; DLCO: Diffusion of carbon monoxide in the lungs; EOS: Eosinophilia; SD: Standard deviation; IQR: Interquartile range.

Table 5. Different BPT degrees in patients with lung diseases.

| BPT degrees | Case No. | ENO (mean ± SD, median, IQR) | FEV1 (mean ± SD, median, IQR) | FVC (mean ± SD, median, IQR) | FEV1/FVC (mean ± SD, median, IQR) |
|-------------|----------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| I           | 250      | 48.89 ± 43.42                | 95.11 ± 62.95                | 77.37 ± 7.90                 | 4.15 ± 4.69                  |
| II          | 70       | 104.19 ± 77.15               | 86.99 ± 10.12                | 9.45 ± 16.95                 | 2.45 ± 4.62                  |
| III         | 51       | 90.20 ± 81.07                | 81.76 ± 10.83                | 98.35 ± 10.24                | 5.27 ± 4.96                  |

BPT: Bronchial provocation test; ENO: Exhaled nitric oxide; FEV1: Forced expiratory volume of first minute; FVC: Forced vital capacity; DLCO: Diffusion of carbon monoxide in the lungs; EOS: Eosinophilia; SD: Standard deviation; IQR: Interquartile range.

Table 6. Different BDT degrees in patients with lung diseases.

| BDT degrees | Case No. | ENO (mean ± SD, median, IQR) | FEV1 (mean ± SD, median, IQR) | FVC (mean ± SD, median, IQR) | FEV1/FVC (mean ± SD, median, IQR) |
|-------------|----------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| I           | 375      | 54.79 ± 47.86                | 57.18 ± 16.95                | 81.14 ± 16.76                | 56.14 ± 10.31                |
| II          | 154      | 47.11 ± 39.87                | 45.95 ± 15.06                | 72.22 ± 15.98                | 50.71 ± 9.54                 |
| III         | 74       | 44.30 ± 31.13                | 35.42 ± 14.67                | 64.03 ± 19.45                | 44.45 ± 8.60                 |

BDT: Bronchial dilation test; ENO: Exhaled nitric oxide; FEV1: Forced expiratory volume of first minute; FVC: Forced vital capacity; DLCO: Diffusion of carbon monoxide in the lungs; EOS: Eosinophilia; SD: Standard deviation; IQR: Interquartile range.

for the diagnosis of lung diseases although the indexes had
obvious difference.

**Differences of BPT and BDT indexes in lung diseases with different BPT and BDT grades**

Three BPT degrees have been discovered in all lung diseases. Pairwise comparison has been performed among these three groups (Table 5). Then, we found that ENO level was distinctly higher in second (104.19 ± 77.15, 87.00, 118.90) and third (90.20 ± 81.07, 60.00, 87.00) degrees of positive BPT than first degree (48.89 ± 43.42, 32.00, 42.00) respectively (p < .001 and p = .004, respectively). FEV1 level was significantly lower in II (86.99 ± 10.12, 84.15, 11.325) and III (81.76 ± 10.83, 82.30, 12.00) BPT degree than in I BPT degree (95.11 ± 62.95, 97.45, 16.95) (p = .002 and p < .001). Moreover, in comparison with the second BPT degree, the third BPT degree showed lowest (p = .026). FEV1/FVC level was highest in I BPT degree (77.37 ± 7.90, 78.405, 16.95), higher in II degree (75.06 ± 12.91, 74.50, 11.445), lowest in III BPT degree (70.23 ± 9.15, 75.065, 9.15). Significant differences had been discovered between III vs. II BPT degrees (p = .021). Obviously higher EOS level has been discovered in II BPT degree than I BPT degree (p < .001), moreover, III BPT showed lower level than II BPT degree (p = .025). However, FVC and DLCO had no significant difference among different BPT degrees (p > .05).

Three degrees have been discovered in lung diseases patients with positive BDT results (Table 6). ENO had no significant difference between these three degrees (p > .05 for all). Significantly higher FEV1 level existed in I BPT degree than that in II and III BDT degrees (p < .05 for all). Similar results have been discovered in FVC and FEV1/FVC levels between different degrees (p < .05 for all).
Identification for different lung diseases using BPT and BDT

Lung diseases with complete positive BPT results included bronchitis (39 cases), asthma (180 cases), cough (141 cases), COPD (6), lung cancer (1 case) and other lung disease (5 cases) (Table 7). When compared with bronchitis patients, asthma patients had significantly lower FEV1 (87.93 ± 10.21 vs. 75.84 ± 10.76, \( p < .001 \)) and FEV1/FVC levels (99.88 ± 19.56 vs. 83.19 ± 13.86, \( p < .001 \)), higher ENO levels. COPD patients had distinctly lower FEV1 (69.14 ± 10.71 vs. 68.05, 19.755, \( p = .046 \)) and FEV1/FVC (77.06 ± 7.73 vs. 75.77, 22.00, \( p = .013 \)) levels. While COPD patients had distinctly lower FEV1 (69.14 ± 10.71 vs. 68.05, 19.755, \( p = .046 \)) and FEV1/FVC (77.06 ± 7.73 vs. 75.77, 22.00, \( p = .013 \)) levels discovered in ACOS patients (75.63 ± 12.92 vs. 73.49 ± 18.39 vs. 73.90 ± 13.85, \( p = .001 \); f, COPD vs. bronchitis, \( p < .001 \)); g, COPD vs. bronchitis, \( p < .001 \); h, COPD vs. bronchitis, \( p < .001 \); i, ACOS vs. bronchitis, \( p = .019 \); j, ACOS vs. bronchitis, \( p < .001 \); k, ACOS vs. bronchitis, \( p = .046 \); l, ACOS vs. bronchitis, \( p = .030 \).

Discussion

Previous studies showed that many indexes were used in the diagnosis of lung diseases. Li and colleagues suggested that ENO had no sufficient sensitivity and specificity for asthma diagnosis [21]. Francisco et al. found that FEV1 has high sensitivity in large airway tests [22]. FEV1 and FEV1/FVC were all contributed to the diagnosis of COPD [23]. FEV1, FVC and FEV1/FVC levels were significantly lower in children with severe stable asthma than in mild and moderate children [24]. Liu et al. reported that the analysis results of BPT or BDT had no significant association with FeNO values among the patients with asthma [25]. Due to the divergences on this issue, we analyzed the effects of BPT and BDT for the

### Table 7. Comparison of BPT indicators among different lung diseases.

| Disease type            | Case No. | ENO (mean ± SD, median, IQR) | FEV1 (mean ± SD, median, IQR) | FVC (mean ± SD, median, IQR) | FEV1/FVC (mean ± SD, median, IQR) | DLCO (mean ± SD, median, IQR) | EOS (mean ± SD, median, IQR) |
|-------------------------|----------|-------------------------------|------------------------------|-----------------------------|-----------------------------------|-------------------------------|-----------------------------|
| Bronchitis              | 39       | 54.09 ± 54.18 (114.47 ± 157.08) | 100.79 ± 14.38 (74.60 ± 8.25) | 74.03 ± 17.43 (69.14 ± 10.71) | 3.59 ± 4.37                     |                               |                             |
| Cough                   | 141      | 51.77 ± 51.46 (39.00, 39.25) | 99.79 ± 13.57 (77.06 ± 7.73) | 71.03 ± 42.32 (71.25 ± 82.64) | 3.74 ± 3.24                     |                               |                             |
| COPD                    | 6        | 71.25 ± 82.64 (30.80, 39.50) | 91.41 ± 13.80 (84.60, 20.70) | 75.63 ± 12.92 (78.13, 17.45) | 6.56 ± 8.62c                    |                               |                             |
| Other lung diseases     | 5        | 74.50 ± 81.32 (35.80, 32.00) | 78.63 ± 9.99 (56.30 ± 15.71) | 39.90 ± 24.20 (35.80 ± 15.71) | 5.51 ± 8.62c                    |                               |                             |

Notes: COPD, chronic obstructive pulmonary disease; ACOS, asthma-chronic obstructive pulmonary disease overlap syndrome; BPT: bronchial provocation test; ENO: exhaled nitric oxide; FEV1: forced expiratory volume of first minute; FVC: forced vital capacity; DLCO: diffusion of carbon monoxide in the lungs; EOS: eosinophilia; SD: Standard deviation; IQR: Interquartile range; a, asthma vs. bronchitis, \( p = .025 \); b, asthma vs. bronchitis, \( p = .016 \); c, COPD vs. bronchitis, \( p = .034 \).

### Table 8. Comparison of BDT indicators among different lung diseases.

| Disease type            | Case No. | ENO (mean ± SD, median, IQR) | FEV1 (mean ± SD, median, IQR) | FVC (mean ± SD, median, IQR) | FEV1/FVC (mean ± SD, median, IQR) | DLCO (mean ± SD, median, IQR) | EOS (mean ± SD, median, IQR) |
|-------------------------|----------|-------------------------------|------------------------------|-----------------------------|-----------------------------------|-------------------------------|-----------------------------|
| Bronchitis              | 50       | 33.88 ± 29.29 (25.00, 19.30) | 56.34 ± 17.84 (78.85, 20.12) | 80.98 ± 17.55 (55.425, 17.959) | 55.99 ± 11.05                    |                               |                             |
| Asthma                  | 213      | 58.09 ± 45.48 (45.00, 46.50) | 54.02 ± 17.58 (80.50, 22.40) | 78.86 ± 17.11 (55.90, 15.615) | 55.79 ± 10.08                    |                               |                             |
| Cough                   | 37       | 76.47 ± 68.20 (56.50, 103.925) | 63.09 ± 15.40 (84.20, 16.60) | 85.22 ± 16.95 (64.57, 10.73) | 59.56 ± 8.91d                    |                               |                             |
| Pulmonary emphysema     | 3        | 35.50 ± 19.20 (–)            | 63.17 ± 20.48 (43.11 ± 8.62) | 54.02 ± 10.08 (49.37 ± 9.59g) | 55.59 ± 11.05                    |                               |                             |
| COPD                    | 229      | 41.98 ± 32.88 (33.00, 31.75) | 46.78 ± 17.20 (73.49 ± 13.89) | 73.90 ± 13.85 (48.61, 15.615) | 49.37 ± 9.59g                    |                               |                             |
| Pneumocooniosis         | 7        | 60.14 ± 15.87 (61.60, 12.90) | 83.19 ± 13.86 (79.20, 24.10) | 83.19 ± 13.86 (53.81, 22.52) | 57.32 ± 16.82                    |                               |                             |
| Lung cancer             | 5        | 49.56 ± 14.07 (48.80, 24.30) | 68.94 ± 8.53 (70.10, 14.80) | 68.94 ± 8.53 (55.02, 20.705) | 55.59 ± 11.68                    |                               |                             |
| ACOS                    | 27       | 69.86 ± 57.22 (23.90, 23.25) | 46.22 ± 20.02i (72.09 ± 19.85) | 84.91 ± 16.10 (48.91 ± 10.66k) | 55.59 ± 11.68                    |                               |                             |
| Other lung diseases     | 28       | 28.63 ± 14.98 (49.50, 81.75) | 52.69 ± 15.18 (43.30, 23.10) | 72.81 ± 15.71 (68.90, 25.90) | 57.03 ± 8.40 (49.74, 16.07)     |                               |                             |

BPT: bronchial dilation test; ENO: exhaled nitric oxide; FEV1: forced expiratory volume of first minute; FVC: forced vital capacity; DLCO: diffusion of carbon monoxide in the lungs; EOS: eosinophilia; SD: Standard deviation; IQR: Interquartile range; a, asthma vs. bronchitis, \( p = .001 \); b, cough vs. bronchitis, \( p = .013 \); c, cough vs. bronchitis, \( p = .013 \); e, COPD vs. bronchitis, \( p = .001 \); f, COPD vs. bronchitis, \( p < .001 \); g, COPD vs. bronchitis, \( p < .001 \); h, ACOS vs. bronchitis, \( p = .019 \); i, ACOS vs. bronchitis, \( p = .019 \); j, ACOS vs. bronchitis, \( p = .046 \); k, ACOS vs. bronchitis, \( p = .034 \).
differentiation diagnosis of lung diseases in the current study. We found that the patients with different lung diseases exhibited the significant differences of BPT and BDT indexes.

First, we compared the BPT and BDT indexes between patients with lung diseases and those with non-lung diseases, so as to make sure whether indexes were different between the two groups in patients with positive BPT (or BDT) results. Unfortunately, we failed to find any significant difference of BPT indexes and BDT indexes between lung disease and non-lung diseases. Therefore, we considered that lung diseases could not be identified from all sorts of diseases only based on BPT and BDT results.

Soon after, we detected the differences of positive and negative BPT (or BDT) results in patients with lung diseases. Then, we found that ENO, FEV1 and FEV1/FVC levels were significantly different between negative and positive BPT patients with lung diseases. Distinct differences were also discovered in ENO, FEV1, FVC and FEV1/FVC levels between positive and negative BPT patients with lung diseases. It suggested that BPT and BDT indexes were significantly different between positive and negative results. Hence, it could be considered that BPT and BDT are useful method for the diagnosis of many diseases.

Differences of BPT and BDT indexes in lung diseases with different BPT and BDT grades were also compared in this study. For ENO level in lung disease patients with positive BPT results, significant highest level existed in II BPT degree, next in III BPT degree than that in I BPT degree. FEV1 level was significantly lower in III BPT degree than I BPT degree and II BPT degree. Obviously lower FEV1/FVC level was discovered in III BPT degree than II BPT. The patients with II BPT degree had significantly higher EOS values. For BDT degree comparison, FEV1, FVC and FEV1/FVC levels were significantly higher in I BPT degree than II and III BPT degrees, respectively. These results demonstrated that indexes were distinctly different between BPT and BDT degrees, that is, differences of BPT and BDT indexes could present different diseases. A prospective birth cohort study carried out by Hallas et al. demonstrated that among 367 children born to mothers with asthma, the children developing asthma exhibited obviously deceased FEV1 at cold dry air challenge and after exercise [26]. BPT and BDT indexes might be helpful in differentiation diagnosis of lung diseases.

In order to certify the effects of BPT and BDT in the identification of different lung diseases, we compared the indexes between different types of lung diseases. In comparison with bronchitis patients, asthma patients had significantly lower FEV1 and DLCO levels, COPD patients had significantly lower FEV1/FVC level, in the positive BPT group. For BDT results, asthma and cough patients had significantly higher ENO level than bronchitis patients. COPD patients had obviously lower FEV1, FVC and FEV1/FVC levels than bronchitis patients. When compared with bronchitis patients, ENO, FEV1, FVC and FEV1/FVC levels were all had significant difference in ACOS patients. These differences showed that BPT and BDT indexes were helpful to identify the different lung diseases. Shi and coworkers also found that ENO, FEV1, FEV1/FVC were different between ACOS and COPD or cough [27]. Slobodan et al. reported that among the patients presenting perennial asthma symptoms, the patients having hypersensitivity showed significantly lower levels of FEV1 and FEV1/FVC [28].

Several limitations in the current study should be stated. Conspicuous limitation in this study was the lack of discussion on the critical values of different lung diseases. All the included individuals were from the same hospital that might cause selection bias. Besides, the sample size was relatively small, especially the number of patients with the specific lung disease, that might influence the accuracy of our results, and the results obtained in our study had not been verified in another group. Given the mentioned limitations, the application of BPT and BDT indexes for the diagnosis of different lung diseases might cause diagnostic errors. The results obtained in our study might be employed as an auxiliary tool for primary confirmation.

In conclusion, for patients presenting the clinical symptoms of lung diseases, BPT and BDT indexes may be a diagnostic biomarker of lung diseases, moreover, the levels of BPT and BDT indexes in different lung diseases were also significantly different. But whether BPT and BDT indexes are effective biomarker for the diagnosis of different lung diseases are necessary to find out in the future.

Disclosure statement

No potential conflict of interest was reported by the authors.

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