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Case report

Rapid weaning from mechanical ventilation and bronchial thermoplasty for near-fatal asthma: A case report

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A R T I C L E I N F O

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A B S T R A C T

Background: The action mechanism of bronchial thermoplasty (BT) is poorly understood. Generally, patients with severe asthma who are in desperate need of treatment have relatively low baseline values. In this paper, we describe the case of an asthmatic patient who was saved by a combination of therapy and bronchial thermoplasty.
Case information: A patient with near-fatal asthma was initially treated in our hospital with conventional medication, but his condition did not improve. The patient was next subjected to invasive mechanical ventilation, which did not provide significant relief. Additionally, he was treated with BT in conjunction with mechanical ventilation, which promptly reversed his status asthmaticus and stabilized his condition.
Conclusion: Patients with near-fatal asthma who do not react effectively to aggressive therapy may benefit from BT.

1. Introduction

Bronchial thermoplasty (BT), a novel non-drug treatment for asthma, is now used for the elective treatment of relatively stable severe asthma, and its efficacy and safety have been validated [1–6]. Clinically, people with severe asthma who are in desperate need of treatment frequently have symptoms that are far more severe than those of patients included in randomized clinical studies of BT. Consequently, it is crucial to examine the efficacy and safety of BT in these individuals.

Through this case study report of a patient with near-fatal asthma who did not respond to conventional medication and was successfully rescued by combining BT with conventional treatment, we aim to investigate additional indications for BT and provide additional reference data and values for the clinical use of BT. We discovered that this is the first instance of the use of BT in a patient with near-fatal asthma after reviewing the current literature. The following are the specifics.

1.1. Case presentation

A 30-year-old male was admitted to our hospital on March 23, 2017, with chief complaints of "recurrent asthma since over 6 years

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and exacerbation with dyspnea for 1 day." The patient's previous pulmonary function test revealed severe mixed ventilation dysfunction, with a positive bronchodilator test [the increase in absolute forced expiratory volume in 1 s (FEV1) of 250 mL, the improvement rate of 24%, FEV1 PreD of 26%, and FEV1/forced vital capacity (FVC) percent of 56% after 15 minutes of inhalation with 400 g Ventolin], a score of 9 on the Asthma Control Test, and a score of 6 on the Asthma Control Questionnaire. Consequently, bronchial asthma was identified as the underlying medical condition, and the patient was prescribed "salbutamol aerosol and budesonide and formoterol fumarate powder (160/4.5 g/dose, three times/day) inhalation therapy." He was brought to the intensive care unit for "severe asthma" one year ago and was treated with mechanical ventilation by tracheal intubation. The patient was moved to the regular ward after receiving treatment for more than 10 days. Symptoms worsened, so the patient spent a day in another hospital being treated with intravenous methylprednisolone (precise dose unclear), antispasmodic, and antiasthmatic medications. His wheezing got progressively worse, and he eventually ended up in our hospital's emergency room.

A physical examination taken upon admission revealed the following vital signs: body temperature of 35.5 °C, a pulse rate (P) of 121 beats/min, a respiratory rate (R) of 32 times/min, blood pressure of 169/100 mmHg, and oxygen saturation (SpO_2) of 83% (no oxygen inhalation). The patient also presented with orthopnea, cyanosis of the lips, profuse sweating, the three-concave sign, hyperresonance in the percussion of both lungs, accelerated respiration, and loud and diffuse wheezing rales in both lungs. Blood gas analysis revealed a pH of 7.137, partial pressure of carbon dioxide (PCO_2) of 74.7 mmHg, partial pressure of oxygen (PO_2) of 95.0 mmHg, sulfur dioxide (SO2) of 94.0%, and the fraction of inspired oxygen (FiO_2) of 41.0%. The oxygenation index was 232 mmHg. Routine blood test results demonstrated white blood cells (WBCs) of 15.51 $\times$ 10^9/L, neutrophil percentage (NEU%) of 74.2%, and eosinophil percentage (EOS%) of 7.2%. The remaining biochemical and coagulation parameters were normal. Computerized tomography (CT) of the chest revealed no major abnormalities (Fig. 1A-F).

On admission, the patient was diagnosed with acute (critical) bronchial asthma, type II respiratory failure, and respiratory acidosis.

After admission, he immediately received high-flow oxygen through face mask (oxygen concentration of 60%), and was given intravenous infusion with 3.75 g piperacillin sodium and tazobactam sodium (once/8 h) and 60 mg ambroxol (once/day), intravenous injection with 80 mg methylprednisolone (once/8 h), and inhalation with 0.8 mg beclometasone dipropionate and 5 mg salbutamol sulfate (once/8 h).

After 2 hours of this treatment, the patient's condition worsened, his SpO2 dropped to 75%, and he eventually became unconscious. The patient was immediately started on invasive mechanical ventilation [volume-assist/control ventilation (V-A/C); parameters: respiratory frequency (F), 24 times/min; vital capacity (VC), 500 mL; FiO2, 60%] (Table 1) through tracheal intubation, after which SpO2 increased to 94%. Blood gas analysis was repeated 4 hours later, indicating pH of 7.206, PCO_2 of 61.5 mmHg, PO_2 of 90.0 mmHg, SO2 of 95.0%, FiO_2 of 60.0%, and oxygenation index of 150 mmHg.

The patient also received continuous inhalation of 0.8 mg beclometasone dipropionate and 5 mg salbutamol sulfate mixed with 500 mg ipratropium bromide once every 8 hours, as well as intravenous injections of 40 mg methylprednisolone once every 6 hours and positive end-expiratory pressure (PEEP) at 5 cm H_2O (Table 1).

On March 24th, 2017, despite 18 hours of active therapy with high-dose steroids (anti-inflammation, spasmolysis, and antiasthma) and mechanical ventilation, the patient's condition had not appreciably improved. Thus, a BT treatment program incorporating both

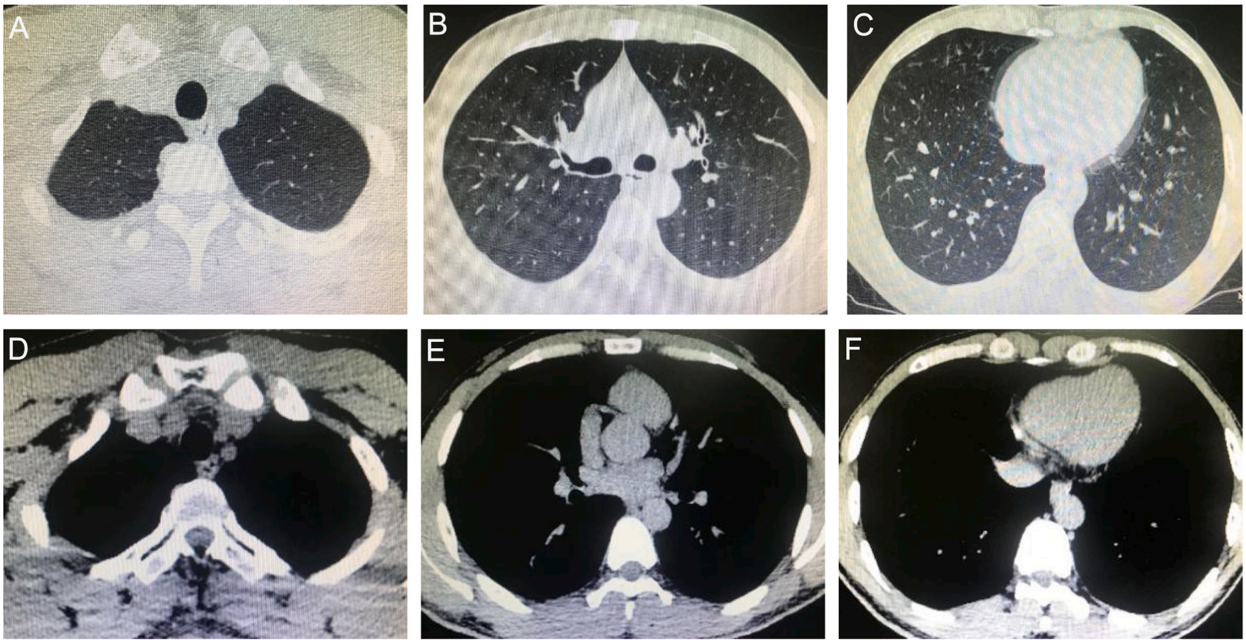

Fig. 1. The lungs and the heart appear normal on the chest CT. 1A, 1B, 1C: CT examination finding of the lung; 1D, 1E, 1F: CT examination finding of the heart.

Table 1
Mechanical ventilation parameters.

Ventilator parameters	2h after admission	4h after admission	1h after BT	17h after BT
Ventilation mode	V-A/C	V-A/C	V-A/C	V-SIMV-PS
Ventilation frequency (times/min)	24	24	16	12
VC (ml)	500	500	450	400
FiO_2 (%)	60	60	40	35
Ps (cmH_2O)	0	0	0	10
PEEP (cmH_2O)	0	5	0	0
Peak pressure (cmH_2O)	38	36	32	28
Plateau pressure (cmH_2O)	33	32	29	25
Mean pressure (cmH_2O)	13.2	12.8	9.2	7.3
PEF (peak expiratory flow)	35	37	45	51
Cdyn (dynamic lung compliance, mL/cmH_2O)	34	34	39	42
Work of Breathing (J/min)	1.02	0.99	0.78	0.63

approaches was considered. After obtaining the family's signed consent, intraoperative intravenous anesthetic (intravenous propofol [400 mg; 100 mg/h] to maintain sedation) was delivered and BT therapy was administered for 1 hour (Fig. 2A and B).

SpO2 was stable at 98% 1 hour after the BT therapy, and blood gas analysis results showed pH of 7.380, PCO_2 of 42.6 mmHg, PO_2 of 71.0 mmHg, SO2 of 95.0%, FiO_2 of 40.0%, and oxygenation index of 177.5 mmHg. The patient's SO2 remained steady between 95% and 98.0%, as evidenced by the ECG, which also showed a decrease in heart rate to 116 beats/min, a resolution of the three-concave sign, and a lessening of the wheezing rales in both lungs. In light of this, the following adjustments were made to the ventilator settings (1 h after BT): V-A/C; F, 16 times/min; VC, 450 mL; FiO2, 40% (Table 1).

After 17 hours, the patient's vital signs were stable, he had clear breathing sounds in both lungs, and there were just a few scattered wheezing rales, all of which indicated a marked improvement in his health following the combination BT therapy. The mechanical ventilation was then set to the V-synchronized intermittent mandatory ventilation (SIMV)-pressure support (PS) mode, with settings of 14 breaths/min F, 400 mL VC, PS at 10 cm H_2O, and 35% FiO_2 (17 h after the surgery) (Table 1). Additionally, methylprednisolone dose and administration schedule were modified to 40 mg and once every 12 hours, respectively. The pH of the blood was determined to be 7.358, the PCO2 to be 43.3 mmHg, the PO2 to be 95.0 mmHg, the SO2 to be 98.0%, the FiO2 to be 35.0%, and the oxygenation index to be 271 mmHg after 4 hours of adjusting the ventilator settings. The patient was conscious, his oxygen saturation had improved, he was no longer having substantial wheezing rales in either lung, and his status was stable, therefore he was weaned off the ventilator. His blood oxygen saturation (SpO2) stayed constant at 98% after 2 hours of receiving continuous low-flow oxygen (oxygen concentration of 33%). Once the tracheal cannula was no longer needed, oxygen was given through the low-flow nasal cannula (oxygen concentration of 29%). After the patient's condition improved, he was released from the hospital.

After 3 weeks of follow-up, the patient was prescribed budesonide and formoterol fumarate powder (160/4.5 g per inhalation, twice a day) and experienced no BT complications or further acute asthma attacks. On April 21, 2017, the patient underwent a bronchoscopy for a follow-up examination. Pulmonary function tests showed moderate to severe obstructive ventilation dysfunction (FEV1: 2.2L, FVC: 3.77L, FEV1%pred: 56.9%, FEV1/FVC%: 69.8%, PEF:5.88L/s), ACT 23 points, ACQ 0 points. The patient underwent BT therapy a second time of the left lower lobe in the order—anterior inner basal segment, outer basal segment, posterior basal segment, and dorsal segment (Fig. 2C). For personal reasons, the patient decided not to undergo BT for a third time. After a year of follow-up, he no longer experienced acute asthma attacks and continued to take the same dose of medicine (Table 1).

The patient in this study have consented to the publication of all images and clinical data in the manuscript.

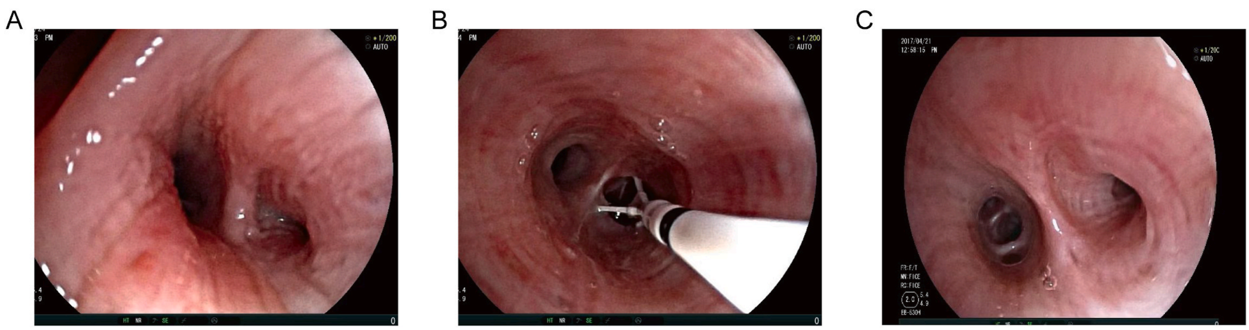

Fig. 2. Conclusions drawn from the endoscopic examination. A: The bronchial mucosa at the aperture of the right lung's inferior lobe is enlarged and congested before the first BT, and the lumen is narrow and there are copious secretions. B: Endoscopic findings after the first BT are as follows: Radiofrequency ablation was performed on the bronchi of the inferior lobe of right lung (ablation order: inner basal segment, anterior basal segment, outer basal segment, posterior basal segment, and dorsal segment). C: Endoscopic examination 28 days after the initial BT revealed normal bronchial mucosa, free of hyperemia and edema, with an unobstructed lumen and no secretion or sputum embolism in the right inferior lobe of the lung.

2. Discussion

Near-fatal asthma is a serious respiratory condition that, if not treated effectively, can put patients' lives in danger. In this instance, the patient was provided invasive mechanical breathing as soon as his health deteriorated and was actively treated with asthma control medication. However, despite improvements in clinical symptoms and oxygenation, the patient remained in status asthmaticus. In an emergency situation, BT therapy was administered, and it quickly and favorably affected the therapeutic outcome.

Before undergoing BT, this patient spent tens of hours receiving a variety of anti-inflammatory, antispasmodic, and antiasthmatic treatments at our facility and another facility, including the administration of high dosages of steroids and bronchodilators. Despite this, the patient continued to deteriorate and eventually required mechanical ventilation due to his persistent wheezing, dyspnea, and lack of improvement in wheezing rales in the lungs.

As a second measure, the steroid dose was gradually increased while bronchodilators were utilized continually while the patient was being mechanically ventilated. After 18 hours of treatment, the patient's condition did not improve. The blood gas analysis also revealed a worsening of the patient's health over time, with increasing levels of hypoxia, CO_2 retention, and loss of consciousness. There is reason to believe that the patient acquired status asthmaticus and that anti-inflammatory steroids, bronchodilators, and other drugs did little to help stabilize the patient's condition. Medication and mechanical ventilation barely kept the patient's oxygen levels stable. These two observations imply that the patient's health improved beyond what can be explained by the anti-inflammatory and bronchodilatory medication that was previously administered.

In contrast, after only 1 hour of BT treatment, the patient's wheezing and rales were significantly decreased, and blood gas analysis results had improved. If BT had exacerbated the mucosal edema and airway obstruction, the patient would have had much more severe symptoms and worse blood gas analysis results (including hypoxia and CO2 retention). Instead, none of the above conditions occurred in this case, and the symptoms, indications, and blood gas analysis results of the patient improved swiftly following the BT treatment. The patient was therefore rapidly weaned off the ventilator.

Multiple mechanisms, including ablation of airway smooth muscles, contribute to BT's effectiveness, although their precise nature has not yet been determined [7]. BT's therapeutic effects may arise from its differential effects on the airway's many cell types and structures, including inflammatory cells, epithelial cells, and the complex airway wall. Originally developed in 2015, endoscopic targeted lung denervation (TLD) is a promising new technology for the treatment of chronic obstructive pulmonary disease (COPD) that allows for the safe, long-term, targeted manipulation of vagal and sympathetic nerves in the lung via a minimally invasive technique. One possible reason for BT's effect on patients with asthma is that it reduces the nerves in narrow airways, which has a denervation effect on the lungs [8]. After receiving BT treatment, the patient's vital signs, consciousness, and oxygenation steadily improved, and the patient was quickly weaned of mechanical ventilation within a short amount of time (1 day postoperatively), all while oxygen saturation was maintained at stable levels throughout. This case demonstrates how rapid symptom relief and long-term asthma management can be achieved using a combination of BT therapy for patients with near-fatal asthma. The therapeutic effect is due to a combination of BT's ablation of smooth muscle, its influence on the airway epithelium in reducing the release of inflammatory mediators, and its denervation effect on the lung. These last two considerations may be the therapeutic mechanisms at work here, allowing for the rapid efficacy of BT.

The following is a synopsis of our medical treatment: (1) When the results of standard pharmacological therapy and mechanical ventilation are poor in individuals with severe asthma, the addition of BT may immediately alleviate wheezing if lung function is not a restriction. (2) The following scenarios call for coordinated efforts between the Anesthesia and Respiratory Critical Care units: (a) To keep the patient from coughing or moving around unnecessarily during the procedure, sedation or general anesthesia may be employed. The evidence suggests that the success of the BT technique is influenced in certain ways by the anesthetic and sedation used [5–7]. (b) Before beginning BT treatment, an artificial airway should be established for mechanical ventilation to provide adequate alveolar ventilation. (c) Constant monitoring of vitals after surgery and a methodical approach to care are both essential. (3) To ensure efficient ablation and reduce the length of time needed for the procedure as a whole, surgeons and assistants performing the BT should have solid surgical skills and a steady and gentle hand. There was some concern raised about the effectiveness of BT treatment in a previous study due to a high ablation failure rate [8]. (4) It is important to quickly eliminate secretions from the respiratory tract during and after surgery to minimize airway mucus obstruction and to maintain an open airway. (5) BT therapy is also safe and effective for acute asthma attacks when combined with mechanical ventilation.

The present case represents a novel effort to investigate the therapeutic application of BT due to the patient's effective treatment. The therapeutic effectiveness of BT in this instance occurred unexpectedly quickly and precisely. Nonetheless, several concerns remain: Is BT effective for severe asthma in certain patients? In what ways can we improve the efficiency and precision of our patient eligibility screenings? To gather more useful information for clinical usage, how can we ensure the safety of BT's use in times of emergency? Is the ablation of airway smooth muscle the only component of the BT mechanism? Additional investigations are needed to validate the rapid effectiveness seen in this case, which implies other possible mechanisms.

Author contribution statement

All authors listed have significantly contributed to the investigation, development and writing of this article.

Data availability statement

Data will be made available on request.

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Declaration of interest's statement

The authors declare no conflict of interest.

References

[1] Y. Nong, N. Su, J. Lin, et al., Clinical efficacy and safety of bronchial thermoplasty for severe bronchial asthma [J], Chin. J. Tuberc. Respir. Dis. 39 (3) (2016) 177–182.
[2] S. Li, Clinical significance of bronchial thermoplasty [J], Chin. J. Tuberc. Respir. Dis. 39 (3) (2016) 166–168.
[3] Ajay Sheshadri, Mario Castro, Alexander Chen, Bronchial thermoplasty: a novel therapy for severe asthma[J], Clin. Chest Med. 34 (3) (2013) 437–444.
[4] Peter I. Bonta, Chanez Pascal, Jouke T. Annema, et al., Bronchial thermoplasty in severe asthma: best practice recommendations from an, Expert Panel[J]. Respiration. 95 (5) (2018) 289–300.
[5] Hanne Madsen, Daniel Pilsgaard Henriksen, Vibeke Backer, et al., Efficacy of bronchial thermoplasty in patients with severe asthma[J], J. Asthma (2019) 1–7.
[6] Fayez Kheir, Adnan Majid, Bronchial thermoplasty: a nonpharmacologic therapy for severe asthma, Clin. Chest Med. 39 (1) (2018) 261–269.
[7] N. Sui, Discussion on the selection of the sign of bronchial heat plasty for severe asthma [J], Chinese J. Appl. Internal Med. (8) (2016) 632–634.
[8] G. Cox, N.C. Thomson, A.S. Rubin, et al., Asthma control during the year after bronchial thermoplasty [J], N. Engl. J. Med. 356 (13) (2007) 1327–1337.