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# Application Effect of External Diaphragm Pacemaker Combined with Active Respiratory Circulation Technology in Pulmonary Rehabilitation of Perioperative Lung Cancer Patients

**Linjuan Zeng**[*]**, Gaoyang Duan, Dandan Liu, Heping Wu**[#]

Cancer Prevention and Treatment Center, Department of Thoracic Surgery, Sun Yat-sen University, Guangzhou, China
Email: #641922356@qq.com

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## Abstract

Aim: To explore the application effect of external diaphragm pacemaker combined with active respiratory circulation technology in pulmonary rehabilitation of perioperative lung cancer patients. Methods: A total of 98 lung cancer patients admitted to our hospital from April 2020 to November 2021 were selected as the observation objects, and then divided into a control group and an observation group using the random number table method, with 49 cases in each group. The control group received routine admission guidance and active respiratory circulation training, while the observation group was supplemented with external diaphragm pacemaker on the basis of the control group. The intervention effect was evaluated by blood gas indicators, pulmonary function indicators, diaphragm function indicators, sputum comfort degree, and activity tolerance indicators before and after intervention. Results: Before intervention, there were no significant differences in blood gas analysis indicators, pulmonary function indicators, diaphragm function indicators, sputum comfort degree, and activity tolerance indicators between the two groups ($P > 0.05$). After intervention, the improvement degree of the above indicators in the observation group was higher than that in the control group ($P < 0.05$). Conclusions: The application of external diaphragm pacemaker combined with active respiratory circulation technology in pulmonary rehabilitation of perioperative lung cancer patients is significant, which can effectively improve the pulmonary function, blood gas function, and diaphragm function of lung cancer patients after surgery, and improve the activities of daily living and quality of life of patients.

*First author.
#Corresponding author.

**Keywords**

The Extracorporeal Diaphragm Pacemaker, Active Breathing and Circulation Training, Lung Cancer, Diaphragmatic Mobility, Pulmonary Function

## 1. Introduction

Lung cancer refers to the tumor that occurs in the bronchial mucosal epithelium, also known as bronchial lung cancer [1], and its incidence and mortality rate rank first in the world [2]. According to the data from the National Cancer Center in 2019, lung cancer ranks first in the incidence of malignant tumors and is also the main cause of malignant tumor death among residents, which has become a major public health problem [3]. The main treatment methods of lung cancer include surgery, radiotherapy, chemotherapy and immunotherapy, and surgical resection is the most preferred treatment [4]. However, thoracotomy has destroyed the integrity of the patient's thorax, severely affected the respiratory function, and reduced the oxygen exchange efficiency. In addition, postoperative patients often suffer from pain and scar tissue formation, resulting in decreased diaphragmatic activity and lung compliance. A large number of respiratory secretions block the airway, and the incidence of pulmonary complications such as pneumonia and atelectasis has increased significantly [5], thereby increasing the operative mortality, prolonging the length of hospital stay, and increasing hospital costs [6]. Conventional pulmonary function rehabilitation generally adopts respiratory muscle controlled deep and slow breathing exercise, so that the patient's breathing form changes from shallow to deep and slow. However, due to the slow onset of respiratory muscle training and cumbersome actions, most patients have low compliance with exercise, resulting in patients missing the best opportunity for pulmonary function rehabilitation [7]. External diaphragm pacing (EDP) stimulates the phrenic nerve of patients through the body surface electrode of the external diaphragm pacemaker, improves the excitability of the phrenic nerve, improves the contractility and mobility of the diaphragm, increases the chest volume, increases the blood flow and lung ventilation of the diaphragm, and improves the lung ventilation function [8]. It is simple to operate, convenient for patients to use at home, and can improve the compliance of patients with long-term lung rehabilitation treatment. EDP has achieved good results in the clinical application of patients with mechanical ventilation [9], but there are few reports on the application of EDP in patients with lung cancer surgery at home and abroad. In this paper, EDP was applied in the adjuvant treatment of perioperative lung cancer patients, objective to explore the application effect of EDP combined with active respiratory and circulatory technology in the lung rehabilitation of perioperative lung cancer patients.

## 2. General Information and Methods

### 2.1. General Information

Patients with lung cancer admitted to the Department of thoracic surgery in our hospital from April 2020 to November 2021 were randomly divided into control group and observation group, with 49 cases in each group. The control group consisted of 20 males and 29 females, aged 36 - 69 years, with an average of (52.76 ± 4.67) years. Observation group: 18 males and 31 females, aged 33 - 75 years, with an average of (54.83 ± 4.65) years. There was no statistical difference in the general data between the two groups ($P > 0.05$), which was comparable. Inclusion criteria: (1) patients with confirmed non-small cell lung cancer by pathological cytology under the guidance of fiberoptic bronchoscope and CT, and who planned to undergo lobectomy or segmentectomy under general anesthesia with endotracheal intubation; (2) The age ranged from 18 to 80 years; (3) The vital signs are stable and can participate in this study; (4) Pulmonary function test $FEV1 > 0.8$; (5) Voluntarily participated in this study and signed the informed consent.

Exclusion criteria: (1) patients with pneumonectomy; (2) Distant metastasis of cancer; (3) Patients with other malignant tumors; (4) Those who have serious complications during or after the operation and cannot carry out respiratory function training and pre- and post-test evaluation; (5) Those who are complicated with serious physical or mental diseases and cannot cooperate with the test; (6) Patients wearing cardiac pacemakers, active tuberculosis, pneumothorax, etc.

### 2.2. Method

#### 2.2.1. The Control Group Was Treated with Active Breathing and Circulation Training and Cough Practice

A complete ACBT consists of 4 - 6 respiratory controls, 3 - 5 chest enlargement and deep breathing, 4 - 6 respiratory controls, 2 - 3 forced breathing and effective cough. Before training, instruct the patient to take the end sitting position or semi sitting position, and relax his shoulders. 1) The method of breath control is to breathe deeply and slowly for three times, hold for 3S after the last inhalation, and then perform moderate to low degree of lip retraction exhalation, so as to inhale 1) abdominal lip retraction breath, put one hand on the navel to feel the fluctuation of the abdomen, inhale deeply with the nose, bulge the stomach, hold for 3 seconds, exhale slowly with the mouth whistle, and sit for 4 - 6 times. 2) Expand the chest and breathe deeply. After active deep inspiration, lift the thorax up and expand outward, then slowly exhale the gas, and do 3 - 5 chest expansion and deep breathing in succession to vibrate the secretion. 3) The abdomen coughs gently. After deep inspiration, the abdomen bulges. Use the abdominal force to do 10 - 20 light coughs continuously to loosen the sputum. 4) Breathe hard. After deep inspiration, open your mouth and breathe quickly, just like breathing on a mirror. Try to spit the sputum out to the mouth. 5) Expectoration vigorously in the abdomen: relax the shoulders, lean forward, press the wound with your hands, and after deep inhalation, the stomach will swell up, hold it for a few seconds, and then cough vigorously with the strength of the abdomen for five consecutive times. Patients were continuously guided to perform acbt training and cough practice 5 days before operation and one month after operation, three times a day, each time for about 10 - 15 minutes.

#### 2.2.2. The Observation Group was Treated with EDP on the Basis of the Control Group

The operation methods are as follows: ① firstly, introduce the use purpose, advantages and precautions of EDP-II extracorporeal diaphragm pacemaker (model hlo-gji3 a manufactured by Guangzhou Sherion Biotechnology Co., Ltd.) to the patient, obtain the cooperation of the patient, and improve the treatment compliance of the patient. Use 75% alcohol cotton tablets to clean the local skin, and wait for 1 - 2 min for the alcohol to volatilize. Those with alcohol allergy can use normal saline instead. ② Assist the patient in positioning. You can take a semi recumbent position or a sitting position, so that the patient can relax all over the body, and the head is slightly tilted back. Two small electrodes are pasted on the outer edge of the left and right sternocleidomastoid muscles and the junction of the middle and lower 1/3 of the patient respectively. Pay attention to avoiding the carotid sinus and scar, and fix them properly with adhesive tape. Two large electrode patches are pasted on Feishu acupoints: under the spinous process of the third thoracic vertebra, and 1.5 inches apart from the posterior midline (the location of electrode patches is guided by the doctor when the diagnosis is made). ③ Turn on the machine, connect the lead and electrode slice, and select the default value (treatment time: 30 min/time; pacing times: 9 times/min; stimulation frequency: 40 Hz, and the intensity is adjusted according to the patient's tolerance). Patients were continuously guided to carry out extracorporeal diaphragmatic pacing treatment training 5 days before operation and one month after operation, twice a day (the same time as the control group).

### 2.3. Observation Index

(1) Blood gas analysis indexes: the partial pressure of carbon dioxide ($PaCO_2$), partial pressure of oxygen ($PaO_2$), oxygenation index (po2/fio2) before and after operation were compared between the two groups.

(2) Lung function indexes: the vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1 as a percentage of the predicted value (FEV1/FVC), peak expiratory flow (PEF) of the two groups were compared before and after surgery, and the lung function was detected with a lung function tester (cosmod, quark pft4, Italy).

(3) Diaphragmatic function indexes: the diaphragmatic mobility before and after operation was compared between the two groups; Assessment method of diaphragmatic mobility: first, let the patient lie flat, place the ultrasound probe on the right axillary midline and the left axillary posterior line respectively, observe the position and movement of the diaphragms on both sides using

two-dimensional ultrasound, fine tune the probe, select the best diaphragmatic development section, and switch to M-mode after the diaphragmatic movement is stable and the ultrasound development is clear. After the M-line is nearly vertical to the diaphragm, guide the patient to take a deep breath, let the diaphragm move down or up as much as possible, and then measure the data. After taking the data for the first time, make a positioning mark on the skin surface, and take the average value of three determinations.

(4) Expectoration comfort: VAS pain scale was used to evaluate the expectoration pain of the two groups at 24 h, 48 h and 72 h after operation, with a maximum score of 10 and a minimum score of 0. The score was inversely proportional to the patient's pain.

(5) Activity tolerance index. Activity tolerance assessment: a 6-minute walk test (6 MWT). Patients were instructed to walk for 6 minutes on a 30-meter-long flat and straight corridor with their best strength. Orange cone-shaped traffic signs were placed on the turn back point as signs, and the starting line was marked with colorful strips on the ground. The starting line represents the starting point and the end point of a round trip. At the same time, make distance signs (one eye-catching sign every 3 meters). Patients should avoid strenuous exercise within 2 hours before the test and should wear comfortable and suitable sports shoes. Before the test, the patient's pulse, blood pressure, finger pulse oxygen saturation and other vital signs were measured. During the test, the number of turns back of the patient's walking was accurately recorded, and the 6-minute walking distance was calculated. If the test was stopped halfway, the reason for the suspension was recorded. If the test was to be carried out again, it was carried out after 20 minutes. b. Borg index. The degree of dyspnea was assessed with Borg score table, with a score of 0-10. "0" indicates no dyspnea or fatigue at all; "0.5" indicates very, very mild dyspnea or fatigue; A score of "1" indicates very mild dyspnea or fatigue; "2" indicates mild dyspnea or fatigue; A score of "3" indicates moderate dyspnea or fatigue; A score of "6 - 8" indicates very serious dyspnea or fatigue; A score of "9" indicates very, very severe dyspnea or fatigue; A score of "10" indicates extremely severe respiratory distress or fatigue, reaching the limit. The higher the score, the more severe the degree of dyspnea.

### 2.4. Statistical Analysis

Data were input into SPSS24.0 software for processing and analysis. Quantitative data were expressed as mean standard deviation ($\bar{x} \pm s$), and qualitative data were expressed as case number and percentage (%). Intergroup comparison was performed using t-test. $P < 0.05$ was considered as the difference with statistical significance.

## 3. Outcome

### 3.1. Comparison of Blood Gas Indicators between the Two Groups before and after Intervention

Before intervention, there was no significant difference in blood gas indexes between the two groups (P > 0.05). After intervention, $PaO_2$ and po2/fio2 in patients of the observation group were higher than those of the control group, and $PaCO_2$ was lower than that of the control group, with statistically significant difference (P < 0.05), as shown in Table 1.

### 3.2. Comparison of Lung Function Index Levels between the Two Groups before and after Intervention

Before intervention, there was no significant difference in lung function indexes between the two groups (P > 0.05). After intervention, the FEV1, FVC and FEV1/FVC values of patients in the observation group were higher than those in the control group, and the differences were statistically significant (P < 0.05), as shown in Table 2.

### 3.3. Comparison of Diaphragmatic Mobility before and after Intervention between the Two Groups

Before intervention, there was no significant difference in diaphragmatic mobility between the two groups (P > 0.05). After intervention, the diaphragm mobility of patients in the observation group was significantly higher than that in the control group, and the difference was statistically significant between groups (P < 0.05), as shown in Table 3.

**Table 1.** Comparison of blood gas indicators before and after intervention in patients between the two groups ($\bar{x} \pm s$).

| Group | No. | Time | $PaCO_2$ (mmHg) | $PaO_2$ (mmHg) | po2/fio2 |
|---|---|---|---|---|---|
| Control group | 49 | Pre-intervention | 38.63 ± 3.65 | 89.12 ± 15.61 | 416.43 ± 84.39 |
| | | Post-intervention | 41.86 ± 3.08 | 90.98 ± 7.49 | 434.37 ± 36.43 |
| Observation group | 49 | Pre-intervention | 38.92 ± 3.48 | 89.19 ± 14.32 | 416.24 ± 84.21 |
| | | Post-intervention | 39.47 ± 4.32① | 94.93 ± 9.76① | 449.63 ± 48.14① |

Note: compared with the control group after intervention, ① P < 0.05.

**Table 2.** Comparison of lung function index levels before and after intervention in patients between the two groups ($\bar{x} \pm s$).

| Group | No. | Time | VC (L) | FVC (L) | FEV1 (L) | FEV1/FVC (%) | PEF (L/s) |
|---|---|---|---|---|---|---|---|
| Control group | 49 | Pre-intervention | 2.94 ± 0.82 | 2.92 ± 0.81 | 2.33 ± 0.62 | 77.78 ± 11.84 | 7.49 ± 10.66 |
| | | Post-intervention | 1.96 ± 0.62 | 1.99 ± 0.63 | 1.65 ± 0.51 | 81.21 ± 8.71 | 4.08 ± 1.14 |
| Observation group | 49 | Pre-intervention | 2.90 ± 0.82 | 2.92 ± 0.80 | 2.40 ± 0.64 | 77.73 ± 6.07 | 7.80 ± 13.17 |
| | | Post-intervention | 2.40 ± 0.67① | 2.41 ± 0.68① | 2.03 ± 0.57① | 82.74 ± 7.10① | 5.14 ± 1.60① |

Note: compared with the control group after intervention, ① P < 0.05.

Table 3. Comparison of diaphragmatic mobility ( $\bar{x} \pm s$ , cm).

| Group | No. | Pre-intervention | Post-intervention |
|---|---|---|---|
| Control group | 49 | 1.68 ± 0.41 | 0.75 ± 0.40 |
| Observation group | 49 | 1.72 ± 0.39 | 1.69 ± 0.39① |

Note: compared with the control group after intervention, ① P < 0.05.

Table 4. Comparison of comfort level of expectoration between the two groups (points, $\bar{x} \pm s$ ).

| Group | cases | 24 h after surgery | 48 h after surgery | 72 h after surgery |
|---|---|---|---|---|
| Control group | 49 | 5.81 ± 1.60 | 6.56 ± 6.94 | 4.57 ± 1.49 |
| Observation group | 49 | 5.15 ± 1.50 | 3.93 ± 1.26 | 3.18 ± 1.07 |
| T value | - | 2.086 | 2.611 | 5.282 |
| P value | - | 0.040 | 0.012 | <0.001 |

Table 5. Comparison of activity endurance of patients between the two groups before and after intervention.

| Group | Cases | Time | 6 MWT (m) | Borg index |
|---|---|---|---|---|
| Control group | 49 | Pre-intervention | 522.33 ± 69.87 | 0.57 ± 0.20 |
| | | Post-intervention | 466.92 ± 64.27 | 1.08 ± 0.51 |
| Observation group | 49 | Pre-intervention | 528.41 ± 68.41 | 0.58 ± 0.19 |
| | | Post-intervention | 524.76 ± 62.76① | 0.73 ± 0.32① |

Note: compared with the control group after intervention, ① P < 0.05.

### 3.4. Comparison of Comfort Level of Expectoration between the Two Groups

Compared with the control group, the VAS score of the observation group on the 3rd day after operation was significantly lower. The VAS score ratio of the two groups at 24 h after operation was quite poor (P = 0.040). The VAS score ratio of the two groups at 48 h after operation was quite poor (P = 0.012). The VAS score ratio of the two groups at 72 h after operation was statistically significant (P < 0.05), as shown in Table 4.

### 3.5. Comparison of Activity Endurance of Patients between the Two Groups before and after Intervention

Compared with the control group, the 6 MWT of patients in the observation group was much larger than that in the control group, and the Borg index scores were all lower than those in the control group. The differences were statistically significant between the groups (P < 0.05), as shown in Table 5.

## 4. Discussion

Lung cancer is one of the cancers with high incidence and mortality in China and the world. Surgical treatment is the main treatment, and the incidence of postoperative pulmonary complications is as high as 40%, which has seriously affected the lung rehabilitation and prognosis of patients. In lung rehabilitation nursing of lung cancer patients during perioperative period, active respiratory cycle technique (ACBT) can improve lung function, reduce the incidence of postoperative lung complications, help patients to recover quickly, shorten hospital stay, reduce hospital costs, and save medical resources, and it plays an important role in lung rehabilitation. However, this training requires patients to have high compliance and be able to exercise persistently, which is difficult to implement. The motive force of respiration comes from the action of respiratory muscles, the most important of which is the diaphragm [10]. EDP stimulates the phrenic nerve with low-frequency pulses through the body surface electrode pads, which makes the diaphragm regularly contract and relax, and increases the diaphragm mobility, thereby increasing the ventilation volume and gradually recovering the diaphragm function of the patient. It has the advantages of non-invasiveness, simple operation, low cost, and good patient compliance [11]. Roger Ying, *et al*. [12] scholars in the study said that the use of EDP can stimulate the patient's diaphragmatic nerve, improve the patient's diaphragmatic function. At present, it is mostly applied to patients with stroke, spinal cord injury, chronic obstructive pulmonary disease and chronic heart failure in China and abroad, with good results.

Research shows that in patients with cervical spinal cord injury, the application of respiratory training combined with external diaphragmatic pacemaker can increase the diaphragm mobility of patients, to maximize the retention and play of the residual function of the diaphragm to compensate, thus improving the lung ventilatory function of patients and reducing the lung infection rate [13]. Application of external diaphragmatic pacemaker in patients with chronic obstructive pulmonary disease can improve dyspnea and reduce hospitalization days in a short time [14]. Studies have shown that the survival rate of patients increases without any complications in more than 2200 patients who receive diaphragmatic pacing in the Netherlands, which is an effective rehabilitation adjuvant therapy technology [15], but has not been systematically used in lung cancer patients in our country.

The results of this study showed that after intervention, $PaO_2$ and po2/fio2 in patients of the observation group were higher than those of the control group, and $PaCO_2$ was lower than that of the control group ($P < 0.005$) [16]. After 28 days of EDP rehabilitation in 50 patients with tracheotomy after cervical spinal cord injury, their respiratory function and expectoration capacity were significantly improved. The results of the above studies were similar to those of this study, further suggesting that EDP could enhance the diaphragmatic function of patients with lung cancer during perioperative lung rehabilitation, improve their respiratory function, increase their oxygen intake and $CO_2$ output, fully restore the oxygen concentration of the patient's body, and promote the improvement of various blood gas indicators of patients. The expectoration pain level of patients in the observation group three days after surgery was lower than that in the control group, which indicated that the cough comfort level of patients in the observation group was higher than that in the control group, and indicated that the addition of external diaphragmatic pacemaker was conducive to the improvement of symptoms. After intervention, the FEV1, FVC and FEV1/FVC values of patients in the observation group were higher than those of the control group [17]. It has been reported that the pulmonary function of patients with acute COPD was significantly improved after 20-day EDP rehabilitation, suggesting that external diaphragmatic pacemaker could improve the pulmonary function of patients. It is possible that electrical stimulation excited the diaphragmatic nerves, enhanced the activity of the diaphragm, promoted the expansion of the thoracic cavity, and increased the effective alveolar ventilation, thereby improving the lung function of the patient [18]. The human study also showed that the patient's lung function was significantly improved after the in vitro diaphragmatic pacemaker combined with respiratory training, which was also basically consistent with the results of this study. After intervention, the difference in diaphragmatic mobility of patients in the observation group was higher than that in the control group, indicating that the addition of external diaphragmatic pacemaker was conducive to the improvement of diaphragmatic function, which might be related to the use of external diaphragmatic pacemaker to increase the diaphragmatic mobility and enhance the diaphragmatic contractility of patients [19]. It has been shown in the present study that stimulation of the phrenic nerve by electric pulses resulted in an increase in the range of motion of the diaphragm, which is similar to the conclusion of the present study [20]. It has been discovered in the study that EDP treatment and lung function training can increase the diaphragm thickness and range of motion of stroke patients, which is similar to the results of the present study. After the intervention, the observation group's indexes such as 6 MWT and Borg score were significantly superior to those of the control group, suggesting that the use of external diaphragmatic pacemaker could better improve the exercise tolerance of lung cancer patients during the perioperative period. Luo Jianling, *et al.* [21] studies have shown that external diaphragmatic pacing therapy is an electrical stimulation of the phrenic nerve by pulsed current, which increases the intensity and tolerance of diaphragmatic contraction of patients, increases the diaphragmatic blood supply, alleviates the ventilator fatigue of patients, improves the quality of life and motor function of patients, and improves the cardiac function of patients. Similar to the results of the present study, external diaphragmatic pacing therapy has been successfully applied to patients with diaphragmatic contraction.

## 5. Conclusion

In summary, extracorporeal diaphragmatic pacemaker combined with active respiratory cycle training can improve lung function and blood gas function and diaphragmatic function of patients with lung cancer during perioperative period. It is simple and convenient to use, with low cost and fewer complications. It is safe for patients and worthy of further clinical promotion. Our results provide a basis for the lung rehabilitation of lung cancer patients in the perioperative period by using extracorporeal diaphragm pacemaker combined with active respiratory cycle technology, but there are still many areas for improvement in our study. (1) The small sample size may result in our insufficient statistical ability. In future studies, the sample size should be expanded to make the data more convincing. (2) Our research lasted for one month, and no follow-up visit was conducted for the patients. As a result, we were unable to understand the lung rehabilitation recovery after the patient's treatment. In future research, we may consider adding the application of digital lung rehabilitation to improve the patient's stickiness, innovate a new model of serving patients, improve patient management ability, and reduce inefficient labor. (3) Due to insufficient human and material resources, the overall functional status of respiratory muscles and diaphragmatic muscle strength after EDP were not evaluated in time in this study. This aspect can be considered in future studies.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

[1] Li, L. and Lu, Q. (2018) Surgical Nursing. 6th Edition, People's Medical Publishing House, Beijing.

[2] Bray, F., Ferlay, J., Soerjomataram, I., *et al.* (2018) Global Cancer Statistics 2018: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. *CA*: *A Cancer Journal for Clinicians*, **68**, 394-424. https://doi.org/10.3322/caac.21492

[3] Zheng, R., Sun, K., Zhang, S., *et al.* (2019) Epidemiological Analysis of Malignant Tumor in China in 2015. *Chinese Journal of Oncology*, **41**, 19-28.

[4] Chang, M.Y. and Sugarbaker, D.J. (2003) Surgery for Early Stage Non-Small Cell Lung Cancer. *Seminars in Surgical Oncology*, **21**, 74-84. https://doi.org/10.1002/ssu.10024

[5] Guo, X., Jiao, J., Wei, R. *et al.* (2018) Effect of Rehabilitation Training on Postoperative Pulmonary Function of Patients with Lung Cancer Surgery. *Chinese Journal of Physical Medicine and Rehabilitation*, **40**, 306-308.

[6] Asai, M. and Scott, W.J. (2018) Lung Resection in the Postpneumonectomy Patient. *Thoracic Surgery Clinics*, **28**, 19-25. https://doi.org/10.1016/j.thorsurg.2017.08.004

[7] Xu, L., Li, G., Gan, Y., *et al.* (2021) Effect of Dxternal Diaphragm Dacing Combined with Inspiratory Muscle Training on Chronic Obstructive Pulmonary Disease Influence of Arterial Blood Gas Index, Respiratory Mechanics Parameters and Oxidative Stress Response in Patients with Acute Exacerbation of Disease. *Anhui Medicine*, **25**, 777-781.

[8] Gan, L., Wang, L., Gong, Y., *et al.* (2021) External Diaphragm Pacemaker Therapy Combined with Swallowing Function Training Therapeutic Effect of Swallowing Function in Primary Parkinson's Disease. *Nerve injury and Functional Reconstruction*, **16**, 316-318, 322.

[9] Wu, Y., Liang, H., Xi, F., *et al.* (2022) External Diaphragm Pacing Prevents Diaphragm Function in Patients with Noninvasive Mechanical Ventilation Study on the Effect of Obstacles. *Chinese Journal of Nursing*, **57**, 1029-1034.

[10] Fu, Q. (2022) Diaphragm-the Most Important Respiratory Muscle in Human Body. *Everyone's Health*, 30.

[11] Zeng, L. and Hu, R. (2017) Clinical Application and Research Progress of External Diaphragm Pacing. *Journal of Clinical and Pathology*, **37**, 1978-1984.

[12] Luo, J., Han, X., Mao, S., *et al*. (2022) Effect of Early External Diaphragm Pacing on Patients with Mechanical Ventilation. *Chinese Journal of Emergency Medicine*, **31**, 798-803.

[13] Yan, Y., Xiu, Q., Feng, Z., *et al*. (2018) Effect of External Diaphragm Pacemaker Combined with Respiratory Training on Lung Function of Patients with Cervical Spinal Cord Injury. *China Journal of Rehabilitation Medicine*, **33**, 1094-1096.

[14] Fan, Z. and Zhou, C. (2018) Application of External Diaphragm Pacemaker in Lung Rehabilitation of Patients with Severe and Extremely Severe Chronic Obstructive Pulmonary Disease. *Journal of Nursing of PLA*, **35**, 41-44.

[15] Hazenberg, A., Hofker, S.S., van der Aa, J.G., *et al*. (2013) Diaphragm Pacemaker: Alternative for Chronic Ventilatory Support. *Nederlands Tijdschrift voor Geneeskunde*, **157**, A5572.

[16] Fu, J., Zhang, W., Li, X., *et al*. (2014) Application of Postural Drainage under Diaphragm Pacing in Patients with Cervical Spinal Cord Injury Undergoing Tracheotomy. *Chinese Journal of Modern Nursing*, **49**, 655-658.

[17] Ma, J., Tang, H., Xu, Z., *et al*. (2020) Application of External Diaphragm Pacing in Rehabilitation Nursing of Patients with Chronic Obstructive Pulmonary Disease. *Journal of Nursing Science*, **35**, 12-14.

[18] Zhu, Y., Zhu, X., Wang, Y., *et al*. (2020) Effect of External Diaphragmatic Pacemaker Combined with Respiratory Training on Pulmonary Function of Stroke Patients Complicated with Chronic Obstructive Pulmonary Disease. *China Journal of Rehabilitation Medicine*, **35**, 1346-1350.

[19] Glenn, W.W., Holcomb, W.G., Hogan, J., *et al*. (1973) Diaphragm Pacing by Radiofrequency Transmission in the Treatment of Chronic Ventilatory Insufficiency. Present Status. *The Journal of Thoracic and Cardiovascular Surgery*, **66**, 505-520. https://doi.org/10.1016/S0022-5223(19)40583-7

[20] Liu, C., Wan, M., Duan, L., *et al*. (2019) Effect of Respiratory Neurophysiological Promotion Therapy Combined with Functional Electrical Stimulation on Respiratory Function after Stroke. *Chinese Journal of Physical Medicine and Rehabilitation*, **41**, 321-324.

[21] Luo, J., Chu, C., Liu, H., Lin, X., Liu, X., Mao, J. and Bao, X. (2021) Study on Pulmonary Function and Quality of Life of Patients with Chronic Obstructive Emphysema by External Diaphragm Pacemaker Combined with Pulmonary Rehabilitation Therapy. *Massage and Rehabilitation Medicine*, **12**, 31-34.