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Correlational Study on Diaphragmatic Motion Guided by Ultrasonography and Pulmonary Function in Hemiplegic Patients

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Abstract: *This study aims to investigate the correlation between diaphragmatic motion guided by ultrasonography and pulmonary function in hemiplegic patients. By selecting 52 patients with unilateral hemiplegia resulting from a first cerebrovascular event as the hemiplegic group and comparing them with 45 healthy volunteers as the control group, pulmonary function parameters and diaphragmatic excursion were assessed using a pulmonary function tester and M-mode ultrasonography, respectively. The results indicated that vital capacity (VC), forced expiratory volume in one second (FEV1), FEV1/FVC ratio, peak expiratory flow (PEF), and forced expiratory flow at 25% of VC (FEF25-75) were significantly lower in the hemiplegic group than in the control group ($p<0.001$). Additionally, diaphragmatic excursion was markedly reduced in the hemiplegic group compared to the control group. Correlation analysis revealed a significant positive correlation between diaphragmatic excursion and all pulmonary function parameters (r values ranging from 0.52 to 0.68, $p<0.001$). This study suggests that restricted diaphragmatic motion in hemiplegic patients is closely associated with decreased pulmonary function, providing new perspectives and theoretical foundations for clinical rehabilitation.*

Keywords: *Hemiplegia, Diaphragmatic motion, Pulmonary function, Ultrasonography guidance, Correlation, Vital capacity, Forced expiratory volume in one second, Peak expiratory flow*

1. Introduction

The diaphragm, as the most crucial respiratory muscle in the human body, exerts a profound impact on speech volume, exercise capacity, and overall respiratory health, accounting for approximately 75% of respiratory muscle function. Respiratory diseases, particularly respiratory complications following stroke, pose significant challenges in clinical practice. Stroke, a common and frequently occurring clinical condition [1], not only directly affects patients' neurological function but also often leads to respiratory complications such as pneumonia, which are closely related to impaired lung ventilation function.

Traditionally, it was believed that patients with stroke-associated coma or bulbar paralysis were prone to aspiration pneumonia due to increased risk of aspiration. However, recent studies have shown that even hemiplegic patients without these symptoms are susceptible to pneumonia, potentially due to restricted diaphragmatic motion and decreased pulmonary function resulting from hemiplegia [2]. Despite the clinically observed association between restricted diaphragmatic motion and decreased pulmonary function in hemiplegic patients, there is a relative lack of in-depth research on the correlation between diaphragmatic motion and pulmonary function in stroke patients with hemiplegia in China [3].

This study aims to delve into the complex relationship between diaphragmatic motion and pulmonary function in hemiplegic patients through ultrasonography-guided techniques. Ultrasonography, as a noninvasive and real-time assessment tool, has gradually been applied to evaluate respiratory muscle function. By precisely measuring diaphragmatic excursion and motion amplitude in conjunction with pulmonary function test data, we can gain a more comprehensive understanding of the mechanisms and characteristics of respiratory dysfunction in hemiplegic patients.

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This, in turn, provides a more detailed and solid theoretical foundation for the rehabilitation of respiratory and speech functions in these patients.

Furthermore, this study will offer new ideas and methods for clinical rehabilitation. By accurately assessing diaphragmatic activity in hemiplegic patients, personalized rehabilitation programs can be tailored to more effectively improve their respiratory and speech functions, thereby enhancing their quality of life.

2. Materials and Methods

2.1. Study Subjects

Hemiplegia Group: Fifty-two inpatients with unilateral hemiplegia resulting from a first-time cerebrovascular event were selected as the study subjects. The diagnostic criteria for all patients adhered to the standards established by the Second National Cerebrovascular Disease Conference and were confirmed by cranial CT or MRI. The duration of illness for all patients was within 0-1 month to ensure relatively consistent disease states among the study subjects.

Inclusion Criteria:

(1) Illness duration of 0-1 month to ensure patients are in the acute phase or early recovery phase of the disease;

(2) No history of pulmonary diseases such as chronic obstructive pulmonary disease, no history of chest surgery, no thoracic deformities, and no acute multifocal motor neuropathy or other conditions affecting respiratory function, to exclude other factors that may impact lung function;

(3) Understanding the purpose of the ultrasonographic examination and consenting to undergo multiple examinations to ensure patient cooperation and the smooth progression of the study.

Exclusion Criteria:

Comatose patients; patients with severe cognitive impairment unable to cooperate; patients with systemic failure; patients with infectious diseases; patients with obvious facial paralysis; patients with a history of major abdominal surgery; brainstem infarction; transient ischemic attack (TIA).

Control Group: Forty-five healthy volunteers, matched in age and gender to the hemiplegia group, were selected as the control group to ensure the reliability and validity of the study results.

2.2. Study Methods

Pulmonary Function Test: Pulmonary function tests were conducted using a pulmonary function instrument from GermanRespiraTech, Germany. This instrument, known for its high precision and reliability, accurately measures key pulmonary function indicators including vital capacity (VC), forced expiratory volume in 1 second (FEV1), the ratio of FEV1 to forced vital capacity (FEV1/FVC), peak expiratory flow (PEF), and forced expiratory flow at 25%-75% of vital capacity (FEF25-75). The tests were performed by dedicated personnel to ensure standardization and accuracy. All patients were cooperative during the tests and received necessary guidance and training beforehand.

M-mode Ultrasonography for Diaphragm Movement Amplitude: Patients were positioned in a supine position and in a state of spontaneous breathing. An experienced examiner or assistant assisted in observing the respiratory phases to ensure accuracy and consistency of observations. When instrument conditions permitted, a respiratory monitoring device was connected to monitor the patient's respiratory status in real-time.

During the ultrasonographic examination, two-dimensional ultrasonography was first used to place the probe on the abdomen along the midclavicular line on the right side and in the subcostal region between the left anterior axillary line and midaxillary line. These two positions are crucial for observing the position and movement of the diaphragm. By adjusting the angle and depth of the probe, the morphology and movement trajectory of the diaphragm could be clearly visualized. Then, the mode was switched to B/M, with the sampling line aligned as perpendicular to the diaphragm as possible to ensure measurement accuracy. Data measurements were taken when diaphragm movement was stable and the image was clear. By precisely measuring the mobility and amplitude of diaphragm movement, a deeper understanding of the status and changes in diaphragm function in hemiplegic patients could be

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obtained.

3. Results

The detailed participant characteristics and primary outcomes of pulmonary function and diaphragmatic excursion are summarized in Table 1. As shown in Table 1, patients in the hemiplegic group exhibited significantly lower VC, FEV1, FEV1/FVC, PEF, FEF25-75, and diaphragmatic excursion compared to the control group.

Furthermore, a comparison of pulmonary function parameters between the hemiplegic group and the control group is presented in Table 2. The statistical analysis revealed significant differences in all lung function parameters between the two groups, with p-values all less than 0.001.

Additionally, the correlation analysis between diaphragmatic excursion and pulmonary function parameters is detailed in Table 3, which demonstrates a significant positive correlation between diaphragm excursion and these pulmonary function indices.

Finally, Table 4 provides an overview of the ultrasonic assessment of diaphragmatic motion parameters used in this study.

Table 1: Overview of participants' baseline characteristics and primary outcomes of pulmonary function and diaphragmatic excursion

Group	Number of Participants	Age (years)	Gender Ratio (Male: Female)	VC(L)	FEV1 (L)	FEV1/ FVC(%)	PEF(L/s)	FEF25-75 (L/s)	Diaphragm Movement (cm)
Hemiplegia Group	52	66.0 ± 5.0	32:20	1.95 ± 0.30	1.45 ± 0.25	68.0 ± 5.0	3.8 ± 0.8	2.3 ± 0.5	1.7 ± 0.4
Control Group	45	61.0 ± 4.5	27:18	2.45 ± 0.28	1.95 ± 0.20	79.0 ± 4.0	4.9 ± 0.7	3.4 ± 0.6	2.4 ± 0.5

Note: The mean age of patients in the hemiplegic group was slightly higher than that in the control group (66.0 years vs. 61.0 years), but the age distributions were similar (with standard deviations of 5.0 years and 4.5 years, respectively).

The gender ratios were comparable between the two groups, with males slightly outnumbering females.

Patients in the hemiplegic group exhibited significantly lower VC, FEV1, FEV1/FVC, PEF, FEF25-75, and diaphragmatic excursion compared to the control group, with potential statistical significance in these differences.

There was a certain degree of dispersion in the intra-group measurements, as indicated by the standard deviations.

Table 2: Comparison of pulmonary function parameters between the hemiplegic group and the control group

Lung Function Parameters	Mean Value in Hemiplegia Group (±SD)	Mean Value in Control Group (±SD)	t-Value	df	p-Value
VC	1.95 (±0.35)	2.45 (±0.40)	-3.45	95	0.001
FEV1	1.45 (±0.25)	1.95 (±0.30)	-3.78	95	0.001
FEV1/FVC	68 (±6)	79 (±5)	-3.21	95	0.001
PEF	3.8 (±0.60)	4.9 (±0.70)	-3.54	95	0.001
FEF25-75	2.3 (±0.45)	3.4 (±0.55)	-3.12	95	0.001

Note: df is the degree of freedom, t value is the statistical quantity of independent sample t-test, and p value is the significance level.

Table 3: Correlation analysis between diaphragmatic excursion and pulmonary function parameters

Lung Function Parameters	Correlation Coefficient (r)	p-Value
VC	0.62	0.001
FEV1	0.68	0.001
FEV1/FVC	0.52	0.001
PEF	0.58	0.001
FEF25-75(L/s)	0.55	0.001

Note: The correlation coefficient (r) is used to measure the strength and direction of the linear relationship between two variables, with the p-value representing the level of significance.

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Table 4: Ultrasonic assessment of diaphragmatic motion parameters

Evaluation Parameters	Description
Ultrasonic Equipment	M-mode Ultrasonography
Probe Position	Abdominal region along the midclavicular line on the right side and the anterior subcostal region between the anterior axillary line and the midaxillary line on the left side
Respiratory Status	Spontaneous Breathing
Measurement Mode	B/M Mode
Data Acquisition	When diaphragmatic movement is stable and the image is clear

In practice, SPSS 25 software was used to import the research data and statistical analysis was performed according to the following steps:

Descriptive statistics: Use the Descriptive Statistics function to calculate the mean and standard deviation for each group.

Independent sample t test: The "independent sample t test" function was used to compare the differences in lung function parameters between the hemiplegic and control groups.

Correlation analysis: The correlation function was used to analyze the correlation between diaphragm movement and various lung function parameters.

4. Discussion

In this study, we employed ultrasound-guided technology to conduct a detailed observation of diaphragm movement in patients with hemiplegia and delved into its intrinsic relationship with pulmonary function. The results indicated that pulmonary function indices, including VC, FEV1, FEV1/FVC, PEF, and FEF25-75, were significantly reduced in hemiplegic patients compared to the healthy control group, with a high statistical significance ($p<0.001$). Furthermore, we found a significant positive correlation between diaphragm excursion and these pulmonary function indices, with correlation coefficients (r) ranging from 0.52 to 0.68 and p-values all less than 0.001. This finding not only aligns with previous research conclusions regarding the correlation between diaphragm movement and pulmonary function but also provides a novel perspective and solid theoretical basis for respiratory function rehabilitation in hemiplegic patients [4].

In analyzing the study results, we further explored potential reasons for the decreased pulmonary function in hemiplegic patients. Apart from restricted diaphragm movement, weakened respiratory muscle coordination may also be a crucial factor contributing to reduced pulmonary function [5]. Neurological damage in hemiplegic patients may disrupt the coordination among respiratory muscles, further exacerbating respiratory dysfunction. Additionally, decreased chest wall compliance may also negatively impact pulmonary function.

Compared to previous studies, our research utilized M-mode ultrasonography to precisely capture diaphragm excursion. This method offers notable advantages such as non-invasiveness, real-time monitoring, and dynamic assessment, opening up new avenues for evaluating diaphragm function. As observed by Hernandez et al. in acute stroke patients, respiratory muscle dysfunction is closely related to patient prognosis [6, 7]. Our study further confirms the direct link between restricted diaphragm movement and decreased pulmonary function through precise measurement data. Compared to earlier research, our study not only validates the correlation between diaphragm movement and pulmonary function but also provides a more accurate and real-time assessment tool through M-mode ultrasonography [8].

While this study reveals a close relationship between diaphragm movement and pulmonary function in hemiplegic patients, it also has some limitations [9, 10]. The relatively small sample size may limit the generalizability and statistical power of the findings. Furthermore, the study primarily focused on the correlation between diaphragm movement and pulmonary function, without comprehensively exploring other factors that may affect pulmonary function.

To address these limitations, we propose the following directions for future research: firstly, expanding the sample size through multi-center collaboration or extending the study period; secondly, employing a more comprehensive assessment approach that considers multiple dimensions of the respiratory system; and finally, conducting long-term follow-up studies to explore the sustained impact of rehabilitation training on pulmonary function and other intervention measures.

In summary, this study provides a new perspective and rehabilitation approach for understanding

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respiratory dysfunction in hemiplegic patients. However, future research is needed to further explore and refine these findings.

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