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Clinical Application of 3D Reconstruction Technique in Surgery of Early Lung Cancer

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Abstract

Objective: To investigate the clinical value of 3D reconstruction in patients with lung cancer undergoing thoracoscopic segmental resection. **Methods:** A total of 80 patients who underwent pulmonary segmentectomy due to pulmonary nodules in Deyang People's Hospital from July 2022 to July 2023 were retrospectively analyzed, including 40 patients in the control group and 40 patients in the 3D reconstruction group. The clinical data of all patients were collected, and the differences in operation duration, intraoperative blood loss, postoperative drainage volume, drainage tube removal time, postoperative hospitalization time, and perioperative complications were analyzed. **Results:** There was no significant difference in the basic data between the two groups, which was comparable. Compared with the control group, the operation duration and intraoperative blood loss in the 3D reconstruction group were reduced, and the difference was statistically significant. There was no significant difference in postoperative drainage flow, drainage tube removal time, postoperative hospital stay, and perioperative complication rate between the two groups ($P > 0.05$). **Conclusion:** The 3D reconstruction technique is helpful to shorten the intraoperative blood loss of lung cancer operation time, and is worthy of clinical application.

Keywords

Three-dimensional reconstruction; Thoracoscopic surgery; Lung cancer

1. Introduction

Lung cancer remains the leading cause of cancer death in China and worldwide [1]. Although the treatment options for lung cancer are increasingly diverse, surgical resection is still the mainstream option. Minimally invasive surgery such as video-assisted thoracoscopic surgery and robot-assisted thoracoscopic surgery has achieved remarkable results in the treatment of early non-small cell lung cancer and has been gradually popularized. Segmental resection for early lung cancer has achieved a good long-term prognosis while maximizing the removal of the lesion and protecting lung function [2]. However, segmental resection requires a clear understanding of the location of the target tumor and the anatomical structure of the target lobe, segment, bronchiolar duct, and arteriovenous structure. With the development of imaging techniques such as multi-detector computed tomography and three-dimensional computed tomography bronchography and angiography, two-dimensional (2D) images can be converted into three-dimensional (3D) imaging [3]. In order to reduce the intraoperative risk, accurately locate the lesion, improve surgical safety, and achieve accurate resection, three-dimensional reconstruction has emerged and developed rapidly, especially in thoracic surgery. In this study, the clinical data of 60 patients with lung cancer were retrospectively analyzed to investigate the clinical application value of 3D reconstruction in thoracoscopic surgery.

2. Data and Methods

2.1 General Data

A total of 80 patients who underwent lung segmentectomy due to high-risk pulmonary nodules in Deyang People's Hospital from July 2022 to July 2023 were retrospectively selected and divided into a control group and a 3D reconstruction group, with 40 cases in each group. The control group included 25 males and 15 females, aged 30 to 75 years old, (56.45 ± 7.89) years old. In the 3D reconstruction group, there were 23 males and 17 females, aged 31-78 years, (56.64 ± 8.01) years.

Inclusion criteria: (1) The surgical indications were in line with the Chinese cancer prevention guidelines, and the diameter of the lung tumor was ≤ 2.0 cm; (2) Histologically it was carcinoma in situ; (3) The results of CT examination were ground glass ≥ 50.05%; (4) Imaging results showed that the doubling period of tumor diameter was ≥ 400 d; (5) Suspected lung metastases.

Exclusion criteria: (1) a history of pulmonary surgery; (2) thoracic adhesion; (3) Concomitant with other lung diseases, such as pulmonary fibrosis; (4) Poor physical condition, cannot tolerate surgery, do not accept lung segment resection surgery.

2.2 Three-dimensional reconstruction and preoperative preparation

According to the position of the lesion in the three-dimensional image, the shape and variation of pulmonary blood vessels and bronchus, the resection and incision plan were designed manually, and personalized treatment plans were formulated.

2.3 Control group

The surgeon performed the operation with reference to the preoperative CT of the patient.

2.4 Procedure

General anesthesia, double cavity tracheal intubation, and single lung ventilation were used. All patients underwent thoracoscopic anatomic partial lobectomy (APL) through a three-port approach. Target bronchus and vascular structures were separated separately. After segmentating the target artery and bronchus, the cutting plane/internode line was determined by the inflation-contraction method. The extent of excision depends on whether the excision margin is sufficient. Management of the incisional/intersegmental-surface (electrocautery, stapling, or a combination of each) is thought to be associated with postoperative complications (i.e., air leakage, hemoptysis). If the rapid freezing pathology of any lymph node is found to be malignant during surgery, hilar and mediastinal lymph nodes should be collected or systematically dissected. The control group was similar to the 3D reconstruction group. In the 3D reconstruction group, virtual visualization of 3D images was used to confirm anatomic variation and preoperative planning.

2.5 Outcome measures were compared

(1) The perioperative duration of the two groups was compared. (2) The amount of intraoperative blood loss was compared between the two groups. (3) Postoperative drainage volume was compared between the two groups. (4) The extraction time of the drainage tube was compared between the two groups. (5) The postoperative hospital stay of the two groups was compared. (6) Surgical complications were compared between the two groups.

2.6 Statistical Methods

SPSS 21.0 statistical analysis software was used for statistical analysis of all data. The measurement data were measured by χ^2 test. Dose data were measured by *t*-test and expressed as mean ± standard deviation. $P < 0.05$ means that the difference is statistically significant.

3. Results

The basic data of the two groups were compared in terms of gender, age, smoking history, pulmonary function segmental resection, and other clinical basic data between the two groups, showing no statistical significance ($P > 0.05$), and the results were comparable, as shown in Table 1.

Table 1. Basic data of two groups of patients

Clinical data		Control group	Three-dimensional reconstruction group	t/χ^2 value	P
Age		56.4 ± 7.89	56.64 ± 8.01	0.189	> 0.05
Gender	Male	25	23	0.321	> 0.05
	Female	15	17		
Smoking	Yes	14	16	0.532	> 0.05
	No	26	24		
Lung function	≥ 1.5 L	37	38	0.561	> 0.05
	< 1.5 L	3	2		

A comparison of perioperative indicators between the two groups is shown in Table 2. Compared with the control group, the operation duration and intraoperative blood loss in the three-dimensional reconstruction group were significantly reduced, and the difference was statistically significant ($P < 0.05$). There were no significant differences in drainage flow, drainage tube removal time, and hospital stay between the control group and the 3D reconstruction group ($P > 0.05$).

Table 2. Comparison of perioperative indexes between the two groups

Index	Control group	Three-dimensional reconstruction group	t/Z value	P
Operation duration (min)	125.3 ± 30.11	100.10 ± 21.67	3.54	0.003
Drainage rate (mL)	457.54 ± 163.68	453.52 ± 141.26	17	0.256
Intraoperative blood loss (M (P25, P75) mL)	50.00 (49.00, 78.00)	50.00 (32.00, 54.00)	1.87	0.045
Drainage tube removal time (d)	3.0	3.0	0.256	0.654
Length of stay (d)	4.3	3.9	0.658	0.527

A comparison of the results of surgical complications between the two groups is shown in Table 3. The incidence of complications in the control group and the 3D reconstruction group was 25.0% and 22.5% respectively, and the incidence of complications in the control group was slightly higher than that in the 3D reconstruction group, with no statistical significance between the two groups ($P > 0.05$). Both groups of patients were discharged from hospital and no death occurred.

Table 3. Comparison of surgical complications between the two groups

Category	Control group	Three-dimensional reconstruction group
Hemoptysis	3	3
Pneumoderm	2	2
Pulmonary air leaks	4	4
Conversion thoracotomy	1	0
Total	10	9

4. Discussion

Lung cancer is a malignant tumor with the highest incidence worldwide in recent years, posing a serious threat to human health [4]. In the treatment of lung malignant tumors, surgical resection is the main way. Segmental resection of the lung has a higher 5-year survival rate in the treatment of early lung cancer, but the lung has more anatomical variation, and the limited surgical field of view under thoracoscopy requires higher surgical skills [5]. Compared with two-dimensional CT images, three-dimensional reconstruction can visualize lung tissue, pulmonary arteries, and

veins in three dimensions, providing decision-making reference for the formulation of clinical individualized surgical procedures [6]. Previous clinical studies have found that the effect of total thoracoscopic segmental resection in the treatment of early-stage lung cancer is comparable to that of lobectomy, and it has advantages in preserving lung function and reducing postoperative complications in patients with stage IA NSCLC [7]. However, the implementation of thoracoscopic segmental resection is a relatively complex problem, involving the spatial location, morphological structure, and spatial relationship of adjacent structures of pulmonary nodules or ground glass shadows, as well as anatomical problems related to the disfiguration and variation of pulmonary trachea and pulmonary arteriovenous. With the rapid development of digital medical imaging technology, three-dimensional digital models are constructed based on two-dimensional CT images, and three-dimensional reconstruction software is applied to carry out virtual surgical planning, which plays an important role in segmental resection [8]. Studies have shown that pulmonary segmental resection under three-dimensional reconstruction technology can clarify the shape and distribution of target segment blood vessels and bronchus, thus saving operation time [9].

Studies have shown that 3D reconstruction can clearly display the exact lung segment structure, reduce the occurrence of intraoperative accidental injury, and then reduce intraoperative blood loss, shorten the operation time, and improve the safety of thoracoscopic segmental resection for early lung cancer [10]. The results of this study showed that the thoracic tube indentation time, bed rest time, exhaust time, defecation time, antibiotic application time, and hospital stay of patients in the 3D reconstruction group were shorter than those in the conventional endoscopic pulmonary segmental resection group. The reason for the analysis is that the 3D reconstruction technique can display the pulmonary arterio-venous and bronchial variation and anatomical pattern of patients in a stereoscopic way, which can provide an effective basis for clinicians to make surgical plans. Preoperative confirmation of the target lung arteriovenous and bronchial tubes can shorten the intraoperative determination time, reduce excessive and blind tissue separation, and avoid accidental structural damage, thus reducing intraoperative blood loss [11]. Studies have shown that 3D reconstruction technology can shorten the operation time, reduce the amount of intraoperative blood loss, help surgeons to work out accurate individualized surgery plans, reduce the difficulty of surgery, and perform surgery more safely and quickly [12].

In this study, perioperative conditions of the two groups of patients were observed, and it was found that total thoracoscopic pulmonary segmental resection with 3D reconstruction technology could shorten the operation time, postoperative extubation time, hospital stay, intraoperative blood loss, perioperative period and incidence. The data from this study confirmed that 3D reconstruction technology has a high advantage in relatively complex thoracoscopic segmental resection, which can improve the surgical effect and safety. At present, 3D reconstruction technology has several main advantages in NSCLC applications:

(1) An individualized 3D visualization model was established with CT image data through 3D visualization software, which could more accurately display the spatial anatomical relationship between the lesions and the pulmonary arteriovenous bronchus and the surrounding organs, and simulate the length and Angle of the pulmonary arteriovenous bronchus. Clinicians can be encouraged to accurately locate the lesion before the operation, determine the distribution and shape of the surrounding bronchus and arterio-vein in advance, and then plan the scope and procedure of surgical resection to ensure the safe, effective, and rapid implementation of surgery [13, 14].

(2) During the operation, the 3D model can be adjusted at any Angle, position, size, etc., and properly adjusted according to the corresponding position during the operation, so as to reduce the errors between the manual operation and the model, achieve the highest compatibility between the two, and make the operation safer [15].

(3) Pulmonary arterio-venous and bronchial tubes have a lot of variation, and the three-dimensional model can understand the anatomical situation of patients with variation, which encourages surgeons to predict and plan the anatomical structure of segmental doors before surgery and formulate personalized surgical plans, so as to ensure the smooth operation of complex pulmonary segmental resection and obtain good perioperative outcomes [16].

In summary, thoracoscopic surgery with 3D reconstruction has more advantages than non-reconstruction in terms of operation time, intraoperative blood loss, extubation time, postoperative drainage volume and hospital stay, etc. At the same time, this technology can improve the accuracy and safety of surgery and reduce the incidence of postoperative complications, but its long-term therapeutic effect needs further discussion.

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