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Division of the intersegmental demarcation using the "modified hand-tearing method" is safe and feasible in thoracoscopic anatomical segmentectomy

Zhen Feng[1] | Benchuang Hu[1] | Shuliang Yu[2] | Chenran Guo[1] | Zhongmin Peng[1]

[1]Department of Thoracic Surgery, Shandong Provincial Hospital Affiliated to Shandong First Medical University, Jinan, China

[2]Department of Oncology, The First Affiliated Hospital of Shandong First Medical University and Shandong Provincial Qianfoshan Hospital, Jinan, China

Correspondence
Zhongmin Peng, Department of Thoracic Surgery, Shandong Provincial Hospital Affiliated to Shandong First Medical University 9677 Jing 10 Road, Jinan 250000, China.
Email: pengzhm@163.com

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Abstract

Background: The accurate and safe division of the intersegmental demarcation (ISD) is critical and challenging during thoracoscopic anatomical segmentectomy. Here, we provide an improved technique which emphasizes the application of an electric hook and blunt division of ISD. The technique is termed as the "modified hand-tearing method" (MHT method) with combined application of an electric hook and staplers. The study aimed to review the outcomes of patients who underwent thoracoscopic anatomical segmentectomy, with or without the MHT method in our institute and assess its feasibility and safety. In addition, we compared the feasibility between video-assisted thoracoscopic surgery (VATS) and robot-assisted thoracoscopic surgery (RATS) using the MHT method.

Methods: From 2018 July to 2021 June, we retrospectively analyzed 701 patients who underwent segmentectomy. Using propensity score matching, data of two well-matched pairs of 276 cases in the MHT method and non-MHT method groups, and two well-matched pairs of 40 cases in the VATS and RATS subgroups were obtained. The clinical and perioperative characteristics of patients were compared between groups.

Results: Compared with the non-MHT method group, the MHT method group had shorter operation time and shorter postoperative hospital stay. Period of chest tube drainage and postoperative total drainage and postoperative complications had no between-group difference. Compared with VATS, the RATS subgroup had less intraoperative bleeding and shorter postoperative hospital stay.

Conclusion: Division of ISD using the MHT method has advantages in precision and ease of operation, so it has the potential to become a feasible and effective method for thoracoscopic anatomical segmentectomy.

KEYWORDS
intersegmental demarcation, intersegmental plane, robot-assisted thoracoscopic surgery, segmentectomy

INTRODUCTION

Due to the increased use of computed tomography (CT) and easier access to medical care than before, more pulmonary nodules (diameter ≤ 2.0 cm) including solid and ground-glass nodules (GGNs) are detected. Thus, thoracoscopic anatomical segmentectomy is gathering increasing interest among thoracic surgeons.

As a parenchyma-sparing operation with better quality of life and comparable survival,[1,2] segmentectomy has been proposed as a viable alternative to lobectomy for early stage non–small cell lung cancer (NSCLC).[3] What is more, it will be a standard treatment for selected patients if the superiority in pulmonary function and noninferiority in overall survival are confirmed.[4] In order to achieve the goals of preserving pulmonary function and obtaining sufficient tumor margins, an accurate and safe division of the intersegmental demarcation (ISD) is the most critical surgical procedure. The ISD is not a straight line, a flat plane, or a curved plane, but a

Zhen Feng and Benchuang Hu contributed equally to this work and should be considered co-first authors.

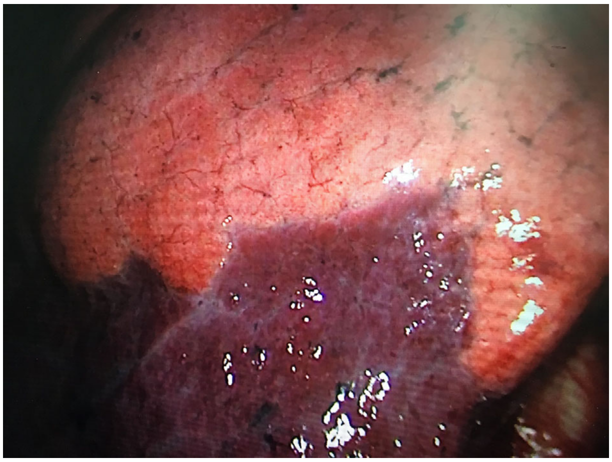
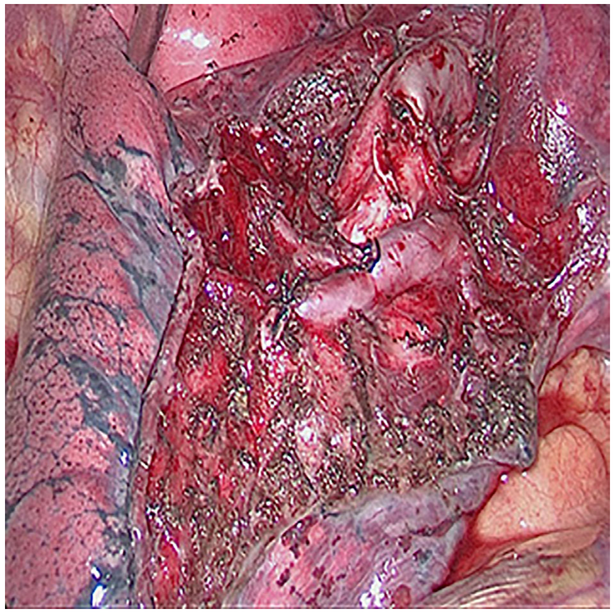


FIGURE 1 The intersegmental demarcation (ISD) obtained by the modified inflation-deflation method via pure oxygen. The ISD between LS1 + 2c and LS4 obtained through a modified inflation-deflation method; the expanded segment is LS1 + 2c, and the collapsed segment is LS4. The ISD is not a straight line, a flat plane, or a curved plane, but a 3D intricate boundary. Even just seen from the surface of visceral pleura, it is also an irregular and indented line

three-dimensional (3D) intricate boundary. Even just seen from the surface of visceral pleura, it is also an irregular and indented line (Figure 1). Several methods have been reported for identifying the ISD,[5] each with its pros and cons, and the same is true for dividing the ISD.[6–9] Staplers, energy devices (electrocautery or ultrasonic scalpel) or a combination of both are used to divide the ISD. Stapling is a fast and easy division method and is superior to electrocautery in controlling bleeding and preventing air leakage. However, the ISD is usually neither linear nor plane. As a result, the application of a linear stapler is prone to be inaccurate, especially when the pulmonary parenchyma between the anvil of stapler and nail box is thick. That is to say, if any linear stapler is used, either surgical margin or adjacent pulmonary parenchyma could possibly be compromised. In addition, according to our experience, the application of stapler devices alone may restrict full expansion of the preserved segments due to fixation of the visceral pleura to the staple line (Figure 2(a)). Theoretically, electrocautery using an electrotome is believed to be better than stapling in accuracy and expansion of preserved segments. However, in clinical practice, the actual ISD in deep pulmonary parenchyma is easily covered by eschars during electrocautery (Figure 2(b)). Then, inaccurate division with electrocautery deviating from the actual ISD in deep pulmonary parenchyma will easily lead to air leakage. The eschars caused by electrocautery, as well as prolonged air leakage, are also unfavorable for complete expansion of preserved segments. When it comes to energy devices, the greatest disadvantage is that it is relatively expensive. Based on the above methods, Wang et al. proposed the gate opening and dimensional tailoring technique for stapler-based division of ISD,[10] and Zheng et al. proposed the combined dimensional reduction technique using ultrasonic scalpel and staplers.[11]

We have provided an improved technique termed the "modified hand-tearing method" (MHT method) for division of the ISD, which emphasizes the application of an electric hook and blunt division of the ISD. Electrocautery with an electric hook, which is similar to an electrotome, is only used to assist sharp dissection and hemostasis. Blunt division using an electric hook, as a result of our experiences of hand-tearing during open segmentectomy, is actually more important. The study aimed to review the results of patients who underwent thoracoscopic anatomical segmentectomy in our institute and assess the feasibility and safety of our modified technique.

Division of the ISD using the MHT method has advantages in precision and ease of operation.



METHODS

Patients

We performed this study rigorously complying with the Declaration of Helsinki, and obtained approval from the Medical Ethical Committee of the Shandong Provincial Hospital Affiliated with Shandong First Medical University.

From 2018 July to 2021 June, 701 patients with lung nodules ≤2.0 cm underwent thoracoscopic anatomical segmentectomy at Shandong Province Hospital. Inclusion criteria for intentional segmentectomy were confirmed to comply with guidelines before surgery: (1) Nonmalignant or metastatic lung nodule located in the deep parenchyma, unsuitable for wedge resection. (2) Peripheral nodule suspicious of early lung cancer (diameter ≤ 2.0 cm), with at least one of the following characteristics: (a) pure adenocarcinoma in situ (AIS)

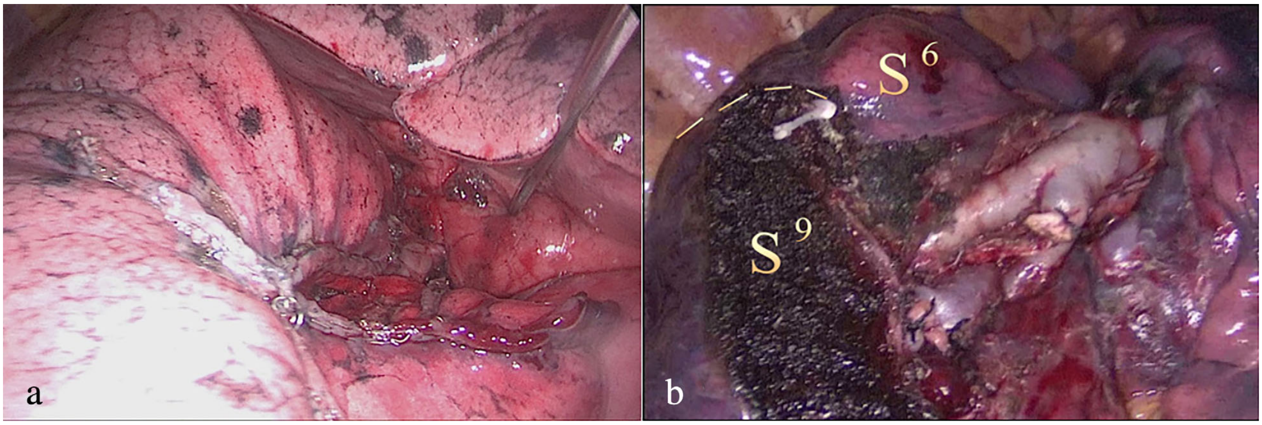


FIGURE 2 The intersegmental demarcation (ISD) divided by stapler and electrotome. Both figures are RS8 segmentectomy. (a) Division using staplers alone will restrict full expansion of the preserved segments due to fixation of the visceral pleura to the staple line. (b) The eschars caused by electrocautery using an electrotome is unfavorable for distinguishing the actual ISD and complete expansion of preserved segments

histology; (b) consolidation-to-tumor ratio (C/T) ≤50%; (c) tumor doubling time (TDT) ≥ 400 days confirmed by radiological surveillance. Exclusion criteria: (1)Poor cardiopulmonary reserve or other major comorbidity contra-indicating surgery. (2)Conversion to extended lobectomy due to mistaken division of bronchovascular anatomy, lymph node metastasis, insufficient surgical margin, frozen-section pathology, etc.(3)Unclear intersegmental demarcation following modified inflation-deflation method due to severe emphysema and interstitial pneumonia. Eventually, 682 patients met the selection criteria and were enrolled in our study (Figure 3).

Propensity score matching was performed to reduce any possible preoperative characteristic bias. Based on clinically relevant variables such as age, sex, smoking status, and complexity of target segmentectomy, a logistic regression was used to generate the propensity scores. According to our experiences, resection of the apical, posterior, or dorsal segment was simple segmentectomy, while resection of the anterior segment or each basal segment, combined segmentectomy and combined subsegmentectomy were classified into complex segmentectomy. After matching, there were 276 patients in the MHT method group and 276 patients in the non-MHT method group. At the same time, we collected an additional 40 cases of segmentectomy using robot-assisted thoracoscopic surgery (RATS) during the same period with the same inclusion and exclusion criteria as above, matched with the above-mentioned MHT group, then obtained 40 cases of RATS and 40 cases of video-assisted thoracoscopic surgery (VATS).

3D reconstruction

Thin-section CT contrast-enhanced scans were performed using a Toshiba 320-slice volume CT scanner (Aquilion ONE, Toshiba Medical Systems) within 2 weeks before surgery. Using 0.625 or 1.3 mm thick slices, CT data of all patients in the Digital Imaging and Communications in Medicine (DICOM) format were imported in the CAS (Hisense Medical) for 3D reconstruction. The virtual 3D reconstruction model could be used for recognition of anatomical variations, localization of lung nodules, preoperative planning, surgical simulation and intraoperative navigation (Figure 4(a,b,c)).

Surgical procedure

All surgeries were performed by the same surgical team. VATS was performed via a thoracoscopic incision (about 3 cm long) with a thoracoscope-entering port (about 1 cm long). Compared with VATS, RATS had one more incision (about 1 cm long), and other surgical procedures were consistent except for robot operation, all intrathoracic operations were performed by robotic arms, except for the use of staplers. Dissection of the targeted segmental bronchus, artery, and intersegmental vein was navigated by the virtual 3D reconstruction model (Figure 4(d)). The ISD was determined by expansion-collapse boundary using the modified inflation-deflation method[12] via pure oxygen (Figure 4(e)). The followed management of ISD was classified into the MHT method group and non-MTH method group. In the non-MHT method group, we used the above-mentioned traditional method to divide the ISD. The MHT method included two critical steps: "dimensionality-reduction" division with a monopolar electric hook along the proximal demarcation (Figure 4(f)) and linear tailoring with a stapler along the distal demarcation (Figure 4(g)). First, by grasping and lifting the distant stumps of dissected bronchovascular structures, a blunt-sharp combined division from hilum to visceral pleura was conducted using an electric hook along the proximal ISD and intersegmental veins. Blunt division with an electric hook is actually more important, and electrocautery was only used for sharp dissection and

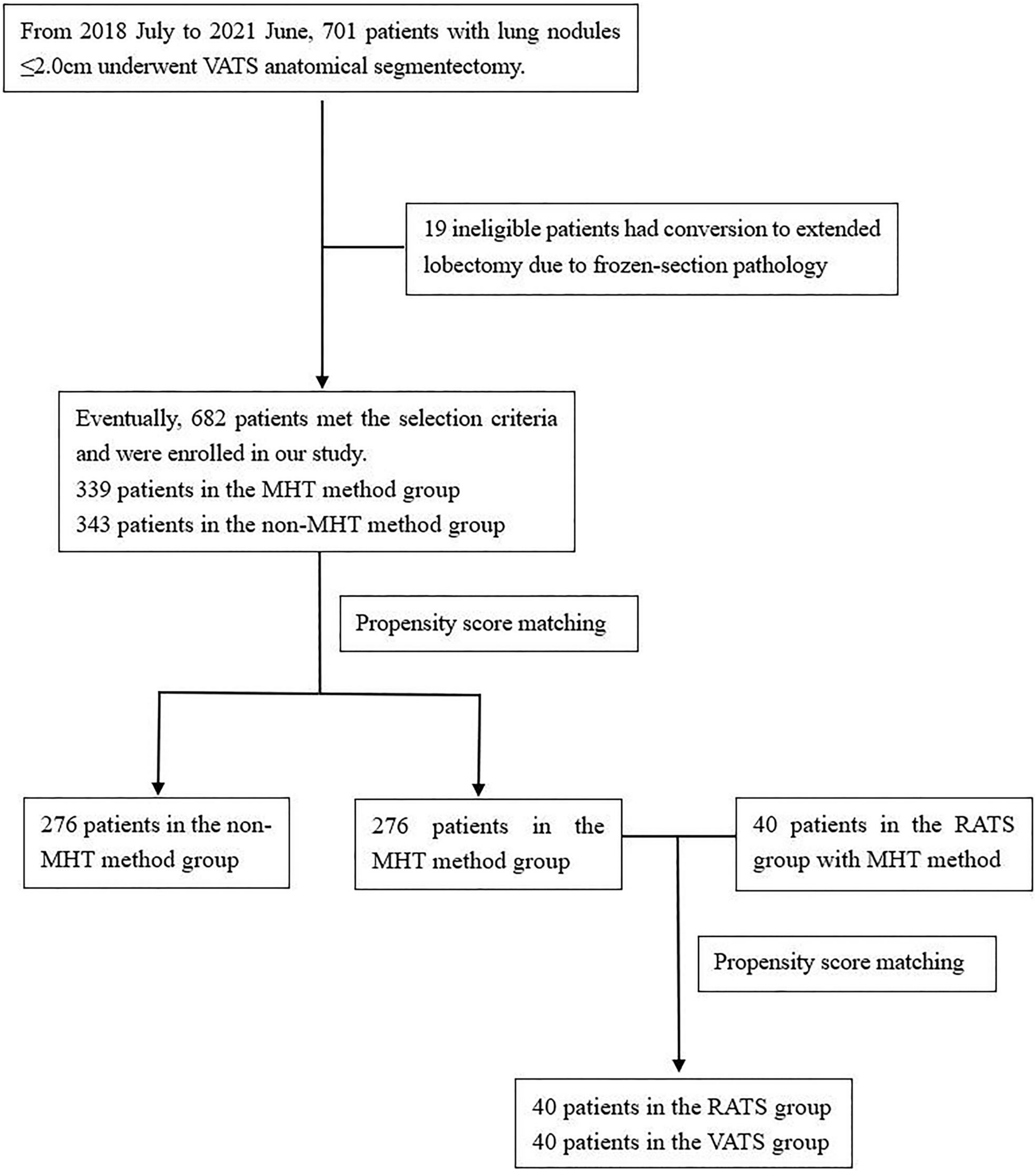


FIGURE 3 Trial profile. A total of 40 patients in the RATS group were additionally collected. Abbreviations: MHT method, modified hand-tearing method; RATS, robot-assisted thoracoscopic surgery; VATS, video-assisted thoracoscopic surgery

hemostasis if necessary. The division was then extended to at least three-fourths of the peripheral border, which aimed to convert the 3D intricate boundary into nearly "a two-dimensional (2D) linear plane" and reduce the use of the stapler as much as possible. Second, with explicit exposure, "the 2D linear plane" was easily tailored with staplers under guidance of the distal ISD (Video S1 and **S2**).

Postoperative management

Routinely, through the thoracoscope-entering port, a chest tube (26 Fr) was inserted in the top of the chest for drainage of both effusion and air. Extubation criteria of the chest tube were generally considered to meet all the following conditions: (1) absence of air leakage;

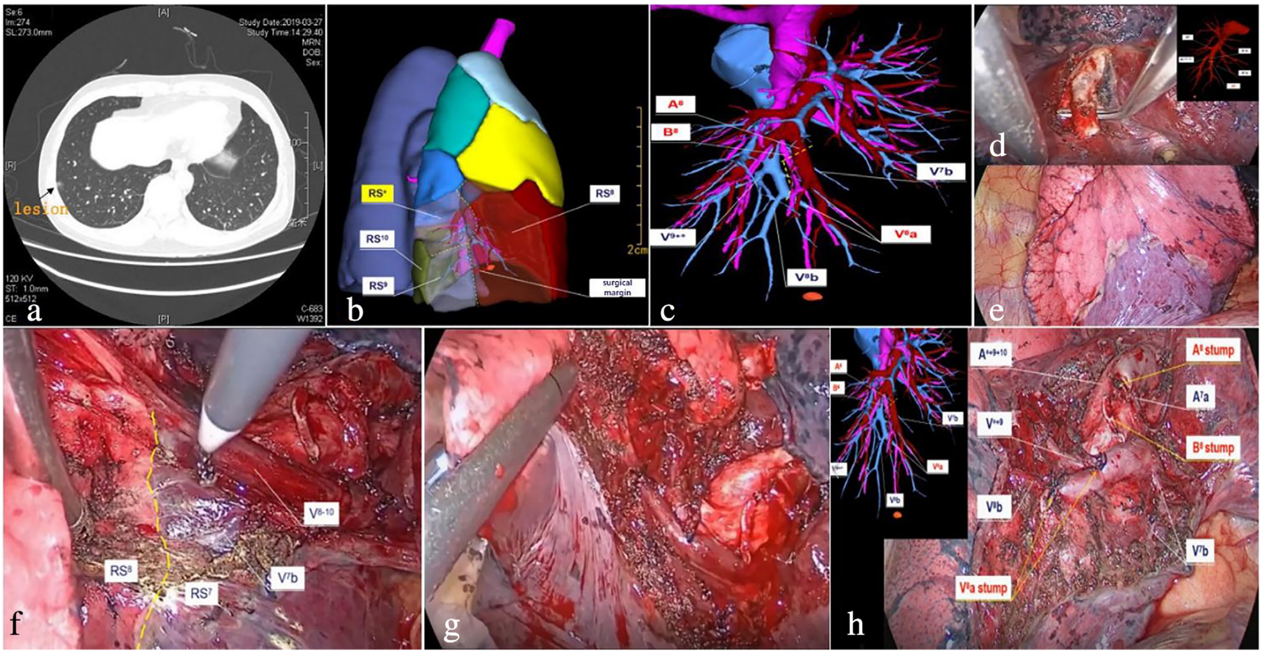


FIGURE 4 Perioperative procedure of the modified hand-tearing method (MHT) method. (a) Targeted pulmonary nodule on axial computed tomography. (b, c) Preoperative planning navigated by 3D reconstruction, including evaluation of the surgical margin and simulation of the surgical procedure. (d) Dissection of targeted segmental bronchovascular structures navigated by 3D reconstruction. (e) The intersegmental demarcation (ISD) is determined by the expansion-collapse boundary through a modified inflation-deflation method. (f) Division of the proximal ISD using an electric hook along the expansion-collapse boundary and intersegmental vein, blunt division is free from eschar. (g) Stapling is recommended to divide the peripheral 1/4 ISD where the pulmonary parenchyma is thin enough. It is also under guidance of the expansion-collapse boundary. (h) The divided ISD is stretched and free from air leakage, and the preserved intersegmental vein is clear

(2) drainage per day was under 200 ml and (3) no hemothorax, chylothorax or pneumothorax.

Follow-up

All patients were followed-up at our out-patient department 1 month after surgery, and each patient underwent the following examinations: medical history, physical examination, and chest CT scan.

Data and statistical analysis

We compared the perioperative characteristics between the MHT method and non-MHT method groups. In order to control the potential between-group differences in the preoperative characteristics of patients and reduce the bias of the study, we performed propensity score matching. According to the clinically relevant preoperative variables, the variables used to generate the propensity score included age, gender, smoking status, and complexity of target segmentectomy. Patients were matched 1:1 by the nearest neighbor matching without replacement, and the caliper value was set to 0.05.

Perioperative data were collected from the hospital chart and electronic medical record of each patient. The data of interest in our study included the operation time, blood loss, pathology reports, total drainage, period of chest tube drainage, postoperative hospital stay, postoperative complications and perioperative mortality. Operation time was defined as the time from skin incision to skin closure. Blood loss was defined as the bleeding volume during surgery. Pathology reports included intraoperative frozen pathology and postoperative paraffin pathology. Period of chest tube drainage was defined as the date from surgery to removal of chest tube. Postoperative hospital stay was defined as the date from surgery to discharge. Postoperative complications mainly consisted of air leakage, pneumonia, chylothorax, delayed pneumothorax, and re-insertion of chest tube. Air leakage was defined as prolonged air leakage lasting 7 days or more. Pneumonia required clear clinical evidence with positive sputum cultures. Chylothorax required clear clinical evidence with positive results from chylous assay. The chylothorax complication cases included in this study were all cured by conservative treatment without reoperation. Delayed pneumothorax was defined as pneumothorax or increasing dead space after removal of the chest tube. Perioperative mortality was defined as any patient who died within the first 30 days postoperatively.

First, the Shapiro–Wilk was used to test the normality of continuous variables. Continuous variables of normal distribution are represented by mean ± standard deviation, nonnormal distributions are represented by median (P25, P75), and categorical variables are represented by frequency. A Student's t test was used to compare the continuous variables of the normal distribution, and the Mann–Whitney

U test was used to compare the continuous variables of the non-normal distribution. Categorical variables were tested using Fisher's exact probability method. Bilateral $p \leq 0.05$ was considered statistically significant. R version 4.0.0 (The R Foundation for Statistical Computing, 2020) software was used for propensity score matching and statistical analysis.

RESULTS

MHT method and non-MHT method groups

Propensity score matching generated two matched pairs of 276 patients in both groups, and the clinical characteristics are summarized in Table 1. In the MHT method group, there were 184 female and 92 male patients with a median age of 56 years old, and 49 smokers and 227 nonsmokers. A total of 182 patients and 94 patients underwent simple and complex segmentectomy, respectively. In most cases, postoperative paraffin pathology showed lung adenocarcinoma. In the non-MHT method group, there were 181 female and 95 male patients with a median age of 55 years old, and 45 smokers and 231 nonsmokers. A total of 183 patients and 93 patients underwent simple and complex segmentectomy, respectively. In most cases, postoperative paraffin pathology showed lung adenocarcinoma. There were no significant differences in observed clinical characteristic variables such as age, gender, smoking status, and type of segmentectomy.

The perioperative characteristics are shown in Table 2 and include operation time, blood loss, postoperative total drainage, period of chest tube drainage, postoperative hospital stay, and postoperative complications. The operative time in the MHT method group was shorter than that in the non-MHT method group (148 [120, 180] min vs.162.5 [136, 200] min) ($p < 0.05$). There was no difference in intraoperative blood loss between the MHT method and non-MHT method groups (60 [50, 100] vs. 80 [50, 100] ml) ($p > 0.05$). Postoperative hospital stay in the MHT method group was shorter than in the non-MHT method group (3 [3, 5] vs. 4 [3, 5] days) ($p < 0.05$). There was no significant difference in period of chest tube drainage, postoperative total drainage and postoperative complications. ($p > 0.05$). Air leakage was the most common postoperative complication in 10 cases, three of whom were in the MHT method group and seven in the non-MHT method group. The distribution of other complications is shown in Table 2. There was no 30-day postoperative death or readmission in either group. In the MHT group, the operation time ranged from 80–360 min, blood loss was 20–350 ml, and hospital stay was 2–37 days. In the non-MHT group, the operation time ranged from 70–340 min, blood loss was 20–500 ml, and hospital stay was 2–28 days.

VATS and RATS subgroup in MHT method

Propensity score matching generated two matched pairs of 40 patients in both subgroups. The clinical characteristics are summarized in Table 3. There was no significant difference in observed clinical characteristic variables such as age, gender, smoking status, and complexity of target segmentectomy. The perioperative patient characteristics are shown

TABLE 1 Clinical characteristics of patients in the non-MHT method and MHT method groups

Characteristics	Non-MHT method group ($n = 276$)	MHT method group ($n = 276$)	p-value
Age (median [P25, P75])	55 (49, 62)	56 (50, 63)	0.352
Sex			0.857
Male	95	92	
Female	181	184	
Type of segmentectomy			1
Simple segmentectomy	183	182	
Complex segmentectomy	93	94	
Smoking status			0.734
Yes	45	49	
No	231	227	
Pathological diagnosis			0.002
Lung adenocarcinoma	243	264	
Other malignancy	4	2	
Benign lesion	29	10	

Abbreviation: MHT method, modified hand-tearing method.

TABLE 2 Perioperative period characteristics of patients in the non-MHT method and MHT method groups

Characteristics	Non-MHT method group ($n = 276$)	MHT method group ($n = 276$)	p-value
Operation time (min)	162.50 (136, 200)	148 (120, 180)	<0.001
Blood loss (ml)	80 (50, 100)	60 (50, 100)	0.164
Period of chest tube drainage (days)	3 (2, 3)	3 (2, 4)	0.571
Postoperative hospital stay (days)	4 (3, 5)	3 (3, 5)	0.006
Postoperative total drainage (ml)	510 (370, 695)	480 (350, 680)	0.354
Postoperative complication (cases)			0.914
Delayed pneumothorax	1	0	
Air leakage	7	3	
Pneumonia	1	1	
Reinsertion of chest tube	2	1	
Chylothorax	2	3	
Postoperative bleeding	1	1	

Abbreviation: MHT method, modified hand-tearing method.

TABLE 3 Clinical characteristics of patients in the VATS and RATS subgroups

Characteristics	VATS group ($n = 40$)	RATS group ($n = 40$)	p-value
Age (median [P25, P75])	56.93 ± 8.144	55.10 ± 11.043	0.403
Sex			1
Male	16	15	
Female	24	25	
Type of segmentectomy			0.482
Simple segmentectomy	28	24	
Complex segmentectomy	12	16	
Smoking status			1
Yes	7	6	
No	33	34	
Pathological diagnosis			1
Lung adenocarcinoma	39	38	
Benign lesion	1	2	

Abbreviations: RATS, robot-assisted thoracoscopic surgery; VATS, video-assisted thoracoscopic surgery.

TABLE 4 Perioperative period characteristics of patients in the VATS and RATS subgroups

Characteristics	VATS group ($n = 40$)	RATS group ($n = 40$)	p-value
Operation time (min)	140 (120, 177.5)	137.5 (125, 172.5)	0.916
Blood loss (ml)	100 (50, 100)	50 (50, 100)	0.003
Period of chest tube drainage (days)	3 (2, 4.5)	2 (2, 3)	0.057
Postoperative hospital stay (days)	3 (3, 5)	3 (2, 3)	0.009
Postoperative total drainage (ml)	490 (375, 735)	470 (365, 675)	0.658
Postoperative complication (cases)			1
Air leakage	0	1	
Chylothorax	1	0	
Reinsertion of chest tube	1	0	

Abbreviations: RATS, robot-assisted thoracoscopic surgery; VATS, video-assisted thoracoscopic surgery.

in Table 4. There was no difference between the operation time of patients in the VATS and RATS subgroups (140 [120, 177.5] vs. 137 [125, 172.5] min) ($p > 0.05$). The RATS subgroup had less intraoperative blood loss (50 [50, 100] vs. 100 [50, 100] ml) ($p < 0.05$) and shorter postoperative hospital stay (3 [2, 3] vs. 3 [3, 5] days) ($p < 0.05$) than the VATS subgroup. There was no statistically significant difference in postoperative total drainage and period of chest tube drainage and postoperative complications between the two groups ($p > 0.05$). There was no 30-day postoperative death or readmission in either group.

DISCUSSION

In recent years, a number of studies have reported that thoracoscopic anatomical segmentectomy appears to be a viable alternative to lobectomy for selected patients with early-stage NSCLC.[13–16] Compared with lobectomy, the parenchyma-sparing procedure of segmentectomy is believed to be superior in postoperative pulmonary function and noninferiority in postoperative prognoses.[17] However, the optimal method of identifying and dividing the ISD remains controversial and challenging.

There have been many terminologies which have described the boundary between lung segments,[18,19] such as the intersegmental line, intersegmental septum, intersegmental fissure, and intersegmental plane. Each of these terms is a different understanding of the boundary in different perspective or dimension. The actual boundary between the lung segments is different from the interlobar fissure; that is to say, it is not a straight line, flat, or curved plane, but a 3D intricate boundary. Therefore, we define the boundary as the ISD.

According to previous reports and our experience, there are mainly two aspects to evaluate the quality of ISD division: the accuracy in procedure and the safety in outcomes. The accuracy in procedure means as accurate as possible division of the 3D intricate boundary without any injury to the intersegmental vein. Inaccurate division of the ISD may lead to residual of targeted segment, injury to the intersegmental vein or adjacent parenchyma of the preserved segment. The safety in outcomes means full expansion of the preserved segments and prevention of complications such as air leakage.

As mentioned earlier, the application of linear staplers is prone to be inaccurate because the ISD in deep parenchyma is out of sight and the pulmonary parenchyma between the anvil of stapler and nail box is thick. Less resection would cause of targeted segment and even an insufficient surgical margin.[8] On the other hand, more extensive resection would injure the intersegmental vein and lead to congestion or hemorrhage in the preserved segments.[20] Meanwhile, the application of staplers will restrict full expansion of the preserved segments due to fixation of the visceral pleura to the staple line. Consequently, the postoperative pulmonary function and quality of life will be unfavourable.[20] In addition, overuse of staplers is less cost-effective than energy devices. Wang et al. previously reported the gate-opening technique to improve the quality of ISD division using staplers.[10] Given the fact that stapling is superior in procedural simplicity and preventing air leakage, stapling is recommended to divide the peripheral 1/4 ISD where the pulmonary parenchyma is thin enough.[11] Only when the lung is severely emphysematous can the surgeon use more staplers to keep air leakage to a minimum.

Compared with stapling, the application of energy devices tends to ensure procedural accuracy and postoperative safety. Through more accurate and sophisticated procedures using an electrotome, electric hook, ultrasonic scalpel or Acrosurg[21] (a scissor-type device using microwave), an accurate division of the ISD leads to intact intersegmental veins, sufficient surgical margin and full expansion of the preserved segments. For electrotome and electric hook, the parenchyma along the ISD is divided by electrocautery cutting and tissue carbonization. However, smoke and eschars caused by electrocautery make it more difficult to accurately distinguish the ISD. What is more, to a certain extent, the solid eschars are unfavorable for full expansion of the preserved segments. For ultrasonic scalpel, Acrosurg, or other energy devices, the parenchyma along the ISD is grasped with the jaws of the device, and then sealed by dehydration fixation. Just like a tiny stapler, the ISD in deep parenchyma within the jaws is also out of sight. The uniform, solid coagulation layer caused by sealing may also be unfavorable for recognization of the ISD. Compared with stapling, the inferiority of energy devices mainly include more complex procedures, increased risk of air leakage;[22–25] and dependence on clear and persistent ISD. Therefore, an appropriate combination is believed to be better than alone.[9,11]

So far, the ideal device or optimal technique for division of the ISD remains controversial because each energy device has its strengths, as well as drawbacks. In our opinion, all energy devices and traditional techniques have focused on sharp division of the ISD. To improve the quality of ISD division using energy devices, we have provided an MHT technique which emphasizes blunt division. The superiority of our method compared with the traditional technique includes the following: (1) The 3D boundary is clearly visible during the whole procedure using an energy device. (2) The adverse effect of smoke, eschar and coagulation layer are minimized. (3) Cost-effectiveness, for reducing the application of both special energy devices and staplers.

To the best of our knowledge, our study is the first to focus on blunt division of the ISD using an electric hook. We propose a new ISD management technique "modified hand-tearing method" based on our experiences of open and thoracoscopic segmentectomy. Our research shows that the MHT method group had shorter operation time and postoperative hospital stay than the non-MHT method group. There was no between-group difference in intraoperative blood loss, period of chest tube drainage, postoperative total drainage or postoperative complication. The MHT method has been suspected to increase the risk of air leakage. However, the results of our study did not support this theory. First, air leakage is mainly caused by inaccurate division of the ISD, especially accidental injury to the parenchyma or bronchus of preserved segments. In our method, the 3D boundary was clearly visible during the whole procedure using an electric hook, and the peripheral 1/4 ISD was divided by stapling. Improvement of accuracy leads to reduction of accidental injury and air leakage. Second, the blunt division of our method would minimize the adverse effect of sharp injury and eschar, and ensure the full expansion of the preserved segments. Even if a small alveolar pleural fistula is caused by accidental injury, the small air cavity will be quickly enveloped by fully-expanded preserved segments and then absorbed.

Through subgroup analysis, the RATS subgroup had less intraoperative bleeding and shorter postoperative hospital stay than the VATS subgroup. To carry out the MHT method, RATS may be a better choice than VATS. The reasons are summarized as follows. First, the surgical field in the RATS procedure is more highly defined and stereoscopic. Second, compared with an electric hook in the VATS procedure, blunt division using a permanent cautery hook in the RATS procedure can be performed with more dexterity and stability.

Through propensity score matching and inclusion criteria of the same surgical team, we managed to control potential bias factors as much as possible. However, our method and study still have some limitations. The MHT method depends on clear and persistent expansion-collapse boundary. When the patient has severe emphysema or the expansion-collapse boundary is not clear enough, it is difficult to carry out this method. Our study was a single-center retrospective study and the sample size was not large enough. A multicenter large-scale prospective study is expected to further confirm our results. In future, the comparison of RATS and VATS using the MHT method for ISD division is worthy of in-depth study.

In conclusion, the MHT method improves the accuracy of ISD division and makes the ISD clearer during surgery. Division of the ISD using the MHT method is feasible and safe for thoracoscopic anatomical segmentectomy. The MHT method should be recommended as a general standard method for dividing the ISD. RATS may be a better choice than VATS to carry out the MHT method.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

ORCID

Benchuang Hu https://orcid.org/0000-0001-6204-8657

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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