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Management and Progress of Pneumothorax and Pulmonary Air Leak After Lung Resection

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Abstract: Background: Pneumothorax and pulmonary air leakage (PAL) are common emergency and complication in the clinical department of thoracic surgery, the treatment measures of air leakage including observation of conservative, needle aspiration, chest tube drainage, surgical operation and pleurodesis. In the selection of treatment methods, there is not a unified and feasible standard to choose a reasonable, effective and economic therapeutic regimen. Inapposite treatment will prolong hospitalization days, increase cost, even may lead to a death. Therefore, Sorting out and summarizing the therapies is vitally important for clinical conduction. Method: We retrieved about 80 papers in Pubmed, Science Direct, and China How Net while searched "Pneumothorax" or "longer air leakage" And "treatment" as keywords or title in recent ten years, 40 reports have been reviewed. We summarize the selection and development of the treatments for pneumothorax and PAL. Conclusions: According to the cause, age, urgency and other symptoms, the clinician should take different treatment. The minimally invasive closed drainage will become a preference for the pneumothorax needing drainage, it may replace the traditional tube closed drainage. VATS will become the preferred treatment of pneumothorax with bubble. Autologous blood is a facilitate getting adhesive agents, its procedure is easy and safe with few complications, and it is also an economical method with a high success rate. However, it still needs further studies to taking the economical, effective, appropriate treatment for a special pneumothorax and postoperative lung air leak.

Keywords: Pneumothorax, Pulmonary Air Leak, Management

1. Introduction

Pneumothorax refers to the presence of air or gas in the pleural cavity, which caused by the trauma to the lung or chest wall or occurs spontaneously. Spontaneous pneumothorax is defined as occurs without an apparent cause, which triggers a series of the syndrome, is a common acute thoracic disease. It is divided into primary pneumothorax and secondary pneumothorax. Primary spontaneous pneumothorax tends to occur in a young adult, and the average age of secondary pneumothorax patient is more than 55 years [1]. Pneumothorax has a relatively high recurrence rate. Due to the different treatment and follow-up applied, the recurrence rate has a big difference in the different report results. Studies have shown that the recurrence rate of primary pneumothorax for 16%~52%; secondary pneumothorax recurrence rate for 40%~56%, and recurrence occurred within 6 months after the onset [2]. Pulmonary air leak after the operation is a common complication which results from the lung resection margins from lung tissue or lung lesion leakage. Pulmonary air leak (PAL) can be considered as pneumothorax, because they have the same management, and the incidence rate of PAL is 3%~25% [3]. Prolonged air leak is defined as an air leak lasting more than 5 days, and which is defined as persistent air leak more than 7 days initially. We searching from Pubmed, Science Direct and CNKI China nearly a decade, and we retrieve more than eighty relevant papers, 40 papers were reviewed and the progress of treatment of pneumothorax and

pulmonary air leak as follows.

2. Management

2.1. Conservative Treatment

Conservative treatment and observation is safe and effective for following situations, including small primary pneumothorax (defined as <30% of the volume of the hemithorax). No obvious symptoms such as breathless, postoperative pulmonary air leak<3 d And the occult pneumothorax, The conservative method includes bed rest, oxygen therapy, appropriate easing pain, sedative, cough-relieving, constipation and supportive care. Oxygen therapy can promote the absorption of gas in the thorax. The specific method recommended: oxygen flow1 L/min, 2 times per day, 20 min one time. Studies have shown that the lung recruitment takes average 6.12~8.13d after conservative treatment [4].

2.2. Evacuating Air

Evacuating the air should be taken as long as the air volume without reducing, no relief of symptoms or even worsening by conservative treatment. There are many methods: Aspiration, intercostal closed drainage, chest drainage suction, etc.

2.2.1. Aspiration

Evacuation by the British Thoracic Society (BTS) or the American College of Chest Physicians (ACCP) provisions lung is compressed 15%~ 30% by conservative bed rest 3Days or more, with no obvious gas absorption or worsening symptom, while those should be taken aspiration [5]. In recent years, thoracentesis takes a continuous improvement, apply by the intravenous catheter, central venous catheter, etc., the use of special equipment increases medical expenses, except that, it greatly improved the traditional thoracentesis practicality, safety, and effectiveness. For spontaneous primary pneumothorax, the amount of the gas <2000 ml or traumatic pneumothorax, compared with aspiration and thoracic drainage there was no significant (68% vs. 80.6%, P= 0.28) at the success rate. Aspiration has shorter hospital stays at the same time [6]. Moreover, Samuel J. Chang et [7] researchers with the anterior axillary line at the fourth intercostal needle puncture (4AAL), and the needle do comparison 5cm midclavicular line in the second intercostal puncture (2MCL), due to the fourth intercostal chest wall is thinner, the former can be reduced air effectively (66-81% & 96%). Also Hatch. Q etc. [8] instead of using the piercing 5mmTrocar rescue tension pneumothorax for more timely and effective.

2.2.2. Intercostal Closed Drainage

The indications of intercostal closed drainage: (1) Severe symptoms with dyspnea, more than 30% of the volume of the hemithorax; (2) Symptoms have no relief or ever aggravated by the aspiration; (3) By using the positive pressure ventilation; (4) Severe lung injury, persons with poor respiratory reserve; (5) intrathoracic trachea or bronchus rupture; (6) recurrent pneumothorax [9].

In recent years, emerging closed drainage improvements: (1) Closed drainage by central venous catheter (CVC):Patients take the sitting or semi-recumbent position, puncture points located at the ipsilateral clavicular line 4 or intercostal anterior axillary line 4~5 intercostal (4-5AAL), routine sterilized, wear gloves, drape fenestrated sheet, local anesthetic, a one-time CVC puncture needle (1.7-mm diameter, 16-gauge) was inserted at the lower edge of the vertical, gas back to the booster, insert the guide wire, pull out the needle, guide tube along the guide wire to dilated skin incision, along the guide wire insert CVC implanted wire 10~15 cm, Pull out the guide wire, topical bandage, fixed, connecting water seal bottle [10]. (2) Closed drainage by intravenous catheter: the steps substantially with the former method, the general specifications of the intravenous catheter selected the 18G× 1.16 [11]. (3) pigtail type catheter closed drainage: Pigtail catheter system with a trocar (10~16F) is a new drainage tube, the insert method by ultrasound-guided is the same as the CVC, Chen [12] Studies have shown that the overall success rate of the pigtail catheter drainage for pneumothorax in obstructive pulmonary disease and cancer for76%, comparable to the large diameter chest tube closed drainage. (4) small thoracic drainage tube: Rivas, etc. [5] Studies have shown that small tube (12~14F) with the therapeutic effect of large tube pleural drainage tube equivalent, but the operation is more simple and convenient relatively.

Compared to traditional closed drainage，minimally invasive closed drainage have the similar operational method without different piercing tools. The advantages of the minimally invasive operation: (1) Intravenous catheter has better tissue compatibility with lesser damage to the human body; (2) Smaller wound, less pain and no scars, postoperative recover rapidly; (3) Take the extension tube as a drainage tube, easily obtained, low prices; (4) Operation is comparatively simple, it always done with one puncture which could avoid repeated puncture bring about visceral pleura injury, the physician could perform single-handed, can be extended widely in basic hospital, it also has obvious advantages when patients need rescue with severe illness and in poor health [11, 13].

However, the minimally invasive closed drainage also has disadvantage: (1) Due to the small tube leading to less gas drainage. On this point, the operator could take intermittent suction side hole, reducing the liquid level of the water seal bottle and shorten the drainage tube line [14]. (2) The small tube can be easily blocked and lacuna out, preventing plugging in the pipe can shorten the length of the tube in the thoracic cavity, while preventing slippage can take appropriate conduit and external fixation, in addition, saline irrigation of the catheter can reduce the incidence of plugging [15]. Particular note: When severe compression, more than 75% by compression, a large break traffic pneumothorax or tension pneumothorax, since the air leaking into the chest cavity with fast speed and a large amount, using a small tube to drainage is an ineffective treatment which must be changed to thick tube drainage.

2.3. Surgical Treatment

Indications for surgical treatment [16]: (1) A large amount of gas leakage into the thoracic cavity leading to atelectasis; (2) Persistent air leak with bullae; (3) Recurrent pneumothorax (2 times or more episodes); (4) With complications of pneumothorax (hemothorax, empyema, chronic pneumothorax); (5) Secondary pneumothorax requiring surgery; (6) special work and conditions (flying, diving, living in remote areas, pregnancy), However Nwaejike, N. et [17] pointed out that for 78% of pregnant women can be treated conservatively, some severe pneumothorax requires surgery, and no significant effect on pregnant women and infants; (7) with a history of contralateral pneumothorax; (8) Bilateral simultaneous pneumothorax; (9) Chest X-ray examination shows that large lung cyst. Even with intracapsular infection. Surgery method: thoracotomy, surgical chemical pleurodesis, front axillary thoracotomy with thoracoscopic assisted, video-assisted thoracic surgery.

2.3.1. General Thoracotomy

General anesthesia with tracheal intubation by double-lumen endobronchial tubes, unilateral lung ventilation, selected the anterolateral or posterolateral 8~14cm incision at ipsilateral, by 5th intercostal thoracotomy, gradually separate the adhesion, bullae were excised and ligated, the fiber on lung surface is stripped. Place chest tube drainage at axillary line 7th intercostal in the operation. The indications of general thoracotomy are more stringent. For the patients with the poor general condition, poor lung function or more serious merger situation, lung volume reduction surgery is often choosen for the complexity pneumothorax [18].

2.3.2. Video-assisted Thoracic Surgery (VATS)

General anesthesia with tracheal intubation by double-lumen endobronchial tubes, unilateral lung ventilation, selected the axillary line 6th or 7th intercostal as viewing aperture, the anterior axillary line 3th or 4th intercostal, or axillary line 4th or 5th as operational aperture, Resection the lung bubble by staplers at the edge 0.5~1.0 cm of the bubble, then remove diseased lung tissue and take lung expansion in the water to checked for no leak [19].

With the development of the endoscopic techniques, more and more surgeon could perform the operation with uniportal at axillary line 4th or 5th 3cm incision, and without tracheal intubation instead of laryngeal mask with spontaneous breathing. In the treatment of pneumothorax, VATS can be alternatively, or even replace the general thoracotomy, VATS has become a preferred method at first. Yang Futao [20] compared to the general thoracotomy and VATS with control study group, VATS group has an obvious advantage, such as the operative time, drainage tube indwelling time and hospital stay were significantly shorter, also with less blood loss, postoperative pulmonary infection, persistent pulmonary air leak lower incidence of complications, Furthermore, VATS has minimally invasive with little scar, it is more receptive for patients, It also shows no recurrence rate statistical significance ($P > 0.05$). One of VATS disadvantage is the higher medical cost, Morimoto Wait [21] found that treatment of early spontaneous pneumothorax by VATS take double cost compared to chest tube drainage. However, from a cost-benefit perspective, consider the recurrence in the future, the high cost of VATS is acceptable for young patients.

2.3.3. Video-assisted Minithoracotomy (VAMT)

Anesthesia, intubation, and position are the same with general thoracotomy, armpits 4th intercostal 6~10 cm incision, Small distractor mild distraction intercostal. Making a 1.5 cm incision as thoracoscopy aperture at the axillary line in the 7th intercostal. Assisted by a small incision increase the operative field, using conventional instruments for separation of adhesions, hemostasis, bulla resection. Shugao Ye [22] report 43 cases of patients with spontaneous pneumothorax were cured by VAMT. Ador.NP etc. [23] made a clinical contrast of VAMT vs VAST, found that no significant difference between the two methods on safety and efficacy, and long-term postoperative pain is not increased, and the VAMT is more effective for leakage in the apex, need be large block lung resection and patients with more extensive adhesions. Therefore, VAMT as a supplementary method of VATS, it is useful for the patients with serious pleural adhesions, big huge lung bubble, and with hemothorax.

2.3.4. Minithoracotomy

General anesthesia with tracheal intubation by double-lumen endobronchial tubes, axillary 3~4 intercostal incision for upper lobe lesions, selected 5~6 intercostal incision for lower lobe lesions, taken along the ribs (7.0 ± 2.5) cm transverse incision, [24]. It may also take axillary line or anterior axillary line longitudinal incision length of 6 ~8 cm, Selecting the 4th intercostal thoracotomy, using small distraction to expanding intercostal incision into a rectangular shape, which provides the greatest range of surgical procedures without expanding skin incision [19], It is seen that the minithoracotomy has the same advantages and disadvantages with VAMT.

2.3.5. Thoracoscopic Water Pleurectomy

Andreetti.c [25] using a modified thoracoscopic pleural resection. General anesthesia with tracheal intubation by double-lumen endo-bronchial tubes, seventh or eighth intercostal make an incision (approximately 1cm), if necessary, in the second intercostal make another incision (about 0.5cm), as the auxiliary aperture for bullae resection. Under endoscopic direct vision using 50ml syringe of 0.9% saline percutaneous puncture to the pleural invasion, from second intercostal gradually down to the incision intercostal (typically seventh or eighth). By water diffusion, have a broad isolated parietal between pleura and thoracic fascia beginning from cupula pleura, it is easier to decorticate pleural, reduce unnecessary damage and bleeding, and the pleural resection available from the apex to the crypt costophrenic. Comparison with conventional surgery pleural resection, thoracoscopic

water pleurectomy simplifying the surgical procedure, removing the pleura faster and easier, while reducing postoperative bleeding complications, it has no difference in the effect of conventional surgery for the repeated recurrence of pneumothorax.

2.4. Pleurodesis and Pleural Adhesions

Pleurodesis refers to the procedure of taking a physical, or chemical, or biological methods make aseptic pleural inflammation reaction enable visceral and parietal pleura adhere to each other, in order to eliminate the pleural cavity, reducing gas and liquid exuded. For the persistent or recurrent spontaneous pneumothorax, with history of bilateral pneumothorax, who cannot tolerate the presence of pulmonary dysfunction treatment thoracotomy, and postoperative persistent air leak (> 3 d), in all these cases, pleurodesis or pleural adhesions were clinically used, the clinical success rate is about 60%~94% [26].

2.4.1. Pleurodesis

Pleurodesis is refer to mechanically irritating the parietal pleura be performed via thoracotomy or thoracoscopy. Except for youth, large bubble without other lung diseases need not pleurodesis, the rest of pneumothorax should be performed by pleurodesis. Muramatsu Wait [27] recommend that appropriate portion visceral pleura resection surgery or irritating. While Lee et al. [28] research that using PGA (polyglycolic acid sheet/ NEOVEIL), fibrin glue, etc. to prevent postoperative leakage and recurrence. The followings are the procedure: spraying fibrin glue uniformly on the lung cutting edge, using the PGA material covering lung margin, may could be sprayed fibrin glue on the lung surface one more time. The results showed that the incidence of PGA group of the postoperative persistent air leak (> 3day) is 2.3%, significantly lower than those have not use the PGA (7.8%), and the recurrence rate is also lower. So, it indicates that the using of PGA can effectively prevent postoperative pulmonary air leak and reduce the recurrence rate. However, Uramoto. H etc. [29] Clinical Study of ROCM (regenerated oxidized cellulose mesh), PGA and TC (TachoComb) and other biological materials, the preliminary conclusion that ROCM is better than PGA / TC with faster postoperative and lower recurrence rate (0 & 10-14.2%), and shorten the length of stay.

2.4.2. Chemical Pleural Adhesions

There is a variety of chemical substances to perform the pleural adhesion, but the procedure is substantially the same. Take the hypertonic glucose as an example: Patients taking supine position, 50% glucose 60ml mixed with 2% lidocaine 10ml, then inject into thoracic cavity through the chest drainage tube, clamped the tube, or placing the bottle above the thoracic chest about 50cm, To prevent that hypertonic glucose flowing out, while keeping the gas drainage open; In order to distributed drug uniformly in the pleura, patient rotated in different directions every 5 ~ 20 mins, and opening the chest drainage tube 2 ~ 3 h later; Observing 48h, the above operation could be repeated 2 to 3 times in need, until without gas discharging from the tube [30]. The total effective rate of hypertonic glucose pleurodesis was 92%, part of (53%) patients has chest pain after the glucose pleurodesis. [31].

Researchers and clinicians had used a variety of chemical substances as an adhesive agent, all of them have advantages and disadvantages: (1) antibiotics: In the 1980s, Tetracycline was used as pneumothorax adhesive agent preventing recurrence rate was 75% to 91% [3], but its worst side-effect is severe chest pain. In the 1990s, Many countries have basically stopped production of intravenous tetracycline, leading to extreme shortage of tetracycline, thus the tetracycline as an adhesive agent is restricted. There are also studies of erythromycin 1.5g and gentamicin 32,0000U mixed with 50% glucose 40ml as compound-adhesive agents, compared to talc group, erythromycin and gentamicin group have the advantage of lower recurrence rate and lesser adverse reactions [32]. (2) Talc: Studies have shown that take talc suspension pleurodesis was significantly superior to conventional pleurodesis via VATS for spontaneous pneumothorax, however talc pleurodesis has more adverse reactions, Such as several chest pain, pleural effusion, fever, occasional shock by pleural reaction [33]. In addition, the usage and sterilization of talcum powder were fussy, and asbestos-free talc iodide is also difficult to get. Also, there are many researchers of silver nitrate [34] The basic method is the same versus talcum powder, and the application is also restricted. (3) Fibrin Glue: Biomedical fibrin glue (BFG) also known as fibrin sealant (FS), the main biological glue comprising purified fibrinogen and thrombin from mammalian blood, it can close the wound tissue, biological hemostatic, sterilization, adhering split organ, promoting tissue growth and repair, and without causing inflammatory tissue necrosis and fibrosis, it is similar with human physiological characteristics, can be completely degraded and absorbed into the organization, it is a safe biomaterial. Clinical studies have shown that joint by fibrinogen 2g + thrombin 500 IU injecting into the thoracic cavity through drainage tube, whose effective rate was higher (34.2%) than a simple tube drainage [35]. (4) autologous blood: RobinsonWait [36] earliest report of 50 ml autologous blood per intrathoracic injection, 1-3times more after treatment, about 85% patient can be cured. At present the recommended amount of blood was 50ml to 120 ml [37]. Athanassiadi etc. [37, 38] show that the cure rate was 91.7%~96%, significantly better than hypertonic glucose pleurodesis (54.5%, $P<0.05$), the recurrence rate was 0% ~29%, which the rate of closed tube drainage was 35% ~41%. Therefore, autologous blood pleurodesis is a simple, painless method with a high success rate for and preventing postoperative pulmonary air leak and recurrent pneumothorax, it also can reduce the length of stay.

Also, there are many other biological adhesive agents such as recombinant human interleukin-2 (IL-2), bronchitis vaccine, parvovirus vaccine corynebacterium, white cell interleukins, OK-432 (a bacterin hemolytic Lin Su lactis strain by penicillin treatment, made of freeze-dried) [39], and the javanica oil was being used to tuberculous pneumohydrothorax [40] its clinic

effect needs further study.

Before the pleurodesis, it also can continuous suction with negative pressure in first, the lung wound could be able to heal in 1 week, and the suction can be stopped until the air leak disabled 48h later. It might also be noted that we should be cautious to use suction for pneumothorax, because suction could raise intrapulmonary pressure and pleural pressure, which results in fistula site prolonged healing, even cannot be healed.

3. Conclusion

According to the cause, age, urgency and other symptoms, the clinician should take different treatment. In the future, the minimally invasive closed drainage will become a preference for the pneumothorax needing drainage, it may replace the traditional tube closed drainage. With the maturity of thoracoscopic techniques, basic hospital equipped with thoracoscopy wildly, VATS will become the preferred treatment of pneumothorax with bubble. Autologous blood is a facilitate getting adhesive agents, its procedure is easy and safe with few complications, and it is also an economical method with a high success rate. With improving acceptance of patients and their families, the autologous blood pleurodesis is worthy to be widely spread.

4. Outlook

The clinical treatment of pneumothorax and pulmonary air leak after lung resection have basically become norms. However, it still needs further studies that the economical, effective, appropriate treatment for a special pneumothorax and postoperative lung air leak, continued pneumothorax, senile obstinate recurrent pneumothorax, and pneumothorax in children. We believe that the treatment will be more standardized, effective and reasonable for pneumothorax and postoperative air leak.

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