ORIGINAL RESEARCH

Efficacy of Deep Venous Catheterization in the Management of Pneumothorax: A Clinical Study Utilizing Conventional Closed Thoracic Drainage

Zhongneng Xu, MM; Yaojun Ni, MM; Biao Gu, MM; Hao Zhou, BD; Yonggang Luo, MM; Nunu Li, BD; Sheng Chen, MM

ABSTRACT

Background • Currently, conventional closed thoracic drainage for pneumothorax involves a painful procedure with a higher risk and wider (1~1.5 cm) incision. Minimally invasive catheterized drainage techniques are urgently needed to address this challenge.

Objective • This retrospective study aims to observe the effects of conventional closed thoracic drainage with deep venous catheterization drainage techniques on pneumothorax patients.

Design • It was a retrospective study.

Setting • This study was conducted at Huaian No.1 People's Hospital, Affiliated with Nanjing Medical University.

Participants • A total of 105 pneumothorax patients who underwent conventional closed thoracic drainage (CCTD) or deep venous catheterization drainage technique (DVCDT) procedures at the hospital from 1st February 2020 to 30th October 2022 were selected.

Interventions • Patients received either CCTD or DVCDT.

Primary Outcome Measures • Included: (1) clinical variables; (2) catheterization procedure-related features; and (3) visual analogue scale (VAS) scores from pneumothorax patients.

Results • Both conventional closed thoracic drainage and deep venous catheterization drainage techniques were successfully performed in all 105 (100%) patients, comprising 67 (63.8%) spontaneous pneumothorax, 20 (19%) iatrogenic pneumothorax, and 18 (17.1%) traumatic pneumothorax cases. Significant differences were observed between the enrolled spontaneous pneumothorax and traumatic pneumothorax patients in the two groups (CCTD and DVCDT) ($P = .01$ and $P < .0001$). Additionally, 55 (52.4%) patients underwent deep venous catheterization, while 50 (47.6%) patients underwent conventional closed thoracic drainage. The deep venous catheterization insertion procedure had a shorter mean timing (7.51±1.66 min) compared to the conventional closed thoracic drainage procedure (12.44±1.73 min) ($P < .0001$). Furthermore, VAS scores were significantly lower in pneumothorax patients undergoing deep venous catheterization (2.1±0.99) compared to conventional closed thoracic drainage (5.1±0.81) ($P < .0001$).

Conclusion • Deep venous thoracic drainage technique appears to be safer and more beneficial than conventional closed thoracic drainage procedures for treating pneumothorax. This technique offers advantages such as minimal scarring, lower VAS scores, and shorter insertion time, thereby improving safety and surgical outcomes. (*Altern Ther Health Med.* [E-pub ahead of print.])

Zhongneng Xu, MM; Yaojun Ni, MM; Biao Gu, MM; Yonggang Luo, MM; Sheng Chen, MM; Department of Thoracic Surgery, The Affiliated Huaian No.1 People's Hospital of Nanjing Medical University, Huai'an, China. **Hao Zhou, BD;** Department of Thoracic Surgery, Guanyun People's Hospital, Guanyun, China. **Nunu Li, BD;** Department of Sanatorium 1, Air Force Health Care Center for Special Service Hangzhou Sanatorium 5, Hangzhou, China.

Corresponding author: Sheng Chen, MM
E-mail: chenshengnj@outlook.com

INTRODUCTION

Plural cavities refer to airtight spaces beneath the pleural cavity devoid of gas. When gas infiltrates the pleural cavity, inducing a state of pneumatization, it results in pneumothorax.[1] Symptoms of pneumothorax encompass chest pain, dyspnea, cough, and chest tightness. While some patients may experience symptoms following strenuous physical exertion or while lifting heavy objects, pneumothorax can also manifest during routine activities or at rest.[2] Pneumothorax manifests in three primary forms: spontaneous, traumatic, and iatrogenic-induced.[1,3]

Severe cases of pneumothorax can pose life-threatening risks but are manageable with prompt diagnosis and appropriate treatment. Diagnosis primarily relies on imaging modalities such as computed tomography (CT) or chest X-rays, which reveal evidence of pneumothorax and lung compression.[4,5] When lung compression exceeds 30%, interventions such as puncture, aspiration, closed drainage of

the thoracic cavity, or surgical intervention are typically warranted. Conversely, in cases where lung compression is less than 30%, patients may opt for conservative management strategies such as oxygen therapy and bed rest.[3-6]

The effectiveness of pneumothorax treatment hinges on the drainage outcome following tube insertion, ensuring efficient removal of gas and fluid from the thoracic cavity. Evaluation of drainage effectiveness typically entails post-procedural X-ray or CT imaging to assess lung re-expansion capability. Once lung condition improves, air leakage ceases, and the drainage tube can be safely removed.[6,7]

Currently, conventional closed thoracic drainage (CCTD) for pneumothorax is associated with considerable discomfort due to its painful nature, heightened risk, and wider (1~1.5 cm) incision.[8] This procedure is often poorly tolerated by patients and leaves behind noticeable incision scars upon removal. In contrast, the deep venous catheterization drainage technique (DVCDT) represents a minimally invasive alternative akin to the placement of retention needles. DVCDT offers significantly lower risk, reduced pain, and comparable efficacy to CCTD.[9] Importantly, DVCDT minimally disrupts patients' daily activities and results in no scarring upon removal of the drainage tube.

Meanwhile, CCTD carries a relatively high risk of intercostal bleeding, whereas the risk of bleeding is significantly lower with micro-drainage procedures. In certain cases of pneumothorax, tube insertion for drainage becomes necessary to alleviate chest tightness and prevent exacerbation of pneumothorax.[10-12] During such instances, micro-drainage offers a viable alternative, substantially alleviating patient discomfort and improving their condition. Hence, there is an urgent need for minimally invasive catheterized drainage techniques to manage pneumothorax effectively.

Clinically, pneumothorax primarily arises from chest trauma and the accumulation of gas within the thoracic cavity. The prevailing clinical approach to pneumothorax treatment involves CCTD, yet patients often endure considerable pain during the drainage procedure, necessitating the exploration of alternative treatment modalities.[13] In this regard, a minimally invasive DVCDT is being investigated as a potential solution and is compared with the CCTD technique. Therefore, our study aimed to assess the impact of CCTD and DVCDT on pneumothorax patients within a single-center cohort.

MATERIALS AND METHODS

Study Design

A retrospective study was conducted comprising 105 pneumothorax patients who underwent either CCTD or DVCDT procedures at Huaian No.1 People's Hospital Affiliated with Nanjing Medical University between February 1, 2020, and October 30, 2022, retrospectively. Patients were stratified into two groups based on the procedure received: the CCTD group and the DVCDT group. Strict ethical standards were meticulously followed throughout the study, aligning with the principles outlined in the Declaration of Helsinki. Approval was obtained from the ethics committee of Huaian No.1 People's Hospital, Affiliated with Nanjing Medical University, ensuring compliance with ethical guidelines. Informed consent was obtained from all patients during their hospital stay prior to participation in the study.

Inclusion and Exclusion Criteria

Inclusion criteria were as follows: (1) This study included young and middle-aged patients without significant emphysema who required tube drainage as a preparatory measure before pneumothorax surgery; (2) elderly patients without significant emphysema were also considered for inclusion in the study. Exclusion criteria: (1) Patients with multiple pulmonary bullae; (2) those with tension pneumothorax; and (3) individuals with significant emphysema were excluded from the study; (4) Additionally, patients presenting active bleeding were also not considered for inclusion.

Diagnosis of Pneumothorax

Pneumothorax was diagnosed through anterior-posterior X-ray or CT scan examinations, followed by clinical evaluation by attending physicians prior to initiating drainage procedures.

Conventional Closed Thoracic Drainage (CCTD) Procedure. During the CCTD procedure, the patient assumed a supine position, and the 4th intercostal space in the anterior axillary line was identified. A standard iodophor disinfection sheet was applied to the site. Local infiltration anesthesia with lidocaine was administered, and an incision of approximately 1~1.5 cm was made. Subsequently, vascular forceps were employed to penetrate the chest cavity bluntly, and a 9.3 mm (28-gauge) × 45 cm chest tube (manufactured by PAHSCO Co. Ltd., Taiwan, China) was inserted to the appropriate depth, sutured, and securely fixed. A drainage-sealed bottle was then attached to the tube. The patient was instructed to cough, allowing observation for any gas escape, and the wound surface was covered with gauze.

Deep Venous Catheterization Drainage Technique (DVCDT) Procedure. During the DVCDT procedure, the patient assumed a supine position with the right (left) upper limb slightly abducted. The 4th intercostal space in the anterior axillary line was selected, and a standard iodophor disinfection sheet was applied. Local infiltration anesthesia with lidocaine was administered. Subsequently, a 5 mL syringe was initially utilized, followed by the use of a 10 mL syringe from a deep vein catheterization kit to extract gas once observed. A guide wire (0.89 mm × 60 cm) was then inserted, and the syringe was withdrawn. A deep venous drainage tube measuring 20 cm (manufactured by FORNIA Co. Ltd., Guangzhou, China) was advanced along the guide wire, sutured, and securely fixed. A drainage-sealed bottle was then attached. The subsequent steps mirrored those of the CCTD procedure.

Visual Analogue Scale (VAS) Score

The VAS score was employed to quantify the level of pain experienced by patients. A linear scale, approximately

10 cm in length, was utilized, with "0" denoting an absence of pain and "10" representing the highest level of unbearable pain. The score assigned corresponded proportionally to the severity of pain reported by the patient.

Statistical Analysis

Statistical analysis was conducted using SPSS software (version 20.0, SPSS Inc., Chicago, USA) and GraphPad software (version 8, CA, USA) throughout the study. Measurement data were expressed as mean ± standard deviation ($\bar{x} \pm s$), and a comparison between variables of the two groups was performed using the t test. Descriptive clinical data and variables were presented as proportions [n (%)], with the Chi-square test (x^2) utilized for between-group comparisons. A significance level of $P < .05$ was considered statistically significant.

RESULTS

Patient Demographics

Our study included a total of 105 pneumothorax patients, comprising 50 (47.61%) who underwent CCTD and 55 (52.39%) who underwent DVCDT procedures. In the CCTD group, there were 26 males (52%) and 24 females (48%), with a mean age of 34.58 ± 13.27 years. Conversely, in the DVCDT group, there were 30 males (54.55%) and 25 females (45.45%), with a mean age of 32.29 ± 14.35 years. Notably, patients with pneumothorax presented with various comorbidities, including chronic obstructive pulmonary disease (COPD), pulmonary tuberculosis, heart failure, renal insufficiency, and pleural adhesion, ranging from 4% to 9%. However, no significant differences were observed in terms of gender, age, body mass index (BMI), or comorbidities between the two groups ($P > .05$), refer to Table 1.

Procedural Success and Patient Distribution Analysis

Overall, successful CCTD or DVCDT procedures were performed in all 105 (100%) patients, with 67 (63.8%) presenting spontaneous pneumothorax, 20 (19%) experiencing iatrogenic pneumothorax, and 18 (17.1%) suffering traumatic pneumothorax. Specifically, there were 40 cases of spontaneous pneumothorax in the CCTD group and 27 cases of spontaneous pneumothorax, along with 18 cases of traumatic pneumothorax in the DVCDT group. Statistical analysis revealed significant differences between the enrolled spontaneous pneumothorax and traumatic pneumothorax patients in the CCTD and DVCDT groups ($P = .01$ and $P < .0001$). Refer to Table 2.

Comparative Efficacy of Two Catheterization Procedures in Pneumothorax Patients

During the comparison, it was noted that the DVCDT procedure exhibited a significantly shorter mean duration (7.50 ± 1.67 min) compared to CCTD (12.43 ± 1.75 min) ($P < .0001$). Additionally, the VAS score was notably higher among pneumothorax patients undergoing CCTD (5.1 ± 0.81) compared to those undergoing DVCDT (2.12 ± 0.99) ($P < .0001$). Patients treated with both modalities typically had an average indwelling time of 3-5 days post-catheterization, with no significant difference observed ($P = .8425$). Refer to Table 3.

Table 1. Baseline Characteristics of Patients Undergoing Different Drainage Techniques [n (%)]/ ($\bar{x} \pm s$)[a]

Characteristics	CCTD Group *n*=50	DVTDT Group *n*=55	*P* value
Gender			
Male	26 (52%)	30 (54.55%)	.794
Female	24 (48%)	25 (45.45%)	
Age (mean±SD)	34.58±13.27	32.29±14.35	.399
Range (years)	(16~80)	(17~80)	
Body-Mass Index (BMI)	26.6±3.38	27.52±2.96	.137
Comorbidities[a]			
COPD	2 (4%)	3 (5.45%)	
Pulmonary Tuberculosis	2 (4%)	3 (5.45%)	.544
Heart Failure	2 (4%)	1 (1.81%)	
Renal Insufficiency	2 (4%)	4 (7.27%)	
Pleural Adhesion	4 (8%)	5 (9.09%)	

[a]Excluding other comorbidities: Not available/Not recorded.

Note: The table underscores the essential baseline characteristics necessary for understanding patient profiles in the context of pneumothorax management.

Abbreviations: COPD, Chronic Obstructive Pulmonary Disease; CCTD, Conventional Closed Thoracic Drainage; DVTDT, Deep Vein Thoracic Drainage Technique

Table 2. Distribution of Pneumothorax Types among Enrolled Patients [n (%)]

Types	CCTD Group n=50	DVCDT Group n=55	*P* value
Spontaneous Pneumothorax			
Yes	40 (80%)	27 (49.09%)	.01
No	10 (20%)	28 (50.91%)	
Iatrogenic Pneumothorax			
Yes	10 (10%)	10 (18.18%)	.812
No	40 (80%)	45 (81.82%)	
Traumatic Pneumothorax			
Yes	NA	18 (32.73%)	<.0001
No	50(100%)	37 (67.27%)	

Note: This table presents the distribution of enrolled patients categorized by the type of pneumothorax and the drainage technique employed. Patients were either treated with conventional closed thoracic drainage (CCTD) or deep vein thoracic drainage technique (DVCDT).

Table 3. Comparison of Catheterization-Related Outcomes in Pneumothorax Patients

Variables	CCTD Group n=50	DVCDT Group n=55	*P* value
VAS	5.1±0.81	2.12±1.001	<.0001
Insertion time	12.43±1.75 (min)	7.50±1.67 (min)	<.0001
Indwelling time	3.74±0.80 (Day)	3.70±0.78 (Day)	.8425

Note: This table presents a comparison of catheterization-related outcomes between patients undergoing conventional closed thoracic drainage (CCTD) and those undergoing deep vein thoracic drainage technique (DVCDT). The outcomes assessed include VAS score, insertion time (in minutes), and indwelling time (in days).

Abbreviations: VAS, Visual Analogue Scale/Score.

DISCUSSION

The clinical application of medical techniques to evacuate intrathoracic gas and enable efficient catheterization of lung tissue has proven highly effective in managing patients with

pneumothorax.[14,15] The primary method for treating pneumothorax involves making an incision in the thoracic wall and inserting a drainage tube, commonly referred to as the CCTD method. This method ensures unimpeded gas drainage within the chest cavity, thereby promoting the resolution of pneumothorax and lung lacerations.[15,16]

However, the traditional drainage procedure is characterized by its complexity and invasiveness. Patients undergoing this treatment often experience unbearable pain, increased risk of bleeding, and potential lung injury, which can impede their prognosis and recovery.[17] In recent years, there has been a shift towards utilizing minimally invasive technology, such as the adoption of deep venous drainage tubes instead of traditional chest tubes for closed thoracic drainage. This approach is favored due to the softer texture of the tubes and the smaller size of the incisions required.[18]

The DVCDT procedure is characterized by its simplicity and efficiency. With a small lumen and minimal wound size, the procedure is relatively less painful, resulting in fewer complications and higher patient acceptance. The needle used is composed of second-generation polyurethane-based material, which is histocompatible and facilitates easy puncture. Importantly, it remains firm upon entry into the body, minimizing damage to surrounding tissues and blood vessels. These features make central venous closed thoracic drainage particularly suitable for elderly patients.[19-22]

The puncture operation can be conducted independently without the need for skin incision, resulting in minimal tissue damage and facilitating bedside emergencies. It allows for gradual aspiration until lung re-expansion is achieved. It can be repeated or transitioned to closed drainage for pneumothorax treatment. In case of catheter blockage, recanalization can be achieved through air injection or guidewire insertion. This minimally invasive procedure typically entails the placement of only one tube, promoting scarless wound healing and minimal disruption to the patient's daily activities.[21,22]

For certain pneumothorax patients, such as young individuals, middle-aged adults, or children with pneumothorax and good lung quality without significant emphysema, the use of DVCDT as a drainage method is favored. This approach offers several advantages, including low procedural complexity, minimal tissue injury, mild discomfort, enhanced patient comfort, and smaller incisions post-decannulation, resulting in minimal scarring. Additionally, DVCDT can effectively serve as a transitional treatment for pneumothorax patients before surgery, thereby alleviating patient discomfort. However, drawbacks of DVCDT include inadequate drainage in some cases, necessitating re-cannulation, and further drainage procedures.[22,23]

In the current study, both CCTD and DVCDT procedures were successfully conducted in all 105 patients diagnosed with pneumothorax. The mean insertion procedure time was (9.85 ± 3.01) minutes, with a 100% success rate achieved, highlighting the effectiveness and ease of the catheterization methods. Pneumothorax diagnosis was confirmed through X-ray or CT scan prior to drainage procedures. Patients who did not require additional treatments underwent either CCTD or DVCDT as per routine protocol.

The present study revealed the successful implementation of catheterization procedures, namely CCTD or DVCDT, in a majority of cases, including 67 (63.8%) spontaneous pneumothorax patients, 20 (19%) iatrogenic pneumothorax cases, and 18 (17.1%) traumatic pneumothorax cases. This observation aligns with the findings of Huang et al.,[23] who similarly found that the minimally invasive approach yielded superior outcomes compared to conventional methods, as evidenced by improved bed mobilization, lower VAS scores, and reduced incidence of complications.

In our study, both CCTD and minimally invasive DVCDT were employed as common methods for treating pneumothorax clinically. CCTD involves making an incision in the patient's skin during the procedure, and the drainage tube used is thicker, resulting in increased trauma to the patient. Additionally, the procedure duration is prolonged, potentially leading to complications such as subcutaneous edema and incision infections.

The minimally invasive DVCDT procedure stands out for its simplicity and utilization of central venous catheter drainage, which minimizes the risk of tissue compression or damage. This approach not only reduces patient trauma but also alleviates postoperative pain, facilitating early resumption of daily activities and expediting recovery.[24,25] Particularly for young pneumothorax patients, DVCDT offers a less traumatic alternative with enhanced postoperative recovery outcomes and reduced complication rates.[24-27] Compared to CCTD, this minimally invasive approach ensures greater safety, diminishes the likelihood of adverse reactions, and upholds the life safety of pneumothorax patients, thereby demonstrating satisfactory clinical utility.

However, DVCDT is less complex and requires simpler operating techniques and procedures, which makes it more accessible for young physicians.[28] Nonetheless, a drawback is that some patients with significant pneumothorax leakage may experience inadequate drainage, leading to complications such as subcutaneous emphysema, necessitating the replacement of the conventional chest tube during the CCTD procedure.[29-31] Therefore, DVCDT is primarily indicated for younger patients without COPD, typically with more severe conditions. Our study demonstrated successful CCTD or DVCDT procedures in all patients without any major complications observed.

Study Limitations

While our study provides valuable insights into the comparative efficacy of CCTD and DVCDT procedures in treating pneumothorax patients, several limitations should be acknowledged. Firstly, the retrospective design of the study may introduce inherent biases and limit the generalizability of the findings. Additionally, the study was conducted at a single center, which may limit the diversity of patient demographics and clinical presentations. Moreover,

the relatively small sample size might affect the statistical power and precision of our results. Furthermore, the lack of long-term follow-up data limits our ability to assess the durability and sustained effectiveness of the catheterization procedures. These limitations underscore the need for larger prospective studies with longer follow-up periods to validate our findings and further explain the optimal management strategies for pneumothorax patients.

CONCLUSION

In conclusion, our study suggests that DVCDT offers potential advantages over CCTD in the management of pneumothorax. With its minimal scarring, lower VAS scores, and shorter insertion time, DVCDT presents as a safer and more beneficial alternative for patients undergoing pneumothorax treatment. The findings of this study contribute valuable insights into the clinical approach to pneumothorax management, highlighting the potential benefits of DVCDT in improving safety and surgical outcomes. These results serve as a valuable reference for clinicians seeking to optimize treatment strategies for pneumothorax patients, emphasizing the importance of considering minimally invasive techniques such as DVCDT in clinical practice.

COMPETING INTERESTS

The authors report no conflict of interest.

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AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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