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Management of traumatic hemothorax by closed thoracic drainage using a central venous catheter

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Abstract: Objective: To evaluate the efficacy and safety of the treatment of traumatic hemothorax by closed pleural drainage using a central venous catheter (CVC), compared with using a conventional chest tube. Methods: A prospective controlled study with the Ethics Committee approval was undertaken. A total of 407 patients with traumatic hemothorax were involved and they were randomly assigned to undergo closed pleural drainage with CVCs (n=214) or conventional chest tubes (n=193). The Seldinger technique was used for drainage by CVC, and the conventional technique for drainage by chest tube. If the residual volume of the hemothorax was less than 200 ml after the daily volume of drainage decreased to below 100 ml for two consecutive days, the treatment was considered successful. The correlative data of efficacy and safety between the two groups were analyzed using t or chi-squared tests with SPSS 13.0. A P value of less than 0.05 was taken as indicating statistical significance. Results: Compared with the chest tube group, the operation time, fraction of analgesic treatment, time of surgical wound healing, and infection rate of surgical wounds were significantly decreased ($P<0.05$) in the CVC group. There were no significant differences between the two groups in the success rate of treatment and the incidence of serious complications ($P>0.05$), or in the mean catheter/tube indwelling time and mean medical costs of patients treated successfully ($P>0.05$). Conclusions: Management of medium or large traumatic hemothoraxes by closed thoracic drainage using CVC is minimally invasive and as effective as using a conventional large-bore chest tube. Its complications can be prevented and it has the potential to replace the large-bore chest tube.

Key words: Central venous catheter, Drainage, Trauma, Hemothorax
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1 Introduction

Traumatic hemothorax commonly occurs after trauma. Medium or large traumatic hemothoraxes are treated primarily by closed thoracic drainage, traditionally by inserting a large-caliber chest tube (in China, a 2-cm diameter stiff silicone tube is typically used) through an incision along the sixth or seventh spatium intercostale around the midaxillary line on the affected side. The insertion and indwelling of the chest tube, however, are painful procedures. Parker *et al.* (1989) introduced the use of small-caliber (2.66–4.66 mm diameter) pig-tail catheters to replace the traditional large-caliber chest tubes for the management of large malignant pleural effusions. They found that these small-caliber catheters had a performance similar to large-caliber tubes, but with substantially reduced pain levels. The advantages of small-caliber catheters have subsequently been confirmed in numerous studies (Grodzin and Balk, 1997; Clementsen *et al.*, 1998; Putnam *et al.*, 2000; Parulekar *et al.*, 2001) and the British Thoracic Society (BTS) guidelines for the management of malignant pleural

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effusions (Antunes *et al.*, 2003) recommend the use of small-caliber catheters in lieu of larger-caliber chest tubes.

Inspired by the success of small-caliber catheters, we recently investigated the treatment of traumatic hemothorax by closed thoracic drainage using central venous catheters (CVCs) instead of traditional chest tubes. In this study, we compared the efficacy and safety of CVCs with those of traditional chest tubes.

2 Subjects and methods

2.1 Subjects and groups

This randomized prospective study, approved by the local Ethics Committee, recruited subjects from patients admitted to the emergency center of the Second Affiliated Hospital, School of Medicine, Zhejiang University between July 2003 and December 2009. All patients were confirmed by ultrasonography or computed tomography (CT) to have hemothorax caused by blunt trauma, with bleeding volumes of over 500 ml in the thoracic cavity, measured according to our reported method (Zhang *et al.*, 2007; 2011). Patients with any of the following conditions were excluded from the study: coma, being prescribed sedative or anodyne within 2 d, coagulated hemothorax, infectious hemothorax, hemopneumothorax, bilateral hemothorax, euplastic hemothorax, or coagulation dysfunction. Patients with a history of tumor, pleurisy, or pleural effusion were also excluded.

A total of 417 subjects (151 females and 266 males, 14–86 years old with a mean age of 36.4 years) were recruited, including 283 with traffic injuries, 89 with fall injuries, 21 with crush injuries, and 24 with other injuries. Their injury severity scores (ISSs) ranged from 14–41 (mean 23.4±10.4). They were assigned to undergo the treatment with CVCs (n=220) or chest tubes (n=197), according to whether their dates of admission were even- or odd-numbered. The two groups were similar in terms of age, sex ratio, and ISS (all P>0.05).

2.2 Treatments

2.2.1 Drainage with a central venous catheter

The position, direction, and depth of puncture were planned with the assistance of type-B ultrasonics. Most of the puncture points were located at the fifth or sixth spatium intercostale along the midaxillary line. A CVC (1.7-mm diameter, 16-gauge; Arrow International, Reading, PA, USA) was then inserted at the puncture point using the Seldinger technique to a depth of 8–15 cm. The external end of the CVC was connected to a drainage bag and the CVC was rinsed with 20 ml of physiological saline once every 8 h.

2.2.2 Drainage with a chest tube

The skin was incised along the sixth or seventh spatium intercostale around the midaxillary line on the affected side. A silicone chest tube (about 2 cm external diameter) was inserted through the incision according to BTS guidelines for the insertion of a chest drain (Laws *et al.*, 2003). The external end of the tube was connected to a water-sealed drainage bottle, which was replaced once daily.

2.3 Clinical observations

When the 24-h drainage volume was <100 ml on two consecutive days, the residual volume of blood in the thoracic cavity was determined by ultrasonography, as described in our reports (Zhang *et al.*, 2007; 2011). If the residual volume was <200 ml, the treatment was considered to have been successful and the study was completed. The catheter/tube was then removed. If the residual volume was ≥200 ml, the treatment was regarded as unsuccessful, and the study was also terminated. Further treatment was needed after termination of the study in the latter cases; e.g., the depth and direction of the catheter/tube might have needed adjustment, or closed thoracic drainage might have needed to be performed again. Thoracotomy or video-assisted thoracoscopic surgery was also performed if required.

The following conditions were considered to be severe complications of the procedure: intraoperative pneumothorax, stabbing of organs in the thoracic or abdominal cavities by puncture needle, severe pleural reaction (respiratory rate ≥30 min^{-1}, systolic blood pressure <90 mmHg), postoperative reexpansion pulmonary edema, infectious hemothorax, or coagulated hemothorax. A euplastic hemothorax considered by the thoracic surgeon to require thoracotomy or video-assisted thoracoscopic surgery was also classed as a severe complication.

Data from every patient in the two groups were monitored, including drainage volumes throughout the study, operation time, wound healing time, incidence of severe complications, requirement of postoperative analgesia, infection of surgical wounds, and treatment efficacy (success or failure). Moreover, the catheter/tube indwelling time and medical cost were recorded in the successfully treated patients.

2.4 Statistical analyses

The ratios and incidences were compared using chi-squared tests, and mean values were analyzed by two independent sample *t*-tests. A P value of <0.05 was considered statistically significant.

3 Results

Six patients in the CVC group and four patients in the chest tube group developed progressive hemothorax during clinical observations. They were immediately assigned to undergo emergency chest surgery, and were excluded from this study. The other 407 patients completed the study, and their outcomes are listed in Table 1.

The CVC group had significantly shorter operation time and wound healing time compared with the chest tube group; moreover, a significantly smaller fraction of patients required postoperative analgesia and developed postoperative wound infections (all $P<0.05$). However, there was no statistical significance between the two groups in the mean drainage volume throughout the drainage period ($P>0.05$), or in the ratio of treatment success ($P>0.05$). The successfully treated patients in both groups had similar catheter/tube indwelling time and medical costs (both $P>0.05$). Furthermore, the two groups showed a similar incidence of severe complications ($P>0.05$), as shown in Table 2.

In the CVC group, one patient developed severe pleural reactions and two developed reexpansion pulmonary edema. In the chest tube group, three and two patients, respectively, experienced these two complications. All eight cases were identified promptly and relieved completely after standard treatment procedures. Seven patients in the CVC group and six in the chest tube group underwent chest surgery (thoracotomy or video-assisted thoracoscopic surgery) because of coagulated or euplastic hemothorax. Three patients in the CVC group who developed pneumothoraxes were switched to continuous negative-pressure suction treatment and their conditions improved after 3–4 d. In comparison, the three patients in the chest tube group who developed infectious hemothoraxes were treated with additional antibiotics and thoracic cavity rinsing, and their conditions improved within four weeks. Two patients in the CVC group experienced puncture damage to their hearts during puncturing of their left thoracic cavities. Both patients developed arrhythmia and low systolic blood pressure (<90 mmHg) immediately, and pericardial effusion was detected by subsequent bedside ultrasonography. They were treated by immediate bedside thoracotomy followed by cardiac massage. After incising the pericardium, a 1.5-cm-long rupture and a 1.1-cm-long rupture, respectively, were found on the external wall of the left ventricle in the two patients. The patients' hemodynamic conditions gradually stabilized after repair of the ruptures. However, the first patient died of subsequent cardiac arrest 2 d after cardiac repair, and the other patient died of multiple organ failure 5 d after cardiac repair.

Table 1 Comparison of correlative data between the CVC group and the chest tube group

Variable	Value		P value
	CVC group (n=214)	Chest tube group (n=193)	
Drainage volume throughout the study (ml)	890±150	840±110	>0.05
Operation time (min)	4.5±1.5	9.4±3.0	<0.05
Surgical wound healing time (d)	2.9±0.4	8.2±5.0	<0.05
Patients with analgesic treatment	8 (3.7%)	44 (22.8%)	<0.05
Patients with wound infection	0 (0%)	15 (7.8%)	<0.05
Patients with severe complications	15 (7.0%)	14 (7.3%)	>0.05
Success rate by the first thoracic drainage	175 (81.8%)	154 (79.8%)	>0.05
Catheter/tube indwelling time of successfully treated patients (d)	4.6±2.5	5.0±1.7	>0.05
Medical costs of successfully treated patients (CNY)	158.2±18.0	168.0±20.4	>0.05

Table 2 Comparison of the incidence of severe complications between the CVC group and the chest tube group

Complication	Number	
	CVC group (n=214)	Chest tube group (n=193)
Severe pleural reaction	1	3
Reexpansion pulmonary edema	2	2
Organ wound by puncture needle	2	0
Pneumothorax	3	0
Coagulated or euplastic hemothorax, chest surgery performed	7	6
Infectious hemothorax	0	3
Sum	15 (7.0%)	14 (7.3%)

4 Discussion

This study suggests that the results from the treatment of traumatic hemothorax by closed thoracic drainage using a CVC are similar to those from using a traditional chest tube, in terms of efficacy and medical cost. Additionally, CVCs offer the major advantages of a simpler operation, minimal invasion, less interference with patients' activities and sleep, and no remaining scars. CVCs are therefore more acceptable to both clinicians and patients.

The limitations of this study should be acknowledged before we consider its implications and possible explanations for the outcomes. First, we used a new method to measure pleural effusion volume based on measuring the area of effusion by ultrasound. The method is more efficient and reliable than traditional methods, but its accuracy cannot be confirmed (Zhang *et al.*, 2007; 2011) as it is very difficult to measure pleural effusion volume. Second, because there has not been an accepted standard up to now, we created our own standard for the successful treatment of traumatic hemothorax based on our clinical experiences, which may not be accepted by other clinicians. Despite these limitations, the study's outcomes should not be affected because identical methods and standards were applied to the two groups.

CVCs are characterized by their small caliber, and clinicians may therefore be concerned about the possibility of obstruction, and that their slow drainage speed could negatively affect the identification of 'progressive hemothorax' during drainage. Although considerably thinner than chest tubes, CVCs are made from second-generation polyurethane with excellent biocompatibility. In this study, CVCs had a similar success rate to regular chest tubes, and were no more susceptible to obstruction. Moreover, the indwelling time was similar in successfully treated patients in both groups. If catheter obstruction does occur, it can be cleared by simply rinsing with physiological saline or, even more effectively, by using the guide wire supplied with the catheter (Shang and Lou, 2001; Singh *et al.*, 2003). In contrast, obstructed chest tubes are difficult to clear, and patients can be treated only by replacing the catheter/tube or by repeated puncture tapping.

The occurrence of 'progressive hemothorax' is indicated by an accelerated pulse rate, reduced systolic blood pressure, and decreased hemoglobin concentration. It can also be effectively identified by the important criterion of a closed thoracic drainage volume of >200 ml/h for three consecutive hours (Wu and Wu, 2003). Although the drainage speed of a CVC is slower than that of a chest tube, we found that a CVC was still able to drain >1 000 ml of effusion fluid per hour in large hemothorax cases. Singh *et al.* (2003) used CVCs to drain pleural effusions in 15 patients and recorded a mean drainage volume of (454±241) ml in the first hour after catheterization, substantially higher than 200 ml/h. This suggests that use of an unobstructed CVC would not hinder the identification of progressive hemothorax. In this study, progressive hemothoraxes were promptly identified on the basis of abnormal drainage speed in six patients in the CVC group, and all these cases were confirmed by subsequent surgery. Indeed, CVCs can produce a high drainage speed, similar to chest tubes, and can even induce subsequent reexpansion pulmonary edema. We experienced two such cases during the early phase of this study, before we became aware of this risk. Reexpansion pulmonary edema can pose a major risk to the patient, with a mortality of up to 20% (Trachiotis *et al.*, 1997). The CVC should therefore be clamped intermittently to control the drainage speed and prevent the occurrence of reexpansion pulmonary edema, provided that the diagnosis of progressive hemothorax is not negatively affected.

The complications associated with the insertion of a CVC should not be ignored. Most involve the stabbing of organs in the thoracic or abdominal cavities during the puncture. In the first year of this study, we experienced two cases of heart injury by puncture needle, the most severe complication, during the operation of left chest drainage. In the first case, the sonographers in our hospital were so busy that they could tell us only the puncture point and depth at the beginning and did not have enough time to guide us throughout the thoracentesis. In the second case, the operators had not been adequately trained and advanced the puncture needle inappropriately and rapidly. So, ultrasound-guided puncture and a skillful operator are the key requirements for preventing complications. Fortunately, we mastered the technique of focused assessment with sonography for trauma (FAST) after one year (Scalea *et al.*, 1999; Habib and McKenney, 2004), and could then guide ourselves throughout a thoracentesis. With the help of FAST and proficient operators, there were no more severe complications from October 2005 to the end of the study. In addition, for patients with an enlarged left heart shadow on a chest X-ray, or if the heart is close to the left chest wall because of pneumatothorax or atelectasis, the planned point of the left chest puncture should be located closer to the left posterior axillary line; alternatively, the patient may be treated using a traditional chest tube. Heart injury by the puncture needle should be first suspected in the event of cardiac arrhythmia, heart arrest, or the syndrome of pericardial tamponade during puncture. Once the diagnosis is confirmed, the patient should be immediately managed by cardiopulmonary cerebral resuscitation, pericardial drainage, or thoracotomy.

Infection of the surgical wound and thoracic cavity is another potential complication after closed thoracic drainage. A CVC is inserted by direct puncture, generating a minimal gap in the adjacent soft tissues. This relatively tight seal means that blood cannot leak from the pleural cavity to the puncture site during the indwelling of the CVC. After removal of the CVC, the soft tissues can readily close the puncture hole and prevent the effusion of blood. Blood effusion can promote the growth of bacteria on the body surface and even their translocation to the thoracic cavity along the catheter/tube. Consequently, the puncture site rarely develops infection if the CVC indwelling time is shorter than one week. However, a chest tube is typically inserted through an incision in the skin, generating a larger gap in adjacent soft tissues. Blood effusion can thus leak from the incision more easily, both during the indwelling phase and after removal of the tube, resulting in an increased risk of wound infection, and even empyema. Accordingly, we observed no cases of wound infection in the CVC group in the current study, while the chest tube group had an infection rate of 7%, including two cases of empyema. This difference was significant, demonstrating another advantage of CVCs.

Whether by CVC or large-caliber chest tube, closed thoracic drainage for the treatment of traumatic hemothorax still has some limitations. Besides the severe complications, the success rates of the first closed thoracic drainage in the two groups in our study were not satisfactory, both being about 80%. The confined body position of the traumatic patient was the probable reason and the success rate could perhaps be elevated by encouraging the patients to change their body positions or, in the case of CVC patients, even to get out of bed after sufficient analgesia. In addition, about 3% of patients in each of the two groups in our study eventually underwent chest surgery (thoracotomy or video-assisted thoracoscopic surgery) because of a coagulated hemothorax or a serious euplastic hemothorax. How to prevent the incidence of coagulated or euplastic hemothorax during closed thoracic drainage is still an intractable question deserving further exploration.

5 Conclusions

The use of an indwelling CVC is efficacious for the drainage of uncomplicated medium or large traumatic hemothoraxes, with the advantages of simple operation and minimal invasion. Although some severe complications may occur, they can be prevented by ultrasound-guided puncture and the use of adequately trained operators. Accordingly, it has the potential to replace the large-bore chest tube in the drainage of such hemothoraxes.

References

Antunes, G., Neville, E., Duffy, J., Ali, N., 2003. BTS guidelines for the management of malignant pleural effusions. *Thorax*, **58**(s2):ii29-ii38.

Clementsen, P., Evald, T., Grode, G., Hansen, M., Krag, Jacobsen, G., Faurschou, P., 1998. Treatment of malignant pleural effusion: pleurodesis using a small percutaneous catheter, a prospective randomized study. *Respir. Med.*, **92**(3):593-596. [doi:10.1016/S0954-6111(98)90315-8]

Grodzin, C.J., Balk, R.A., 1997. Indwelling small pleural catheter needle thoracentesis in the management of large pleural effusions. *Chest*, **111**(4):981-988. [doi:10.1378/chest.111.4.981]

Habib, F.A., McKenney, M.G., 2004. Surgeon-performed ultrasound in the ICU setting. *Surg. Clin. North Am.*, **84**(4):1151-1179. [doi:10.1016/j.suc.2004.04.003]

Laws, D., Neville, E., Duffy, J., 2003. BTS guidelines for the insertion of a chest drain. *Thorax*, **58**(s2):ii53-ii59.

Parker, L.C., Charnock, G.C., Delany, D.J., 1989. Small bore catheter drainage and sclerotherapy for malignant pleural effusions. *Cancer*, **64**(6):1218-1221. [doi:10.1002/1097-0142(19890915)64:6<1218::AID-CNCR2820640609>3.0.CO;2-V]

Parulekar, W., di Primio, G., Matzinger, F., Dennie, C., Bociek, G., 2001. Use of small-bore VS large-bore chest tubes for treatment of malignant pleural effusions. *Chest*, **120**(1):19-25. [doi:10.1378/chest.120.1.19]

Putnam, J.B.Jr., Walsh, G.L., Swisher, S.G., Roth, J.A., Suell, D.M., Vaporciyan, A.A., Smythe, W.R., Merriman, K.W., DeFord, L.L., 2000. Outpatient management of malignant pleural effusion by a chronic indwelling pleural catheter. *Ann. Thorac. Surg.*, **69**(2):369-375. [doi:10.1016/S0003-4975(99)01482-4]

Scalea, T.M., Rodriguez, A., Chiu, W.C., Brenneman, F.D., Fallon, W.F.Jr., Kato, K., McKenney, M.G., Nerlich, M.L., Ochsner, M.G.Jr., Yoshii, H., 1999. Focused assessment with sonography for trauma (FAST): results from an international consensus conference. *J. Trauma*, **46**(3):466-472. [doi:10.1097/00005373-199903000-00022]

Shang, Q., Lou, Q., 2001. Nursing care in the closed thoracic drainage with central venous catheter for pneumothorax. *Chin. J. Nursing*, **36**(4):277 (in Chinese).

Singh, K., Loo, S., Bellomo, R., 2003. Pleural drainage using central venous catheters. *Crit. Care*, **7**(6):R191-R194. [doi:10.1186/cc2393]

Trachiotis, G.D., Vricella, L.A., Aaron, B.L., Hix, W.R., 1997. Reexpansion pulmonary edema. *Ann. Thorac. Surg.*, **63**(4):1206-1207. [doi:10.1016/S0003-4975(97)00193-8]

Wu, Z.D., Wu, Z.H., 2003. Surgery, 6th Ed. People's Medical Publishing House, Beijing, China, p.338 (in Chinese).

Zhang, M., Yang, J., Liu, Z., Gang, J., Xu, S., Jiang, G., 2007. Study on distribution and precise quantification of pleural effusion in mechanically ventilated patients. *Chin. J. Crit. Care Med.*, **27**(10):874-877 (in Chinese).

Zhang, M., Yang, J., Xu, S., Ba, L., Liu, Z., Hong, Y., Gang, J., Xu, S., Jiang, G., 2011. Development of a new method to measure pleural effusion volume by ultrasound in critically ill patients. *Chin. J. Ultras*, **20**(2):129-133 (in Chinese).