Asian Biomedicine Vol. 7 No. 3 June 2013; 325-331
DOI: 10.5372/1905-7415.0703.183

Original article

Effectiveness assessment when treating with a closed thoracic drainage system

Hong Li[a], Na Li[b], Li-Li Chen[a]
[a]*Department of Nursing Administration,* [b]*Department of Surgical Intensive Care Unit, Fujian Provincial Hospital, Fu Zhou 350001, China*

Background: The role of nursing in the management of chest drains is diverse and important. There is a paucity of data regarding the management of chest drains by nurses.

Objective: To establish an evaluation system for nurses to help guide the care of patients being treated with closed thoracic drainage tubes.

Methods: An ADC (availability, dependability, and capacity) model was used as the framework to evaluate treatment guidelines. A questionnaire was developed and tested for reliability and validity based on experimental models of thoracic drainage. Patients were subsequently randomly selected and screened using the effectiveness assessment form.

Results: Overall dimension scores and subgroups were correlated (r > 0.7). Test–retest reliability met required standards (r = 0.769–0.889, $p < 0.01$). The correlation coefficient between scores of each dimension and total score was 0.542 to 0.920, and correlation coefficients for each item and its dimension were 0.429 to 0.887.

Conclusions: The proposed assessment form provides an evidence-based tool for nurses to effectively manage patients with closed thoracic drainage systems. Experimental and clinical measures confirm the tool's reliability and validity.

Keywords: Closed thoracic chest drain, evidence-based, nurses

Closed thoracic drainage is a widely applied therapeutic postsurgical intervention in respiratory and cardiothoracic care [1]. The purpose of closed thoracic drainage is to remove air, blood or other fluids from the pleural cavity and mediastinum in order to maintain stability of heart and lung function, and hemodynamics [2]. Inappropriate management of a drainage tube can result in numerous complications, including drainage failure, prolonged hospital stay, or even death under certain circumstances [3, 4].

Nurses play a very important role in the effective maintenance of drainage tubes. It is the responsibility of a well-trained nurse to maintain an appropriate drainage tube position, to observe and manage the drainage system when transferring the patient, and to ensure overall patient safety [5]. Nursing care of patients with chest tube drainage systems has long been based on anecdotal evidence, rather than evidence-based research [6]. Lack of uniformity in nursing methods and lack of evidence-based guidelines promotes uncertainty in the effective management and maintenance of closed thoracic drainage systems [1].

Despite the publication of management guidelines for thoracic drainage by the British Thoracic Society, whose focus has been primarily for physicians to execute indwelling and drainage tube removal, there remains a paucity of data and standards for nurses to refer to when maintaining and managing a closed thoracic drainage system. A correct, accurate, and proper evaluation of a drainage system to determine overall effectiveness is needed; as well as, an evaluation system to help guide nurses in their care of patients being treated with drainage tubes.

There are many methods for effectiveness analysis, ADC (availability, dependability, and capacity), is widely used. The ADC method has been applied broadly to the evaluation of system effectiveness. The three factors, availability, dependability and capacity, are used to evaluate a system and can be presented in combination for a single measurement of total

Correspondence to: Hong Li, Fujian Provincial Hospital, Fujian Medical University Affiliated Clinical Medical Institute, Nursing School of Fujian Medical University, No. 134, East Street, Fuzhou City Fujian, China. E-mail: michikoaihara25@gmail.com

performance. Briefly, the factors represent a system's state of readiness (availability), its ability to function dependably (dependability), and the system's ability to complete the task in an effective manner (capacity). System effectiveness is the product of these three dimensions (E = ADC). The effectiveness evaluation system for a closed thoracic drainage system was established using the framework of an ADC model.

Methods

Establishing guidelines for closed thoracic drainage included four stages: (1) optimizing the closed thoracic drainage system conditions under experimental conditions to test key effectiveness factors; (2) selection of evaluation guidelines and content validity test; (3) clinical evidence investigation; and (4) assessment form reliability and validity test. All data were collected between March 2010 and March 2011. The study was approved by the Institutional Review Board of Fujian Provincial Hospital. We obtained written informed consent from all participants involved in the study, and informed written consent from the next of kin, carers or guardians on the behalf of the minors/children participants involved in the study.

Optimizing chest drainage

Drainage tube diameter and length were examined under experimental conditions to determine drainage effectiveness. The results based on this model were then integrated into the assessment system. Briefly, normal saline was used to replace pleural transudate and 62% (mass percentage) glycerol (viscosity = 11.11 millipascal-second [equal to blood viscosity]) was used to replaced pleural effusion in the experiment (**Figure 1**). At a room temperature of 25°C, 1000 ml normal saline was effused via pressure port into the pleural cavity of the drainage model. Heart rate was set to 20 bpm. Pleural cavity setting was closed and pleural cavity negative pressure was adjusted to-10 mmHg. Drainage time for normal saline and glycerol with variable drainage tube diameter (16F to 36F), drainage tube length (100 to 180 cm), and tube position (vertical, curved, and circular) was measured to an accuracy of 0.1 second. Height of drainage was set to 76 cm. All experimental conditions were repeated 10 times in order to minimize inaccurate/variable measurements. An average was calculated after the highest and lowest scores were eliminated for each subject.

Selection of evaluation guidelines and content validity test

An ADC model was used as the framework to evaluate guidelines. The dimensions of the current analysis tool were: "A" (availability), "D" (dependability), and "C" (capacity). The dimension of availability included four items (drainage setting complete and available, qualified hospital staff, sound regulations, and safe and regulated environment). The dimension of dependability included five items (safety of the drainage system, patency of the drainage system, aseptic level of the drainage system, closeness of the drainage system, and levels of humanistic care). The dimension of capacity included four items (assessment of drainage effectiveness, assessment of complications, assessment for pain of patients, and assessment for comfort of patients). As part of the development, 25 experts (13 cardiothoracic surgeons/ ICU clinical medical experts, and 12 ICU senior

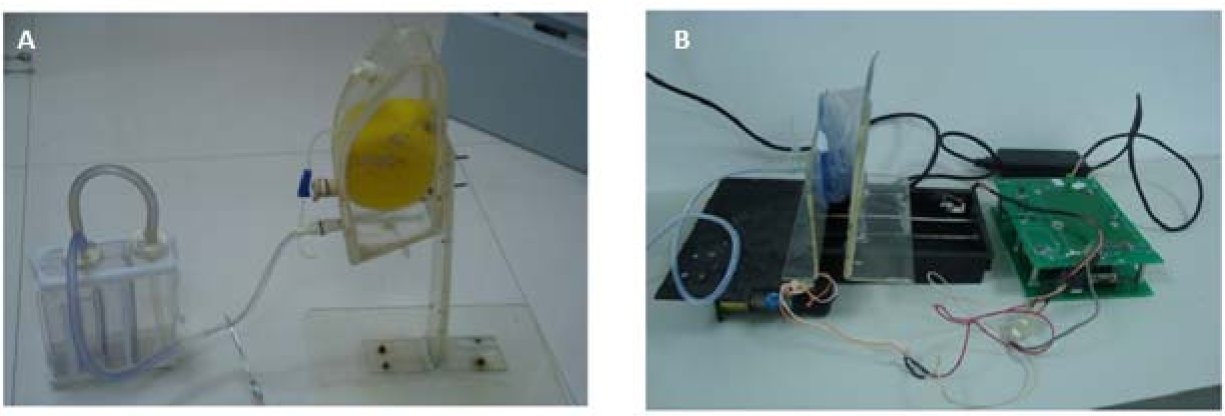

Figure 1. A: Simulated pleural cavity setting and **B:** Simulated respiratory power setting.

nursing experts) were invited to provide insight regarding items categorized within each dimension. Overall importance was ranked 1 through 5 (1 = not important, 5 = very important). Expert consultation was obtained regarding the items within each dimension. The CVI of each item was 0.88 to 0.96 with an average CVI of 0.9410. Confirmed items were included as part of the study.

Clinical evidence investigation

Patients were randomly selected from hospitals in Fujian Province, China. Patients were eligible for inclusion if they were aged ≥18 years, conscious, and willing to participate. Exclusion criteria included patients currently with two thoracic drainage tubes, or another peritoneal cavity drainage tube, and lack of consciousness. Each dimension was assessed by the investigators of this study and scored using the effectiveness assessment form. Scores for each item ranged from 1 to 4 (1 = not achieved, 2 = partly achieved, 3 = mostly achieved, 4 = fully achieved). Scores for each item, plus the sum of all scores, were used to determine total score. The investigation period included the time from indwelling to drainage tube removal.

Statistical analysis

All statistical analyses were performed using SPSS 15.0 statistics software (SPSS, Chicago, IL, USA). Drainage time between saline and glycerol groups was performed using a two-sample *t* test. Hydrostatic pressure was compared between groups using a one-way ANOVA with a Bonferroni adjustment. The score of each guideline of closed thoracic drainage system were summarized as mean ± SD with a range (minimum, maximum) for each of item. All statistical assessments were considered significant if $p < 0.05$. An adjusted significance level 0.0167 ($p = 0.05/3$) was applied for the Bonferroni approach comparison.

Results

Optimizing closed thoracic drainage conditions

The flow pattern of normal saline and blood substitute (glycerol) was in accordance with Poiseuille's law (volume of a fluid passing per unit time through a capillary tube is directly proportional to its internal radius). In the drainage tubes currently examined (16F, 22F, 28F, 30F, 32F, and 36F); the drainage time between saline and glycerol was significantly different in each type of drainage tube (**Figure 2**). Draining volume per unit time was not different between examined fluids—when the internal tube diameter increased to ≥28F the difference between groups remained significant, but was reduced between fluid types.

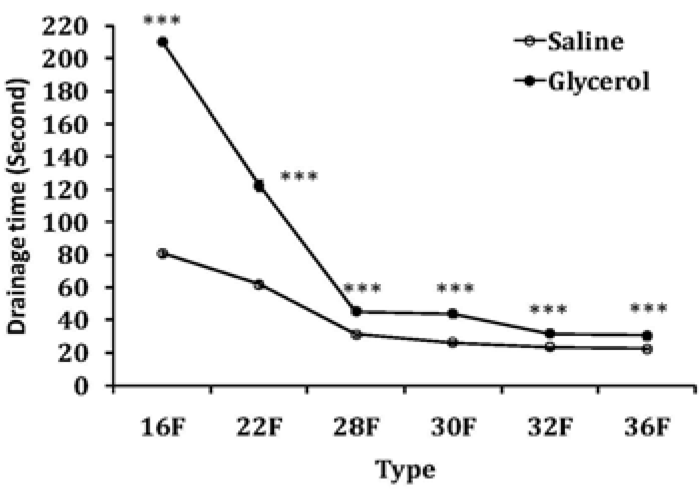

Figure 2. The drainage time between saline and glycerol (mean ± SD). Comparisons were made using a two-sample *t* test. ***$p < 0.001$, indicates significantly different between saline and glycerol (n = 10 per condition).

Drainage time was also influenced by tube length (**Figure 3**). In the saline group, the drainage time was 1.56 ± 0.01 minutes, 2.45 ± 0.03 minutes, 2.58 ± 0.16 minutes, 2.57 ± 0.15 minutes, and 3.08 ± 0.03 minutes for drainage tube lengths of 100 cm, 120 cm, 140 cm, 160 cm, and 180 cm, respectively. Whereas, glycerol drainage time was observed as 3.17 ± 0.03 minutes, 4.05 ± 0.04 minutes, 4.14 ± 0.02 minutes, 4.14 ± 0.02 minutes, 7.15 ± 0.03 minutes for drainage length 100 cm, 120 cm, 140 cm, 160 cm, and 180 cm, respectively. Draining volume per unit time of each fluid was inversely proportional to drainage tube length. When the length of the drainage tube was between 120 cm and 160 cm there was no significant difference in drainage volume per unit time between saline and glycerol; however, when drainage tube length was increased to 180 cm, the required time to drain equal fluid volumes increased and this difference was more readily apparent in glycerol.

The mean hydrostatic pressure was measured in vertical-, curved-, and circular-tubes (**Figure 4**). The curved tube resulted in significantly increased hydrostatic pressure compared with the vertical tube (7.05 ± 1.35 cmH_2O) vs. 1.99 ± 0.76 cmH_2O, $p < 0.001$) and the circular tube resulted in significantly reduced hydrostatic pressure compared with the curved tube (2.24 ± 0.28 cmH_2O vs. 7.05 ± 1.35 cmH_2O, $p < 0.001$).

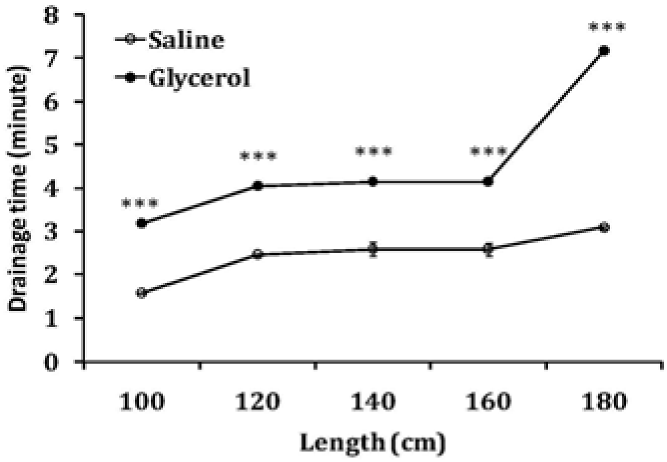

Figure 3. The drainage time between saline and glycerol using different length tubing (mean ± SD). The drainage time between saline and glycerol for a given length of drainage tube was compared using a two-sample *t* test. ****p* < 0.001, indicates significantly different between saline and glycerol (n = 10 per condition).

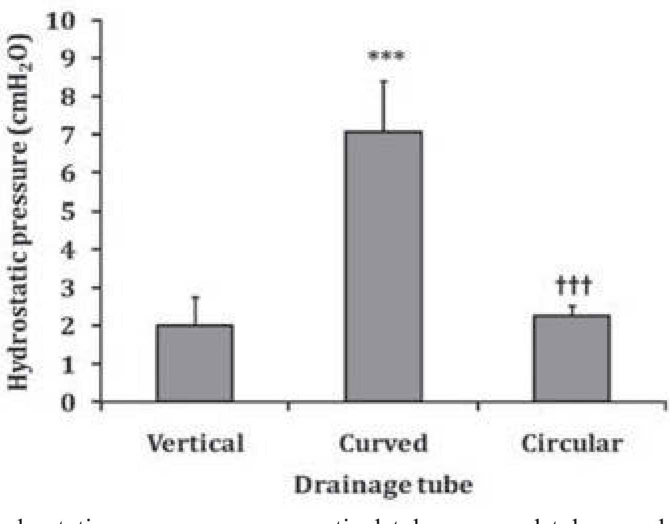

Figure 4. Comparison of hydrostatic pressure among vertical tubes, curved tubes, and circular tubes. Hydrostatic pressure is presented as a bar graph (mean ± SD) by group. Comparisons were made using a one-way ANOVA with a Bonferroni adjustment approach (n = 10 per group). The observed hydrostatic pressure was 1.99 ± 0.76 cmH_2O, 7.05 ± 1.35 cmH_2O, and 2.24 ± 0.28 cmH_2O in each group, respectively. ($p < 0.001$ through one-way ANOVA) ****p* < 0.001, indicated significantly different when compared with the vertical tube, †††*p* < 0.001, indicated significantly different as comparing with the curved tube.

Clinical evidence investigation

A total of 201 patients were randomized for participation in the current study (142 (70.7%) men and 59 (29.3%) women. Patients were being treated for esophageal cancer (37.8%), spontaneous pneumothorax (29.4%), traumatic hemothorax (20.9%), and lung cancer (11.9%). Additional subject- and drainage-system characteristics are presented in **Table 1**. The average hospital stay for all subjects was 12.16 ± 5.11 days, and the average time of indwelling tube was 9.75 ± 4.30 days. Assessment scores for each guideline of closed thoracic drainage system are presented in **Table 2**. Among the 201 subjects, the total score was 83.9 ± 6.0 (range: 65 to 94). The mean score for the three dimensions of the ADC model was 25.2 ± 1.9 (availability), 31.8 ± 3.9 (dependability), and 20.1 ± 2.1 (capacity), respectively.

Construct validity of the assessment form

Kaiser–Meyer–Olykin (KMO) Measure of Sampling Adequacy was used to examine the appropriateness of factor analysis. KMO for the assessment form was 0.864, and Bartlett's Test of Sphericity was χ^2 = 1970.136 (p = 0.000), which indicated it was suitable for factor analysis. Overall, factor analysis was performed on 13 items included on the assessment form and 73.2% of the total variance was explained by 3 factors. This was indicative of the overall structure of the assessment form. According to the largest factor load of each item, the factor load for the three factors was ≥0.4 (examined by varimax orthogonal rotation). The correlation coefficient between item scores within each dimension and total score was 0.542 to 0.920. The correlation coefficient of each item and its dimension was 0.429 to 0.887.

Table 1. Subjects' characteristics (n = 201)

Variables	Number (%)
Sex	
Males	142 (70.7)
Females	59 (29.3)
Disease type	
Esophageal cancer	76 (37.8)
Spontaneous pneumothorax	59 (29.4)
Traumatic hemothorax	42 (20.9)
Lung cancer	24 (11.9)
Drainage classification	
I	56 (27.9)
II	78 (38.8)
III	67 (33.3)
Drainage type	
Central venous catheter	26 (12.9)
28F	35 (17.4)
30F	60 (29.9)
32F	40 (19.9)
36F	40 (19.9)
Drainage material	
CVC	25 (12.4)
Silicon	68 (33.8)
PVC	108 (53.7)
Drainage length	
120 cm	54 (26.9)
125 cm	45 (22.4)
130 cm	66 (32.8)
140 cm	36 (17.9)

Table 2. The distribution of the score of each guideline of closed thoracic drainage system (n = 201)

	Mean ± SD	Range (Minimum, Maximum)
Factor 1 Availability dimension	**25.2 ± 1.9**	**(22, 30)**
1. drainage setting complete and available	5.8 ± 1.7	(3, 9)
2. qualified hospital staff	7.2 ± 1.2	(4, 8)
3. sound regulations	6.5 ± 0.8	(5, 7)
4. safe and regulated environment	5.6 ± 0.8	(4, 6)
Factor 2 Dependability dimension	**31.8 ± 3.9**	**(27, 42)**
5. safety of the drainage system	7.6 ± 1.4	(2, 9)
6. patency of the drainage system	6.4 ± 1.7	(2, 9)
7. aseptic level of the drainage system	5 ± 1.5	(3, 8)
8. closeness of the drainage system	7.5 ± 1	(5, 8)
9. level of humanistic care	5.3 ± 1.5	(3, 8)
Factor 3 Capacity dimension	**20.1 ± 2.1**	**(16, 27)**
10. assessment of drainage effectiveness	5.8 ± 1	(5, 9)
11. assessment of complications	6.2 ± 1.2	(2, 7)
12. assessment poor management	4.9 ± 0.4	(3, 5)
13. assessment of subjective comfort	3.2 ± 0.7	(1, 6)
Total score	**83.9 ± 6.0**	**(65, 94)**

Reliability of the assessment form

Overall, scores for each dimension of the assessment form and the total score were highly correlated (r > 0.7). Test–retest reliability was evaluated by selecting 30 patients with closed thoracic drainage and results conformed to the required criteria (r = 0.769-0.889, $p < 0.01$).

Discussion

To establish a reliable and valid assessment form, a strong theoretical base is required [7]. The current assessment tool was created using a classic ADC model, with three dimensions to consider: availability, dependability, and capacity. These dimensions were used to assess the effectiveness of nursing technique when treating patients with a closed thoracic drainage system. Briefly, the developed assessment tool utilized accurate, reasonable, clear, and easy to understand language, and was in accordance with the clinical nursing quality management at 10 hospitals in Fujian Province, China. Content validity was assessed by experts using a cumulative volume index (CVI). The current results met the guidelines outlined with a CVI greater than 0.8, which is considered acceptable. Furthermore, the average CVI index in the current assessment form was 0.941. The overall Cronbach's α of the assessment form with 39 assessment basis is 0.949. Cronbach's α of each dimension respectively was more than 0.7, which demonstrated internal consistency, reflecting the concept of nursing effectiveness for closed thoracic drainage.

From the time a chest drain is inserted there is a critical role for nurses [8]. Although chest drain insertion is typically carried out by the physician, there are several complications that nurses need to be aware of, including bleeding, infection, subcutaneous emphysema, pain, and lung trauma. The goal for each patient is to restore adequate oxygenation, promote lung re-expansion, and prevent complications; therefore, attention to each patient is important to ensure proper healing [9]. Anecdotally there appears to be a lack of consensus among nurses on the major principles of chest drain management. Many decisions by nurses have been reported to be based on personal factors, rather than evidence-based medicine supported with clinically-based research. These factors lead to inconsistent treatment regimens creating a general uncertainty regarding the care of patients with chest drains [1].

There is a paucity of data on the nursing management of chest drains and the literature reports a general lack of standardized guidelines for this population [8, 11]. Providing nurses with effectiveness assessments tools will provide a much needed resource in their treatment of patients with chest drains. In the current study, assessment guidelines are presented that address those items that require the most attention in a closed thoracic drainage system.

This will allow for prospective measures to be taken based on evidence-based clinical research.

With respect to the limitation of the study, total of 10 hospitals took part in the current research study and were all tertiary Hospitals and used convenience sampling; therefore, adequate representation was insufficient. Tests for criterion-related validity have not been performed. Furthermore, in the process of establishing and applying the guideline system, some guidelines were not quantized objectively. Lastly, more detailed subordinated items should be established, thereby making the assessment system more practical.

Conclusions

Overall, the primary purpose of establishing an effectiveness assessment system for closed thoracic drainage is to estimate the effect of this procedure on a patient and to potentially identify which factors contribute most to their recovery. Establishment of the effectiveness assessment system enhances nursing quality and prompts improvement of nursing service.

The authors have no conflict of interest to report.

References

1. Lehwaldt D, Timmins F. The need for nurses to have in service education to provide the best care for clients with chest drains. J Nurs Manag. 2007; 15: 142-8.
2. Kam AC, O'Brien M, Kam PC. Pleural drainage systems. Anaesthesia. 1993; 48:154-61.
3. Aru GM, Dabbs AP, Cummins ER, Reno WL, Harrison NP, English WP, et al. Selective use of chest tubes in thoracotomies for congenital cardiovascular procedures. Ann Thorac Surg. 1999; 68:1376-9.
4. Sim KM, Ng AS. A questionnaire survey on practice of chest tube management. Singapore Med J. 1996; 37:572-6.
5. Durai R, Hoque H, Davies TW. Managing a chest tube and drainage system. AORN J. 2010; 91:275-80; quiz 281-3.
6. Tang A, Hooper T, Hasan R. A regional survey of chest drains: evidence-based practice? Postgrad Med J. 1999; 75:471-4.
7. Bear M. Theoretical issue in measurement. In: Moody LE, eds. Advancing nursing science through research, Vol. 2. Newbury Park, Calif: Sage Publications; 1990.
8. Sullivan B. Nursing management of patients with a chest drain. Br J Nurs. 2008; 17:388-93.
9. Coughlin AM, Parchinsky C. Go with the flow of chest tube therapy. Nursing. 2006; 36:36-41.
10. Charnock Y, Evans D. Nursing management of chest drains: a systematic review. Aust Crit Care. 2001; 14: 156-60.