Comparison of the Amount of Air Leakage Into the Thoracic Cavity Associated with Three Thoracostomy Tube Materials in Canine Cadavers

Hun-Young Yoon,[1] DVM, PhD

Jin Suk Kim,[2] DVM, PhD

Suhwon Lee,[3] PhD

Soon-wuk Jeong,[4]* DVM, PhD

[1]Department of Veterinary Surgery, College of Veterinary Medicine, and the Veterinary Science Research Institute, Konkuk University, Seoul 143-701, Korea

[2]Department of Veterinary Pharmacology and Toxicology, College of Veterinary Medicine, and the Veterinary Science Research Institute, Konkuk University, Seoul 143-701, Korea;

[3]Department of Statistics, University of Missouri, Columbia, MO 65211, USA

[4]Department of Veterinary Surgery, College of Veterinary Medicine, Konkuk University, Seoul 143-701, Korea

**Corresponding author*

KEY WORDS: thoracostomy tube materials, air leakage, cadaver

ABSTRACT

This study was performed to compare the amount of air leakage into the thoracic cavity associated with three thoracostomy tube materials (silicone, polyvinyl chloride, red rubber) in canine cadavers. Differences in intrapleural pressures (IPPs) measured before and after tube placement and before and after tube removal were calculated. The duration of air leakage around the tubes was assessed by use of a 3-chamber thoracic drainage system. A greater IPP difference was detected between before and after tube placement for a red rubber tube than a polyvinyl chloride tube (P = 0.0127). No significant difference was detected among the three groups between before and after removing the thoracostomy tube (P = 0.8145). No significant difference in bubbling duration was detected among the three groups (P = 0.2302). More intermittent bubbling after the continuous bubbling endpoint occurred in a red rubber tube than a polyvinyl chloride tube while the tube remained in the thoracic cavity (P = 0.03). In conclusion, the use of a polyvinyl chloride tube appears to be more effective than the use of a red rubber tube in preventing air leakage around the thoracostomy tube during placement and during the period that the tube remains in the thoracic cavity.

INTRODUCTION

A thoracostomy tube is a drain surgically placed through the chest wall. Thoracostomy tube placement is indicated for the management of significant accumulation of pleural effusion that necessitates repeated pleural drainage and when thoracocentesis has failed to control pneumothorax.[1,2] Tube-associated pneumothorax can be a fatal complication of thoracostomy tube use.[3,4] Pneumothorax may occur after tube placement, while the tube remained in the thoracic cavity as a result of tube mutilation by the patient, loosening of tube connections and adapters, or inadvertent extraction of the tube, and after tube removal.[3,5] Avoidance of iatrogenic pneumothorax are essential goals for successful usage of thoracostomy tubes.[6,7]

Silicone, red rubber, and polyvinyl chloride tubes have been described for the management of dogs and cats with pleural effusion or pneumothorax. In silicone and red rubber tubes, a large curved forceps is used to create a tunnel through the subcutaneous tissues or under a latissimus dorsi muscle.[8,9,10] In a polyvinyl chloride tube, a specifically designed trocar thoracostomy tube is used to provide easier manipulation than tubing attached to hemostatic forceps.[11,12,13] The thoracostomy tube material that best prevents air leakage around the tube or through the tunnel following extraction of the tube would provide the safest protection from tube-associated pneumothorax. To the authors' knowledge, there are no published data demonstrating which of the commonly employed thoracostomy tube materials is the most advantageous for use in dogs.

The purpose of our study was to compare the amount of air leakage around tubes immediately after tube placement, while the tube remained in the thoracic cavity, and along the thoracostomy tunnel immediately after tube removal among each of the following three thoracostomy tube materials:

- A silicone tube
- A polyvinyl chloride tube
- A red rubber tube

MATERIALS AND METHODS

Cadavers

Twenty-four cadavers (weight range, 2.0 to 10.0 kg) of dogs that were euthanatized for reasons unrelated to the study were used. For each cadaver, sex was recorded, and the breed was estimated. No respiratory tract problems were evident in any of the dogs prior to euthanasia. Physical examination was performed on the cadavers to rule out evidence of blunt trauma. Thus, no cadaver with thoracic injury was included in the study. All cadavers were randomly assigned to one of the three thoracostomy tube materials groups.

Study Procedures

Experiments were performed in four separate sessions. Six cadavers were used in each of four experimental sessions. Three thoracostomy tube materials were used in each session (two cadavers/material). A commercially available 4.7 mm polyvinyl chloride thoracostomy tube (PVC Thoracic Catheter; Sewoon Medical Co, LTD, Korea) in the outer diameter was used in eight cadavers. A 4.7 mm silicone tube (Bio-sil; Sil-med Corporation, Korea) in the outer diameter was used in eight cadavers. A 4.7 mm red rubber tube (Pure Latex French Catheter; Shine Medical Co, LTD, Korea) in the outer diameter was used in the other eight cadavers.

In each silicone or red rubber tube, two additional side holes were made, similar to holes present in the polyvinyl chloride tube. These holes were no greater than a third of the diameter of the tube. All thoracostomy tubes were placed in the left thoracic wall entering the pleural cavity at the eighth intercostal space. The same surgeon (HY) placed all thoracostomy tubes in all cadavers. By use of three tube materials, three experimental groups (eight cadavers/group) were created—the polyvinyl chloride, silicone, red rubber tubes groups.

Thoracostomy Tube Placement

A stab incision was made by use of a No. 11 scalpel blade through the skin over the 11th rib in the region of the dorsal third of the left lateral thoracic wall. A curved mosquito hemostat forceps was used to create a tunnel as wide as the width of the forceps through the subcutaneous tissues from the eleventh rib to the eighth intercostal space in the middle third portion of the thoracic wall, and the curved mosquito hemostat forceps was removed. The tip of a thoracostomy tube was grasped in the tip of the forceps with the tube parallel to the body of the instrument. The forceps bearing the thoracostomy tube was then passed through the subcutaneous tunnel from the eleventh rib to the eighth intercostal space.

Once the tip of the forceps reached the eighth intercostal space, the forceps was raised perpendicular to the thoracic wall. The forceps bearing the thoracostomy tube was then firmly grasped at a distance of 1 to 2 cm from the body wall with one hand, while the other hand was used to pop the forceps tip and thoracostomy tube through the thoracic wall musculature into the pleural space. Following entry of the thoracostomy tube into the pleural space, the forceps was removed, and the tube was advanced in a cranioventral direction without resistance until the predetermined length of the tube to be inserted from the skin incision to the thoracic inlet was in place. The tube was marked with an indelible marker to indicate the insertion length. After tube placement, the tube was sutured to the skin, and the underlying fascia with four friction sutures using #1 nylon (Blue Nylon; Ailee Co., LTD, Korea).[14]

Measurement of Intrapleural Pressure (IPP)

- Cadavers were placed in right lateral recumbency. Before the thoracostomy tube was placed, a thoracocentesis catheter (TURKEL Safety Thoracocentesis System; Tyco/Healthcare/Kendall, Mansfield, MA) was inserted into the pleural cavity in the dorsal third portion of the left lateral thoracic wall through a tiny stab skin incision over the sixth intercostal space to measure IPP. A transducer (Pressure monitoring kit; Biosensors international, Singapore) was connected to a monitor (Patient monitor; Votem, Korea) and the thoracocentesis catheter by use of a 3-way stopcock to measure and record IPP. The transducer was positioned at the level of table and zeroed with the 3-way stopcock opened to air and closed to the cadaver. Then, the 3-way stopcock was opened to the cadaver, and the pressure value was recorded after the pressure on the monitor was stabilized (1 minute after manipulation). IPP was measured seven times:
- before placement of the thoracostomy tube
- after placement of the thoracostomy tube and its connection with a thoracic drainage unit
- after manual evacuation of air via the thoracostomy tube (if there was air leakage into the thoracic cavity)
- after injection of air through the thoracostomy tube into the pleural space
- after evacuation of air using thoracic drainage system
- after manual evacuation of all air via the thoracostomy tube (all residual air was manually evacuated via the thoracostomy tube after bubbling stopped in the thoracic drainage system)
- after removal of the thoracostomy tube.

Measurement of the Duration of Air Leakage Around Tubes

Following placement, the thoracostomy tube was attached to a large Y-connector. One part was connected to a 3-way stopclock to inject air, and the other part was connected to a commercial thoracic drainage system (Thora-Seal III; Tyco/Healthcare/Kendall, Mansfield, MA) that was comprised of three chambers. The capillary tube of the water seal chamber was submerged 2 cm below the surface of the water level in the bottle.

The capillary tube of the suction chamber was submerged 10 cm below the surface of the water level in the bottle and attached to a vacuum line via a regulator (Vacutron; Allied Healthcare Products, St Louis, MO). A clamp placed on the line connected to the collection chamber was closed and the Ru-

Table 1. *Amounts of air (ml) injected into the pleural space prior to thoracic drainage and residual air after completion of thoracic drainage unit bubbling in three thoracostomy tube materials: a silicone tube; a polyvinyl chloride tube; and a red rubber*

Amount of air (mean ± SD, ml)	Silicone (n=8)	Polyvinyl chloride (n=8)	Red rubber (n=8)	Total (n=24)
Injected	294 ± 127	270 ± 113	293 ± 132	285 ± 119
Residual*	17 ± 27	7 ± 13	31 ± 22	19 ± 21

For either variable, there were no significant ($P > 0.05$) differences among the three groups.
** The thoracic cavity was manually evacuated via the thoracostomy tube after bubbling stopped in the thoracic drainage system.*

mel-style mattress suture placed around the skin incision was secured. Air was injected into the pleural cavity through the thoracostomy tube via the 3-way stopclock to mimic a pneumothorax. On the basis of data provided in a previous study,15 the volume of air injected into the pleural space was 1.75 × 0.032 × body weight (in kg)1.05 L.

The 3-way stopclock was locked after air injection, and the Rumel-style mattress suture placed around the skin incision and the clamp placed on the line connected to the collection chamber were released. The suction chamber was maintained at 10 cm H2O to provide consistent suction and the regulator was turned on. The interval from the onset of bubbling in the water seal chamber until the continuous bubbling in the water seal chamber stopped was measured by use of a stopwatch. If bubbling in the water seal chamber stopped, chamber was observed for 2 minutes to detect whether bubbling recurred.

Statistical Analysis

All data were expressed as mean ± SD. A 1-way ANOVA was used to compare mean values of cadaver weights, the amounts of air injected, and the amounts of residual air among the three materials groups. Comparisons of IPP differences and durations of water seal chamber bubbling were performed by use of a 1-way ANOVA. Fisher's exact test was performed to determine if the use of different materials was independent of the presence of continuous bubbling, and kinks and malposition of the tubing. Data analysis was run with SAS (SAS®, v.9.1; SAS Institute INC, Cary, NC). A value of $P \leq 0.05$ was considered significant for all comparisons.

RESULTS

Twelve male and 12 female canine cadavers were studied. Breeds represented within each group were:

- A silicone tube–mixed breed dogs (n=6) and Shih Tzu (n=2);
- A polyvinyl chloride tube–mixed breed dogs (n=6), poodle (n=1), and cocker spaniel (n=1)
- A red rubber tube–mixed breed dogs (n=4), Shih Tzu (n=3), and Dachshund (n=1). Mean (± SD) body weight for cadavers in each group was 4.8 ± 1.9 kg for a silicone tube; 4.4 ± 1.7 kg for a polyvinyl chloride tube; and 4.8 ± 2.0 kg for a red rubber tube.

There was no difference in body weight of cadavers among three groups ($P = 0.914$).

Manipulation of Thoracostomy Tube

Red-rubber-tubing and silicone-tubing attached to a hemostatic forceps were more difficult to manipulate for introduction of the tube in the chest than the technique using a polyvinyl chloride tube. More additional manipulation including traction, rotation, and advancement of the implant was required to advance the red rubber tube and silicone tube to the thoracic inlet than the polyvinyl chloride tube. There were kinks in six (silicone tube, n=2, and red rubber tube, n=4) cases on introducing the tubes into the thoracic cavity. There were more kinks and malposition in the red rubber tube than the

Table 2. Intrapleural pressures in three thoracostomy tube materials: a silicone tube; a polyvinyl chloride tube; and a red rubber tube before and after tube placement, after injecting air, and before and after tube removal

Intrapleural pressure (mean ± SD, mmHg)	Silicone (n=8)	Polyvinyl chloride (n=8)	Red rubber (n=8)	Total (n=24)
Before placement of the thoracostomy tube	−3.1 ± 2.6	−2.6 ± 1.9	−2.3 ± 1.7	−2.7 ± 2.0
After placement of the thoracostomy tube and connection with thoracic drainage unit	−1.5 ± 2.4	−1.8 ± 1.7	−0.1 ± 0.9	−1.1 ± 1.9
Difference between above two pressures*	−1.6 ± 0.9	−0.7 ± 0.7	−2.2 ± 1.0	−1.5 ± 1.0
After injecting air through the thoracostomy tube into the pleural space	5.1 ± 1.2	6.5 ± 2.5	5.0 ± 2.0	5.5 ± 2.0
After manually evacuating all air via the thoracostomy tube	−4.8 ± 3.0	−5.2 ± 2.2	−5.0 ± 4.1	−5.0 ± 3.0
After removing the thoracostomy tube	−4.1 ± 2.1	−4.5 ± 2.3	−4.2 ± 3.9	−4.2 ± 2.8
Deference between above two pressures	−0.7 ± 1.4	−0.7 ± 0.7	−0.7 ± 0.8	−0.7 ± 1.0

**For this variable, findings in a red rubber tube group differ significantly (P = 0.0127) from the findings in a polyvinyl chloride tube group.*

polyvinyl chloride tube on introducing the tube into the thoracic cavity (P = 0.023).

Amount of Air Injected

Mean (± SD) amounts of air injected into the pleural space and mean (± SD) amounts of residual air after evacuating air using thoracic drainage system in the three groups are recorded in Table 1. There was no significant difference in the amounts of air injected into the pleural space among the three groups (P = 0.911). There was no difference in the amounts of residual air in the pleural space among the three groups (P = 0.342)

Intrapleural Pressure

Mean (± SD) intrapleural pressures and mean (± SD) differences in intrapleural pressures in the three groups are recorded in Table 2. A greater intrapleural pressure difference was detected between before and after thoracostomy tube placement for a red rubber tube than a polyvinyl chloride tube (P = 0.0127). However, no significant difference was detected in a silicon tube compared to a red rubber tube (P = 0.4206) or a polyvinyl chloride tube (P = 0.1829). No significant difference was detected among the three groups between after manually evacuating all air via the thoracostomy tube and after removing the thoracostomy tube (P = 0.8145).

Measurement of the Duration of Air Leakage around Tubes

Mean (± SD) durations of water seal bubbling immediately after thoracostomy tube placement and injection of air are recorded in Table 3. No significant difference in bubbling duration was detected among the three groups (P = 0.2302). Seven (silicone tube, n=3, and red rubber tube, n=4) cases began bubbling intermittently after the continuous bubbling endpoint and continued until the thoracic drainage unit was turned off in

Table 3. *Measurement of duration (seconds) from the onset of water seal bubbling until bubbling stopped immediately after tube placement in three thoracostomy tube materials: a silicone tube; a polyvinyl chloride tube; and a red rubber tube*

Time (mean ± SD, seconds)	Silicone (n=8)	Polyvinyl chloride (n=8)	Red rubber (n=8)	Total (n=24)
After injecting air through the thoracostomy tube and turning on the regulator	27.8 ± 4.6	25.2 ± 12.9	36.0 ± 4.9	28.5 ± 10.1

For the variable, there was no significant (P = 0.2302) difference among the three groups.

preparation for the next step in the experiment. More intermittent bubbling after the continuous bubbling endpoint occurred in a red rubber tube than a polyvinyl chloride tube while the tube remained in the thoracic cavity (P = 0.03).

DISCUSSION

Although multiple factors determine the choice of tube materials, on the basis of results of the present study to evaluate thoracostomy tube materials in cadaveric dogs, the use of a polyvinyl chloride tube appears to be more effective than the use of a red rubber tube in preventing air leakage around the thoracostomy tube during placement and during the period that the tube remains in the thoracic cavity.

The use of a silicone tube, a polyvinyl chloride tube, or a red rubber tube, has advantages or disadvantages respectively. Compared with a silicone tube and a red rubber tube, a polyvinyl chloride tube was easier to manipulate and caused less tunneling trauma. It was easier to position the polyvinyl chloride tube into the thoracic inlet. A red rubber tube is comparatively less expensive, which may be more readily available to most practicing veterinarians, but causes more kinks and malposition during introducing into the thoracic cavity than does a polyvinyl chloride tub.3,4,5,7

The three tube materials evaluated in the present study differed with regard to flexibility of the tubes that provided a proper manipulation. Of the techniques, a red rubber tube was least able to prevent air leakage during tube placement. A red rubber tube is more flexible than the other tubes, which causes more kinks and malposition during the introduction into the thoracic cavity than a polyvinyl chloride tube that has rigidity. The use of a red rubber tube created a tunnel larger than that created by use of the polyvinyl chloride tube because of the additional manipulation, including traction, rotation, and the advancement of the red rubber tube that was required during the introduction of the red rubber tube to the thoracic inlet, whereas the polyvinyl chloride was guided into the thoracic inlet without additional manipulation. The facts that the use of a red rubber tube required additional manipulation for introduction of the tube into the thoracic inlet likely contributed to the greater IPP difference for the red rubber tubing, compared with the IPP difference for the polyvinyl chloride tubing.

To assess air leakage, the duration of bubbling in the water seal chamber of a 3-chamber thoracic drainage device that was connected to the thoracostomy tube after placement was monitored, and the occurrence of intermittent bubbling after the study endpoint (ie, cessation of continuous bubbling) was recorded for each tube material. Compared with a polyvinyl chloride tube, bubbling duration was not longer in a red rubber tube and a silicone tube during the period that the tube remained in the thoracic cavity. However, intermittent bubbling was evident in a red rubber tube and a silicone tube groups. The intermittent bubbling that occurred later in some of the red rubber tube and silicone tube cadavers may have been caused by air trapped between lung lobes in the thoracic cavity. However, air leakage around tubes seems to be the most plausible explanation, because intermittent bubbling continued until the thoracic drainage unit was turned off in preparation for the next stage in the cadaver experiment.

Other factors determining choice of tube materials include tissue reaction to the tube materials, tube anchoring techniques, and tube physical properties. A red rubber tube resulted in more gross and histologic evidence of inflammation than a silicone tube and a polyvinyl chloride tube. A silicone tube retained their physical properties better than the other tube types.16 Additionally, the silicone tube has better axial force and displacement to failure than the red rubber and polyvinyl chloride tubes.14 These findings suggest that the use of a red rubber tube is reluctant choice for thoracostomy tube and a silicone tube might also be preferable to a polyvinyl chloride tube when long implantation times are needed.

IPP has been measured in dogs by previous investigators. Farhi et al. recorded IPP in anesthetized dogs, ranged from -3.77 mmHg to -6.87 mmHg.17 Ednick et al. performed telemetric recording of IPP in conscious dogs.18 Results indicated pressures of approximately -10.8 mmHg. These investigations found lower intrapleural pressures than the values measured in the present study. In the present study, mean IPP measured in all cadavers before thoracostomy tube placement was -2.7 mmHg. Interestingly, this IPP value (presumably created by vacuum pressure that resulted from elastic recoil in the cadavers19) was different to the mean baseline IPP (-5.4 mmHg) measured in our previous study.20 The only difference between our present and previous studies in experimental animals is the body weight of cadavers (mean values: present study; 4.7 kg and previous study; 19.1 kg). A study of IPP of dogs with different weight is warranted to better find relationship between body weight and IPP.

CONCLUSIONS

On the basis of results of the present study to evaluate thoracostomy tube materials in cadaveric dogs, the use of a polyvinyl chloride tube appears to be more effective than the use of a red rubber tube in preventing air leakage around the thoracostomy tube during placement and during the period that the tube remains in the thoracic cavity.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government [NRF-2009-353-E00034].

REFERENCES

1. Holtsinger RH, Beale BS, Bellah JR, et al. Spontaneous pneumothorax in the dog: a retrospective analysis of 21 cases. *J Am Anim Hosp Assoc* 1993; 29: 195-210.
2. Ludwig LL. Surgical emergencies of the respiratory system. *Vet Clin North Am Small Anim Pract* 2000; 30: 531-553.
3. Hawkins EC. Chest tube: indications and placement. In: Nelson RW, Couto CG eds. *Small Animal Internal Medicine.* 2nd ed. St. Louis, MO: Mosby, 1998; 323-326.
4. Kahn SA. Thoracostomy tube placement in the dog. *Lab Anim* 2007; 36: 21-24.
5. Fossum TW. Surgery of the lower respiratory system: pleural cavity and diaphragm. In: Fossum TW ed. *Small Animal Surgery*. 3rd ed. St. Louis, MO: Mosby, 2007; 898-903.
6. Holmberg DL. Management of pyothorax. *Vet Clin North Am Small Anim Pract* 1979; 9: 357-363.
7. Tillson DM. Thoracostomy tubes. Part II. Placement and maintenance. *Comp Cont Educ Pract Vet* 1997; 12: 1331-1337.
8. Crowe DT, Devey JJ. Thoracic drainage. In: Bojrab MJ ed. *Current Techniques in Small Animal Surgery.* 4th ed. Baltimore, MD: Williams & Wilkins, 1998; 403-411.
9. Ford RB, Mazzaferro EM. Emergency diagnostic and therapeutic procedure. In: Ford RB, Mazzaferro EM eds. *Kirk and Bistner's Handbook of Veterinary Procedures & Emergency Treatment.* Philadelphia, PA: Saunders, 2007; 53-55.
10. Harvey CE, O'Brien JA. Management of respiratory emergencies in small animals. *Vet Clin North Am Small Anim Pract* 1972; 2: 243-258.
11. Bauer T. Pyothorax. In: Kirk RW ed. Current veterinary therapy IX. Philadelphia, PA: Saunders, 1986; 292-295.
12. Robertson SA, Stoddart ME, Evans RJ, et al. Thoracic empyema in the dog; a report of twenty-two cases. *J Small Anim Pract* 1983; 24: 103-119.
13. Tseng LW, Waddell LS. Approach to the patient in respiratory distress. *Clin Tech Small Anim Pract*

2000; 15: 53-62.

14. Song EK, Mann FA, Wagner-Mann CC. Comparison of different tube materials and use of Chinese finger trap or four friction suture technique for securing gastrostomy, jejunostomy, and thoracostomy tubes in dogs. *Vet Surg* 2008; 37: 212-221.
15. Bennett RA, Orton EC, Tucker A, et al. Cardiopulmonary changes in conscious dogs with induced progressive pneumothorax. *Am J Vet Res* 1989; 50: 280-284.
16. Apalakis A. An experimental evaluation of the types of material used for bile duct drainage tubes. *Br J Surg* 1976; 63: 440-445.
17. Farhi L, Otis AB, Proctor DF. Measurement of intrapleural pressure at different points in the chest of a dog. *J Appl Physiol* 1957; 10: 15-18.
18. Ednick MD, Pagala M, Barakat JP, et al. Telemetric recording of intrapleural pressure. *J Surg Res* 2006; 138: 10-14.
19. King JM, Dodd DC, Roth. Representative stages of post mortem lung inflation. In: King JM, Dodd DC, Roth eds. *The Necropsy Book*. Gurnee, IL, Davis Louis Davis, DVM Foundation Publisher, 2002; 101-102.
20. Yoon H, Mann FA, Lee S, et al. Comparison of the amounts of air leakage into the thoracic cavity associated with four thoracostomy tube placement techniques in canine cadavers. *Am J Vet Res* 2009; 70: 1161-1167.