Original Article

Comparative study of the resistance of manual and mechanical sutures in the bronchial stump of dogs submitted to left pneumonectomy*

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Abstract

Objective: To compare the resistance of manual suture with that of mechanical suture immediately after the suture of the left bronchial stump of dogs submitted to pneumonectomy. **Methods:** A total of 15 mixed-breed dogs of both genders, each weighing between 8 and 23 kg, were randomly divided into 2 groups. In group I (n = 7), the bronchial stump was sutured manually (the Sweet method) and, in group II (n = 8), it was stapled. Immediately after the closure of the bronchial stump, the intratracheal pressure was progressively increased in a controlled manner. **Results:** The mean rupture pressure of the bronchial stump suture line was 33.71 mmHg in group I and 89.87 mmHg in group II ($p < 0.01$). **Conclusion:** These data allowed us to conclude that mechanical suture of the bronchial stump, submitted to pressure immediately after closure, is more resistant than is manual suture in dogs submitted to pneumonectomy.

Keywords: Comparative study; Suture techniques; Bronchial fistula; Pneumonectomy.

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Introduction

The use of pulmonary resection in the treatment of benign and malignant diseases can lead to complications, among which we highlight pulmonary complications, cardiovascular complications, and bronchopleural fistula (BPF), the last being defined as a passage between a segmental or lobar lung bronchus and the pleural space.[1] It represents one of the greatest challenges to thoracic surgeons and is more common after pneumonectomy than after lobectomy or segmentectomy.[2] Although its incidence has been decreasing in recent years, BPF remains a significant complication of lung resection,[3-5] leading to other complications such as empyema, hemorrhage, and pneumothorax, as well as to a high mortality rate.[6] Various pre-, intra-, and post-operative factors influence the genesis of BPF.[1,5-8]

The technique of bronchial stump closure is one of the principal factors responsible for the appearance of BPF. This closure can be made by manual or mechanical suture. There are various studies, including experimental ones, comparing the efficacy of these types of suture. However, there are some variations among them.

Studies comparing manual and mechanical sutures of the bronchial stump show that the latter is more resistant on post-operative day 14,[9,10] that it is more resistant from post-operative day 1 to post-operative day 14,[11-13] especially when covered with bovine pericardium and biological glue,[14] and that it presents a lower incidence of BPF.[4,6,14,15] It is accepted that, although mechanical suture is safe, easily performed, and rapid, it is not totally free of complications. However, no statistically significant difference has been found between manual mechanical sutures.[16] There are those who state that manual suture results in a lower incidence of BPF[17] and those who state that manual suture is better in general.[18]

From what has been stated above, most of the studies show that mechanical suture causes a lower incidence of fistula, as well as greater resistance to pressure, than does manual suture. However, there have been few studies either on the resistance of the bronchial stump submitted to a gradual increase in pressure or on the determination of the rupture pressure immediately after the suture. The objective of the present study was to compare the resistance of manual suture with that of mechanical suture immediately after the suture of the left bronchial stump of dogs submitted to pneumonectomy by controlled and progressive intraluminal insufflation of oxygen.

Methods

The present study was approved by the Ethics in Research Committee of the Heliópolis Hospital, in São Paulo, Brazil, under number 379, and the handling of animals was in accordance with the guidelines for animal research established by the Brazilian College of Animal Experimentation.[19]

A total of 15 mixed-breed dogs (*Canis familiaris*) of both genders (9 males and 6 females), each weighing between 8 and 23 kg, were obtained from the Municipal Pound in the city of Vitória, located in the state of Espírito Santo, Brazil. All of the animals presented good general health status, with no apparent nutritional deficits, and all were clinically healthy. The animals were housed at the animal facilities of the *Santa Casa de Misericórdia* Hospital of Vitória School of Medicine. The experiment was performed in the period from November 29 to December 6 of 2005.

The animals were divided into two groups: group I (n = 7): manual suture of the left bronchial stump with separate stitches using sutures (the Sweet method); and group II (n = 8): mechanical suture using a linear stapler.

The stapler employed was a Proximate® model TA-30 (Ethicon Endo-surgery, Johnson & Johnson, Cincinnati, OH, USA), which uses a linear stapling cartridge with two parallel rows of 30-mm titanium staples. Manual suture was carried out using 4.0 polypropylene cardiovascular nonabsorbable sutures (Prolene®; Ethicon Endo-surgery, Johnson & Johnson).

Initially, the animals received an intramuscular injection containing 12.5 mg/kg of sodium thiopental. Subsequently, phleboclysis was performed so that a lethal dose of potassium chloride could be administered. After sacrifice, the animals were placed in the dorsal decubitus position on an operating table, to which their paws were fixed. A median sternotomy was performed, and the chest cavity was examined. Subsequently, the left pulmonary artery and veins were dissected and ligated, after which ipsilateral pneumonectomy was performed. For the closure of the bronchial stump, the animals were divided into two groups: in group I, manual suture with separate stitches (the Sweet method) was carried out using 4.0 polypropylene nonabsorbable sutures at approximately 1.0 cm from the carina (Figure 1); in group II, the main left bronchus was drawn away slightly so that the mechanical TA-30 stapler could be fitted, at approximately 1.0 cm from the carina. The stapling cartridge was subsequently inserted, the distal part of the left bronchus was sectioned, and pneumonectomy was performed (Figure 2). The right pulmonary hilum was then clamped, the pressure measurement system was connected, and the pressure was measured.

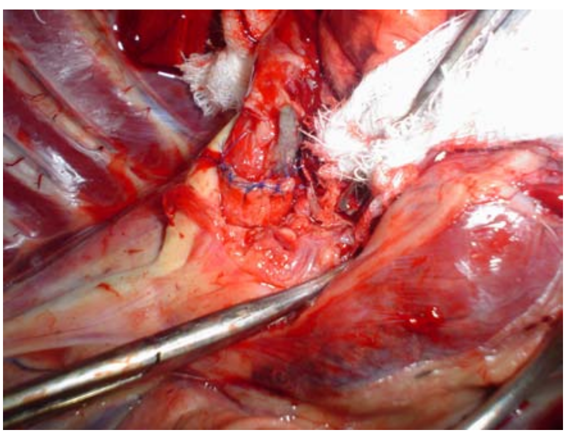

Figure 1 - Final aspect of the left bronchial stump suture line after the bronchial stump was sutured manually using a 4.0 polypropylene suture (the Sweet method). Note: 1) suture line; 2) aorta; 3) lymph node; and 4) heart.

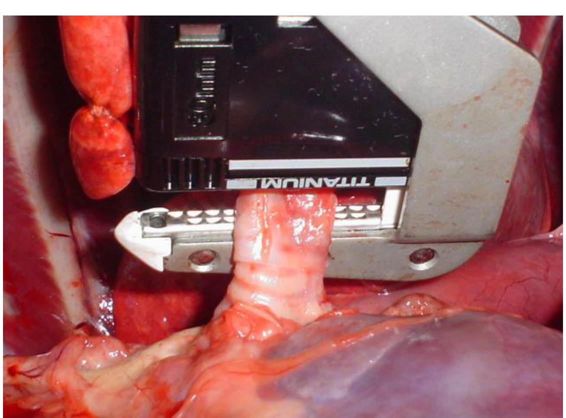

Figure 2 - Aspect of the left bronchial stump prepared for closure with a mechanical stapler.

In order to determine the air leak pressure, we built a system consisting of siliconized tubes, a collection bottle from the thoracic drainage system, a pressure regulating valve, and a manometer (Figure 3). The system was assembled in order to allow the oxygen coming from the oxygen cylinder to flow through the tube and pass through the pressure regulating valve, which, in turn, was attached to the manometer. Subsequently, the oxygen entered the collection bottle in order to reduce the pressure variation when the air (oxygen) began to leak. The air then passed through another hose until it reached the previously connected number 06 orotracheal tube and, when it reached its maximum limit of rupture pressure, exited through the suture line, which was submersed in water: ‘tire fitter’ test. Oxygen insufflation occurred in such a way that pressure varied every 5 mmHg, in steps.

The Student’s t-test for independent samples was used to compare the air leak pressure in the bronchial stump of animals in the manual suture group with that of animals in the mechanical suture group. The same test was used to compare the two groups in terms of body weight. The level of statistical significance for the tests was set at 5% ($p < 0.05$).

Results

The experiment progressed smoothly. Killing the animals prior to initiating the surgery facilitated the surgical procedure and the subsequent evaluations.

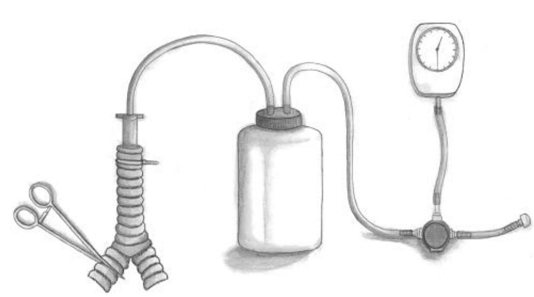

Figure 3 - Scheme illustrating the system for measuring pressure used in the experiment: a) site for the entrance of oxygen from the oxygen cylinder; b) pressure regulating valve; c) manometer; d) collecting bottle used in pleural drainage systems; e) orotracheal tube; f) trachea; and g) brace. The right mainstem bronchus is clamped using hemostatic forceps and the left mainstem bronchus is sutured manually or is stapled.

Figure 4 shows the individual pressure values obtained.

One animal (dog number 09) presented a small infected wound in its left lower limb, a fact that did not interfere with the experiment. In one animal (dog number 14), orotracheal intubation was difficult and cervical tracheostomy was necessary for the introduction of an orotracheal tube, whose fixation with the plastic brace was performed without difficulty. The experiment then proceeded normally.

The experimental model developed demonstrates that the technique for performing left pneumonectomy is perfectly viable in dogs and allows the comparative study of manual and mechanical sutures.

There was no statistically significant difference between the animals in group I and those in group II in terms of body weight ($p > 0.05$). Table 1 shows that the mean rupture pressure of the bronchial stump suture line in group II was significantly greater than that observed in group I ($p < 0.01$).

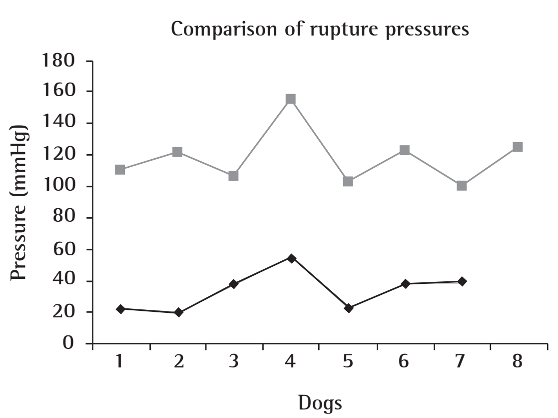

Figure 4 - Rupture pressure values. Black line (group I): manual suture; and gray line (group II): mechanical suture.

Table 1 - Comparison of the rupture pressure of the bronchial stump suture line in animals submitted to bronchial suture.

Groups	Rupture pressure		p
	mean	SD	
I (n = 7)	33.71	12.7	
II (n = 8)	89.87	19.4	<0.01

Group I: manual suture of the bronchial stump; group II: mechanical suture of the bronchial stump using a stapler; mean: arithmetic mean; SD: standard deviation; p: probability; Student's t-test for independent samples.

Discussion

The type of animal selected, *C. familiaris*, is widely used in experimental studies in Brazil. It is a resistant animal, with dimensions that facilitate the surgical procedure, and it is easy to handle and obtain. Since the dogs were killed prior to surgery, there was minimal bleeding and this facilitated the entire surgical procedure. The vessels of the pulmonary hilum were easily identified, and the bronchial stump presented ideal dimensions for manual or mechanical sutures. The system used to measure the rupture pressure, which consisted of a source of compressed air or an oxygen cylinder and a manometer attached to an orotracheal tube with a system of rubber bands, was comparable to similar constructions described in other studies. In addition, the system used in this experiment had a connection with a collection bottle used in water seal pleural drainage systems. This modification makes the pressure tend to fall more slowly after the rupture of the suture line.

Pulmonary resection can cause various types of complications: surgical complications (empyema with or without bronchopleural fistula, bronchopleural fistula, chylothorax, hemothorax, infection of the incision site, thoracotomy dehiscence, need to repeat the operation); respiratory complications (pneumonia, atelectasis, respiratory failure, prolonged mechanical ventilation, need for reintubation); and cardiac complications (arrhythmias, acute myocardial infarction, angina, pulmonary edema, arterial hypertension).[6] Among all these complications, BPF is one of the most feared, since it can lead to other complications and even to death. For this reason, all efforts should be made in order to prevent it. Therefore, it is fundamental to identify and minimize risk factors in the pre-operative phase (chemotherapy, radiotherapy, use of systemic steroids, immunosuppression, and diabetes), intra-operative phase (surgeon inexperience, pneumonectomy, long bronchial stumps, right resections, right pneumonectomy, devascularization of the bronchial stump, bronchial margin affected by neoplasia, tension in the bronchial stump suture, failure to recognize BPF prior to the closure of the cavity, and inappropriate surgical technique used to close the bronchial stump), and post-operative risk factors (prolonged mechanical ventilation, use of systemic steroids, and reintubation).[1] There are other factors that should also be borne in mind: a) pulmonary resection for tuberculosis, which, in the examination of the bronchial secretion culture, is found to be caused by *Mycobacterium tuberculosis*[5]; b) radical mediastinal lymphadenectomy, since it increases bronchial devitalization[6,20]; c) age above 60 years.[21]

The influence of neoadjuvant chemotherapy is controversial. Some studies[4,18] have demonstrated a high incidence of BPF in patients who underwent chemotherapy or radiotherapy prior to surgery. Other authors[6,22] have not found such a relationship.

Prolonged mechanical ventilation or reintubation would favor the appearance of BPF in two ways. The first is the use of mechanical ventilators generating high pressure, which can traumatize the bronchial tissue. And the second is the iatrogenic introduction of bacteria from the oropharynx.[6,22]

The size of the bronchial stump is also a source of controversy. A long stump can cause accumulation of secretions, which, in turn, can generate infection and result in ischemia due to the devascularization. Even a short bronchial stump may present excessive devascularization due to technical failure. Both can cause BPF.[6] Since the rupture pressure was measured immediately after the closure of the bronchial stump, it is not possible that ischemia at the suture line influenced the results.

Mediastinal lymphadenectomy, as performed in oncologic surgery, can cause excessive devascularization, especially in relation to the perihilar lymph nodes. The resulting ischemia can favor the appearance of BPF.[6,20]

Another risk factor involved is the presence of residual disease in the bronchial stump, altering the normal process of cicatrization.[4]

One of the main influential factors in the formation of BPF, either due to the use of manual or mechanical sutures, is the level of surgeon experience.[21] The issue of the surgical strategy becomes secondary, since each surgeon uses the technique that is the most convenient and familiar. Studies show that surgeries performed by the same team present more significant results. In the present study, the operations were all performed by the same surgeon.

Various authors have implicated the chronic use of corticosteroids, diabetes, states of immunosuppression, hypoproteinemia, and states of malnutrition as factors contributing to the formation of BPF, since these factors exert effects throughout the process of cicatrization.[1,4,6,21] Although it was not possible to evaluate the nutritional status of the animals, all of them apparently presented good nutritional status.

Suture of the bronchial stump warranted special attention given its risk factors for BPF. Comparative study of the techniques of bronchial stump closure is necessary, since it shows us which is the best technique and which materials should be used in this important aspect of the surgical procedure. In recent decades, there have been great advances in the management of the bronchial stump.[6] New suture materials and surgical techniques have contributed to reducing the incidence of BPF.[3] Nevertheless, there is controversy regarding the issue of manual versus mechanical sutures for the closure of the bronchial stump.

The use of mechanical staplers to reduce the incidence of BPF has been advocated by several authors. The manufacture of modern staplers started around 1950 at the Moscow Institute of Research on Surgical Instruments, where the UKB and the UKL-60 models were designed.[23] Approximately one decade later, the Americans at the U.S. Surgical Corporation manufactured the Auto Suture TA models, which are currently the most widely used.[15,23] The advantages reported are the reduced dissection of the bronchus, the symmetry of the staples, the evenness of the tension on the bronchial tissue, the minimal granulomatous reaction, the increased speed of execution, and the radiographically visible suture line.[15,23] In addition, staplers reduce surgical time and are easy to handle.[15,23] However, there are certain disadvantages related to the high cost of the staplers, the inability to visualize the lumen of the stump, and the possible devitalization due to the excessive pressure of the staples. Nevertheless, the cost can be reduced through the resterilization of the material (without compromising its normal functioning), and opening the bronchus prior to stapling allows endobronchial examination.[23] The use of mechanical staples requires favorable conditions. Short, calcified bronchial stumps make it difficult to carry out the procedure. The TA-30 model used in the present study proved easy to handle, although its handling was facilitated by the favorable anatomy of the type of animal used in the experiment. None of the dogs presented any anatomical or scarring-related alterations, or any alteration of any kind, that might have made it difficult to perform the surgery. One factor that must currently be considered is hospital costs. In this sense, manual suture of the bronchial stump is the technique of choice after pneumonectomy, often being preferable to mechanical suture.[18] According to some authors, using manual polypropylene sutures is safe, and its cost is 10-times lower than that of mechanical suture.[18] Therefore, it can be easily adopted in all hospitals.

In our study, mechanical suture was found to be more resistant than manual suture. It is of note that the mean rupture pressure of the bronchial stump suture line in group II was significantly higher ($p < 0.01$) than that observed in group I. These results are in accordance with those obtained by various authors.[9-14] The incidence of fistulas has also been less frequent after mechanical suture,[15,16,26] although some authors have found the frequency of this complication to be higher.[17,27] The rupture pressure values obtained by various authors suggest that the process of cicatrization can have a beneficial effect on the increased resistance to pressure. The authors of three separate studies[9,10,12] obtained significantly higher rupture pressure values in animals submitted to mechanical suture and killed on post-operative day 14: 273.4 ± 37.3 mmHg, 251.25 ± 82.9 mmHg, and 251.2 ± 29.3 mmHg, respectively. The animals killed at an earlier time (on post-operative day 1) presented lower rupture pressure values: approximately 60 mmHg.[12] In the present study, the rupture pressure value was determined immediately after the suture of the bronchial stump and was found to be 89.87 ± 19.4 mmHg.

One group of authors[12] observed an increase in collagen production during the experimental period, and another author[28] concluded that there was no significant difference in the cicatrization of the bronchial stump of 18 dogs submitted to manual or mechanical sutures and killed on post-operative days 7, 15, and 36. However, some factor contributed to the gradual increase in rupture pressure observed in the groups of the first study. Mechanical suture presented a lower foreign-body type tissue response than did manual suture in 6 of the dogs operated and subsequently killed on post-operative days 7, 15, and 36.[29] Some authors believe that granuloma at the suture line is a risk factor for BPF.[30]

In addition, it is important to report that, with the exception of the two variables evaluated in the present study, all of the variables that potentially interfere with dehiscence of the bronchial stump can be controlled. We attempted to distribute the animals randomly into two groups and found that there was no significant difference between these groups in terms of body weight. It is of note that we tested the resistance of the bronchial suture immediately after closure. This fact is important since it gives us an idea of the status of the suture resistance immediately after closure and of the need for any additional measure to increase resistance and prevent BPF. Therefore, we can have more confidence in the technique we used.

Experimental studies involving bronchial suture vary, surgical techniques undergo changes over time, and surgical materials evolve at an even faster pace. This line of research presents many paths to be explored. The present study was easily carried out, especially due to the fact that survival of the animals after surgery was not necessary. Large-scale experiments, in which animals are divided into various groups and killed many days after surgery, require appropriate support staff and infrastructure, such as well-equipped animal facilities, specialized handling by technicians and veterinarians, post-operative monitoring by the team performing the procedure, and balanced nutrition. Researchers must constantly search for the ideal suture or procedure that can make it possible to perform surgeries more safely. This relentless search has gone on for years and will go on for many more.

We conclude that, in dogs submitted to pneumonectomy, suture of the left bronchial stump, submitted to pressure immediately after closure, is more resistant when mechanical, rather than manual, suture is used.

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