4 - ORIGINAL ARTICLE
MODELS, BIOLOGICAL

Laparoscopic correction of experimentally induced diaphragmatic rupture in dogs[1]

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ABSTRACT

PURPOSE: To describe the dog as a model for studying laparoscopic correction of experimental diaphragmatic ruptures.

METHODS: Five male dogs were used in this study. Under laparoscopic approach, a defect of 7cm was created on the left ventral insertion of the diaphragm. Fourteen days after this procedure, the abdomen was explored using laparoscopic access and the diaphragmatic defect was corrected with intracorporeal suture. The dislocated organs, surgical time, and suturing time were recorded. Analgesia and clinical condition were monitored during the postoperative period.

RESULTS: All animals recovered well from the diaphragmatic rupture creation. After 14 days, abdominal organs (liver, spleen, omentum and/or intestine) were found inside the thoracic cavity in all animals. It was possible to reposition the organs and suture the defect by laparoscopic access in three animals. These animals showed excellent postoperative recovery. It was not possible to reposition the liver safely when it was friable.

CONCLUSIONS: Laparoscopic creation of diaphragmatic rupture in dogs is feasible. Dogs are a good model for training and studying the correction of experimentally created diaphragmatic rupture by the laparoscopic approach. A friable liver is a complicating factor that should be taken into account. Animals submitted to laparoscopic correction showed excellent postoperative recovery.

Key words: Diaphragm. Rupture. Laparoscopy. Models, Animal. Dogs.

Introduction

Traumatic diaphragmatic rupture is a medical condition that allows abdominal organs to migrate into the thoracic cavity. Treatment commonly requires the replacement of dislocated organs and suture of the diaphragmatic defect, usually by open laparotomy or thoracotomy[1].

The use of laparoscopy to diagnose diaphragmatic rupture was first described in 1984[2], but the first laparoscopic correction of this disease was reported only in 1994[3]. Since then, several authors have reported the early recovery and low incidence of postoperative complications in patients submitted to this minimally invasive approach[4-13].

The development of an animal model for experimental and/or training purposes regarding laparoscopic correction of diaphragmatic rupture is of interest, but has not been reported yet. Thus, the objective of the present study is to describe the dog as a model for diaphragmatic rupture development and correction, both by minimally invasive approaches.

Methods

All experiments were performed in accordance with Brazilian laws on scientific use of animals, and the project was approved by the institutional ethics committee (CEUA-012-06).

Five healthy male mongrel dogs weighing 15-25 Kg were used in the study. Clinical examinations were performed, and the animals were observed for at least 15 days before the experiment.

Dogs were housed together in an area with space of 5 m^2/dog. There was free access to water and the animals were fed with commercial dog food, twice a day. The dogs were allowed to walk and play in a ~5,000 m^2 outdoor area twice /day.

Creation of diaphragmatic rupture

Animals were premedicated with acepromazine (0.05 mg/Kg, IM) and fentanyl (0.003 mg/Kg, IM). The anesthesia was induced with propofol (3mg/kg, IV) followed by Atracurium (0.5 mg/Kg, IV) and maintained with isoflurane in oxygen. The whole abdomen, from the xiphoid to the pubis, was prepared for aseptic surgery.

Pneumoperitoneum of 12 mmHg was created with a Veres needle and then a first 10mm trocar was introduced on the umbilical scar in order to insert the laparoscope (30°). After initial inspection, a 10 mm trocar and a 5 mm trocar were placed in the right and left cranial abdominal quadrants. The table was tilted to a 15° Fowler position, intra-abdominal pressure was reduced to 6 mmHg and the diaphragm was incised on the left ventral insertion with scissors and hook, applying monopolar energy. Hemorrhagic points were coagulated with bipolar energy. The defect created was measured with a piece of polypropylene tube from a butterfly needle, previously cut to 7 cm. This tube was introduced from a reducer and stretched with two forceps (Figure 1a). The cavity was desuflated, the 10 mm port incisions and skin were closed. Needle thoracocentesis was performed for drainage of residual CO_2.

Correction of diaphragmatic rupture

Fourteen days after the creation of the diaphragmatic rupture, dogs were anaesthetized with the same protocol and prepared for laparoscopy. Pneumoperitoneum of 6mmHg was created by Hasson technique with introduction of the first trocar 2 cm caudal to the umbilicus. Other trocars (10 mm and 5 mm) were inserted at the right and left side just caudal to the first surgery's scars. After complete inspection of the cavity with special attention to the diaphragm, the table was tilted to a 15° Fowler position, dislocated organs were replaced into the abdominal cavity and intracorporeal simple continuous suture was placed on the defect using 2-0 polyglactin 910. The cavity was desuflated and the 10 mm port incisions and skin were closed. Needle thoracocentesis was performed for drainage of residual CO_2.

Postoperative evaluation and analgesia

The animals were individually monitored during the first seven days following surgery. Rectal temperature, general state, behavior, dyspnea, food and water consumption, production of feces and urine, wound state and any other abnormal findings were evaluated.

Cetoprofen was administered just after the anesthetic induction (1 mg/Kg, IV) and during the following three days (1 mg/Kg, PO, q 24h). Tramadol (2 mg/Kg ,IM) was administered in case of a score higher than 8 based on the University of Melbourne Pain Scale[14]. This postoperative protocol was used for the surgeries to create and correct of the diaphragmatic rupture.

Results

Creation of diaphragmatic rupture

The use of scissors and hook with monopolar energy was successful in promoting the diaphragmatic defect. Some small hemorrhagic points were promptly cauterized with bipolar forceps.

The insertion of a piece of polypropylene tube was an easy and useful maneuver to measure the created defect.

After the first incision on the diaphragm, the passage of gas from the abdominal to the thoracic cavity was observed, even after the reduced insufflation pressure of 6 mmHg. This procedure left the thorax in a barrel shape. This insufflation pressure was enough to perform all maneuvers. No abdominal organ was found displaced through the thoracic cavity at the end of this surgery. The mean surgical time was 47.5 minutes.

Correction of diaphragmatic rupture

In all animals studied, both the diaphragmatic defect and dislocated organs were promptly visualized during laparoscopy. The liver was the most frequently dislocated organ (60%) and in two animals (40%) it was seen congested and very friable. Pleural effusion was present in those two animals (Figure 1b). The omentum (40%), spleen (20%), and small intestine (20%) were the other organs found in the thorax. It was possible to notice in some animals adherences among the falciform ligament, omentum and the edge of the diaphragmatic defect.

The major difficulty observed in the surgeries was repositioning the dislocated friable liver. The traction of the organ with laparoscopic instruments was not a practical method, since in one of the animals it provoked parenchymal lesions. As a consequence, bleeding was observed after repositioning of the organ into the abdomen, requiring conversion to open surgery. In the other animal with friable dislocated liver, conversion to open surgery was performed after unsuccessful attempts of repositioning the organ into abdominal cavity.

All other dislocated organs, including the liver without congestion, were easily replaced by traction with Babcock forceps. The adherences here observed were promptly dissected with Hook or Maryland forceps.

Intracorporeal diaphragmatic suture was successfully performed in three dogs in an average time of 54 minutes, from the introduction to the removal of the needle from the cavity (Figures 1c and d). The mean surgical time in the animals that were submitted to intracorporeal suture was 106 minutes.

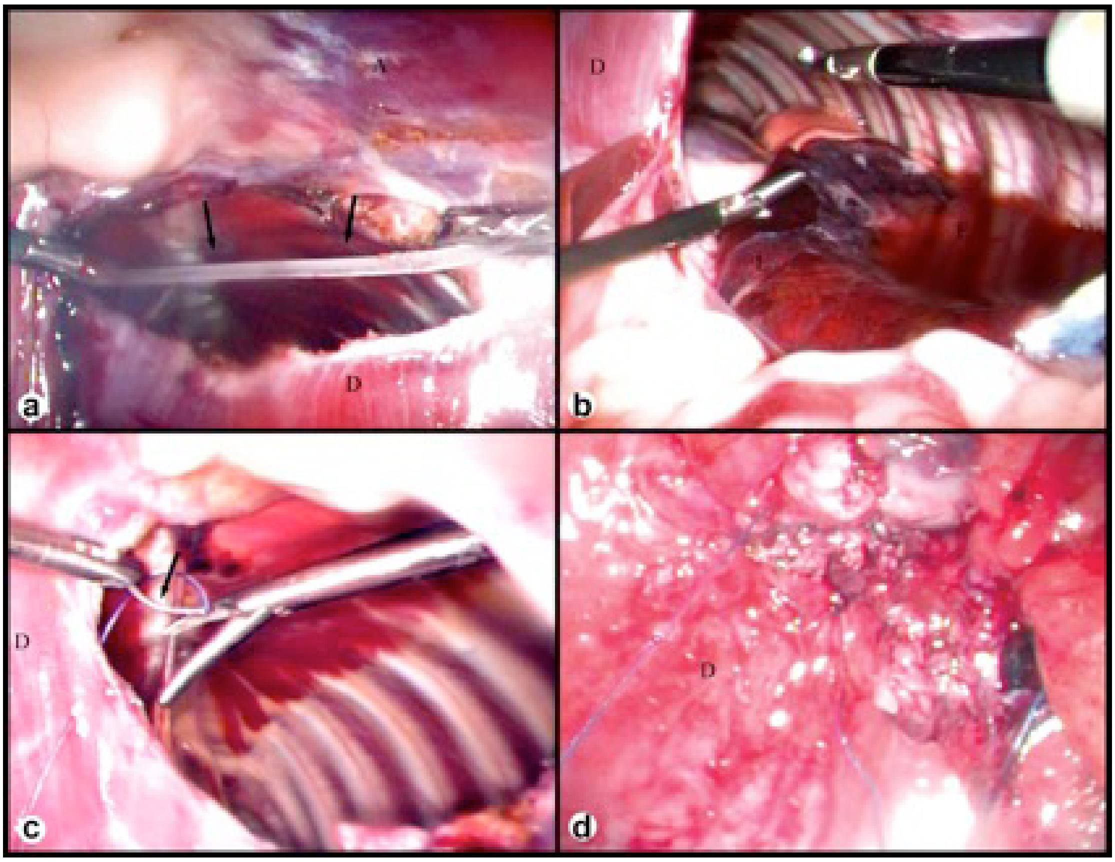

FIGURE 1 - Laparoscopic images. **a)** Polypropylene tube (arrows) stretched with two forceps used to measure the diaphragmatic defect. A, abdominal wall; D, diaphragm. **b)** Congested and friable liver (L) inside the thoracic cavity with effusion (E). **c)** Intracorporeal suturing for correction of diaphragm rupture. Needle (arrow) being inserted in the diaphragm. **d)** Final aspect of the sutured diaphragmatic defected.

Postoperative evaluation and analgesia

The animals submitted to laparoscopy showed excellent recovery after anesthesia. They promptly accepted food less then 30 minutes after extubation. No changes in rectal temperature, food and water intake, production of feces and urine and behavior were noted. Surgical wounds did not show any sign of infection, healing uneventfully. Dyspnea was also absent in all animals. None of these animals needed administration of tramadol.

The dogs that underwent laparotomy for correction of the diaphragmatic defect showed inapetence and apathy in the early postoperative period, with slower anesthetic recovery. After 24 hours, food and water were accepted, but the animals general state was not good, and higher rectal temperature (39.7ºC), behavior changes and dyspnea were observed. Analgesic evaluation showed scores of 9 and 10, thus requiring administration of tramadol. An improvement in the general state, return to normal behavior as well a reduction of dyspnea were observed by the third and fourth postoperative day.

Discussion

In our study it was possible to correct with laparoscopy diaphragmatic rupture experimentally induced in dogs when the liver was not friable. The major difficulty concerned the proper replacement of this organ, since it could not be securely grasped with laparoscopic instruments. The repositioning of the liver dislocated to thoracic cavity was previously reported[15], but the authors did not find the organ friable as in the present experiment.

It is well known that when excessive hepatic manipulation is needed during laparoscopic surgery, a hand-assisted approach may be indicated, in order to avoid parenchymal injuries by the laparoscopic instruments, allowing fast manual compression of hemorrhagic points and preserving tactile sensation of the organ[16]. Therefore the hand-assisted approach may be of benefit when a friable liver is found during laparoscopic correction of diaphragmatic rupture.

Intracorporeal suturing is considered an advanced minimally invasive skill that demands a long learning curve[17-19]. Suturing is considered difficult because of the absence of tactile sensation, lack of depth perception, magnification of all movements and limitations of instrument mobility[20]. In our study, intracorporeal suturing was a very time-consuming phase, but did not hamper the use of the minimally invasive technique for correcting the diaphragmatic defect.

The introduction of automatic suturing devices in laparoscopic surgery reduces suturing and operative times[18,20]. However, the use of these devices can also reduce time for correction of diaphragmatic ruptures, although the unavailability did not preclude the procedure.

Laparoscopic correction of diaphragmatic rupture in clinical settings has been reported by many authors and it is always associated with shorter hospital stay, faster return to normal activities and minimal postoperative complications[4-13]. The present study reports comparable postoperative results in experimental animals, which may be another advantage of this technique. Thus, the use of this model can be considered for both training and research purposes. In a previous study, pigs were used to create and immediately correct small diaphragmatic tears[21].

It has been demonstrated that thoracic insufflation with carbon dioxide with or without associated abdominal insufflation causes cardiopulmonary effects such as decrease in oxygen saturation, arterial blood pressure and cardiac output, and increases in peak inspiratory and central venous pressure[22,23]. One study that mentions insufflation pressure for correction of diafragmatic rupture in clinical conditions used 10 mmHg. In that study, the authors postulated that low pressure should be used to avoid CO_2 passage through the mediastinum with potential complications[24]. In our study, using 6 mmHg insufflation, it was possible to observe CO_2 passage to both hemithoraxes, leaving the chest in a barrel shape. We believe that experimental hemodynamic studies of animals submitted to different abdominal insufflation pressures in the presence of diaphragmatic rupture may be important to define safe insufflation pressures.

Conclusions

Dogs can be used as a model for laparoscopic creation of diaphragmatic rupture for research and education purposes. Laparoscopic correction of experimentally created diaphragmatic rupture in dogs is feasible with intra-corporeal suturing. The possibility of a friable liver is a complicating factor that should be taken into account. All animals had the major advantage of excellent postoperative recovery.

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