

Laparoscopic Splenectomy: Posterior Approach Avoiding Hilar Ligature

¹ RICARDO ZORRON, MD, PHD; ² ANDRE LACERDA OLIVEIRA, PROFESSOR OF VETERINARY MEDICINE, PHD; ³ FERNANDA ANTUNES, PROFESSOR OF VETERINARY MEDICINE, PHD; ⁴ MARCELO RIOS QUEIROZ, PROFESSOR OF VETERINARY MEDICINE; ⁵ DANIEL DE JESUS SOARES FLORES, MD; ⁶ MÁRIO ARY PIRES NETO, MD, PHD; ⁷ VIVALDO MOURA NETO, MD, PHD.

¹ Professor and Chairman, Department of Surgery, University Hospital Teresopolis HCTCO-FESO. Division of Surgery- Hospital Municipal Lourenço Jorge – Rio de Janeiro; ² Department of Surgery –Hospital Veterinario UENF, Campos de Goytacazes, Rio de Janeiro- Brazil. ³ Department of Surgery – Veterinarian Hospital UENF, Campos de Goytacazes, Rio de Janeiro- Brazil; ⁴ Department of Surgery – Veterinarian Hospital UENF, Campos de Goytacazes, Rio de Janeiro- Brazil; ⁵ Division of Surgery- Hospital Municipal Lourenço Jorge – Rio de Janeiro; ⁶ Professor Adjunto do Department of Anatomy- Universidade Federal do Rio de Janeiro -U.F.R.J.; ⁷ Professor Titular, Chefe do Department of Anatomy - Universidade Federal do Rio de Janeiro -U.F.R.J.

ABSTRACT

Objective: Laparoscopic splenectomy has become in many centers the standard treatment of hematological disease with surgical indication. However, the learning curve with the technique is still hazardous and restricted to expert surgeons with advanced laparoscopic skills. Also the cost for the use of laparoscopic vascular staplers is still high and prohibitive for community hospitals. An electrothermal bipolar vessel sealer (Electrothermal Bipolar Vessel Sealer- Ligasure, Valleylab, Boulder, Colorado, USA) was developed as an alternative to suture ligatures, hemoclips, staplers and ultrasonic coagulators for ligating vessels and tissue bundles. The method seals vessels up to 7mm in diameter by denaturing collagen and elastin within the vessel wall and surrounding connective tissue. The technique proposed by the author, using the posterior approach and the new electrothermal device discards the use of hemoclips, ligatures and vascular staplers in an animal canine model. This study was designed to determine the efficacy and safety of this technique and delineate its time saving potential in experimental and clinical scenarios. **Methods:** 40 arterial splenic vessels from variable caliber were sealed using the technique, in dogs weighting between 7 to 22kg, and intra- and postoperative parameters were documented. Hystological analysis was done for the sealed resected arterial segments. **Results:** All animals were well after a 30-days follow-up period, there were no complications, nor reoperations. A mean of 6,7 arterial branches (4-13) for animal were found and sealed, and the predominant anatomy pattern was truncal. The equipment was used 150 times during the procedures. Only three vessels (2,0 %) needed re-sealing, and there were no need for use of endoclips or ligatures. Mean operative time was 48,4 min (31-65 min), mean blood loss was 40,0 ml (20-120ml). Hystological analysis of the specimens showed collagen denaturation, and adequate sealing of the arterial lumen in all specimens studied. **Conclusion:** The results of this experimental study suggest that the approach is feasible and safe in sealing splenic vessels in this animal model. Further studies will be necessary to establish its role for clinical use on a routine basis.

Key words: Laparoscopy; laparoscopic splenectomy; surgery; spleen; immune thrombocytopenic purpura; ITP; minimally invasive surgery; Ligasure.

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1. INTRODUCTION

Laparoscopic splenectomy is considered the gold standard treatment for hematologic diseases, in special for immune thrombocytopenic purpura (ITP), spherocytosis and elliptocytosis that usually presents reduced spleen volume. With the evolution of this technique it was established an approach with the

patient placed in lateral decubitus position^{1,2}, in which gravity retracts the organs favoring the technique with a shorter operative time, reduced number of trocar and shorter conversion rates. However, the splenic vessels ligature is performed through its anterior surface resulting technical difficulties for this approach as the anterior surface of the spleen should not be manipulated as it may cause injury and bleeding

especially in patients with ITP³. GOSSOT reported that a posterior approach to the splenic vessels allow a safe vascular control, with low operative bleeding when compared to other approaches^{4,5}. However, splenic vessels ligation is still a challenge for the surgeon as it results in a laborious and difficult operative time. The use of disposable staplers has a high cost and it is not available in majority of the public hospital. For this reason and due to the difficult manipulation of the spleen, which is a solid and fragile organ, the use of this technique is not a routine in most of the Brazilians centers.

An electrothermal bipolar vessel sealer (EBVS-Ligasura, Valleylab, Boulder, CO, USA) was developed as an alternative to suture ligation for sectioning vessel and tissue bundles. O EBVS-Ligasura may seal vessels up to 7mm in diameter by denaturing collagen and elastin within the vessel wall and adjacent connective tissue. According to recent literature^{6,7,8,9}, with this technique it is possible to obtain a shorter operative time in some conventional and advanced laparoscopic surgeries, sparing the use of traditional hemostasis media. Moreover, different from the present ligation media, this technique may have the advantage of not leaving foreign material in the cavity.

The combination of a posterior approach using bipolar electrocoagulation of the splenic vessels and this new technology seems reasonable. The aim of this experimental study in dogs is to evaluate the technical viability of the laparoscopic splenectomy by posterior approach avoiding hilar ligation using EBVS-Ligasura, and its effectiveness in an adequate vascular control, testing vascular sealing in 40 splenic vessels with different calibers.

2. METHODS

All the procedures performed in this study are according the criteria established by the Bioethics Committee of the Biophysics Institute Carlos Chagas Filho and by the Animal Welfare Institute (AWI; Washington, DC, USA). Forty arterial segments of splenic hilum of 6 adult half-breed dogs weighting from 7,0 to 22 kg were used.

Fasting of the animals began on the day before the surgery, and only liquid diet was given on the day before the fasting. Antipneumococcal vaccination (Pneumovax) was performed on the animals 15 days before the surgery, besides it was given prophylactic antibiotic therapy with cefalotin

(2 hours before the incision). The intravenous general anesthesia was administered by an accredited veterinarian, consisting of pre-anesthetic medication with acepromazine(0,1 mg/kg), and a combination of ketamine(2,0 mg/kg) and benzodiazepine(1,0 mg/kg). Postoperative epidural anesthesia with marcaine 0,5% and lidocaine 2%(1,0 ml, 1:1 for each 4,0 kg) was performed in the animals.

Operative Technique

The animal was placed in right lateral decubitus position and reverse 20° Trendelenburg position. The open technique was used to insert the first trocar with a 1 cm incision to the left of the umbilicus 10 cm below the costal margin. The pneumoperitoneum is insufflated with CO₂ through the trocar with a pressure lower than 12mm/Hg. A second 10mm trocar is inserted 10 cm to the left of the first trocar at the level of the mid axillary line. In this trocar is used the EBVS-Ligasura ATLAS bipolar clamp which is characterized by two electrodes of bipolar coagulation with a cutting blade between them



Figure 1 - Splenic pedicle sealing with no ligation using EBVS-Ligasura.



Figure 2 - Section of the splenic pedicle with no residual bleeding.

for transection of the sealed tissue (Figures 1 and 2), thus the port is also used to retrieve the specimen usually without the necessity to enlarge the incision. The third 5mm trocar is inserted well below and to the right of the umbilicus which is available to the left hand of the surgeon. The surgeon and first assistant (camera) are positioned to the right of the animal, while the technical device is placed to his left side.

After the trocars are inserted the spleen is mobilized laterally, thus traction is achieved by the elevation of the spleen with the clamp on the left hand. The limit of the dissection in this side is the gastric fundus and short gastric vessels, when the spleen will be completely mobilized from its posterior aspect and tending to fall to the right side of the animal. A polar artery was identified and sectioned with EBVS-Ligasure© in the lower pole aspect of the spleen.

Subsequently, the section of the short vessels between the gastric fundus and the superior pole of the spleen is performed with EBVS-Ligasure© through the posterior access. Hemostasis is achieved by repeating the use of EBVS-Ligasure© with section of the splenic vessels close to the spleen. The pancreas was visualized and carefully dislocated in each application of EBVS with progression towards the superior pole. Before the section of the last segment, the hilum was revised to evaluate the presence of reinident bleeding. In this case, a new attempt with bipolar electrocoagulation is performed, using hemoclips and ligatures as a last resort, due to the fact that the use of other techniques instead of the EBVS-Ligasure© is considered a failure to the technique that has been proposed.

The spleen is placed into a durable plastic bag and extracted through the most lateral trocar (Figure 3). The incision performed was enough to insert a conventional Duvall forceps to perform the morcellation of the splenic tissue inside the bag, to remove the whole tissue. The arterial segments of the extracted organ were selected and measured then they were sent to histopathological examination. At the end of the procedure the collected blood was aspirated and measured. The anatomy of the splenic vessels of each animal was studied, regarding the main vessels caliber in millimeters, its segmentation and peculiarities. The weight of the morcellated spleen (fragmented through intraoperative procedure) was documented, and the result calculated to the spleen intact weight by following the formula established by WALSH¹⁰ (intact weight(g)= morcellated weight x 1,34

+ 45), which enables nowadays the calculus of the real weight of the spleen from the specimen obtained during surgery. The final aspect is three 0,5 to 1,2 cm incisions which a good cosmetic result (Figure 4).

The use of electro-surgery was evaluated in regard to its capacity to seal large caliber vessels preventing resealing or ligature through unabsorbable thread and other techniques which would mean failure of the technology as the only mean to achieve hemostasis. The percentage of technical failure of electrosealing applications for each procedure was evaluated. Samples of arteries and large caliber vein of the splenic hilum of each animal were analyzed regarding permeability and denaturing with lumen obstruction, besides being compared to non-sealed vascular segments. The segments were fixed in formalin and paraffin blocks and stained with hematoxylin-eosin. It was not used additional special stain and the visualization of the lumen of the collagen and the vascular wall was obtained by magnification of 100 to 400 times.



Figure 3 - Placement of the spleen in plastic bag.



Figura 4 - Final Aspect.

3. RESULTS

Forty arterial segments were sealed through the method described in six male dogs weighing between 7 and 22 kg. These animals underwent laparoscopic splenectomy under the posterior access technique avoiding hilar ligation with hemostasis achieved by bipolar electrosealing with EBVS-Ligasura. Intraoperative data were documented as well as the postoperative evolution, complementary examinations and histological aspects of the vessels after hemostasis. All the procedures were performed without significant complications and no conversion to conventional surgery.

The main surgical data obtained are showed in table 1. The data with calculus of the mean are exposed as mean \pm standard deviation. The total operative time (anesthetic time) varied from 50 to 75 minutes (mean of $64,0 \pm 3,8730$ min), with surgical time of 31 to 65 minutes (mean $48,3333 \pm 4,9171$ min). The time necessary to the vascular section which represents the longer period of the laparoscopic splenectomy was only $18,7383 \pm 2,2655$ min (varying from 14 to 26 min), while the extraction of the specimen through the plastic bag was similar with mean

of $18,5000 \pm 1,1180$ minutes, with results between 15 and 21 min.

The vascular anatomy of the spleen in this experimental model depicted prevalence of the truncal segment, a bifurcation of the splenic artery next to the parenchyma was observed with different types of branches measuring from 2 to 3 cm varying from 4 to 13 branches, with a mean of 6,8 branches per animal (Figure 1). Polar arteries, either superior or inferior were observed in all cases. The greatest artery caliber varied from 3,0 to 5,0 mm with mean value of 4.0 mm.

Mild intraoperative complications were observed in three cases: a laceration in the disposable bag with a small amount of blood leakage to the abdominal cavity, a laceration of the splenic capsule that was already in the bag, and a perforation of the splenic capsule while the first trocar was being inserted at the beginning of the surgery. The three cases were easily managed with simple aspiration, bipolar hemostasis or replacement.

The evaluation of the operative bleeding through the measurement of the aspirated blood collected from the abdominal cavity depicted only a mean bleeding of $40,0 \pm 16,1761$ ml. The size of the

Table 1 - Results of the Experimental Study. Operative Data.

	Animal 1	Animal 2	Animal 3	Animal 4	Animal 5	Animal 6	Mean \pm standard deviation
Weight (kg)	17,0	7,0	10,0	15,0	22,0	16,0	14,5 \pm 2,1718
Time of anesthesia	74	50	65	60	60	75	64,0 \pm 3,8730
Time of Surgery	59	31	45	45	45	65	48,4 \pm 4,9171
Time of Ligation	24:55	18:17	16:51	14:40	12:50	26:30	18,7383 \pm 2,2655
Time of extraction	20	15	21	15	20	20	18,50 \pm 1,1180
Bleeding estimative (ml)	120	20	20	20	25	35	40,0 \pm 16,1761
Number of arteries	13 Distributing	5 Truncal	4 Truncal	5 Truncal	7 Truncal	6 Truncal	6,6667 \pm 1,4
Artery caliber(mm)	4,3,3,3,3,3,3,2,2,2,2,1,1	4,3,3,2,2	4,3,3,2	3,3,3,2,1	4,4,3,2,2,2,1	3,3,2,2,2,1	2,5722 \pm 0,1177
Incision 1 (cm)	1,0	1,2	1,0	1,2	1,2	1,2	1,1333 \pm 0,0422
Incision 2 (cm)	1,0	1,0	1,2	1,3	1,2	1,2	1,1500 \pm 0,0500
Incision 3 (cm)	0,5	0,5	0,6	0,5	0,4	0,6	0,5167 \pm 0,0307
Ligation(application)	32	25	30	21	19	23	25,0000 \pm 2,0817
Ligation(failure)	0	Reapplic. 2 vasos	Reapplic. 1 vaso	0	0	0	0,5000 \pm 0,3416

incisions were in average $1,1333 \pm 0,0422$ mm for the first incision (camera), $1,15 \pm 0,0500$ mm for the second incision (clamps in the right hand) and $0,5167 \pm 0,0307$ mm for the third incision (left hand), avoiding the tissue trauma of the medium or transverse incision usually greater than 15 cm.

Electrothermal bipolar vessel sealer with EBVS Ligasureã was applied a mean of 43 times per animal for hemostasis and splenic hilar section. Electrocoagulation and section of the artery and the vein were performed at the same time to facilitate the sealing effect. The use of EBVS was effective in order to avoid bleeding in most of the cases, although reapplication was performed twice on the second animal (8%) and once on the third animal (3,3%). Thus, in 150 applications it

was necessary reapplication in three cases because of bleeding with a mean failure of 2,0%. The 40 arteries studied were successfully treated with this method. In none of the cases it was necessary hemostasis with monopolar scalpel, clips, suture or vascular staplers. Hemostasis of large caliber vessels with EVBS-Ligasuraã during intraoperative time was proved to be reliable, which facilitates the execution of the technique without using other hemostatic methods.

Laboratory data collected postoperatively within 24 hours presented significant change in their values in all animals when compared with the preoperative basal values (Table 2). Either hemoglobin or hematocrit values mean reduced from $10,86 \pm 1,0717$ mg/dl to $9,54 \pm 0,9244$ mg/dl and from $33,94 \%$

Table 2 - Results of the Experimental Study. Extra-Operative data.

	Animal 1	Animal 2	Animal 3	Animal 4	Animal 5	Animal 6	Mean \pm standard deviation
Weight intact spleen (g)	219,2	112	98,6	85,2	162,92	98,6	129,4200 \pm 21,0882
Weight fragmented spleen (g)	130	50	40	30	88	40	63,0000 \pm 15,7374
Hematocrit preoper(%)	32,6	43,4	23,9	31,6	38,2	-	33,9400 \pm 3,2841
Hematocrit postoper (%)	31,1	34,9	20,8	24,7	33,2	-	28,9400 \pm 2,6699
Hemoglobin preoper (g/dl)	10,7	14,0	7,6	9,9	12,1	-	10,8600 \pm 1,0717
Hemoglobin postoper (g/dl)	10,1	12,1	6,8	8,2	10,5	-	9,5400 \pm 0,9244
Platelets preoper/mm ³	104 000	254 000	37 000	21 000	161 000	-	115400,000 \pm 42706,6740
Platelets posoper /mm ³	227 000	264 000	69 000	261 000	309 000	-	226000,000 \pm 41356,9825
Intraoperative Complications	Spleen Injury inserting trocar	0	Spleen laceration placing in plastic bag	0	0	0	0,3333 \pm 0,2108
Postoperative Complications	0	0	0	0	0	0	-
arterial luminal sealing	complete	complete	complete	complete	complete	complete	100,0000 \pm 0,0000
Reoperation	0	0	0	0	0	0	-
Death in 30 days	0	0	0	0	0	0	-

$\pm 3,2841$ to $28,94 \% \pm 2,6699$, respectively probably due to the lost of the massive organ, operative bleeding and hemodilution from crystalloid infusion. The value of platelet counts have also changed significantly compared with preoperative values. The high number of platelets due to splenectomy was found in animals in which laboratory exams were checked, increasing the mean values from $115\,400 \pm 42706,6740$ to $226000 \pm 41356,9825 / \text{mm}^3$.

The histopathologic exam of a sample of splenic pedicle was performed the areas that were sealed with EVBS-Ligasuraã were marked and the areas with vessels were protected. It was demonstrated that protein denaturation in the splenic vessels caused their complete sealing (Figures 5 and 6).

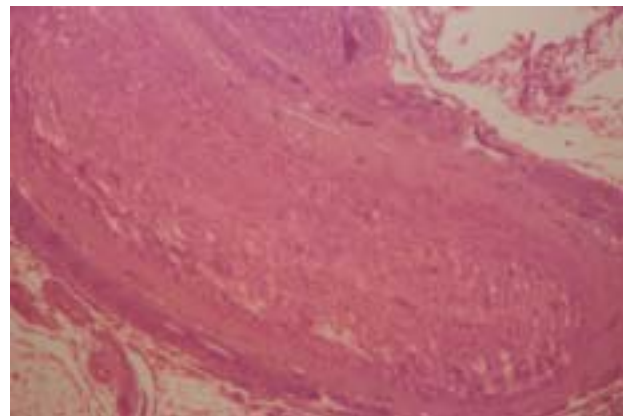
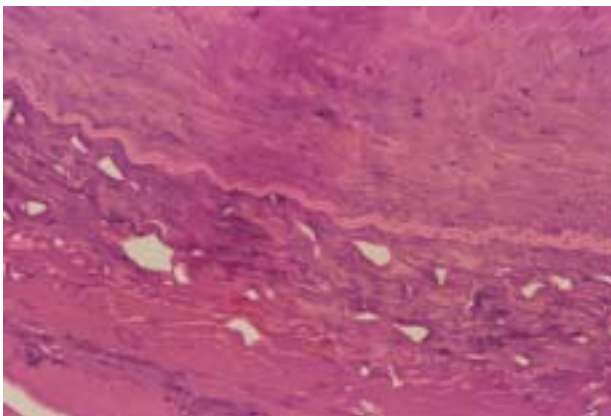
A postoperative follow-up was performed with adequate analgesia and hydration of the animals which were observed during 30 days. Postoperative complications, necessity of new surgery and death of animals were not observed in any of the cases studied.

4. DISCUSSION

Since it was first described in 1991¹², laparoscopic splenectomy has become a widely accepted technique relying on clinical studies with good results^{13,14,15,16,17,18,19,20}. Problems regarding the procedure concerning technical difficulties, steep learning curve and cost of disposable material such as linear staplers which hinder the technique to be performed in large scale, therefore a considerable part of the population are deprived of a less invasive procedure.

The results of this initial experience with the use of laparoscopic splenectomy by posterior approach avoiding hilar ligature were satisfactory as they depicted the feasibility of the method and its clinical applicability. First, it was shown that the technique was easily executed without severe complications. All the procedures were performed with no abnormalities and the animals maintained a good postoperative evolution after 30 days follow-up. The operative bleeding was small, the use of new EVBS-Ligasuraã technology was effective for hemostasis, the operative time was shorter and there were no conversion to open surgery. Second, it is visualized its application for controlled clinical series, and it was also observed that the new way to achieve hemostasis was effective for vessels of different caliber.

An approach with only three trocars (instead of the usual four or five) promotes a smaller operative invasion besides better cosmetics. The placement of the animal in complete lateral decubitus position during the procedure allowed the spleen, a solid and fragile viscus, to be approached without being necessary to retract other organs as well as it reduced manipulation. The small estimative of operative bleeding during surgery (mean of 40,0ml) evinces the reduced trauma of this approach in the experimental model. In this study, hemoglobin and hematocrit values also decreased considerably which is common after splenectomy and that might be reflecting the loss of the blood withheld in the organ as there was not an expressive bleeding in any of the cases. Platelets level increased considerably (from a preoperative mean



Figures 5 and 6. Histopathologic aspect of the vessels submitted to EVBS-Ligasuraã sealing. It is observed the degeneration of the lumen of the arterial vessels with the filling of the neofomed material with no coagulum (arrows). Coloration by Hematoxilin-eosin; 100 x (Figure 5), e 400 x (Figure 6).

of 115400 to a postoperative mean of 226000), which is an expected and physiological reaction to splenectomy^{21,22}.

The satisfactory result with the use of EBVS-Ligasure© to achieve hemostasis of large caliber vessels which are also present in the human anatomy is quite stimulating. There is an estimative that arteries and large caliber veins of human splenic hilum usually have a diameter of 4 to 7 mm, and that all of them can be sealed and sectioned through this new technology as it was demonstrated in the current study and in other recent experimental studies^{6,7,8,9,23,24}. The study showed the feasibility to seal vessels with the use of this technology. In this study, the EBVS-Ligasure© is used through controlled applications by the surgeon with the intention to seal all the vessels of the splenic hilum, without the use of ligature and endoclips. In average the device was surgically used 25,4 times per animal with a total of 150 applications. In only three occasions the device fails in achieve hemostasis during the first application, being necessary a new application which stopped the bleeding in all cases. Thus, in the current investigation there was an incidence of 2,0% of failure to achieve hemostasis after the first application.

HAROLD studied different types of available hemostasis comparing the bursting pressure of arteries sealed with ultrasonic coagulating shears (UCS-Ultracision©), electrothermal bipolar vessel sealer (EBVS-Ligasure©), titanium laparoscopic clips or plastic laparoscopic clips⁹. In addition, it was studied the degree of thermal injury from the ultrasonic shears and the bipolar sealer in which was observed a small variation in the extent of the tissue injury, about 2mm for both approaches with no significant difference. Results demonstrated that UCS-Ultracision© was only effective in vessels smaller than 3mm, which is not appropriate to achieve hemostasis of large caliber vessels. On the contrary sealing with EBVS-Ligasure© was effective in burst strengths at least three times greater than the physiologic arterial pressure, being evident that with this technology the surgeon would adequately seal the majority of the vessels encountered in day-to-day surgery, including mesenteric and splenic vessels.

KENNEDY found similar result studying the effects of hemostasis using this technology in 331 arteries and veins in experimental animals and fresh abattoir vessels. He compared the bursting strength

using bipolar coagulation, UCS-Ultracision©, EBVS-Ligasure©, endoclips and ligatures. The respective probabilities ($\pm 90\%$ confidence intervals) for burst strengths being less than 400 mmHg (\sim systolic pressure $\times 3$) were 0.95 (0.82–1.00) for the ultrasonic coagulator, 0.28 (0.19–0.38) for the bipolar coagulator, 0.02 (0.00–0.06) for the sealer, 0.04 (0.00–0.13) for clips, and 0.00 (0.00–0.13) for ligatures. The feedback control, that is, the capacity of the mechanism to determine the necessary amount of time to completely seal a vessel through the energy that pass to the vessels walls while the tissue is being tightly held represents additional safety. When the device sounds after 2,0 to 5,0 seconds it means that the vessel is sealed and it may be safely sectioned. The sealed segment has an acute burst strength approximating that of ligatures and endoclips, and is easier to be executed as no devascularized vessel stump or foreign material are left behind, free of tissue reactivity and adhesions.

It was also demonstrated that protein denaturation in the lumen of the splenic vessels caused their complete sealing when comparing to non-coagulated segment. This finding has been also documented in clinical and experimental studies^{6,7,23,24}. The adequate sealing, depending on the surgical aspect, is characterized by translucency and resistance to deformation. As shown microscopically, the internal elastic lamina was preserved, and occasional collagen bundles were seen crossing and obstructing the vascular lumen. However, there is no luminal thrombus in the segment sealed. The area of thermal alterations reaches between 1,5 and 3,3mm within-the-jaw tissue which is more reliable to avoid thermal injury in adjacent structures than the monopolar and bipolar coagulators^{7,9}.

The posterior approach has shown to be satisfactory due to the simplicity and anatomic exposition of the arteries and veins of the spleen. The treatment of the vessels by posterior approach after spleen mobilization in medial direction regarding working space represents the opposite of the medial approach used in most of the institutions that perform the laparoscopic technique by lateral or anterior approach. The total time of anesthesia with a mean of 64,0 minutes and mean surgical time of 48,4 minutes allow an approach with reduced exposure to anesthetics. The time of treatment of the splenic pedicle (mean of 18,7min) represents a small fraction of the total operative

time, in which is known the technical difficulty to perform the same procedure through ligation or individual clipping of the vessel²⁰.

The videosurgery of the spleen is an attractive proposal for patients and for the entire health system. It allows a minimally invasive technique with less suffering and complications for the patients, in addition to allow a short period of hospital stay, in which more hospital beds will be available. Laparoscopic splenectomy through posterior approach avoiding hilar ligature represents a technical improvement that aims at simplify the access and learning of the technique spreading the knowledge of this approach.

5. CONCLUSION

Laparoscopic Splenectomy approach through the posterior approach avoiding hilar ligature with the use of EVBS-Ligasure© was safe and feasible controlling all the vessels during laparoscopic splenectomy in this experimental model. The histologic study shows that the vessels were completely sealed, occurring protein denaturation inside their lumen.

The learning curve seems to be less steep when compared with ligation by suture, in spite of allowing the permanence of foreign material inside the organism.

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Correspondence Address:

PROF. RICARDO ZORRON
University Hospital Teresopolis HCTCO-FESO
Email: rzorron@terra.com.br