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An Effective Way to Prevent Depressurization of Carboxyperitoneum and Extraperitoneal Insufflation During Simultaneous Laparoscopic Interventions

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ABSTRACT Laparoscopic simultaneous surgery (LSS) in patients with multisystem abdominal organs lesion is accompanied by ports' re-installation for subsequent surgical intervention. Preserved trocar wounds (PTWs) pass carbon dioxide from the abdominal cavity, increasing its flow and causing depressurization of the carboxyperitoneum. The incidence of extraperitoneal insufflation during laparoscopy varies from 0.43 to 2% (I.V. Vartanova et al., 2016). The presence of many methods of sealing PTWs indicates their inefficiency.

AIM OF STUDY To develop an easy-to-use, more reliable and effective way of sealing PTWs.

RESULTS As a result, a comparative evaluation of known methods of sealing PTWs, we have developed an easy-to-use, more reliable and effective way of sealing PTWs «Method for sealing punctures of the abdominal wall after removing the trocar during a laparoscopic surgery» (patent RF for the invention № 2621121).

DISCUSSION This method was performed in 55 patients, in all cases it provided reliable PTWs tightness, allowed maintaining stable carboxyperitoneum during laparoscopic interventions, without increasing carbon dioxide flow, which reduced the cost of LSS and prevented the development of both intra- and postoperative complications. The uniqueness of this method is that PTW is sealed from the side of the abdominal cavity, preventing carbon dioxide from penetrating into either the preperitoneal or subcutaneous tissue.

CONCLUSION An increase in the number of patients with combined surgical pathology necessitates the use of the developed method for sealing punctures when moving trocars and neutralizing sub- and postoperative complications. In addition, this method allows to reduce carbon dioxide flow.

Keywords: laparoscopic simultaneous surgery, preserved trocar wound, catheter Foley, sealed carboxyperitoneum, extraperitoneal insufflation, subcutaneous and preperitoneal emphysema

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ACC — acute calculous cholecystitis
CO_2 — carbon dioxide
EPI — extraperitoneal insufflation
LCE — laparoscopic cholecystectomy
LSS — laparoscopic simultaneous surgery
PTW — preserved trocar wound

INTRODUCTION

Laparoscopic simultaneous surgeries (LSS) are increasingly becoming widespread in the era of laparoscopic surgery in order to manage two types of pathology with one surgical intervention [1-8]. The frequency of LSS use is higher in female patients, which is associated with cholelithiasis and genital abnormalities or abdominal hernias [9–12]. In addition, performing two operations within one hospitalization is economically beneficial for a medical organization. When performing LSS upon completion of one operation, trocars have to be reinserted for another surgery. The preserved trocar wound (PTW) disturbes the tightness of the abdominal cavity, which contributes to constant fogging of the camera, impaired operating field view,

depressurization of carboxyperitoneum and excessive flow of carbon dioxide (CO_2). In order to prevent these complications, some surgeons suggest suturing the PTW, others tampon it with a swab or press it with a finger, others leave a port in it with a closed valve, and some surgeons close the wound with a gallbladder or another remote organ or its fragment. The presence of many ways to prevent depressurization of the abdominal cavity in PTW indicates not only the unsolved problem of laparoscopic surgery, but als its great relevance. Extraperitoneal CO_2 insufflation (EPI) in 0.43–2.5% of cases leads to the development of subcutaneous emphysema [13, 14]. Researchers believe that the most common cause of this is the ingress of CO_2 into the skin from the abdominal cavity through the PTW after trocar removal or as a result of incomplete desufflation at the end of the operation. The prevalence of subcutaneous emphysema depends on the volume of gas injected extraperitoneally. Depending on the extent, subcutaneous emphysema may reach the tissues of the neck, face, or move in the caudal direction (pneumoscrotum) [13, 15]. Most often, it surrounds the trocar injection zone, but gas can also enter the mediastinum, and then pneumomediastinum develops. The ingress of CO_2 into the preperitoneal space can lead to its spread into the anterior mediastinum and higher to the neck, where the gas forms a dense "collar". The incidence of this complication is 0.03–0.08% [14].

With the introduction of laparoscopic technologies, LSS are becoming highly relevant for this category of surgical patients. In LSS there is a high probability of reinstallation of the ports for the second operation. Extraperitoneal CO_2 leakage is often observed through PTW in LSS. EPI contributes to the development of intra- and postoperative complications. Depressurization of carboxyperitoneum contributes to an increase in the duration of the operation. In connection with the use of devices and methods for sealing PTW in LSS, this is of great economic importance.

The aim of study is to develop a new, simple, but more effective way of closing PTW in order to preserve the tightness of the carboxyperitoneum when performing LSS.

MATERIALS AND METHODS

The article presents an analysis of the results of treatment of 63 patients with acute calculous cholecystitis (ACC) and concomitant surgical pathology who underwent treatment in our clinic from 2014 to 2018. Basically, laparoscopic cholecystectomy (LCE) was performed, then another operation was performed in case of genital pathology or hernia of the abdominal wall. Among them there were 46 women (73%) and 17 men (27%). The age of the patients ranged from 26 to 67 years. During hospitalization, all patients underwent general and biochemical blood tests, general urinalysis, blood amylase and urine diastase tests, electrocardiography, ultrasound examination of the abdominal organs, fibroesophagogastroduodenoscopy, and consultations with related specialists according to indications. Comorbidity was: reflux gastritis in 27 patients (42.9%), hypertension in 20 patients (31.8%), diabetes mellitus in 8 patients (12.7%), ischemic heart disease and exertional angina in 6 patients (9.5%). LSS was performed using the Endomedium laparoscopic complex. The distribution of LSS by type and duration is presented in Table 1.

Statistical analysis of the study results was performed with the calculation of the arithmetic mean, standard deviation and Student's test using Microsoft Excel 2010. The results obtained were considered statistically significant at $p < 0.05$.

Table 1

Distribution LSS according to type and duration

No	Type of the operation	Abs. number	Spec. grav. (%)	Duration of operation (in min.) (M ± m)
1.	LCE + removal of the ovarian cyst	35	55.5	84.5 ± 12.5
2.	LCE + inguinal hernia management	11	17.5	145.0 ± 17.3
3.	LCE + hernia removal with abdominal alloplasty	8	12.7	165 ± 22.7
4.	LCE + colon resection	6	9.5	188.0 ± 31.0
5.	LCE + resection of the small intestine	3	4.8	110,0 ± 21.7
	Total:	63	100.0	123.7 ± 19.7

Notes: LCE – laparoscopic cholecystectomy; LSS – laparoscopic simultaneous surgery

The data presented in Table 1, indicate that the combination of LCE and removal of the ovarian cyst occupies the largest share among LSS, LCE and inguinal hernia management is in second place, LCE and hernia management with alloplasty of the abdominal wall is in the third place, LCE and colon resection is in the fourth place, and LCE and resection of the small intestine is in the fifth place. In the early postoperative period, local subcutaneous emphysema around the PTW in a radius of 5-10 cm was diagnosed in 6 patients (9.5%), in 2 (3.2%) of them, subcutaneous emphysema occupied the entire anterior abdominal wall spreading to the lumbar region, chest wall and neck area.

Clinical case no. 1

A 63-year-old male patient D.K., (medical history No. 10358) was hospitalized on Sep 22, 2018 in the emergency surgery clinic SBI MH RD "RCH-EMS" with a diagnosis of acute intestinal obstruction. From the anamnesis: he has been ill for about 3 days, 10 years ago he underwent suturing of a perforated duodenal ulcer. On the anterior abdominal wall in the epigastric region,

a postoperative scar is determined after an upper median laparotomy measuring 12.0x0.5 cm. Under endotracheal anesthesia, the first 10 mm trocar was introduced according to Hasson in the left lateral region of the abdomen along the anterior axillary line at the level of the navel. Diagnostic laparoscopy revealed an adhesive conglomerate consisting of a greater omentum and loops of the small intestine, adhered to the postoperative scar. Above 10 mm of the trocar, an additional 5 mm trocar was inserted, and the adhesions were dissected. After that, AIO was diagnosed with an increase in the size of the gallbladder (130x40x40 mm), tension and hyperemia of its wall. It became necessary to move trocars to typical points for performing LCE. PTW was sealed by stitching. LCE was performed with technical difficulties. By the end of the operation, subcutaneous emphysema of the left lateral region of the abdomen spreading to the left lumbar region was revealed. 4 hours after the operation, subcutaneous emphysema spread over the entire anterior abdominal wall and the left half of the chest wall. Injection needles were installed in the subcutaneous tissue, and by the end of 2 days the subcutaneous emphysema gradually resolved. The patient was discharged on the 6th day after surgery in satisfactory condition.

At the beginning of our study, 55 patients had the loss of CO_2 released from the abdominal cavity to the outside through PTW after moving 5 and 10 mm ports to another region of the abdominal wall, which were used in the first stage of LSS. Of these, 33 patients (60%) were obese, which degree was determined by the formula of Adolphe Quetelet (1869). The body mass index in 15 patients (49.5%) varied in the range of 31.5-34.3 (obesity of the 1st degree), in 12 (38.4%) - 35.3-38.2 (obesity of the 2nd degree) and in 6 (18.2%) - 41.2–43.5 (third degree obesity). The data of EPI CO_2 through PTW from the abdominal cavity to the outside were obtained using the domestic electronic insufflator INS-15-02- "Endomedium +" No. 5111-03 0150816.

When the trocar was transferred from one area of the abdominal wall, we observed an increase in CO_2 flow on the monitor. The data obtained in this case is presented in Table 2.

Table 2

Loss of carbon dioxide through the left trocar wound of different diameter

No.	Trocar diameter	Carbon Dioxide Flow in Patients (L/min.)		R
		Non-obese patients (n = 8)	Obese patients (n = 55)	
1.	Trocar 5 mm	7.3 ± 1.2	6.6 ± 1.5	> 005
2.	Trocar 10 mm	8.3 ± 0.7	7.3 ± 0.9	> 005

The data presented in Table 2, indicates that the CO2 flow through the PTW after transferring the 5 mm port to another area of the abdominal wall in non-obese patients averaged 7.3 ± 1.2 L/min, and 8.3 ± 0.7 L/min for the 10 mm port (p> 0.05). In obese patients, the EPI CO_2 through PTW of 5 mm port reached an average of 6.6 ± 1.5 L/min, and 7.3 ± 0.9 L/min for the 10 mm port (p> 0.05). Thus, we have established that the difference in the EPI of CO_2 through the PTW of 5 and 10 mm ports is statistically insignificant, which, in our opinion, is associated with the difference in the rates of gas exit from the abdominal cavity to the outside.

In addition to the indicated data, to determine the CO_2 flow (Q_g), we used the following formula (T.I. Trofimov. Course of Physics, 2006. Chapter 6. P. 57–64):

$V=S\cdot v\cdot \Delta t$, (1)

where S is the sectional area of the hole; v, Δt is gas flow velocity and time.

Dividing both sides of the expression by Δt, we obtained the gas flow rate per unit time:

$Q_g=S\cdot v$ (2)

The gas outflow velocity v can be found using the equation describing the dynamic pressure:

$$P=(\rho\cdot v^2)/2, \quad (3)$$

where P is the pressure in the cavity (12 mm Hg), ρ is the gas density (ρ CO_2= 1.9768 kg/m3).

Then equation (2) will take the following form:

$$Q=S\cdot\sqrt{(2P/\rho)} \quad (4)$$

For trocars with diameters of 5 mm and 10 mm, the corresponding cross-sectional areas S1 = 19.6 mm2, S2 = 78.5 mm², the CO_2 flow from the wound left after their removal and calculated by formula (4) will be:

Q_1= 0,78 L/sec; Q_2=3,2 L/sec.

The maximum value of the gas flow rate by the device (endoscopic electronic insufflator INS — 15-02 - "Endomedium +") is 0.5 L/s. This value is less than Q1 and Q2. Consequently, the pressure in the abdominal cavity will drop until the volume of the supplied gas becomes equal to the volume of the outgoing gas per unit time. These calculations were carried out under the guidance of associate professor of the Department of Physics of Dagestan State Technical University, candidate of physical and mathematical sciences M.K. Guseynov.

The obtained results showed that when a trocar with a diameter of 5 mm is removed, the pressure in the cavity can decrease to 5–6 mm Hg, which leads to a deterioration in visualization and limits manipulations in the abdominal cavity during surgery.

When PTW was tamped or sutured to seal the carboxyperitoneum in non-obese patients, CO_2 EPI was observed past the sutures and the tampon, which indicated the absence of complete tightness of carboxyperitoneum and CO_2 overrun. The desired effect was not achieved even with finger pressing of the PTW by an assistant. In the process of searching for a more reliable way of sealing the PTW of the abdominal wall in LSS, a new simple and effective method was developed: a Foley catheter 14 Fr. was inserted into the abdominal cavity through the trocar to be removed, then its cuff was inflated (1) to the required diameter (5–10 mm is enough). Then the port was removed from the abdominal cavity, and the catheter with an inflatable cuff was pulled

out from the abdominal cavity until the surface of the inflated cuff (1) was tightly adhered to the parietal peritoneum (2) and the PTW was completely sealed. Outside, the catheter was clamped against the skin with forceps (Fig. 1).

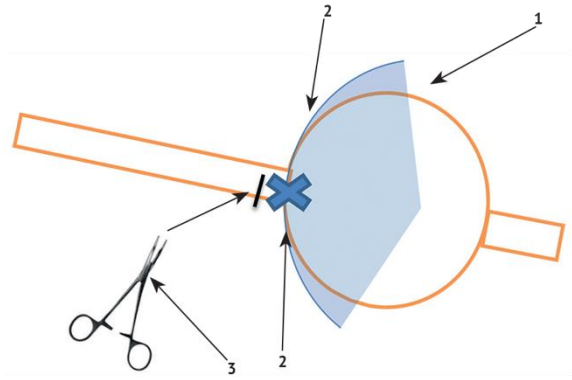

Fig. 1. Schematic representation of PTW sealing with a Foley catheter

To eliminate obstacles, the distal part of the catheter behind the cuff was cut off 5 mm from its end before insertion into the abdominal cavity, without affecting the tightness of the cuff. RF patent for invention No. 2621121 "Method of sealing abdominal wall punctures after trocar removal during laparoscopic operations" was received.

This method is easy to use and highly effective in all cases, provides complete and stable tightness of PTW of the abdominal wall, completely eliminates the EPI of CO_2 through PTW, ensures the tightness of the carboxyperitoneum throughout the LSS, creating optimal conditions for the surgeon's work and freeing the assistant from the "finger" sealing the puncture.

Clinical example 2

A female patient B., born in 1964, medical card No. 7205, was admitted to the surgical department No. 1 of SBI MH RD "RCH-EMS" with a diagnosis of cholelithiasis and acute intestinal obstruction. The first 10 mm trocar was inserted according to Hassan at the level of the navel along the anterior axillary line on the left. In a diagnostic laparoscopy, an adhesive process was diagnosed along the postoperative scar. After releasing the umbilical region from adhesions of 10 mm, the trocar was reinserted into the supra-umbilical region. A Foley catheter was inserted into the abdominal cavity through the PTW canal; its cuff was inflated to 10 mm in diameter (Fig. 2A). Then the catheter is pulled outward until it stops and the inflated cuff tightly touches the parietal peritoneum and the PTW is completely sealed (Fig. 2B). For better visualization, the end of the Foley catheter behind the inflated cuff was cut 5 mm from its end before insertion into the abdominal cavity (Fig. 2A).

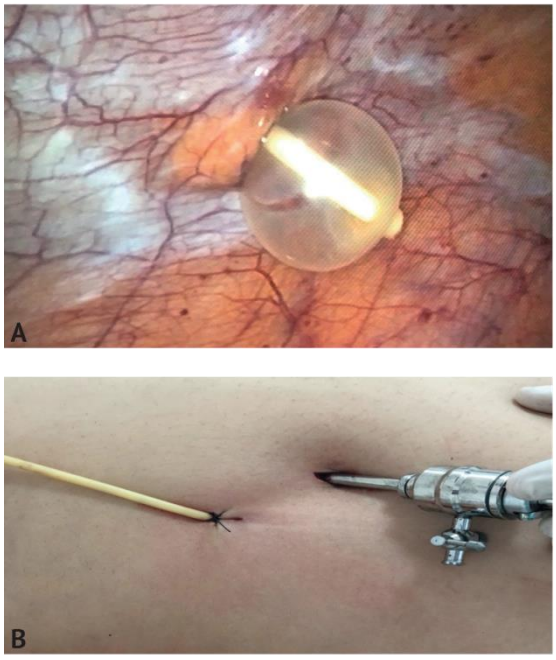

Fig. 2. Folley Cateter with inflated cuff: A — from the abdominal cavity, B — form the outside

RESULTS AND DISCUSSION

The method of OTP sealing we developed was used in 55 patients in LSS without any side effects and complications. The results obtained convincingly indicate the high efficiency of the developed method. In patients who underwent PTW sealing, we did not observe a single case of EPI CO_2 and depressurization of carboxyperitoneum. The average duration of operations for different types of LSS is given in Table 3.

Table 3

The mean duration of surgeries in different types of LSS

Clinical diagnosis	Total duration LSS (min) (M±m)	Duration of second operation (min) (M±m)
LCE + removal of the ovarian cyst	84.7 ± 8.3	24.7 ± 7.8
LCE + inguinal hernia management	145.0 ± 7.8	70.4 ± 15.7
LCE + hernia repair with abdominal alloplasty	165.0 ± 10.5	95.6 ± 12.2
LCE + colon resection	188.0 ± 7.9	115.8 ± 9.8
LCE + resection of the NK intestine	110.0 ± 11.8	68.3 ± 11.8

Notes: LCE – laparoscopic cholecystectomy; LSS – laparoscopic simultaneous surgery

The data presented in Table 3 shows that the second operation (removal of the ovarian cyst) takes on average 24.7 ± 7.8 minutes. Inguinal hernia management takes on average 70.4 ± 15.7 minutes, the average duration of elimination of a postoperative hernia is 95.6 ± 12.2 minutes. Colon resection takes, on average, 115.8 ± 9.8 minutes. The duration of small intestine resection lasts 68.3 ± 11.8 minutes, on average. For the entire time spent on the second operation, there is a loss of CO_2 through PTW, which leads to additional CO_2 flow and contributes to the occurrence of intra- and postoperative complications. The average duration of the second operation convincingly confirms the need to develop a method that completely excludes the flow of CO_2 through PTW when performing LSS.

CONCLUSION

The need to perform laparoscopic simultaneous surgery often occurs in female patients with calculous cholecystitis and genital pathology. In this case, for the next operation, it becomes necessary to reinstall the ports to another area of the abdominal wall. After that, we observed extraperitoneal gas insufflation, which increases the flow of carbon dioxide, impairs visualization, and increases the duration of the operation. In order to level these shortcomings, we have developed a method for sealing the left trocar wound, and received a Russian patent for an invention. The developed method is easy to use and ensures complete tightness of the preserved trocar wound throughout the operation, reduction of carbon dioxide flow, tightness of carboxyperitoneum, which allows to improve visualization and reduce the duration of laparoscopic simultaneous surgery. To do this, we suggest to use a Folley catheter 14 Fr., which is inserted through an open trocar wound into the abdominal cavity, then its cuff is inflated to 5–10 mm in diameter, pulled out of the abdominal cavity until it stops and thus the abdominal wall puncture is sealed. The method reduces the flow of carbon dioxide, maintains the tightness of carboxyperitoneum and reduces the risk of postoperative complications.

1. The increase in the number of patients with concomitant surgical pathology dictates the need to perform laparoscopic simultaneous operations.

2. In order to improve visualization and create optimal conditions for manipulation, performing laparoscopic simultaneous surgery at different levels of the abdominal cavity or the presence of adhesions in the abdominal cavity requires, reinstallation of ports in other areas of the abdominal wall.

3. Extraperitoneal insufflation of carbon dioxide occurs through an open trocar wound from the abdominal cavity, which leads to depressurization of carboxyperitoneum, deterioration of visualization and conditions for performing surgery, increasing carbon dioxide flow and the cost of the operation.

4. Sealing an open trocar wound by inserting a Foley catheter into the abdominal cavity through a trocar is the optimal technique for sealing the abdominal wall.

5. Application of the developed method of sealing an open trocar wound during laparoscopic simultaneous surgery increases its economic efficiency.

6. Using the suggested method in everyday practice allows you to prevent extraperitoneal insufflation of carbon dioxide, create comfortable conditions for laparoscopic operations, and reduce the frequency of both intra- and postoperative complications.

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