Scientific Research Publishing

Surgical Science, 2017, 8, 86-93
http://www.scirp.org/journal/ss
ISSN Online: 2157-9415
ISSN Print: 2157-9407

Continuous Gas Outflow Is More Effective Than Carbon Filters to Evacuate Smoke in Laparoscopic Colorectal Resections: A Comparative Study

Enrique M. Balén*, Javier Suárez, Begoña Oronoz, José M. Lera

Dept of Surgery, Complejo Hospitalario de Navarra, Pamplona, Spain
Email: *ebalen@gmail.com

How to cite this paper: Balén, E.M., Suárez, J., Oronoz, B. and Lera, J.M. (2017) Continuous Gas Outflow Is More Effective Than Carbon Filters to Evacuate Smoke in Laparoscopic Colorectal Resections: A Comparative Study. *Surgical Science*, **8**, 86-93.
https://doi.org/10.4236/ss.2017.82011

Received: August 27, 2016
Accepted: January 22, 2017
Published: January 25, 2017

Abstract

Background: Carbon filters and expensive evacuation machines are available to evacuate surgical smoke in long-lasting laparoscopic operations and achieve good visibility and patient's safety. **Methods:** This study was aimed to determine which of two methods for laparoscopic smoke evacuation is most effective getting the best visibility. 20 patients submitted to elective laparoscopic colorectal resections were allocated to be operated using, either a carbon filter (Group A) or a home-made tubing with a continuous suction (Group B) connected through one of the ports to the hospital vacuum system: both methods were regulated with a roller clamp to increase smoke evacuation in order to obtain good visibility. A mono-polar hook and the LigasureV 5-mm vessel-sealing device were used. Groups were comparable for demographic characteristics, surgical techniques, and malignancy. Mann-Whitney and Fisher's exact test were used for statistics. **Results:** Morbidity was 10%. There was no mortality, and there was no difference between Group A and B according to complications ($p = 1.00$), hospital stay ($p = 0.23$), duration of the operation ($p = 0.79$) and total consumption of CO_2 ($p = 0.36$). However, the number of times that the clamp had to be released (Group A: 3.4 + 1 vs Group B: 1.5 + 1) ($p = 0.006$) and that a port had to be opened freely to quickly evacuate dense smoke (Group A: 0.9 + 0.7 vs Group B: 0) ($p = 0.002$) was very significantly increased in Group A as compared to Group B. Mean follow-up was 60 months and no port site metastases that could be a consequence of "chimney effect" or wound recurrence have been detected. **Conclusions:** The surgeon's subjective impression that carbon filters are less effective for smoke evacuation than continuous outflow of gas through a port connected to the hospital vacuum source was confirmed. This simple method is advised for long-lasting laparoscopic procedures to improve visibility throughout the procedure.

Keywords

Advanced Laparoscopy, Surgical Smoke Evacuation,
Visibility Advanced Laparoscopy, Surgical Smoke Evacuation, Visibility

1. Introduction

Good visibility is essential for patient's safety during laparoscopic operations [1], and technological improvements have produced very high-quality cameras and optical instruments. However, electrosurgical and coagulation devices are necessary during laparoscopy and all of them are responsible of some kind of fogging, thus making visibility worse [2]. Because of a poor vision, surgical smoke may be of great inconvenience for the surgeon during laparoscopic surgery [3], especially in narrow spaces such as the pelvis in colorectal surgery. A simple way of getting rid of surgical smoke during laparoscopy is to open one of the ports, letting gas and smoke particles flow out free into the environment of the operating theatre: this is an easy way of evacuating smoke, but needs to be supplemented with a high-flow CO_2 insufflators (e.g. 30 - 40 liters/minute) and usually makes the optics get misted, due to sudden changes of intra-abdominal temperature. On the other hand, to avoid the risks [4] that surgeons and health care personnel in the theatre can run by aspiration of surgical smoke [5] [6], a variety of closed suction or evacuation systems have been designed for laparoscopic procedures: smoke filters and smoke suction devices have been manufactured to be connected to the ports for constant smoke evacuation (MEGA-VAC™, www.smokeevacuators.com, www.freepatentsonline.com, www.biomedicine.org). An alternative to the latter expensive devices may be carbon filters, but our previous experience with one of them (Laparoshield®) was not satisfactory for laparoscopic visibility, so that we designed a comparative study to look for a better and cheaper way to evacuate smoke from the laparoscopic field in long lasting operations.

2. Patients and Methods

In order to conclude which of two methods for laparoscopic smoke evacuation was most effective to achieve a good laparoscopic vision in colorectal resections expecting to last more than 2 hours, the effect on laparoscopic visibility of a commercially available carbon filter and a home-made tubing connected to the hospital source of vacuum system were analysed and compared. Primary aims of the study were the number of times the evacuation device had to be opened to increase smoke evacuation for an optimal laparoscopic visibility as a variable measuring the subjective sensation of the surgeon of good visibility. Sample size (error α, 0.05 error β 0.2) was calculated to obtain a difference of at least 2 in the mean number of times the clamp had to be opened to increase gas outflow to evacuate smoke and improve visibility (Standard Deviation 1) and once to open a port (Standard Deviation 0.7), and resulted 8 cases per group.

The study was conducted using two types of smoke evacuation systems, based upon the hypothesis that a constant gas outflow to a vacuum system might be better than carbon filters, in order to achieve a better visibility throughout the laparoscopic procedure. During the last few months of 2007, patients scheduled for elective colorectal laparoscopic resection were alternativelly allocated to be operated using either a carbon-filter (LaparoShield^{R}, Pall Medical Europe, Portsmouth, England) (Group A) or a simple home-made tubing connected to the hospital source of vacuum system (**Figure 1**) (Group B) simulating other commercially available smoke-filtering and evacuation machines (MEGA VACPLUS^{TM}, Draper, UT, USA), and also simpler methods of operating theatre wall suction [7]. Laparo Shield^{R} allows a flow rate up to 12 l/min at an intra-abdominal pressure of 15 mmHg. With both methods (Groups A and B), the flow of the evacuation system could be regulated with a roller clamp over the tubing for a faster evacuation of smoke. The cost of the Laparo Shield^{R} was 31 euros per unit, while the cost of the home-made tubing was 3 euros per unit.

The investigators included 20 patients (**Table 1**) in the study (12 males and 8 females) for a laparoscopic colo-rectal resection, usually inserting four ports. Due to logistic reasons, the surgeon could not be blinded to the group assigned.

Table 1. Demographics, operations' data and consumption of gas.

GROUP	Age	Male/Female	BMI	Malignancy	Operation	CO_2 (l.)	Min.	l/min.
A	55	Male	24	Yes	Left Hemicolectomy	470	200	2.35
A	81	Male	26	Yes	**CONVERTED** Rectal Anterior Resection	73	210	**0.35**
A	74	Female	32	Yes (pT1)	Laparoscopic **Assisted** Rectal Anterior Resection	86	170	**0.50**
A	59	Female	23	Yes (Mets)	Sigmoid Resection	420	170	2.47
A	77	Male	28	Yes	**CONVERTED** Sigmoid Resection	498	190	**2.62**
A	59	Male	32	Polyp	Right Colectomy	145	150	0.97
A	59	Male	25	Diverticula	Laparoscopic **Assisted** Rectal Anterior Resection	435	240	**1.81**
A	71	Male	29	Yes	Right Colectomy	380	150	2.53
A	64	Female	24	Yes	**CONVERTED** Sigmoid Resection	40	180	**0.22**
A	56	Male	29	Polyp	Right Colectomy	290	155	1.87
B	68	Male	25	Yes	Right Colectomy	180	120	1.50
B	70	Female	26	Yes	Sigmoid Resection	220	150	1.47
B	81	Male	26	Yes	Laparoscopic **Assisted** Rectal Anterior Resection	113	220	**0.51**
B	70	Female	25	Polyp	Rectal Anterior Resection	235	180	1.30
B	55	Female	40	Yes	Laparoscopic **Assisted** Rectal Anterior Resection	100	190	**0.52**
B	62	Male	29	Polyp	**CONVERTED** Total Colectomy	305	280	**1.09**
B	61	Male	26	Yes	Rectal Anterior Resection	190	160	1.19
B	73	Female	29	Yes	Rectal Anterior Resection	190	160	1.19
B	73	Male	30	Yes	Sigmoid Resection	244	200	1.22
B	43	Female	24	Polyp	Right Colectomy	130	150	0.87

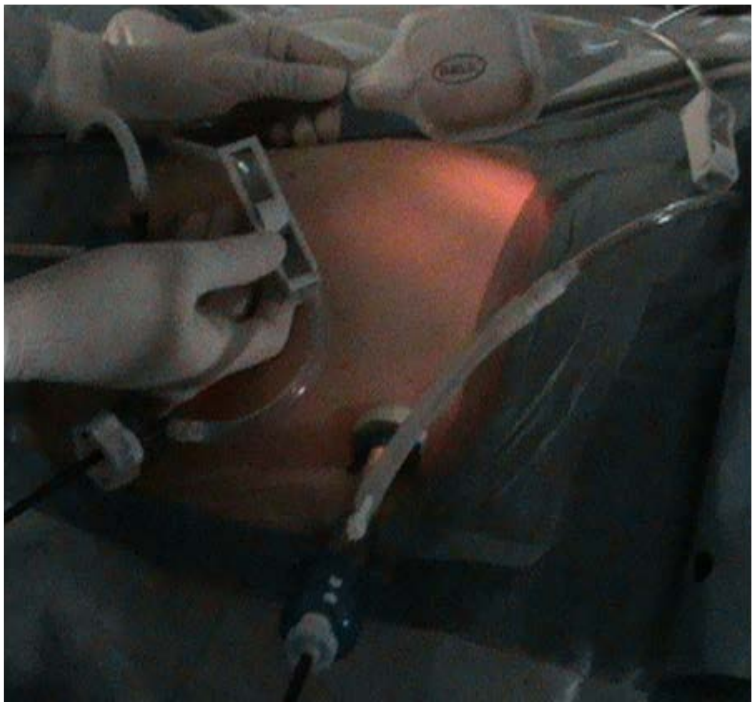

Figure 1. Methods of smoke evacuation (Groups A and B) are shown in this example, both of them controlled by a roller clamp.

The operations performed were 8 anterior rectal resections, 5 sigmoid colon resections, 5 right hemicolectomies, 1 left hemicolectomy, and 1 subtotal colectomy. Right and subtotal colectomies concluded with an extracorporeal hand-sutured anastomosis, while left colectomies and rectal resections were ended with an intracorporeal laparoscopic circular-stapled anastomosis, either Proximate ILS CDH 29 (Ethicon-EndoSurgery, Puerto Rico, USA) or Premium Plus CEEA 31 (Tyco, Norwalk, USA). A mono-polar hook and the Ligasure V 5- mm (LigasureV^{R}, Valleylab-Tyco, Boulder, USA) vessel-sealing device were used in all 20 cases. No vascular staplers or endoclips were used for vascular ligation, as the 5-mm Ligasure sealed all vascular pedicles properly. The carbon-filter (Group A) or the home-made tubing connected to the hospital vacuum system (Group B) were plugged with a luer-lock connection into one of the ports at the beginning of the operation (**Figure 1**), and the clamp was partially opened once the surgeon had the need to improve visibility because of accumulated smoke, having a constant outflow along the operation. From that moment in advance, the clamp was opened some more if necessary to improve visibility on demand of the operating surgeon. The parameters that were compared were complications, hospital stay, duration of the operation (minutes), the consumption of CO_2 (liters), and mainly the number of times the clamp had to be released some more or even a port be opened freely to evacuate dense smoke.

As every laparoscopic colorectal resection has a proportion of the time consumed during the operation without CO_2 insuflation due to the fact that a part of the operation is done in an open fashion (pulling out of the surgical specimen through a minilaparotomy and/or extracorporeal anastomosis) there might be

important differences in liters of CO_2 consumed between groups, depending on the proportion of cases with an extracorporeal anastomosis, and mainly depending on the proportion of patients with a laparoscopically-assisted operation or conversion to open surgery. For this reasons, the total consumption of CO_2 (liters) of each case was also divided by the duration of the operation, therefore calculating the flow rate per minute (Table 1).

To compare qualitative variables (gender, the proportion of patients with malignancy, right-sided colon resections or pelvic operations, postoperative complications and conversions to open surgery) a Fisher's exact test was used, because expected frequencies were always less than 5. Due to the shortness of cases (10 patients, each group) a test of Mann-Whitney was used to compare quantitative variables. Statistics were calculated using the SPSS 14.0 software (Chicago, USA).

3. Results

Among the 20 patients included in the study, 14 (70%) were operated for a malignant tumor (one case in Group A had unresectable multiple liver metastases), 6 patients had right-sided or extended right colectomies (plus hand-sewn ileocolic anastomosis) and 13 patients (65%) had pelvic surgery (rectal or sigmoid colon resection). Mean duration of the operation was 181 ± 37 minutes (range 120 - 280), mean postoperative hospital stay was 5 ± 1 days (range 3-8) and mean consumption of CO_2 was 237 ± 140 liters (range 40 - 498). In general, the 2 surgeons involved in the operations had the subjective impression that carbon filter cases had a worse visibility than vacuum source evacuation cases.

Groups A and B resulted to be comparable for age, gender, body mass index (BMI), the proportion of rectosigmoid operations and right-sided or extended right colectomies, malignancy, and the rate of converted or laparoscopically-assisted operations (Table 2). Most of the operation was performed laparoscopically in all converted cases, where conversion to a minilaparotomy took place in the final part of the operation, usually for a combination of the following reasons: difficulty to manage the specimen due to a large neoplastic mass, a long sigmoid colon or reluctance to divide the rectum without hand-control in cases of cancer of the mid-rectum. There was no postoperative mortality. However, 10 percent of the patients suffered complications, without any difference between groups, as there was one case each: rectal bleeding in Group A and wound infection in Group B. Hospital stay ($p = 0.23$), duration of the operation ($p = 0.79$) and consumption of CO_2, either total consumption ($p = 0.36$) or liters/ minute ($p = 0.33$) were not statistically different between groups. However, the number of times the clamp had to be released and a port had to be opened freely to quickly evacuate dense smoke was very significantly increased in Group A as compared to Group B. All these data are shown in Table 3.

Taking into consideration that laparoscopically-assisted rectal resections or operations converted to open surgery have a substantially higher proportion of the duration of the operation not using CO_2, the comparison of the flow rate

Table 2. No difference between groups according to demographics, or type of operations.

GROUP	Age	Gender Male/Female	BMI	Malignancy	Right-sided colectomies	Pelvic Surgery	Converted or Assisted Surgery
A (smoke filter)	65.5 ± 9	7/3	27.2 ± 3	7/3 (70%)	3/7 (30%)	6/4 (60%)	5/5 (50%)
B (suction tubing)	65.6 ± 11	5/5	28 ± 5	7/3 (70%)	3/7 (30%)	7/3 (70%)	3/7 (30%)
Odds Ratio		0.43		1.00	1.00	1.56	0.43
P	0.91	0.65	0.74	1.00	1.00	1.00	0.65

Table 3. Primary aim of the study (surgeon's good visibility) is shown, measuring the difference according to the number of times the evacuation device had to be opened to increase smoke evacuation for an optimal laparoscopic visibility.

GROUP	Postoperative Complications	Hospital Stay (days) (range)	Duration (minutes) (range)	Gas (liters) consumption (range)	Liters/min.	Clamp release (times) (range)	Open Port (range)	Converted-Assisted/ Non-converted Surgery (liters/min.)
A: Smoke filter	1 (10%)	4.6 ± 1 (4 - 6)	181.5 ± 29 (150 - 240)	283.7 ± 57 (40 - 498)	1.57 ± 1 (0.22 - 2.62)	3.4 ± 1 (1 - 6)	0.9 ± 0.7 (0 - 2)	1.1/ 2.04 ($p = 0.222$)
B: Suction tubing	1 (10%)	5.3 ± 1 (3 - 8)	181 ± 45 (120 - 280)	190.7 ± 64 (100 - 305)	1.09 ± 0.3 (0.51 - 1.50)	1.5 ± 1 (0 - 5)	0 0	0.71/ 1.25 ($p = 0.033$)
Odds Ratio	1.00							0.43
P	1.00	0.23	0.79	0.36	0.33	0.006	0.002	0.65

per minute between laparoscopically-assisted or converted operations (0.952 ± 0.85 (0.22 - 2.62)) versus non-converted surgery (1.577 ± 0.59 (0.87 - 2.53)) were statistically different ($p = 0.045$).

Follow-up was updated in march-2013, with a mean follow-up of 60 months (57 months in Group A and 62 months in Group B): follow-up differences ($p = 0.17$) were due to death of 2 patients in group A (preoperative liver metastasis, and a new primary lung cancer). One patient in group A is alive 59 months after surgery, with pulmonary metastases and local pelvic recurrence after rectal cancer excision. No port site or wound recurrence have been detected.

4. Discussion

Surgical smoke is a troublesome inconvenience for long-lasting laparoscopic procedures, such as colorectal resections, and especially for pelvic surgery, because visibility decreases [1] and has to be managed by some kind of gas evacuation. The authors' previous experience with Laparoshield^{R} was not satisfactory for laparoscopic visibility, and because of safety criteria for operating theatre staff [4] [5] [6], machines for continuous surgical smoke evacuation have been manufactured and offered in the market as very effective, but really very expensive at the same time.

With these facts in mind, the authors' formulated the hypothesis that a simple home-made tubing connected to the hospital vacuum source could be as effective as surgical smoke evacuation machines, while very much cheaper, and at the same time more effective than commercially available carbon filters, such as Laparoshield^{R}. To study the hypothesis as a pilot study, 20 consecutive cases of

elective colorectal laparoscopic resections were included to perform them alternatively using the Laparoshield[R] (Group A-10 cases) or a simple and cheap home-made tubing connected to the hospital source of vacuum (Group B-10 cases) (Figure 1). Surgical results of the 20 cases were satisfactory: no operative mortality, 10% complications, mean hospital stay 5 ± 1 days (range 3 - 8), mean duration of the operation 181 ± 37 minutes (range 120 - 280), 20% conversion rate.

Groups A and B resulted to be comparable for baseline parameters (age, gender, body mass index (BMI), the proportion of rectosigmoid operations and malignancy, right-sided colectomies, and the rate of converted or laparoscopically-assisted operations) (Table 2). They were also comparable for postoperative parameters (hospital stay, duration of the operation, complications and consumption of CO_2 (total consumption and Liters/min.) (Table 3). However, there were significant numerical and statistical differences between both groups regarding the number of times the clamp had to be released to increase outflow in order to improve visibility and even to freely open a port (Table 3), thus reflecting the subjective impression of the surgeon that the home-made continuous evacuation system is much more effective than carbon filters for colorectal resection.

No port-site metastases were detected after a 5 year follow-up, as is consistent with most recent world-wide experience [8], although "chimney effect" has been related to port-site metastases in experimental models [9].

5. Conclusion

In conclusion, the authors confirm their subjective impression on carbon filters and give their advice for long-lasting laparoscopic procedures to connect for smoke evacuation a port to the hospital vacuum source with a roller clamp, in order to improve visibility throughout the procedure: it is cheaper, very simple and possible in any surgical setting, and it seems to be more effective than carbon filters, as the surgeon rarely needs to increase the outflow of gas in order to evacuate annoying smoke for an optimal laparoscopic vision.

Disclosures

Drs. Enrique Balen, Javier Suárez, Begoña Oronoz and Jose M. Lera have no conflicts of interest or financial ties to disclose.

References

[1] Divilio, L.T. (1996) Improving Laparoscopic Visibility and Safety through Smoke Evacuation. *Surgical Laparoscopy & Endoscopy*, **6**, 380-384. https://doi.org/10.1097/00019509-199610000-00009

[2] Weld, K.J., Dryer. S., Ames, C.D., Cho, K., Hogan, C., Lee, M., *et al.* (2007) Analysis of Surgical Smoke Produced by Various Energy-Based Instruments and Effect on Laparoscopic Visibility. *Journal of Endourology*, **21**, 347-351. https://doi.org/10.1089/end.2006.9994

[3] Povel, J.A. (2004) Surgical Smoke. *Surgical Endoscopy*, **18**, 350.

https://doi.org/10.1007/s00464-003-8241-7

[4] CDC (Center for Disease Control and Prevention), U.S. Department of Health and Human Services National Institute for Occupational Safety and Health. NIOSH Hazard Controls (1996) Control of Smoke from Laser/Electric Surgical Procedures,

[5] Wu, J.S., Luttman, D.R., Meininger, T.A. and Soper, N.J. (1997) Production and Systemic Absorption of Toxic Byproducts of Tissue Combustion during Laparoscopic Surgery. *Surgical Endoscopy*, **11**, 1075-1079. https://doi.org/10.1007/s004649900533

[6] Champault, G., Taffinder, N., Ziol, M., Riskalla, H. and Catheline, J.M. (1997) Cells Are Present in the Smoke Created during Laparoscopic Surgery. *British Journal of Surgery*, **84**, 993-995. https://doi.org/10.1002/bjs.1800840724

[7] Marshburn, P.B. and Hulka, J.F. (1990) A Simple Irrigator-Aspirator Cannula for Laparoscopy: The Stewart System. *Obstetrics & Gynecology*, **75**, 458-460.

[8] Ziprin, P., Ridgeway, P.F. and Peck, D. (2002) The Theories and Realities of Port-Site Metastases: A Critical Appraisal. *Journal of the American College of Surgeons*, **195**, 395-408. https://doi.org/10.1016/S1072-7515(02)01249-8

[9] Lee, S.W., Whelan, R.L., Southall, J.C. and Bessler, M. (1998) Abdominal Wound Tumor Recurrence after Open and Laparoscopic-Assisted Splenectomy in a Murine Model. *Diseases of the Colon & Rectum*, **41**, 824-831. https://doi.org/10.1007/BF02235360