Quantifying Intraoperative Laparoscopic Visual Field Opacity

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ABSTRACT

Background and Objectives: Laparoscopic surgery can be complicated by condensation and debris on the lens obscuring the visual field, increasing the risk of surgical error and injury to the patient. Despite, development of possible solutions, little is known regarding the quantitative measure of time lost during surgery because of an obscured visual field. Without this knowledge, the cost of laparoscopic lens fogging cannot be quantified and compared to the cost of antifogging devices. In the present study, we investigated the amount of time a laparoscope is withdrawn for cleaning during surgery.

Methods: This was a prospective, observational study of patients (n = 52) who underwent laparoscopic surgery at Florida Hospital Celebration Health. Patient's age, gender, and body mass index, operative time, wound class, estimated blood loss, type of procedure, and complication (if any) were collected. In addition, intraoperative information on the number of times and total amount of time the laparoscope was withdrawn because of obscured visual field were recorded.

Results: Eighty-two percent (43) of the procedures required laparoscope withdrawal because of fogging. Increased operative time, increased blood loss, and patient age correlated with the number of times ($P < .05$) and amount of time ($P < .05$) the laparoscope was withdrawn.

Discussion: There was a significant correlation between increased laparoscope withdrawal because of an obscured visual field with increased EBL, operative time, and patient age. Possible explanations include change in body composition with age, the increased viewing angles required for more complex procedures, and increasing intraoperative effect on the surgeon of the poor visual field caused by fogging and debris.

Key Words: Laparoscope, Lens fogging, Operative time.

INTRODUCTION

Since the introduction of minimally invasive laparoscopic surgery, this technique has spring boarded to use in numerous applications throughout the field of surgery. The benefits of laparoscopic surgery have been explored extensively. Advantages include decreased incidence of wound infection, decreased recovery time, decreased postoperative pain, and continued long-term relief.[1–3] To optimize the aforementioned benefits, a clear visual field must be maintained while operating. The visual field can be disrupted by condensation and debris.[4] Condensation of water vapor on the lens occurs when moving the laparoscope from a cold operating room into a 37°C humidified body cavity.[5] Debris from inside the body cavity and smoke from cautery tools can collect on the laparoscope during the surgery and increase the risk of surgical error, leading to increased possibility of injury to the patient.

Because of these safety concerns, numerous potential solutions to remove or reduce lens condensation have been studied. These potential solutions include baths, antifogging solutions, and various devices. A hot water bath can be used to warm the laparoscope before surgery to reduce lens fogging.[6] However such warming requires withdrawal of the laparoscope and additional time to clean the port, to maintain a sterile environment. Antifogging solutions, composed of water, alcohol, or surfactant, have been developed that provide prolonged protection of the lens from condensation.[7] These solutions require added time to allow for application and drying of the solution on the lens before optimal results can be achieved. Even noncommercial agents such as baby shampoo have been investigated as antifogging agents.[8] Both hot water baths and antifogging solutions necessitate

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increased operating time. Another suggested method of reducing lens fogging is to use humidified CO_2 insufflation; however, a study in 2004 found no statistically significant reduction in fogging with the use of warm, humidified gas.[9] To clear condensation without increasing operating time, surgeons often resort to cleaning the lens by wiping it on abdominal viscera inside the patient. This method, while decreasing the condensation, results in smears on the lens and the visual field is ultimately obscured. In addition, this method can cause trauma to the viscera.[10]

New devices, such as special lens covers, are currently available for laparoscopes to reduce intraoperative fogging and accumulation of debris on the lens, providing a consistently clear visual field without increased operating time.[11] FloShield (Minimally Invasive Devices, LLC, Columbus, Ohio, USA) is a device that attaches to and fits most 5- or 10-mm laparoscopes and uses in situ vortex barrier technology to provide a continuous flow of dry CO_2 over the tip of the scope, clearing the lens of condensation and debris without withdrawal of the scope.[12] Another lens fog–reducing device is Clearify (Medtronic, Minneapolis, Minnesota, USA), an all-in-one system that uses warmed antifog solution and a trocar wipe inserted into the cannula to reduce lens fogging and remove trocar debris.[13] Numerous other devices are currently marketed and are being developed. These devices are not widely used and were not used in this study because of the current lack of data in the field related to lens fogging. With little data demonstrating the effect of lens fogging on surgical time, hospitals are hesitant to accept the initial cost of these devices. For them to be used, quantitative data are needed that show that they would ultimately be cost effective.

When considering the costs of additional surgical tools, it is important to consider the cost of operating room time. In a 2005 study, the average charge for an operating room was $62/minute (range, $22–$133/minute).[14] The cost to the patient is even higher in many cases because the estimates in the study did not include additional resources specific to the procedure, surgeon and/or anesthesia provider fees. To use these newer technologies, quantitative evidence is needed to measure initial costs versus the cost attributable to increased operating time, because of the need to clean the laparoscope lens.

With little available evidence regarding the quantitative measure of time lost during a surgery because of the need to clean the laparoscope lens, we investigated and measured the amount of time the laparoscope is withdrawn for cleaning during surgery and generated data that can be used to measure quantitatively how much the cost of a surgical procedure is increased by the problem of debris and fog collecting on the laparoscope lens.

METHODS

Study Design

In this prospective, observational study, we measured the effect on intraoperative time of laparoscope withdrawal caused by an obscured visual field during surgery. This study was approved and conducted at Florida Hospital Celebration Health from June to July 2015 (FHCH; IRB approval 48993) in partnership with the University of Central Florida (UCF) College of Medicine (IRB approval SBE-15-11434).

Fifty-two surgical patients were studied, all at FHCH. The inclusion criteria included: age and surgical procedure. The patients' ages ranged from 18 to 91 years. All patients underwent a gynecological or general (gastrointestinal, or urologic, or both) laparoscopic surgical procedure. Of note, two patients underwent multiple procedures (**Table 1**). Data on age, gender, body mass index (BMI), and type of procedure were collected from the patients' electronic medical records (June–July 2015). In addition, intraoperative data were ascertained during the procedure.

Intraoperative Data Collection

Collecting information regarding withdrawal of the laparoscope is not a standard-of-care practice, therefore a systematic method for data collection was devised. One or two of the authors (J.R. and D.A.) were present during the surgical procedures. The researchers timed laparoscope removal with a stopwatch, while counting the number of times the laparoscope was withdrawn. When the surgeon notified the junior investigator (D.A.) that the laparoscope was being removed because of impaired visualization, a stopwatch was started to quantify the total amount of time the laparoscope was withdrawn; the number of times the laparoscope was withdrawn was also tallied. Thus the intraoperative data were collected by one of the investigators (D.A.) while the surgeon performed the surgery. At the end of the procedure, the operative time, estimated blood loss (EBL), wound class, and intraoperative complications were noted.

Statistical Analysis and Data Management

The categorical variables sex (male and female), type of surgical procedure, wound class (I, II, III, and IV) and

Table 1.
Surgical Data

Surgical Procedure	≤30 minutes (n = 26)	>30 minutes (n[a] = 29)
General procedures		
Appendectomy	1 (4)	1 (3)
Cholecystectomy[b]	11 (42)	6 (21)
Colectomy[c]	-	4 (14)
Colostomy	1 (4)	-
Diagnostic laparoscopy	1 (4)	-
Hellar myotomy	-	1 (3)
Inguinal hernia repair[d]	2 (8)	1 (3)
Lysis of adhesion	1 (4)	1 (3)
Nissen fundoplication	-	2 (6)
Sleeve gastrectomy	1 (4)	4 (14)
Ventral hernia repair	2 (8)	2 (8)
Gynecological procedures		
Bilateral salpingo-oophorectomy	1 (4)	-
Hysterectomy with salpingo-oophorectomy[e]	-	5 (17)
Ovarian cystectomy[f]	1 (4)	2 (8)
Tubal ligation	4 (15)	-

Data are presented as number of surgeries (percentage of total). Rounding explains discrepancies in percentages.

[a]Two patients in the >30-minutes group had multiple procedures and are accounted for per procedure on this table. [b]Includes cholecystectomy with and without cholangiogram. [c]Includes sigmoid and right hemicolectomy. [d]Includes right, left, and bilateral repair. [e]Includes right, left, and bilateral salpingoooophorectomy. [f]Includes left and right ovarian cystectomy.

intraoperative complications (yes and no) were reported descriptively, as frequencies and percentages. Continuous variables, such as patient's age, BMI (kg/m²), number of times the laparoscope was withdrawn, length of time the laparoscope was withdrawn (seconds), operative time (minutes), and EBL (in milliliters) are expressed as means ± SD, with SEM and median (minimum–maximum). Both nonparametric and parametric methods were used to analyze the data. It is important to note, however, that no differences across tests were found; thus, only parametric results are reported.

Operative time, EBL, and surgical procedure were used as independent variables to examine differences in number of times and length of time the laparoscope was withdrawn. In this study, operative time was calculated from

incision time to removal of the laparoscope and trocars—the time of suture closure was omitted. Furthermore, operative time was dichotomized as: ≤30 minutes and >30 minutes for further analysis. Similarly, EBL was dichotomized as: ≤10 mL and >10 mL. These cutoffs were driven by clinical relevance and expertise. Finally, surgical procedures were dichotomized as: general surgery and gynecological surgery (see Table 1). To investigate laparoscope outcomes (withdrawal time and number of withdrawals), independent-samples t tests were conducted separately for operative time, EBL, and surgical procedure.

Pearson's correlations (r) and Spearman's rho correlation (r_s) were used to analyze the relationship between laparoscope withdrawal time and clinical outcomes: number of times the laparoscope was withdrawn, operative time, and wound class. In addition, correlations between laparoscope withdrawal and patient characteristics (age and BMI) were calculated. All tests were two sided, and results reaching $P < 0.05$ were considered statistically significant. Statistical analyses were conducted with SPSS 24.0 (IBM; Chicago, Illinois, USA).

RESULTS

In the 52 operations studied (75% of patients were female), the laparoscope was removed for cleaning in 43 (83%) procedures. Sixteen surgical procedures were included as part of this study (see Table 1 for complete details). There were no intraoperative complications. Wound class among the full sample was as follows: I, 15 (29%); II, 33 (63%); and III, 4 (8%). Descriptive statistics on demographic information and overall clinical outcomes are summarized in **Table 2**.

Table 2.
Descriptive Statistics

	Mean (SD)	Median (Minimum–Maximum)
Age (years)	47 (14)	45 (21–76)
BMI (kg/m²)	29.93 (6.16)	27.45 (21.40–45.90)
EBL (mL)	25.58 (39.6)	10 (0–200)
Laparoscope withdrawal (n)	1.96 (1.44)	2 (0–6)
Time laparoscope withdrawn (sec)	17.88 (18.81)	12.65 (0–82)
Operative time (min)	49.44 (28.23)	31 (6–119)

N = 52.

Laparoscope Outcomes Based on Operative Time

There was a statistically significant difference in the mean number of times the laparoscope was withdrawn between the ≤30-minutes (1.58 ± 1.24, SEM = 0.25) and the >30-minutes operative time groups (2.35 ± 1.55, SEM = 0.30) ($t_{50} = -2.22$; $P = .03$) (**Figure 1**). Moreover, there was a statistically significant difference in the mean length of time the laparoscope was withdrawn, ≤30-minutes group (18.81 ± 6.98 seconds, SEM = 1.37) and >30-minutes group (60.08 ± 26.29 seconds, SEM = 5.16) ($t_{50} = 7.74$; $P < .01$) (**Figure 2**).

Laparoscope Outcomes Based on EBL

There was a statistically significant difference in the mean number of times the laparoscope was withdrawn in the EBL groups: EBL ≤10 mL (1.64 ± 1.25, SEM = 0.22) and EBL >10 mL (2.53 ± 1.62, SEM = 0.37) ($t_{50} = 2.23$; $P = .03$) (**Figure 3**). Similarly, there was a statistically significant difference in the mean length of time the laparoscope was withdrawn in the EBL groups: EBL ≤10 mL (12.02 ± 12.07 seconds, SEM = 2.10) and EBL >10 mL (28.04 ± 23.91 seconds, SEM = 5.49) ($t_{50} = 3.214$; $P = .002$) (**Figure 4**).

Laparoscope Outcomes Based on Surgical Procedure

There were no statistically significant differences in the mean number of times the laparoscope was withdrawn

between general surgery cases (1.92 ± 1.40, SEM = 0.23) and gynecological surgery cases (2.07 ± 1.60, SEM = 0.44) ($t_{50} = 0.330$; $P = .74$). Similarly, there was no statistically significant difference in the mean length of time the laparoscope was withdrawn between general surgery cases (19.10 ± 20.53 seconds, SEM = 3.29) and gynecological surgery cases (14.20 ± 12.28 seconds, SEM = 3.41) ($t_{50} = 0.810$; $P = 0.42$) cases.

Relationships Between Laparoscope Withdrawal, Clinical Outcomes, and Patient Characteristics

There was a positive and significant correlation between the number of times and length of time the laparoscope was withdrawn and operative time ($r_s = 0.67$, 0.68, respectively; $P_s < .01$). The number of times the laparoscope was withdrawn and wound class was positive and not significant ($r_s = 0.19$, $P = .18$). The relationship between length of time the laparoscope was withdrawn and wound class was also positive, but not significant ($r_s = 0.15$; $P < .29$).

In regard to patient characteristics, there was a significant and positive relationship between the number of times the laparoscope was withdrawn and age ($r = 0.28$; $P < .041$) and the length of time the laparoscope was withdrawn and age ($r = 0.34$; $P < .014$). On the other hand, there was a negative and nonsignificant relationship between the number of times the laparoscope was withdrawn and the length of time the laparoscope was withdrawn ($r = -0.14$; $P = 0.324$) and BMI ($r = -0.12$; $P = .41$).
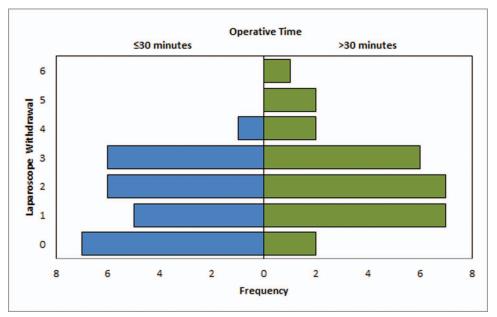

Figure 1. Number of times the laparoscope was withdrawn in the two operative time groups.
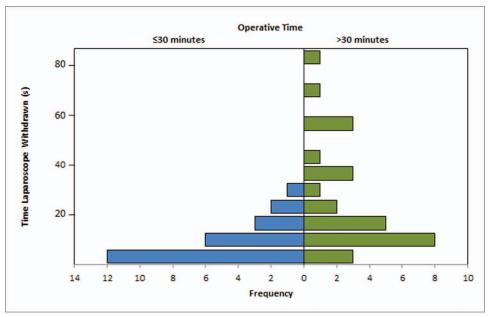
Figure 2. Length of the time the laparoscope was withdrawn in the two operative time groups.
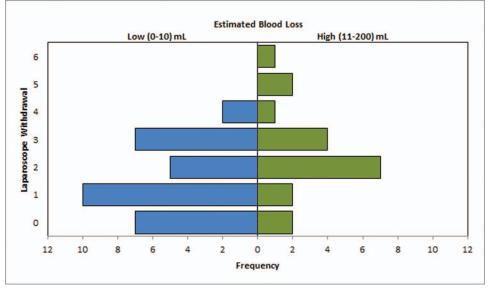

Figure 3. Number of times the laparoscope was withdrawn in the two EBL study groups.

DISCUSSION

The rising cost of operating room time, and the subsequent increased interest in reducing laparoscopic operative times have given rise to development of numerous antifogging solutions, defogging devices, and lens-clearing techniques; however, the opacity of the lens is a safety concern because occluded surgical fields can cause errors that can be costly in terms of extended hospital stay, additional procedures, and greater resource utilization. More important, these errors can imperil patients.

We collected data regarding patient age, gender, BMI, EBL, type of laparoscopic procedure, operative time, number of times and length of time the laparoscope was withdrawn due to obscured visual field and any related intraoperative complications. Of the outcomes studied here, there was a significant difference between laparo-
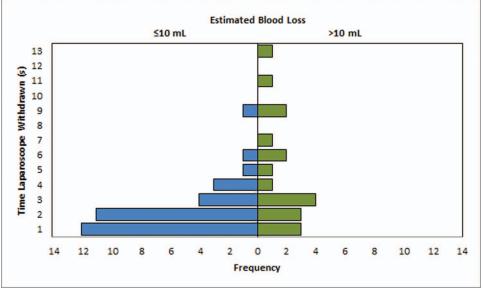
Figure 4. Length of time the laparoscope was withdrawn in the two EBL study groups.

scope withdrawal, both in time and number, with increased EBL and operative time. Possible reasons for increased blood loss include visceral trauma because of an obscured visual field and various anatomical factors. Thus, visceral trauma causes increased intraoperative blood loss that could lead to increased opacity of the visual field.

Although, it is possible that more complex procedures require increased viewing angles, and the surgeon is thus increasingly affected by the poor visual field caused by fogging and debris, our data suggested otherwise. In this study, both the ≤30 minutes and >30-minutes groups were composed of similar surgical procedures—that is, both groups included patients who had undergone a cholecystectomy, with and without a cholangiogram, ventral hernia repair, and ovarian cystectomy. Having the same procedures in both operative time groups demonstrates how operative time can vary significantly, depending on the degree of visual opacity in situ.

BMI was a factor included in the study, but the variable did not have a statistically significant effect on operative time or laparoscope withdrawal. These findings are concurrent with a 2015 study found that initial BMI, gender, and preoperative weight loss did not have an impact on the surgical time for laparoscopic sleeve gastrectomy or intraoperative blood loss.[15] These findings suggest that another of the variables studies could be causative of the increased surgical time and blood loss.

BMI is widely used as an indirect measure of obesity; however, it does not directly measure body fat. This mea-

surement ignores the change in body mass with age. In addition, BMI does not account for variation in fat distribution; patients with central adiposity would have more fat in the surgical field than patients with the same BMI, but no central adiposity. Although time was lost during surgery, BMI was not found to be a significant contributor to lens fogging. Cauterization of body fat produces steam in the abdomen that can then fog the lens, which is why it is often inferred that laparoscopic surgeries performed on individuals with increased body fat mass are complicated by increased lens fogging; however, that was not found to be true in this study.

Both the number of times and the length of time the laparoscope was withdrawn were positively and significantly correlated with age. The average age of the study participant study was 47 years. As an individual ages, the muscle mass decreases and body fat increases. This change is not necessarily reflected in changes in height and weight.[16] Thus, in 2 patients of the same BMI, the older patient is more likely to have increased body fat compared with the younger patient.

Limitations and Further Study

All data were collected from an institution that specifically specializes in minimally invasive surgery by surgeons proficient in use of laparoscopic instruments. Although, surgeon experience was not necessarily a limitation in this study, given that laparoscopic surgery has been shown to need

specialized training,[17–19] we recognize that differing results are likely to be obtained in a hospital with surgeons who perform primarily open surgery and by surgeons in training.

Admittedly, we consider this study a first step and acknowledge that a large randomized prospective study would increase external validity and power, while strengthening the conclusions that may be drawn from our work. Despite this limitation, the findings presented here are the first of this type and studies under different experimental conditions will help us to better understand when to use a lens shield. Moreover, we have identified patient characteristics (e.g., age) that may be related to lens fogging. This further highlights the importance of this work. The authors recommend that future studies consider surgeon experience, as a confounding factor of increased surgical time (e.g., because of inadequate cleaning of the laparoscope) and the role other patient characteristics (e.g., central adiposity) may have in lens fogging.

CONCLUSIONS

Intraoperative lens fogging continues to be a concern in laparoscopic surgery, despite the development of antifogging solution and warming baths. Currently, there are no data ascertaining the effect of laparoscope withdrawal (due to lens fogging) on operative outcomes (e.g., time, EBL). In this study, we found that the length of time and number of times that the laparoscope is withdrawn increased operative time and EBL. In addition, increased patient age correlated with increased withdrawal of the laparoscope because of an obscured visual field. Increased operative time affects financial costs, for both hospital and patients, and our observations warrant acknowledgment and further investigation of laparoscopic lens fogging.

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