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Research Article

A comparative study of open with laparoscopy-related abdominal cancer surgery in particle measurements: a prospective study

Açık ve laparoskopik abdominal kanser cerrahisinde partikül ölçümlerinin karşılaştırılması: prospektif bir çalışma

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Abstract

Aim: In this study, we compared real-time particle measurements at the average head level of a surgical team during open and laparoscopic intra-abdominal cancer surgery.

Material and Methods: Between June 2022 and January 2023, 83 consecutive patients diagnosed with intra-abdominal cancer and scheduled for oncological surgery were included. We recorded the patients' demographic and operative characteristics, including operation time, number of ports in laparoscopic operations, total incision length in laparoscopic operations, and incision length in open operations. The number of particles measuring 0.3, 0.5, 1, 2, 5, and 10 μm in a volume of 0.1 CF (particles/CF) was determined.

Results: Of the 83 patients (mean age 58.4 ± 14.1 years), 38 (45.8%) were women. No significant differences were observed between the open (n = 43) and laparoscopic (n = 40) groups in age, sex, body mass index, body surface area, or operation time. Blood loss was significantly higher in the open surgery group ($p < 0.001$). Particle levels increased during the early intraoperative period in the open surgery group but decreased in the laparoscopic group; however, this difference was not observed in later measurements. Open surgery was associated with higher particle levels during the early intraoperative period.

Conclusion: Particle levels increased with open surgery and decreased with laparoscopic surgery over time, indicating the superiority of the laparoscopic approach. However, regardless of the approach, minimizing surgical duration and ensuring adequate personal protective equipment use remain essential.

Keywords: laparoscopic surgery, open surgery, particle measurement, surgical smoke, occupational exposure

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Öz

Amaç: Bu çalışmada, açık ve laparoskopik intra-abdominal kanser cerrahisi sırasında cerrahi ekibin ortalama baş seviyesindeki gerçek zamanlı partikül ölçümlerini karşılaştırdık.

Gereç ve Yöntemler: Haziran 2022 ile Ocak 2023 tarihleri arasında, intra-abdominal kanser tanısı alan ve onkolojik cerrahi planlanan ardışık 83 hasta çalışmaya dahil edildi. Hastaların demografik ve operatif özellikleri; operasyon süresi, laparoskopik operasyonlardaki port sayısı, laparoskopik operasyonlardaki toplam insizyon uzunluğu ve açık operasyonlardaki insizyon uzunluğu dahil olmak üzere kaydedildi. 0,1 CF hacimdeki 0,3, 0,5, 1, 2, 5 ve 10 µm boyutundaki partikül sayısı (partikül/CF) belirlendi.

Bulgular: Toplam 83 hastanın (ortalama yaş 58,4 ± 14,1 yıl) 38'i (%45,8) kadındı. Açık (n = 43) ve laparoskopik (n = 40) gruplar arasında yaş, cinsiyet, vücut kitle indeksi, vücut yüzey alanı veya operasyon süresi açısından anlamlı bir fark gözlenmedi. Kan kaybı açık cerrahi grubunda anlamlı derecede yüksekti ($p < 0,001$). Partikül seviyeleri açık cerrahi grubunda erken intraoperatif dönemde artarken, laparoskopik grupta azaldı; ancak bu fark sonraki ölçümlerde gözlenmedi. Açık cerrahi, erken intraoperatif dönemde daha yüksek partikül seviyeleri ile ilişkiliydi.

Sonuç: Partikül seviyeleri açık cerrahide artarken laparoskopik cerrahide zamanla azaldı; bu durum laparoskopik yaklaşımın üstünlüğünü göstermektedir. Ancak yaklaşım ne olursa olsun, cerrahi süresinin minimize edilmesi ve yeterli kişisel koruyucu ekipman kullanımının sağlanması temel önemini korumaktadır.

Anahtar kelimeler: laparoskopik cerrahi, açık cerrahi, partikül ölçümü, cerrahi duman, mesleki maruziyet

Introduction

H The COVID-19 pandemic has raised concerns about transmission of to operating room personnel [1]. These concerns relate not only to intubation and extubation of the airway during anesthesia but also to particulate matter originating from surgical smoke. Surgical smoke is a byproduct generated from tissues dissected, excised, or coagulated by heat-generating devices. During surgical procedures, cell membranes are ruptured, and micro-particles, namely particulates, are dispersed into the operating room [2]. Surgical smoke comprises 95% water vapor and 5% particulate matter [3]. The particulate component harbors a wide spectrum of harmful particulates from blood fragments, viable cellular material, bacteria, and viruses as well as chemicals and neurotoxic and carcinogenic agents [4]. The chemical composition of these particles depends on various factors, such as the type of surgery, devices used, and operation time [5]. Accumulated evidence has revealed that exposure to these chemicals can cause harmful effects to operating room staff such as drowsiness, dizziness, headaches, cough, nausea, sneezing and throat burning [6]. Although laparoscopic surgery has largely reduced some of these risks, concerns remain regarding aerosolized droplets released during abdominal desufflation [7]. In addition, few studies have compared minimally invasive and conventional open surgical approaches in terms of the risks of intraoperative particulate matter exposure.

While the risks of surgical smoke have long been recognized, the pandemic has dramatically amplified these concerns. However, some organizations and surgeons have claimed that these concerns have been largely overstated, citing the scarcity of empirical evidence supporting airborne viral transmission via surgical smoke [8-10]. To date, no conclusive evidence exists that infections can be transmitted to humans through surgical smoke [11].

A gap persists between the current recommendations issued by organizations, such as the Occupational Safety and Health Administration, Joint Commission on Accreditation of Healthcare Organizations, National Institute for Occupational Safety and Health, and Association of Perioperative Registered Nurses (AORN), and actual surgical practice. These organizations recommend the use of personal protective equipment, including protective eyewear, to protect against blood splashes or infectious droplets [12]. However, these recommendations do not include, for example, possible hazards from neurotoxic or chemical agents and are based on very limited evidence.

Given these uncertainties, further research on the risks posed by surgical smoke or particulate matter in the operating room is urgently needed. To make a firm risk stratification, quantitative and qualitative measurements of particulate matter in the operating room are required from every type of surgery. Although numerous studies have evaluated the risks of surgical smoke in orthopedic, colorectal, gynecological, gastroenterological, and spinal surgery [13-17], few have focused on oncologic surgery. In this study, we aimed to compare real-time measurements at the head height of a surgical team of particles generated during open and laparoscopic intra-abdominal cancer surgery.

Material and Methods

This prospective study included 83 consecutive patients diagnosed with intra-abdominal cancer who were treated and received follow-up at the oncology clinic of our hospital and who were scheduled for elective oncologic surgery between June 2022 and January 2023. We included patients aged ≥18 years diagnosed with intra-abdominal cancer and scheduled for elective oncologic abdominal surgery. We excluded those who underwent emergency surgery or were scheduled for nononcologic surgical procedures.

Forty-three patients underwent open surgery: esophagus (n = 1), stomach (n = 7), biliary tract (n = 1), liver (n = 7), pancreas (n = 9), small bowel (n = 2), colon (n = 3), rectum (n = 1), and cytoreductive surgery (n = 12). Forty patients underwent laparoscopic surgery: stomach (n = 5), biliary tract (n = 4), pancreas (n = 1), suprarenal surgery (n = 1), colon (n = 10), rectum (n = 12), and diagnostic laparoscopy (n = 7). No sex differences were considered in patient selection.

Patients' demographic characteristics, including age, sex, height, weight, body mass index (BMI), and body surface area, as well as operational characteristics including operation time, number of ports in laparoscopic operations, total incision length in laparoscopic operations, and incision length in open operations, were recorded and compared between laparoscopic and open surgeries.

Particle Measurement

All operations were performed in the same 6.0 × 7.0 × 3.0 m positive-pressure surgical oncology operating room (Figure 1). Particulate measurement was made using a Fluke 983 Particle Counter (Fluke Corporation, Eindhoven, the Netherlands) device as described by the manufacturer. During all operations, the device was fixed at the average head height of the surgical team (Figure 2), which was determined by calculating the mean standing height of the surgical staff members (i.e. between the shortest and tallest team members). The rationale for using the average height was to standardize measurements at a level representative of potential exposure for all team members, rather than favoring extremes. In laparoscopic procedures, particulate measurements were performed immediately after completion of abdominal desufflation, which represents the phase of highest potential particulate exposure for the surgical team. In open surgery, particulate measurements were obtained immediately after complete closure of the surgical incision, corresponding to the final phase of potential intraoperative particulate exposure. All surgeries were conducted in the same positive-pressure surgical oncology operating room equipped with a continuously functioning laminar airflow ventilation system.

Figure 1. A view from the operating room.

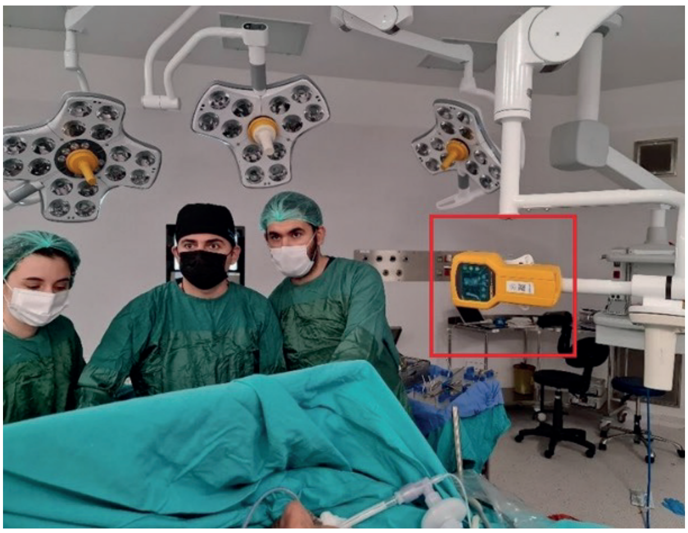

Figure 2. The particle counter, indicated with a red square, was fixed at the average head height of the surgical staff.

Operating of Device

The portable Fluke 983 Particle Counter was used to quantify 0.3, 0.5, 1, 2, 5, and 10 µm particles per 0.1 cubic foot (CF) in 60 s, where CF is defined as the volume of a cube whose sides are one foot (0.3048 m) long (1 CF = 28.3168 L, i.e., 0.1 CF = 2.83 L).

Baseline measurements were taken after the sterile dressing of the patient and surgical preparations were completed, and the 0.1 CF volume was selected to measure 0.3, 0.5, 1, 2, 5, and 10 µm per 0.1 CF on the device following intubation by the anesthesia team. Subsequent measurements were repeated at 30 min intervals, with the final measurement made at the end of the operation. Particle levels recorded at equivalent time points in both the laparoscopic and open surgery groups were compared.

The study was approved by the local ethics committee of our hospital (approval no. 2021-2/3) and conducted in line with the ethical principles of the Declaration of Helsinki. All patients were informed of the study objectives and provided written informed consent.

Statistical Analysis

The data were analyzed using IBM SPSS Statistics version 29.0 (IBM Corp., 2022). Normality of the variables was evaluated using the Shapiro–Wilk test. The independent t-test and Mann–Whitney test were used for between-group comparisons of normally and nonnormally distributed continuous variables, respectively, whereas the chi-square test was used for between-group comparisons of categorical variables. Continuous variables are presented as mean ± standard deviation or median (interquartile range), and categorical variables are presented as frequency (n) and percentage (%); $p < 0.05$ was considered significant.

Results

We included 83 patients (38 [45.80%] women and 45 [54.20%] men) who underwent intra-abdominal surgery. The overall mean age was 58.42 ± 14.18 years. The mean age was not significantly different between the open and laparoscopic groups (60.70 ± 12.49 vs. 55.98 ± 15.60 years, p = 0.130). No significant between-group difference was observed with respect to sex (p = 0.89).

The mean BMI (25.87 ± 4.97 vs. 25.91 ± 5.08 kg/m2, p = 0.97), mean body surface area (1.86 ± 0.20 m2 vs. 1.87 ± 0.21 m2, p = 0.79), and median operation time (114 vs. 109.5 min, p = 0.90) were not significantly different between the open and laparoscopic groups.

The median amount of bleeding was significantly higher in the open surgery group than in the laparoscopic group (100 vs. 50, $p < 0.001$). The distribution of surgical procedure sites was different between the groups ($p < 0.001$). According to the subgroup analysis, liver and pancreas surgeries and cytoreductive surgery were more commonly performed in the open surgery group, whereas colon and rectum surgeries and diagnostic procedures were more commonly performed in the laparoscopic group. Clinicodemographic features are given in table 1.

When particle quantities were examined according to the groups, no significant difference was noted between the open and laparoscopic groups in terms of the amount of particulate matter with sizes of 0.3 (p = 0.580), 0.5 (p = 0.177), 1 (p = 0.232), 2 (p = 0.240), 5 (p = 0.576), and 10 µm (p = 0.720) before incision. Figure 3 presents between-group comparisons of the different-size particles before incision and at the first to ninth measurements.

The differences between the particle levels obtained during the preincision period and each measurement period were calculated, and these differences were compared between the two surgical groups. In the first measurement, the median amount of 0.3 µm particles increased in the open surgery group and decreased in the laparoscopy group compared with the baseline value, and the difference was significant (3634 vs. −859.5, p = 0.021). In the first to fourth measurements, the median amount of 0.5 µm particles increased in the open surgery group and decreased in the laparoscopy group compared with the baseline value, and the difference was significant (1100 vs. −595, p = 0.002; 862 vs. −580, p = 0.003; 260 vs. −700, p = 0.035; 770 vs. −650, p = 0.016). In the first, second, and fourth measurements, the median amount of 1 µm particles increased significantly in the open surgery group and decreased significantly in the laparoscopy group compared with the baseline value (389 vs. −285, p = 0.002; 460 vs. 320, p = 0.002; 510 vs. −320, p = 0.007).

In the first to fourth measurements, the median amount of 2 µm particles increased significantly in the open surgery group and decreased significantly in the laparoscopy group compared with the baseline value (10 vs. −15, p = 0.004; 30 vs. −25, p = 0.001; 0 vs. −20, p = 0.024; 10 vs. −20, p = 0.041). In the first to fourth measurements, the median amount of 5 µm particles increased significantly in the open surgery group and decreased significantly in the laparoscopy group compared with the baseline value (10 vs. −15, p = 0.004; 30 vs. −25, p = 0.001; 0 vs. −20, p = 0.024; 10 vs. −20, p = 0.041). In the first to fourth measurements, the median number of 10 µm particles did not change in the open surgery group but decreased significantly in the laparoscopy group compared with the baseline value (0 vs. −6, p = 0.003; 0 vs. −10, $p < 0.001$; 0 vs. −2, p = 0.016; 0 vs. −1, p = 0.021). No other measurements were significantly different between the two groups.

Figure 4 provides between-group comparisons of the nine measurement points and baseline values.

Figure 5 presents the absolute quantity of each particle size (0.3, 0.5, 1, 2, 5, and 10 µm) at each measurement point throughout the surgical procedures. Figure 6 illustrates the temporal progression of particle counts by size category, demonstrating the dynamic changes over time during open and laparoscopic surgeries.

Table 1. Clinicodemographic characteristics.

	All Patients	Open	Laparoscopic	p
Age (years)	58.42±14.18	60.70±12.49	55.98±15.60	0.130[a]
Sex				
Female	38(45.80%)	20(46.50%)	18(45%)	0.890[b]
Male	45(54.20%)	23(53.50%)	22(55%)	
BMI (kg/m2)	25.89±4.99	25.87±4.97	25.91±5.08	0.972[b]
BSA	1.86±0.21	1.86±0.20	1.87±0.21	0.796[b]
Weight Status				
Underweight	5(6%)	3(7%)	2(5%)	
Normal weight	33(39.80%)	16(37.20%)	17(42.50%)	
Overweight	27(32.50%)	14(32.60%)	13(32.50%)	0.912[c]
Class 1 obesity	15(18.10%)	9(20.90%)	6(15%)	
Class 2 obesity	3(3.60%)	1(2.30%)	2(5%)	
Operation time	113(73:63)	114(80:169)	109.50(68.25:157.75)	0.909[d]
Number of ports in lapa-roscopic surgery	-	-	4(4:5)	-
Total incision length in laparoscopic surgery (cm)	-	-	7(5:8)	-
Incision length in open surgery (cm)	-	29.21±8.88	-	-
Amount of bleeding	100(30:150)	100(50:300)	50(20:100)	<0.001[d]
Surgical Procedure Area				
Esophagus	1(1.20%)	1(2.30%)	0	
Stomach	12(14.50%)	7(16.30%)	5(12.50%)	
Biliary tract/ gallbladder	5(6%)	1(2.30%)	4(10%)	
Liver	7(8.40%)	7(16.30%)	0	
Pancreas	10(12%)	9(20.90%)	1(2.50%)	
Surrenal	1(1.20%)	0	1(2.50%)	<0.001[c]
Jejunum/ileum	2(2.40%)	2(4.70%)	0	
Colon	13(15.70%)	3(7%)	10(25%)	
Rectum	13(15.70%)	1(2.30%)	12(30%)	
Cytoreductive surgery	12(14.50%)	12(27.90%)	0	
Diagnostic	7(8.40%)	0	7(17.50%)	

Data are expressed as mean ± st. deviation, median (interquartile range), and n (%) a: inde-pendent-samples t test, b: chi-square test, c: Fisher–Freeman–Halton test, d: Mann–Whitney, BMI: body mass index, BSA: body surface area, SD: standard deviation, IQR: interquartile

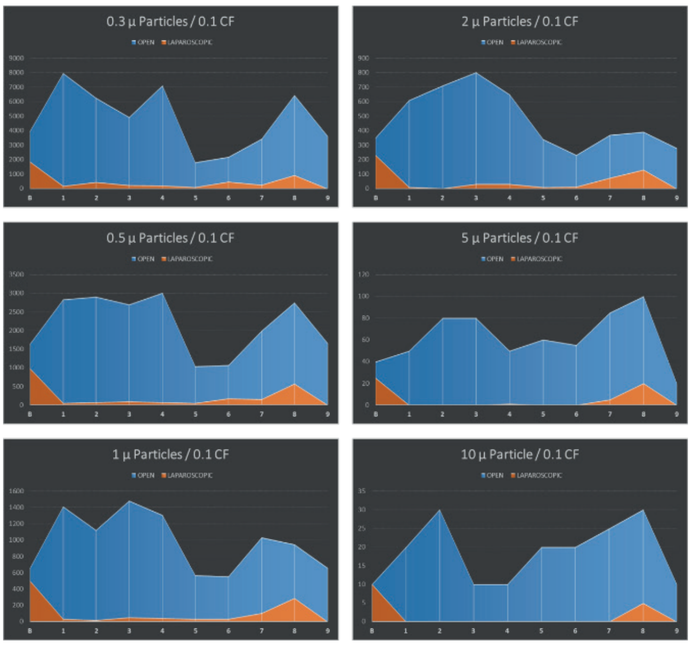

Figure 3. Comparison of the open and laparoscopic groups in terms of the difference-size particles pre-incision and 1,2,3,4,5,6,7,8 and 9th measurement at-30 minute intervals.

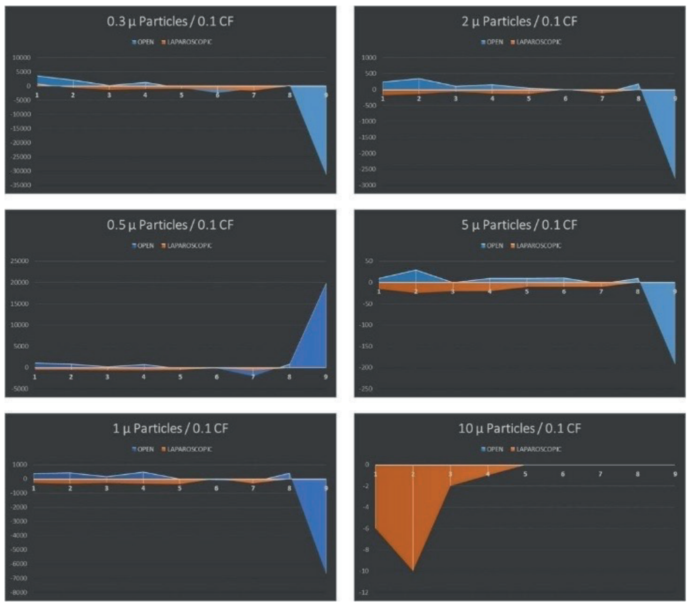

Figure 4. Difference between the open and laparoscopic surgery groups in terms of the difference between the amount of particles at measurement points and baseline.

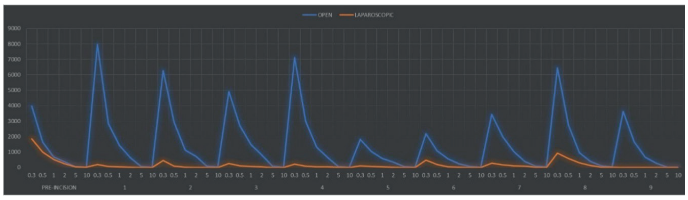

Figure 5. Amount of each particle size at every measurement point.

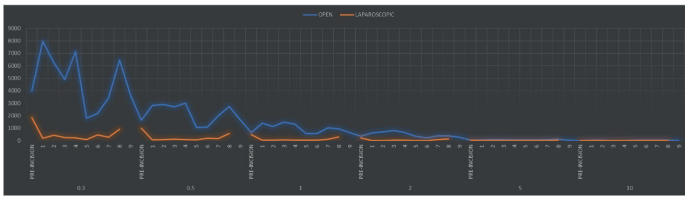

Figure 6. Progression of the amounts of each particle over time.

Discussion

This study found that open intra-abdominal surgeries generated nonsignificantly higher amounts of particulate matter across particle sizes than laparoscopic intra-abdominal surgeries. Particle measurements were made before surgical incision and then every 30 min in each operation, with corresponding values compared between the two groups at each time point.

Limited research has been conducted on the amount of surgical smoke or particulate matter. The only study to investigate the risk of viral transmission during laparoscopic intra-abdominal surgery reported the detection of HBV DNA in 91% of the collected surgical smoke samples [18]. Studies measuring blood splatter contamination on masks and glasses [19] have considered only contamination that can be observed with the naked eye. However, the COVID-19 pandemic has prompted renewed attention to urgently investigate this issue in detail. Despite early concerns about laparoscopic aerosolization during COVID-19, later studies and society recommendations have supported its continued use [20], consistent with our findings. For instance, the Royal Australasian College of Surgeons found no evidence to suggest a higher risk of viral transmission to surgical staff with laparoscopy than with open surgery [21]. Currently, studies are comparing open and laparoscopic operations in terms of transmission through surgical smoke or particulate matter.

Our study included different types of intra-abdominal surgeries in a controlled environment, with all operations performed in the same room and by the same team. This was the first study to measure particles at head level, reducing confounding from gravitational settling. The median age of our cohort was 58.42 ± 14.18 years, with no significant difference between the open and laparoscopic groups. This was lower than the median age of 72 years reported by Kameyama et al. among patients with different diagnoses undergoing colon surgery [14].

Particle levels will be influenced by anatomical features, such as patient weight and height, because the quantity of dispersed particles increases as the surface area of the source increases. In our study, the median BMI value was 25.89 ± 4.99 kg/m2. This value was reported as 21.3 kg/m2 by Kameyama et al. [14], consistent with our result.

Operation time is another critical variable because longer surgeries can increase the exposure time to particles. Kameyama et al. reported an operating time of 192 min, including colon surgeries [14]. In our study, this was 114 min for the open surgery group and 109.5 min for the laparoscopic group, and the difference was not significant. Although we performed colon surgeries, we did not record the operating times for each anatomical site separately.

We also analyzed the changes in particle levels by calculating the difference at each measurement time and before incision. Overall, particle levels increased over time in the open surgery group compared with the laparoscopy group. Notably, small particles increased significantly during the first hour of open surgery and decreased in the laparoscopic group. These findings may reflect the contained nature of laparoscopic procedures. As expected, these differences disappeared as the measurement time at the beginning of the COVID-19 pandemic progressed.

Recent guidelines recommend minimizing operating time possible, and clinicians should perform procedures with which they are most familiar [22]. This view is supported by studies from China and Italy that recommend taking extra precautions to minimize the risk of transmission from surgical smoke or particulate matter [9].

Limitations of the study

This study also has some limitations. First, differences in our study design compared with those of previous studies precluded direct comparisons with the existing literature. Furthermore, widely different measurement techniques across studies made a healthy comparison challenging. Second, we could not analyze particle generation by specific surgery type. This may be subject to further study. Third, we could not analyze the particulate matter content. Fourth, there was considerable heterogeneity in the types of surgical procedures across the two groups. The open surgery group included more complex operations, such as liver resections, pancreatic procedures, and cytoreductive surgeries, whereas the laparoscopic group comprised a greater proportion of less invasive or diagnostic interventions. This procedural diversity may have confounded the observed differences in particle generation, making it difficult to attribute these effects solely to the surgical approach. Fifth, this study was not statistically powered to compare specific surgical procedure subgroups (e.g., liver vs. colon resections), which may limit the generalizability of findings across anatomical sites. Moreover, effect sizes and confidence intervals were not reported in this analysis, which may also limit the interpretation of clinical relevance despite statistical significance. Finally, particle data were analyzed using separate tests at each time point without a repeated measures model. This may have led to an inflated type I error due to the lack of adjustment for within-subject correlation. Future studies with larger sample sizes should apply repeated measures designs or mixed-effects models to more accurately model time trends and interactions and to more comprehensively assess clinical relevance.

This study has several notable strengths. First, it is the first to analyze intraoperative particle generation across a wide range of intra-abdominal surgeries. In particular, we observed that oncological procedures with extensive lymph node dissection produced more particulate matter than other intra-abdominal operations. Second, the measurement was made at head height to control for the bias resulting from gravitational settling. Finally, our sample size was relatively sufficient.

In conclusion, this study demonstrates that open intra-abdominal surgeries generate higher levels of particulate matter than laparoscopic surgical approaches, with the difference being significant in the first hour of surgery. This finding suggests a possible environmental benefit of laparoscopy. However, because particle counts do not directly equate to infectivity or clinical risk, and no viral or toxicological analyses were performed, these clinical implications remain unclear. Regardless of the surgical method, minimizing operative time and ensuring the use of appropriate personal protective equipment remain essential for infection control. Further comprehensive studies with larger samples and a more thorough analysis of particle content are required for more definitive conclusions.

Declaration of conflicting interests

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Ethics approval

This study was approved by the Ethics Committee of the University of Health Sciences, Bursa Faculty of Medicine, Department of Surgical Oncology, Bursa, Türkiye (Approval No: 2021-2/3).

Authors' contributions

Conceptualization: F.A., E.T.; Methodology: F.A., E.T.; Investigation: F.A.; Writing – Original Draft: E.T.; Formal Analysis & Data Curation: F.AS.; Writing – Review & Editing: F.AS.; Supervision: E.T., O.Y.; Validation & Critical Revision: O.Y.

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