



Original Article

Assessment of Knowledge, Attitudes, and Preventive Performance of the Surgical Team Regarding Surgical Smoke Complications in Teaching Hospitals, Yazd, Iran

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Abstract

Introduction: Although the use of advanced surgical instruments has facilitated surgical processes, the smoke generated by them contains hazardous particles, including chemicals and biological agents, endangering the health of the surgical team. Exposure to this smoke can cause eye and skin irritation, respiratory and cardiovascular diseases, and other complications. Therefore, this study aimed to evaluate the knowledge, attitudes, and preventive performance of the surgical team regarding the risks of surgical smoke in the teaching hospitals of Yazd, Iran.

Methods: This descriptive, cross-sectional study was conducted in 2019 using a valid researcher-made questionnaire. The questionnaires were completed by 244 members of the surgical team (surgeons and surgical technologists) in teaching hospitals via the census method, and the data were analyzed using SPSS 21.

Results: The means $\pm$ standard deviations for knowledge, attitudes, and preventive performance were 10.6 ± 1.3 , 43.7 ± 7.2 , and 7.3 ± 1.8 , respectively. There was a significant direct correlation between the knowledge scores of the surgical team and their attitude ($P=0.001$, $r=0.25$). Furthermore, a significant direct correlation was found between knowledge and preventive performance ($P=0.001$, $r=0.27$).

Conclusion: The findings indicated inadequate knowledge, attitudes, and preventive performance practices among the surgical team regarding the risks of associated with surgical smoke. Considering the serious health hazards associated with inhaling surgical smoke, it is essential to strengthen educational policies to increase the awareness, promote appropriate attitudes, and improve preventive practices among surgical team members. These measures can ultimately help protect their health.

Keywords: Attitude, Electrocautery, Knowledge, Preventive Performance, Surgical Smoke, Surgical Team



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Introduction

Modern healthcare delivery requires teamwork and collaboration among professionals with complementary skills, as no individual alone can complete the chain of healthcare services (1). However, the work environment, especially the operating room, imposes significant psychological pressure on individuals, threatening their health (2). As the highest-risk treatment centers (3), hospitals expose staff to numerous occupational hazards, including biological, chemical, physical, and psychological

agents (4, 5). According to research, a high percentage of healthcare workers are exposed to these risks (6), which not only affects their physical health but also imposes a heavy economic burden on organizations (7). Among these hazards, exposure to pathogenic biological agents and resulting infections is of great importance (8). One such risk is surgical smoke, which is generated by different tools, such as lasers, ultrasonic scalpels, drills, and electrosurgical units (monopolar and bipolar) (9, 10). By cutting or coagulating tissue and generating high heat, these devices



cause intracellular fluid evaporation and cell membrane rupture, thereby releasing tissue particles and vapor into the environment (11).

Surgical smoke rapidly distributes in the operating room, and its concentration sharply increases upon the activation of the electrosurgical unit, potentially taking up to 20 minutes to return to baseline levels (12). This smoke consists of 95% water/steam and 5% cellular residues, which contain chemicals, blood and tissue particles, viruses, and bacteria (13). Moreover, the quantity and quality of the smoke depend on the type of surgery, type of tissue, device power, and duration of the surgery (14). Analysis of this smoke has revealed the presence of hazardous substances, such as aromatic hydrocarbons, benzene, formaldehyde, hydrogen cyanide, and carbon monoxide (15, 16). The American Industrial Hygiene Association has identified benzene as carcinogenic to humans and formaldehyde as a suspected carcinogen (17). It should be noted that exposure to surgical smoke is similar to inhaling cigarette smoke and has similar mutagenic and carcinogenic effects; indeed, the thermal destruction of one gram of tissue with an electrosurgical unit has been reported to be equivalent to six cigarettes (18-20).

Complications caused by surgical smoke include headache, eye and skin irritation, cardiovascular and respiratory diseases, nausea, and airway inflammation (15, 16). More dangerously, this smoke contains toxic organic compounds and can transmit live viruses, such as human papillomavirus (21-23). Studies have shown that operating room nurses are twice as likely as other individuals to suffer from respiratory problems (24). Likewise, chronic exposure to surgical smoke is associated with an increased risk of diseases such as Parkinson's and Alzheimer's, as well as breast and prostate cancers (25). Even human immunodeficiency virus-1 viral DNA has been observed in smoke produced by saws, which can survive for up to 14 days (18, 26). In laparoscopic surgeries, smoke is absorbed through the peritoneum and can cause increased carboxyhemoglobin (27). Additionally, most surgical smoke particles are smaller than $1.1\ \mu\text{m}$ (20) and easily penetrate deep into the lungs, causing inflammatory responses (11). Operating room personnel are exposed to these substances for years (16). Although half a million employees are annually exposed to this risk, limited protective measures are taken to reduce exposure to surgical smoke and its associated health risks (9, 28). In addition, safety policies primarily focus on patients, with little attention paid to staff health (29, 30). Standard surgical masks cannot filter particles smaller than five μm and thus cannot protect staff (31). Similarly, general operating room ventilation is insufficient, highlighting the need for portable smoke evacuation systems, local exhaust ventilation, and high-efficiency particulate air filters (9, 32). Therefore, the Association of Perioperative Registered Nurses, in its 2016 guidelines, mandated organizations to create a smoke-free environment, educate personnel, and use appropriate suction systems (33). However, research has shown that staff have limited knowledge of the hazards

associated with surgical smoke (21, 34). Given that limited research has been conducted in Iran, this study has been designed to investigate the knowledge, attitudes, and preventive performance of the surgical team regarding the complications of surgical smoke in teaching hospitals in order to provide a basis for planning and reducing these hazards.

Methods

This descriptive cross-sectional study was performed on all 244 members of the surgical team, including surgeons and surgical technologists at the teaching hospitals of Shahid Sadoughi University of Medical Sciences in Yazd, Iran, in 2019. Individuals were included in the study using a census method based on their willingness to participate. After obtaining ethical approval from Shahid Sadoughi University of Medical Sciences (IR.SSU.SPH.REC.1398.070) and securing an introduction letter to the teaching hospitals, the study objectives were explained to all participants. In addition, written informed consent was obtained, and participants were assured of the confidentiality of their personal information.

The data collection instruments, including knowledge, attitudes, and preventive performance questionnaires regarding the complications of surgical smoke, were developed by the researchers. The questionnaires were designed through an extensive review of relevant literature and existing research instruments in order to ensure comprehensive coverage of the study constructs. Moreover, a pilot study was conducted with 30 surgical team members (15 surgeons and 15 surgical technologists) to assess face validity and item clarity. Participants completed the questionnaire and were asked to identify any ambiguous or unclear items; based on their qualitative feedback, necessary modifications were made to improve the clarity and comprehensibility of the questions.

Then, content validity was quantitatively and qualitatively evaluated by a panel of ten experts in the fields of surgery and health education. The experts assessed the questionnaire items for relevance and necessity based on the study objectives. Likewise, the content validity index was calculated for each item, with all items achieving an excellent score of 0.9 or higher, confirming the content validity of the instrument. In the final stage of tool development, the difficulty level and clarity of the items were evaluated by ten surgical specialists and operating room technologists.

To assess the reliability of the questionnaires, internal consistency was also measured using Cronbach's alpha coefficient. For the attitude section, internal consistency was initially estimated based on a pilot study performed on 20 surgical team members, yielding a value of 0.846. Subsequently, a comprehensive reliability assessment was conducted on a sample of 100 surgical specialists and surgical technologists. The Kuder-Richardson coefficient for the knowledge questionnaire was 0.87. Additionally, Cronbach's alpha coefficients for the attitude and preventive performance questionnaires were 0.90 and 0.88,

respectively, indicating acceptable reliability for all scales.

Following the validation and reliability confirmation, the final questionnaires were distributed among the target population. After completion, all questionnaires were collected and coded for analysis. Ultimately, data were analyzed using SPSS software, version 21. Descriptive statistics (means, standard deviations, frequencies, and percentages) were reported, and the Kolmogorov-Smirnov test was used to assess the normality of data distribution. Based on the results, parametric statistical tests, including independent t-test, one-way analysis of variance, and Chi-square, were employed, and a confidence level of 95% ($\alpha=0.05$) was considered for all statistical tests.

The inclusion criteria for this study encompassed all surgical team members, specifically surgeons and surgical technologists, employed at the teaching hospitals in Yazd. The participants were further required to demonstrate a willingness to partake in the study and provide written informed consent after receiving a brief explanation of the research objectives and being assured of the confidentiality of their personal information. Conversely, the exclusion criteria consisted of a lack of willingness to participate in the study and the submission of incomplete questionnaires, defined as those with more than 10% of the questions left unanswered.

Results

In total, 244 individuals participated in this study. Based on the findings, 123 of the study subjects (50.4%) were female, and the rest were male. About 38.9% held a Bachelor's degree, around 49.6% had a work experience between 1 year and 5 years, and most of them (92.6%) had passed no training course regarding surgical smoke. Further, nearly 48.8% of the study subjects were surgical technologists, and 0.8% of them were pediatric and neurosurgery specialists. In addition, most participants had the role of a surgeon (51.2%) in the surgical team, and the rest had the role of a surgical technologist. Around 21.7% had between 22 and 28 hours of active presence in the operating room during the week, and 3.3% of them had between 50 hours and 56 hours of active presence. Moreover, most individuals (62.3%) stated that the operating room authorities have not established appropriate and mandatory laws for the use of respiratory protective masks by staff during surgery. Furthermore, most individuals (51.6%) had obtained no information regarding surgical smoke and its complications through any means, and among other methods of acquiring information, most of them (36.1%) had gained information through colleagues in the surgical team. Table 1 presents the absolute frequency distribution and frequency percentage of other demographic characteristics of the study subjects.

Based on the results (Table 2), the total knowledge score of the participants was 2604 within the range of 0–6496, and the mean knowledge score per individual was 10.6 within the range of 0–29. Additionally, the lowest and highest scores obtained by the participants were 0 and 24, respectively (range: 0–29).

Likewise, the total attitude score of the participants

Table 1. Absolute Frequency and Percentage Distribution of Demographic Characteristics of the Surgical Team Members Participating in the Study

	Variables	Frequency	Percentage of Frequency
Gender	Female	123	50.4
	Male	121	49.6
Educational qualification	Associate degree	11	5.4
	Bachelor's degree	95	38.9
	Master's degree	13	5.3
	Resident	65	26.6
	Specialist	42	17.2
	Subspecialist	18	7.4
Years of work experience	1–5	121	49.6
	6–10	25	10.2
	11–15	42	17.2
	16–20	35	14.3
	21–25	14	5.7
	>25	7	2.9
Training course on surgical smoke	Yes	18	7.4
	No	226	92.6
Specialty	General surgery	27	11.1
	Orthopedics	21	8.6
	Obstetrics and gynecology	21	8.6
	Ophthalmology	10	4.1
	Otolaryngology (ENT)	6	6.6
	Cardiovascular surgery	5	2.1
	Pediatrics	2	0.8
	Urology	11	4.5
	Plastic surgery	3	1.5
	Oral and maxillofacial surgery	7	2.9
	Neurosurgery	2	0.8
	Surgical technologist	119	48.8
Role in the surgical team	Surgeon	125	51.2
	Surgical technologist	119	48.8
Active presence in the operating room during the week/hours	1–7	12	4.9
	8–14	17	7
	15–21	35	14.3
	22–28	53	21.7
	29–35	42	17.2
	36–42	28	11.5
	43–49	32	13.1
	50–56	8	3.3
	More than 56	17	7
Existence of mandatory regulations	No	152	62.3
	Yes	92	37.7
Source of information	Members of the surgical team/surgical team colleagues	88	36.1
	In-service training classes	4	1.6
	Internet search and review of international guidelines	26	10.7
	None	126	51.6

Note. ENT: Ear, nose, and throat.

was 10656 within the range of 3136–15680, and the mean attitude score per individual was 43.7 (range: 14–70). Similarly, the lowest and highest scores obtained by the participants regarding attitude were 22 and 66, respectively (range: 14–70). Additionally, the total preventive performance score of the participants and the mean preventive performance score per individual were 1792 (range 0–4032) and 7.3 (0–18), respectively. The lowest and highest scores obtained by the participants regarding preventive performance were 2 and 13, respectively, (range 0–18).

The results of the independent t-test (Table 3) indicated a significant relationship between the surgical team's attitude toward complications caused by surgical smoke and gender ($P < 0.05$), the mean score for the female and male groups being 62.4 and 42.7, respectively. Further, there was a

Table 2. Total Score, Mean, Mode, Standard Deviation, Variance, Minimum, and Maximum Score of Knowledge, Attitudes, and Preventive Performance

Dimensions	Observed Score Range	Total Score	Mean	Minimum	Maximum	Standard Deviation
State of knowledge	29–0	2604	10.6	0	24	1.3
State of attitude	70–14	10656	43.7	22	66	7.2
State of preventive performance	18–0	1792	7.3	2	13	1.8

significant relationship between the attitude variable and the individuals' role in the surgical team ($P < 0.05$), such that the mean attitude of surgical technologists (45.08) was significantly higher than that of surgeons (42.3). In addition, a significant difference was observed in the mean preventive performance of the surgical team regarding complications caused by surgical smoke based on previous training received, so that the mean performance of the trained group was higher than that of the untrained group.

Data analysis (Table 4) showed no significant difference in knowledge across surgical specialties ($P = 0.438$), but significant differences were found for attitude ($P = 0.038$) and preventive performance ($P = 0.002$). Regarding attitude, neurosurgery (mean rank: 213), cardiac surgery (177), and maxillofacial surgery (171) surgeons ranked highest. For preventive performance, neurosurgery (163), pediatric surgery (160), and urologic surgery (140) specialists had the highest mean ranks. These findings suggest that while knowledge is consistent, attitude and performance vary, with neurosurgeons demonstrating the highest ranks in both areas.

In addition, the results of the analysis of variance (Table 5) revealed a significant difference in the mean knowledge, attitudes, and preventive performance of the surgical team regarding complications caused by surgical smoke based

Table 3. Results of Independent t-Test to Compare Knowledge, Attitudes, and Preventive Performance of the Surgical Team Based on Different Variables

		Knowledge		Attitudes		Preventive Performance	
		Mean	P-Value	Mean	P-Value	Mean	P-Value
Gender	Female	10.2	0.1	62.4	0.03	7.4	0.5
	Male	11.11		42.7		7.3	
Role in the surgical team	Surgeon	10.7	0.95	42.3	0.003	7.16	0.12
	Surgical technologist	10.65		45.08		7.5	
Previous training	No	10.6	0.42	43.7	0.58	7.3	0.02
	Yes	11.44		42.7		8.22	
Existence of binding laws	No	10.7	0.62	43.4	0.55	7.19	0.09
	Yes	10.5		44.02		7.59	

Table 4. Results of the Kruskal-Wallis Test to Compare the Knowledge, Attitudes, and Preventive Performance of the Surgical Team Based on Surgical Specialty

Expertise	Knowledge		Attitudes		Preventive Performance	
	Average Ranks	P-Value	Average Ranks	P-Value	Average Ranks	P-Value
General surgery	126	0.438	85	0.038	112	0.002
Orthopedics	142		111		69	
Gynecological surgery	112		119		116	
Ophthalmic surgery	122		112		68	
Ear, nose, and throat surgery	110		104		135	
Cardiac surgery	90		177		102	
Pediatric surgery	201		130		160	
Urologic surgery	122		124		140	
Plastic surgery	177		124		110	
Maxillofacial surgery	135		171		93	
Neurosurgery	195		213		163	
Surgical technologist	118		130		138	

Table 5. Results of the Analysis of Variance Test for Knowledge, Attitudes, and Preventive Performance of the Surgical Team Based on Other Variables

		Knowledge		Attitudes		Preventive Performance	
		Mean	P-Value	Mean	P-Value	Mean	P-Value
Experience/year	1–5	10.6	0.19	44.4	0.52	1.3	0.94
	6–10	9.6		43.6		7.4	
	11–15	11.95		43.5		7.2	
	16–20	10.7		42		7.49	
	≥21	9.9		43		7.57	
Education	Associate degree	9	0	44.4	0.02	7	0.02
	Bachelor's degree	10.11		45		4.3	
	Master's degree	16		46.7		9	
	Specialist	10.9		42.25		7.5	
	Subspecialist	10.7		42		7	
Active presence in the operating room/hour	1–14	11	0.89	43.8	0.34	7.4	0.85
	14–28	10.4		43		7.4	
	28–42	10.7		44		7.4	
	≥42	11		44		7.2	

on the education level ($P < 0.05$), so that the mean scores for knowledge, attitudes, and preventive performance of those with a master's degree were substantially higher than those of other educational qualifications.

According to Table 6, the relationship between knowledge and attitude ($r = 0.25$, $P = 0.001$) was weak, positive, and statistically significant. Although significant, the weak correlation indicated that knowledge alone is not a strong driver of attitude, and other factors (e.g., training quality and workplace culture) likely play more substantial roles.

Similarly, a weak but significant relationship was found between knowledge and preventive performance ($r = 0.27$, $P = 0.001$), suggesting that while knowledge contributes to better performance, it is insufficient on its own. Actual performance may be hindered by other critical factors, including the availability of protective equipment and organizational support.

Unlike the other relationships, the correlation between attitude and preventive performance ($r = 0.09$, $P = 0.14$) was not statistically significant. This important negative finding demonstrates that a positive attitude alone is insufficient to guarantee safe performance in the absence of necessary equipment and a supportive environment. Despite having favorable attitudes, individuals may fail to adopt protective behaviors if resources are not readily available, underscoring the critical role of institutional support in bridging the gap between attitude and practice.

Discussion

A comprehensive examination of the status of knowledge, attitudes, and preventive performance of the surgical team in teaching hospitals in Yazd regarding the complications of surgical smoke painted a concerning picture of the level of safety and occupational health in surgical environments. The results of this study indicated that the mean knowledge score of the surgical team (with a score range of 0–29) was 10.6, and the mean preventive performance score

Table 6. Correlation Coefficient Between Knowledge, Attitudes, and Preventive Performance in the Field of Surgical Smoke Complications

Number	Variable	1	2	3
1	Knowledge	1		
2	Attitude	0.25**	1	
3	Preventive performance	0.27**	0.09	1

Note. * $P < 0.05$, ** $P < 0.01$.

(within the range of 0–18) was 7.3, representing a poor level of awareness and inappropriate performance by personnel against the hazards of surgical smoke. Although participants had relative awareness regarding the nature of smoke generation and its respiratory effects, they provided insufficient and occasionally incorrect information regarding the transmission of dangerous diseases (e.g., hepatitis and human immunodeficiency virus-1) through surgical smoke. The main reason for this deficiency has been cited as the lack of standard protective facilities and equipment in hospitals, so that most individuals mentioned that despite being aware of the existence of advanced equipment globally, none of the useful tools, such as suction with special filters or N95 masks, were available in their work environment. This lack of infrastructure, along with the lack of access to occupational protocols and global guidelines, is the main barrier to the correct performance of personnel. These findings are consistent with the results of studies by Ilce et al (9), Chapman et al (21), and Khoshdel et al (34), pointing to the low level of knowledge and preventive performance of surgical teams and the insufficient use of personal protective equipment.

Notable results were obtained when analyzing variables affecting the surgical team's status. Gender-based examination showed no significant difference in knowledge and preventive performance between men and women; however, attitude scores were significantly higher in women, suggesting greater sensitivity to workplace safety

issues.

Regarding team roles, surgeons demonstrated a better status compared to surgical technologists, although both groups had low knowledge and performance levels, which contradicts the results of the study by Ilce et al (9), reporting surgeons as weaker than other personnel in using preventive devices.

Analysis by surgical specialty revealed no significant difference in knowledge across specialties, indicating a lack of specialized education in university curricula. However, significant differences were observed in attitudes and preventive performance. Neurosurgeons ranked highest in both domains. Likewise, cardiologists and maxillofacial surgeons scored high in attitude, while pediatricians and urologists scored high in preventive performance. These differences may be attributed to the nature of their surgeries and greater exposure to surgical smoke-generating equipment.

One of the most important findings was related to the variable of work experience; based on the obtained data, there was no significant relationship between work experience and the level of knowledge, attitudes, or preventive performance. Overall, personnel, whether during their studies or throughout their years of service, had received no effective training regarding surgical smoke, and work experience alone did not lead to the improvement of their awareness.

In contrast, education and receiving previous training had a positive and significant impact on the status of personnel. More precisely, individuals with a master's degree achieved higher scores in the knowledge and attitude sections. This may be due to the greater mastery of these individuals over scientific sources and credible global guidelines. Additionally, although receiving previous training had no significant effect on knowledge and attitude (which may be due to the low quality or forgetting of old trainings), its effect on preventive performance was significant, such that individuals who had received training showed better performance. This highlights the importance of continuous training and is consistent with the findings of studies by Chapman et al (21), Ball (24), the Association of perioperative Registered Nurses (35), and Chavis et al (36), emphasizing the necessity of continuous training to promote behavior change and create a safe environment. Another noteworthy point was that the presence or absence of mandatory workplace laws for mask use had no significant effect on any of the dimensions of knowledge, attitudes, or preventive performance, implying that external obligations are ineffective without internal awareness and sufficient education. Overall, it is suggested that health and education policymakers, through careful planning, incorporate topics related to surgical smoke and safety into university course syllabi. In addition, it is recommended that they hold effective and continuous in-service training courses to familiarize personnel with up-to-date guidelines and protective equipment, thereby improving preventive performance and increasing the health of the valuable workforce in the country's healthcare system by enhancing

awareness and changing attitudes.

Finally, it is important to acknowledge that the data were gathered in 2019. Although this issue does not diminish the validity of the findings, readers should consider that guidelines, training programs, or the availability of protective equipment may have changed in the intervening period.

Conclusion

This study revealed a concerning lack of knowledge and inadequate preventive performance regarding the hazards of surgical smoke among the surgical team in teaching hospitals in Yazd. Despite the availability of advanced equipment globally, the absence of standard protective facilities (e.g., smoke evacuation systems and N95 masks) remains a primary barrier to safety. The findings indicated that while gender and work experience did not significantly influence knowledge or preventive performance, higher education levels and previous training were associated with better outcomes. Notably, the mere existence of mandatory laws proved ineffective without proper awareness and education. Therefore, it is strongly recommended that healthcare policymakers integrate surgical smoke safety into university curricula and implement continuous, high-quality in-service training. It is noteworthy that these measures are essential to enhance staff awareness, improve attitudes, and ensure the occupational health of the surgical workforce.

Implications for Practice and Policy

Based on the study findings, the following actionable recommendations are presented:

Curriculum Integration

Specific modules on surgical smoke hazards should be incorporated into medical, nursing, and surgical technology curricula, covering topics such as health effects, smoke evacuation systems, and proper use of personal protective equipment.

Training Programs

It is recommended that all operating room personnel receive mandatory annual in-service training, including practical workshops and online modules. Refresher courses every six months can reinforce learning and ensure updated knowledge.

Equipment Provision

Hospital administrators and health ministries must prioritize the procurement of smoke evacuation systems and N95 masks as an essential investment in workforce health. Clear protocols for mandatory use during all smoke-generating procedures should be established and monitored as well.

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Competing Interests

The authors declare no competing interests.

Ethical Approval

Written informed consent was obtained from all participants to take part in the study. Participants were also assured of anonymity and confidentiality of their information. In addition, ethical approval was provided by the Research Ethics Committee of Shahid Sadoughi University of Medical Sciences, Yazd, Iran (ethical code: IR.SSU.SPH.REC.1398.070).

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