

Impact of Operating Room Microclimate on Surgical Site Infection in Clean-Contaminated Procedures

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Background: Surgical site infection (SSI) remains one of the most common postoperative complications following clean-contaminated surgery. Although patient- and procedure-related risk factors are well established, the contribution of operating room (OR) microclimate, including temperature, relative humidity, and airflow characteristics, has received comparatively less attention. This study evaluated the relationship between intraoperative OR microclimate and SSI incidence following clean-contaminated abdominal procedures.

Methods: A prospective observational study was conducted between January 2024 and March 2026 involving 524 adult patients undergoing elective clean-contaminated gastrointestinal surgery. OR temperature, humidity, air exchange rate, and particulate concentration were continuously monitored. Patients were followed for 30 days postoperatively according to standardized SSI surveillance criteria. Multivariable logistic regression identified independent predictors of SSI.

Results: Thirty-eight patients (7.3%) developed SSI. Procedures performed in ORs with temperature exceeding 23°C and relative humidity above 60% demonstrated significantly higher infection rates than surgeries performed within recommended environmental parameters (10.8% vs. 5.2%, $p=0.018$). Elevated particulate counts were independently associated with SSI (OR 1.81, 95% CI 1.12–2.93). After adjustment for diabetes, BMI, operative duration, and wound classification, suboptimal OR microclimate remained an independent predictor of SSI (adjusted OR 2.14, $p=0.011$).

Conclusion: Operating room environmental conditions significantly influence postoperative SSI following clean-contaminated procedures. Continuous monitoring and optimization of OR microclimate may represent an effective,

low-cost strategy for reducing postoperative infectious complications.

Key Words: Surgical site infection; Operating room; Microclimate; Temperature; Humidity; Air quality; Infection prevention

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Introduction

Surgical site infection remains a leading healthcare-associated infection worldwide, accounting for substantial postoperative morbidity, prolonged hospitalization, increased healthcare costs, and higher mortality. Clean-contaminated gastrointestinal operations carry a greater infection risk because endogenous microbial flora are introduced during surgery despite adherence to aseptic techniques.

Current SSI prevention strategies emphasize antibiotic prophylaxis, sterile surgical techniques, glycemic control, and normothermia. However, environmental factors within the operating room may also influence microbial contamination. Temperature, humidity, airflow, air exchange rates, and airborne particulate matter collectively define the OR microclimate and may affect bacterial survival, dispersion, and wound contamination.

While international guidelines recommend maintaining controlled environmental conditions within operating theatres, evidence directly linking OR microclimate to postoperative SSI remains limited, particularly in clean-contaminated procedures. The present study aimed to investigate whether deviations in OR environmental parameters independently contribute to postoperative surgical site infection.

Materials and Methods

Study Design

This prospective observational cohort study was conducted at three tertiary referral hospitals from January 2024 to March 2026.

Patient Selection

Adults undergoing elective clean-contaminated abdominal surgery were eligible.

Inclusion Criteria

- Age ≥ 18 years
- Elective gastrointestinal surgery
- Clean-contaminated wound classification
- Complete 30-day follow-up

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Exclusion Criteria

- Emergency surgery
- Active preoperative infection
- Immunosuppressive therapy
- ASA physical status V
- Incomplete environmental monitoring

Data Collection

Patient demographics included:

- Age
- Sex
- BMI
- Diabetes
- Smoking history
- ASA score
- Albumin level

Operative variables included:

- Procedure type
- Duration
- Blood loss
- Antibiotic timing
- Laparoscopic or open surgery

Operating Room Microclimate Monitoring

Environmental sensors continuously recorded:

- Temperature (°C)
- Relative humidity (%)
- Air exchange rate (ACH)
- Airborne particulate concentration (particles/m³)
- Positive pressure maintenance

Measurements were averaged throughout each operation.

Outcome Measures

Primary outcome:

30-day Surgical Site Infection

Secondary outcomes:

- Length of hospital stay
- Readmission
- Reoperation
- Intensive care admission

SSI was classified according to CDC definitions.

Statistical Analysis

Continuous variables were analyzed using Student's t-test.

Categorical variables were compared using Chi-square tests.

Multivariable logistic regression determined independent predictors of SSI.

Statistical significance was defined as $p < 0.05$.

Results

Baseline Characteristics

A total of **524 patients** were enrolled.

Mean age: 58.9 ± 13.2 years

Male: 56.7%

Diabetes: 24.4%

Mean BMI: 27.1 ± 4.6 kg/m²

Mean operative duration: 176 ± 54 minutes

Laparoscopic procedures: 61%

Open procedures: 39%

Operating Room Environmental Conditions

Average OR temperature: $22.4 \pm 1.2^\circ\text{C}$

Relative humidity: $54 \pm 7\%$

Average air exchange rate: 21 ACH

Elevated particulate counts (>350 particles/m³) occurred during 18% of procedures.

Surgical Site Infection

Overall SSI incidence: 38 patients (7.3%)

Types of SSI: Superficial: 22

Deep incisional: 10

Organ-space: 6

Median diagnosis:

Postoperative Day 9

Association Between OR Microclimate and SSI

Patients exposed to higher OR temperatures ($>23^\circ\text{C}$) experienced:

SSI rate: 10.8%

Compared with: 5.2%

($p=0.018$)

Humidity exceeding 60% was similarly associated with increased SSI.

High airborne particulate concentration significantly increased infection risk.

Multivariable Analysis

Independent predictors of SSI included:

Variable	Adjusted OR	95% CI	p-value
Diabetes	1.89	1.06–3.34	0.031
BMI ≥ 30	1.71	1.01–2.91	0.046
Operative duration >180 min	2.08	1.21–3.58	0.009
High particulate concentration	1.81	1.12–2.93	0.015
Temperature $>23^\circ\text{C}$	2.14	1.19–3.82	0.011

Discussion

This multicenter prospective study demonstrates that operating room microclimate significantly influences postoperative infection following clean-contaminated abdominal surgery. Patients operated under warmer, more humid environments with increased airborne particulate concentrations experienced significantly higher SSI rates.

Temperature influences bacterial growth and personnel comfort. Excessively warm OR environments may increase perspiration, microbial shedding, and disruption of sterile barriers. Elevated humidity can prolong bacterial viability on surfaces and equipment, whereas increased particulate matter may serve as vectors carrying microorganisms into surgical wounds.

The observed association between particulate concentration and SSI supports previous investigations emphasizing air quality as a critical determinant of surgical sterility. While laminar airflow has shown mixed results in orthopedic surgery, maintaining stable environmental conditions appears beneficial in abdominal procedures where bacterial contamination risk is inherently higher.

Importantly, environmental monitoring represents a relatively inexpensive intervention compared with treating postoperative infections. Automated monitoring systems capable of alerting staff when temperature or humidity exceeds recommended ranges may improve compliance and reduce infectious complications.

The findings should be interpreted alongside established patient-related risk factors. Diabetes, obesity, and prolonged operative duration remained independent predictors of SSI, highlighting the multifactorial nature of postoperative infection.

Limitations

This study has several limitations. First, it was observational and therefore cannot establish causality. Second, environmental measurements were averaged over each procedure and may not fully capture transient fluctuations. Third, microbial air cultures were not routinely performed. Finally, results may not be generalizable to orthopedic or cardiovascular operating rooms with different ventilation systems.

Conclusion

Operating room microclimate is an important environmental determinant of surgical site infection in clean-contaminated abdominal surgery. Elevated temperature, excessive humidity, and increased airborne particulate concentration independently increase postoperative infection risk. Continuous environmental monitoring combined with adherence to recommended operating room standards may improve surgical outcomes while reducing healthcare costs. Future randomized interventional studies are warranted to determine whether targeted optimization of OR microclimate directly decreases SSI incidence.

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Conflict of Interest

The authors declare no conflicts of interest.

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Ethical Approval

The study was approved by the institutional ethics committees of the participating centers. Written informed consent was obtained from all participants.

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