



Research Article

How Sterile Are Our Operating Rooms? A Comparison of Air Quality During Primary TKA and THA

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Citation: DelliCarpini G, et al. How Sterile Are Our Operating Rooms? A Comparison of Air Quality During Primary TKA and THA. J Ortho Sci Res. 2023;4(1):1-5.

<https://doi.org/10.46889/JOSR.2023.4202>

Received Date: 26-04-2023

Accepted Date: 10-05-2023

Published Date: 17-05-2023



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Abstract

Introduction: Airborne Biologic Particles (ABPs) are a potential risk factor for infection following total joint arthroplasty. Factors such as temperature and humidity may affect the number of ABPs which can increase the risk of infection. Comparisons of ABP count between Total Hip Arthroplasty (THA) and Total Knee Arthroplasty (TKA) have yet to be made. Our study examines the differences in ABP count between primary THA and TKA procedures.

Methods: We analyzed all primary TJA procedures done within the same OR at an academic institution from April 2019 to June 2020. All procedures between the dates of March 15, 2020 - May 4, 2020 were excluded to avoid COVID-related confounding. Intraoperative measurements of temperature, humidity, and ABP count per minute were recorded. A report containing surgical data from the same time was generated using the institution's Electronic Health Records (EHR) system and cross-referenced to the intraoperative measurements using procedure start and end times. ABP was calculated as an average ABP count per minute. Descriptive statistics were used to evaluate differences in variables of interest. P-values were calculated using t-test for continuous variables and chi square for categorical values.

Results: A total of 168 cases were included in the study, comprised of 98 (58.3%) primary THA and 70 (41.7%) primary TKA. No significant differences in room temperature or particle counts across all particle sizes were found between THA and TKA groups. Similarly, time spent in the room was not significantly different between THA and TKA. The only variable that was significantly different between the two groups was average relative humidity, with higher humidity in the THA group (46.9% + 7.56 vs 44.4% + 8.02, p=0.008).

Conclusion: There were no significant differences in temperature or particle count between primary THA and primary TKA procedures, suggesting OR air quality was similar between the two procedure types. Further investigation including additional variables such as OR size, airflow patterns, and different procedure types should be performed to better characterize the role of ABPs in air quality and infection risk.

Keywords: Total Joint Arthroplasty; Operating Room; Total Knee Arthroplasty; Airborne Biologic Particles

Introduction

The incidence of Periprosthetic Joint Infection (PJI) following Total Joint Arthroplasty (TJA) is expected to rise, especially as the demand for primary total joint arthroplasty continues to increase worldwide [1]. Overall rates of PJI are 2.18% for both primary total hip arthroplasty and total knee arthroplasty [2]. PJI specifically increases overall morbidity and healthcare costs, attributable to prolonged hospitalization and potential need for multiple operations [3]. The expected economic burden of periprosthetic infection is thought to be more than \$1.85 billion by 2030 [4-7].

Efforts to minimize risk of PJI have garnered interest in the study of both airborne transmission of bacteria within the operating

room as well as the factors which play a role in reducing perioperative infection risk, including operating room set up, door openings, bacterial decolonization, proper prepping and draping techniques, and administration of perioperative antibiotics [8]. A recent study evaluating instrument set up showed the OR back table and surrounding sterile field have culture positive results in over 10% of specimens upon surgery completion [9]. Airborne bacteria may be introduced into the OR by OR staff and the frequency of door openings [8,10]. However, perioperative antibiotics do not cover all microorganisms that may be present in the operating room and Surgical Site Infection (SSI) can be the result of primary airborne transmission of bacteria [11-15]. Operating room features such as heating, laminar airflow ventilation, and air conditioning play an important role in reducing OR bacterial counts [8]. As the indoor temperature increases by each additional 1°C the bacterial colony count may increase by 9.4 colony forming units per meters cubed (cfu/m³), yet correlation to surgical site infection was not evaluated [16]. Additionally, humidity greater than 60% and temperature greater than 30°C has been found in previous work to increase the risk of deep PJI in patients following TKA [17]. Overall, environmental factors are often difficult to modify due to the existing OR room size and layout, limited design input from operating surgeons and OR staff, and budget constraints [18].

Interventions to decrease bacterial bioburden in the operating room are imperative to examine as a modifiable source of SSI. There is a paucity of literature exploring Airborne Biologic Particles (ABP) detected in the operating room during orthopedic procedures. Specifically, comparisons of ABP between primary Total Hip Arthroplasty (THA) and Total Knee Arthroplasty (TKA) have yet to be examined. In this study we present a comparison of ABP counts between primary THA and TKA in a single operating room to understand the role of procedure type on particle burden.

Methods

A retrospective analysis of patient data from an academic, orthopedic specialty hospital was performed following approval from the institutional review board. All patients who underwent elective, primary TKA and primary THA within the same OR, measuring 501 square feet, from April 2019 to June 2020 were included. All trauma, oncology and non-elective cases were excluded. To prevent COVID-related confounding, all procedures between the dates of March 15, 2020 - May 4, 2020, were excluded. Intraoperative measurements of temperature, humidity, and ABP count per minute were recorded. All readings were determined using a portable filtration device (Illuvia HUAIRS®, Aerobiotix, Miamisburg, Ohio) with a built-in particle counter located within the OR. The device was positioned diagonal from the main OR door entrance. The device utilizes a photolytic chamber that slows the travel of particles to inactivate them, with subsequent removal of particles via a nonturbulent HEPA filter specifically designed for the operating room. The sensor obtains the number of suspended particles in the air to determine concentration and outputs them as digital recordings in real time. A report containing surgical data was generated using the institution's Electronic Health Records (EHR) system and cross-referenced to the intraoperative measurements using procedure start and end times. ABP was calculated as an average ABP count per minute. Descriptive statistics were used to evaluate differences in variables of interest. P-values were calculated using t-tests for continuous variables and chi square for categorical values.

Data Analysis

Statistical analyses were conducted using RStudio (version 1.3.959, Boston, MA). ABP was calculated as an average ABP count per minute. Due to unequal sample sizes between the groups, p-values were calculated using Welch's t-test for continuous variables and chi-square and Fischer's exact testing for categorical variables. A p-value <0.05 was determined as the level of significance.

Results

A total of 168 TJA cases were included in the study, comprised of 98 (58.3%) primary THAs and 70 (41.7%) primary TKAs. The mean age of the included patients was similar between groups (64.52 years + 12.60 for the THA group and 64.89 years + 9.55 for the TKA group) (p-value = 0.424). TKA patients had a significantly higher BMI compared to THA patients (TKA: 33.37 kg/m² + 7.05; THA: 28.52 kg/m² + 5.53; p-value <0.001). A full comparison of patient demographics is listed in Table 1. There were no significant differences in room temperature between the groups (Table 2). Average temperatures were 19.1 °C + 0.845 in the THA group and 19.1 °C + 0.891 in the TKA group (p-value = 0.294). Similarly, there was no significant difference in particle counts across all particle sizes (0.3 um, 0.5 um, 1.0 um, 2.5 um, 5 um and 10 um) found between THA and TKA groups (Table 3). Overall time spent in the room was not significantly different between THA and TKA (THA: 174 +33.2 minutes; TKA: 173 + 44.6 minutes;

p-value = 0.294). The only variable that was significantly different between the two groups was average relative humidity, with higher humidity in the THA group (THA: 46.9% + 7.56; TKA: 44.4% + 8.02, p=0.008).

	Hips (n=98)	Knees (n=70)
Age	63.52 ± 12.60	64.89 ± 9.55
Gender (%)		
Male	37 (37.8)	29 (41.4)
Female	61 (62.2)	41 (58.6)
BMI	28.52 ± 5.53	33.37 ± 7.05
Race (%)		
White	72 (73.5)	39 (55.7)
Black	14 (14.3)	13 (18.6)
Asian	2 (2.0)	3 (4.3)
Other	10 (10.2)	15 (21.4)
ASA		
1	11 (11.2)	2 (2.9)
2	72 (73.5)	49 (70.0)
3	15 (15.3)	19 (27.1)
4	0 (0.0)	0 (0.0)
Smoking Status		
Current	9 (9.2)	3 (4.3)
Former	29 (29.6)	26 (37.1)
Never	60 (61.2)	41 (58.6)
Unknown	0 (0.0)	0 (0.0)
Operative Time	173.97 ± 33.18	172.91 ± 44.63
Length of Stay (hr)	42.60 ± 42.06	43.17 ± 29.31

Table 1: Patient demographics.

	THA (n=98)	TKA (n=70)	p-value
Temp (Celsius)	19.1 ± 0.845	19.2 ± 0.891	0.294
Humidity (%)	46.9 ± 7.56	44.4 ± 8.02	0.0083*
Time in Room (min)	174 ± 33.2	173 ± 44.6	0.508

Table 2: Temperature, humidity and time spent in primary THA vs. TKA.

Particle Size	THA (n=98)	TKA (n=70)	p-value
0.3 um	X	+19.2%	0.987
0.5 um	X	+21.5%	0.951
1.0 um	X	-0.8%	0.727
2.5 um	X	-0.8%	0.802
5.0 um	X	-1.25%	0.527
10.0 um	X	-12.5%	0.695
PM 2.5	X	+19.5%	0.901
PM 5.0	X	+17.4%	0.844
PM 10.0	X	+17.3%	0.913

Table 3: Percent difference in ABP counts/minute in primary THA vs. TKA.

Discussion

Surgical environment optimization can impact air quality within the operating room. Three major factors can affect perioperative surgical site infection: the patient, the surgical environment, and surgical technique [19]. Furthermore, the type of ventilation (turbulent or laminar air flow), number of personnel, and OR traffic can all affect the surgical environment and air quality during surgery.

This retrospective study examined the differences in operating room Airborne Biologic Particles (ABP) between primary TKA and primary THA in a single operating room. There were no significant differences in room temperature or particle counts across all particle sizes between the two groups. The effect of operating room time from incision to skin closure may also play a role as increased operative times are associated with greater complication rates including length of stay, blood transfusion, and overall reoperation rate [20,21]. This can be extrapolated to the amount of time the surgical wound is exposed to surrounding airborne particles in the OR. The present study evaluated the total time spent in the room and found no significant differences between THA and TKA, suggesting that time did not play a role in ABP rates between these procedures [22]. Further research is needed, specifically with a larger patient cohort, to determine if there is a threshold particle count that results in a higher risk of infection following total joint arthroplasty. Interestingly, there was a significant difference in humidity between THA and TKA. A recent study by Khan, et al., demonstrated that surgeons performing THA have a higher heart rate, minute ventilation, and caloric expenditure compared to TKA. Increased body heat due to perspiration and increased work may contribute to the increase in overall room humidity [22]. Again, the implications of an increase in humidity on infection rates remains to be studied.

Here we present findings of a single OR which may help mitigate size of the OR as a potential study confounder. This may increase the strength of this study as size of the operating room has been shown in previous work to affect SSI rates [23]. The use of laminar ventilation was utilized in the observed OR, which has been shown in previous work to reduce OR bacterial counts when compared to turbulent airflow, though the effect on SSI still unclear [6,8]. Further study should be conducted in OR rooms without laminar air flow to evaluate the effect on particle counts. There are several limitations to our study. First, it was performed in an academic orthopedic specialty hospital with high surgical volume, which may limit generalizability to hospitals which may have more variability in surgical procedures and OR practices. Moreover, number of OR personnel and traffic were not explicitly studied, which can affect the measured ABPs in both procedures. According to a study by Andersson et al., high operating room traffic and associated increases in door openings have a profound impact on the number of colony forming units per cubed meter [19]. Variables accounting for foot traffic within the OR studied and surgical staff present during each case were not captured within this data, which, in part, is due to the retrospective design. In addition, ABP baseline was not recorded in this room prior to surgery. As a result, conclusions cannot be made regarding the impact of surgery and OR personnel on the ABP bioburden. Regardless, absolute particle counts present during surgery are also important in determining risk of infection.

Conclusion

Airborne Biologic Particles (ABP) are one of the many factors that can affect perioperative infection in total joint arthroplasty surgery. In this pilot study comparing intraoperative ABP rates, we found no significant differences in ABPs between primary THA and TKA. Future research on the surgical environment including OR design and traffic, number of consoles and trays, and air flow are needed to better characterize important intraoperative risk factors for prosthetic joint infection.

Conflict of Interest

The authors have no conflict of interest to declare.

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