# The Effect of a Door Alarm on Operating Room Traffic During Total Joint Arthroplasty

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## abstract

Operating room traffic has been implicated in several studies to contribute to the risk of surgical site infections and periprosthetic joint infections. The purpose of this study was to evaluate the effect of a door alarm on operating room traffic during total joint arthroplasty. This prospective cohort study evaluated 100 consecutive primary total hip and knee arthroplasty surgeries performed by a single surgeon. An inconspicuous electronic door counter was placed on the substerile operating room door. Door openings and time left ajar were recorded. After 50 cases, an audible alarm was placed on the substerile operating room door that sounded continuously when the door was ajar. Door-opening data were then recorded for an additional 50 cases. There was a significant difference in the overall mean door openings per minute ($P<.001$) between the period with no alarm (0.53±0.1) and with an alarm (0.42±0.1). This effect slowly decreased over the time of the intervention, with door openings per minute increasing by a factor of 1.01. The percentage of time the door was left ajar per case also decreased significantly ($P<.001$) with the alarm (6.63%±1.6%) compared with no alarm (8.65%±1.5%). This study indicates that the use of a door alarm can decrease door openings and potentially the risk for surgical site infection. However, the effect is subject to tolerance and may not result in the elimination of unnecessary operating room traffic long term. [*Orthopedics*. 2017; 40(6):e1081-e1085.]


Periprosthetic joint infection (PJI) occurs following an estimated 1% to 2% of total joint arthroplasty procedures and represents a catastrophic complication.[1] Given the high costs and morbidity of PJI management, numerous practices and policies have been conceived of and deployed aimed at preventing the occurrence of PJIs. Multiple risk factors contribute to the incidence of PJI, including patient factors such as obesity, diabetes, and smoking[2] and surgical environmental factors such as operative time, instrument and field sterility, and surgical technique. In turn, surgeons employ many practices and techniques to mitigate these risk factors, such as appropriate patient selection and education, stringent sterile technique, timely perioperative antibiotic administration, laminar airflow use, and protective suit wear. Despite these measures, PJIs continue to occur, necessitating the development of new strategies for preventing infection.

Operating room traffic has been implicated in several studies to contribute to the risk of surgical site infections and PJIs.[3-8] Several studies have implicated traffic flow in increased contamination of both the air[3] and instrumentation.[9] Increased foot traffic

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**Figure 1:** A door counter (Wireless open-closed sensor; Monnit Corporation, Murray, Utah) was placed on the substerile door.

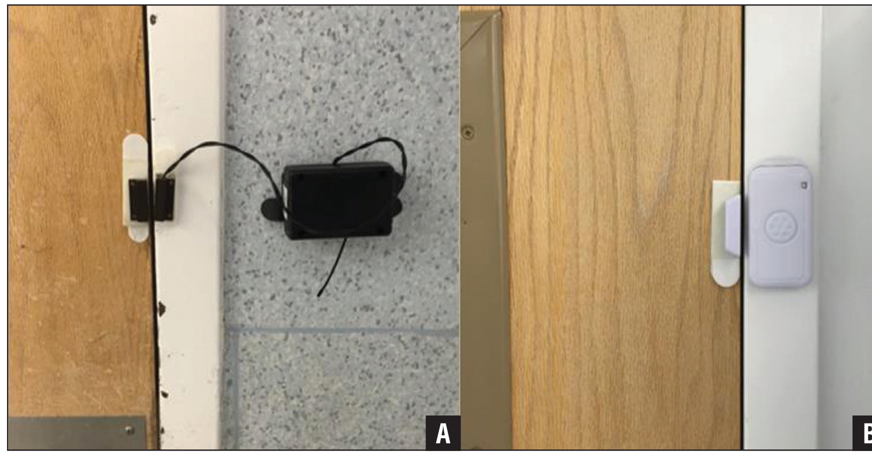


**Figure 2:** A wireless magnetic door counter (Wireless open-closed sensor; Monnit Corporation, Murray, Utah) was placed on the inner substerile door (A). A battery-powered alarm was placed on the inner substerile door (B).

by operating room staff alters the laminar flow system, contributing to faster spread of bacteria.[10] Increased traffic also brings increased opportunity for the introduction of bacteria into the sterile field using the staff as a vector. Previous studies have often measured room traffic indirectly by the frequency of door opening, which in turn has been linked to increased rates of contamination. Door openings allow the release of positive pressure[11] and disrupt the laminar flow, potentially increasing the risk of wound infection.[12] One study reported that any increase in door openings increased the risk of contamination in the operating room by as much as 70%.[9]

The purpose of this study was to evaluate the efficacy of a door alarm in decreasing operating room traffic during total joint arthroplasty by evaluating the change in the number of door openings and the overall time the door was open during the study cases. At the authors' institution, operative suites may be accessed exteriorly through the corridor or via the substerile operating room door. After the patient enters the room, a screen blocks the exterior doors and all traffic occurs through the substerile door. The authors hypothesized that an audible alarm placed on the substerile door would increase awareness of all room entries and serve as a deterrent to nonessential traffic. The authors anticipated that implementation of the door alarm would lead to decreased operating room traffic as measured by decreases in the frequency and duration of door openings occurring during total joint arthroplasty procedures.

## Materials and Methods

Institutional review board approval was obtained for this study. A prospective observational study was undertaken to determine whether installing a door alarm would reduce intraoperative door openings. During the course of 39 consecutive operating room days from September 2015 to January 2016, a total of 100 consecutive patients undergoing primary total joint arthroplasty (67 total knee arthroplasties [TKA] and 33 total hip arthroplasties [THA]) were enrolled in the study. Patients undergoing primary THA or TKA were included. Cases involving surgery other than primary THA or TKA were excluded. The study had 2 phases, with the first 50 cases (31 TKA, 19 THA) in the preintervention phase and the next 50 cases (36 TKA, 14 THA) in the postintervention phase. Patient in room and out of room timing and type of surgical procedure were recorded. A small wireless magnetic door counter (Wireless open-closed sensor; Monnit Corporation, Murray, Utah) (**Figure 1**) was placed on the inner side of the substerile door. The counter collected the time (hours, minutes, seconds) of each door opening and door closure throughout each case from patient entrance into to exit from the operating room. During the preintervention phase, room traffic surveillance was performed without disclosure to members of the anesthesiology team or operative staff.

All patients underwent primary THA or TKA performed by a single surgeon via a standard posterolateral approach. In the preintervention phase, standard institutional measures to reduce room traffic were used. A pull-down screen was used to block access via the exterior corridor door, and a sign reminding personnel to limit nonessential traffic was left in place on the substerile door. The frequency rate and the duration of door openings were calculated from incision until closure using data from the door counter. After 50 procedures, a battery-powered alarm (**Figure 2**) was installed on the substerile door. Opening of the substerile door intraoperatively activated an audible 2-tone chime, which repeated every 3 seconds until the door was closed.

Every other event logged by the counter was interpreted to represent the door opening, and each following event was interpreted to represent the door subsequently closing. Primary outcome measures included the number, frequency, and cumulative duration of door openings during the procedure. Frequency was calculated as the total number of openings divided by the length of surgery in minutes. Cumulative duration was calculated by measuring the total time between door openings and closings during the case.

The authors fit a quasi-Poisson generalized linear regression model to the data. The log of the length of each case (in minutes) was used as an offset to assess rates of door openings. The study day was included as a variable to control for trends over time. The authors made an a priori decision to control for surgery type (TKA vs THA), although this variable did not turn out to be significant. Residual autocorrelations were checked to ensure independence (**Figure 3**). Means for number, frequency, and cumulative duration of door openings during each period were taken, and significance was set at $P \leq .05$.

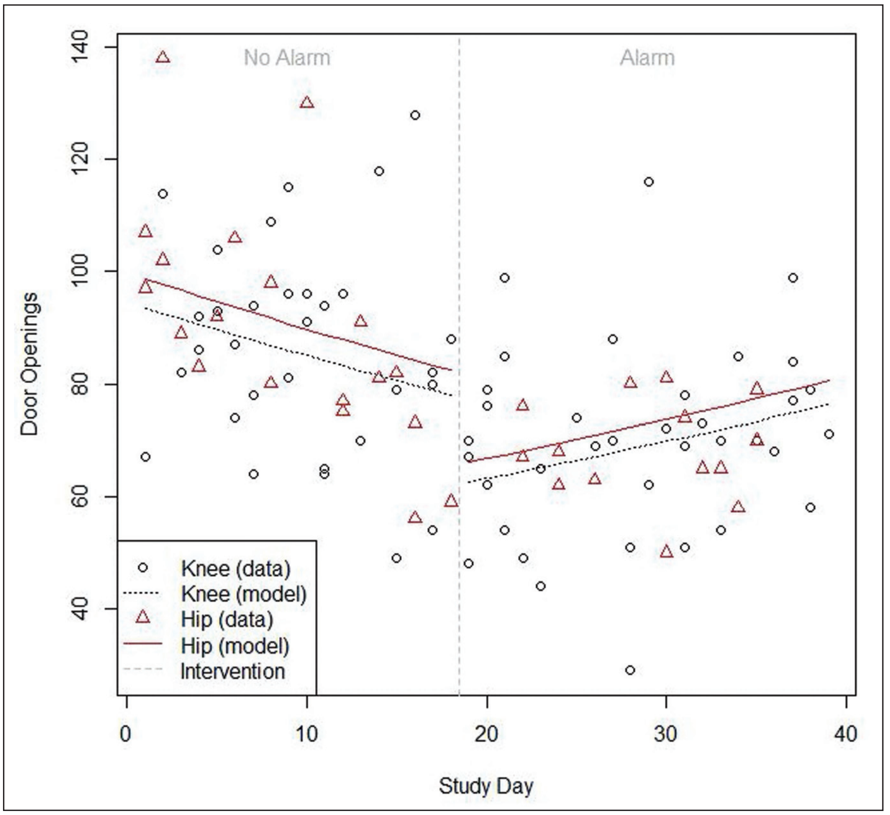


**Figure 3:** Representation of door openings during the course of the study. A quasi-Poisson generalized linear regression model was fit to predict door openings per minute. Door openings decreased sharply after the alarm was installed and slowly increased during the course of the study.

## Results

Significant improvements in all primary outcome measurements were seen in the postintervention group. Prior to the door alarm, the substerile door was opened a mean of 88.12 times per case, or 0.53 times per minute. The door remained open for a mean of 14.45 minutes per case, or 8.65% of overall surgical time. After the door alarm was installed, door openings decreased to a mean of 69.46 times per surgery ($P<.001$), or 0.42 times per minute ($P<.001$). With the door alarm, the mean duration of time that the door remained open also decreased—10.81 minutes per surgery ($P<.001$), or 6.63% of the overall surgical time ($P<.001$) (**Table**). Procedure types and case lengths were similar for the 2 groups (167.68 vs 165.98 minutes per surgery, $P=.733$).

Table

**Comparison of Outcome Measures for Cases Without and Cases With a Door Alarm**

| | Mean±SD | | |
|---|---|---|---|
| **Outcome Measure** | **Cases Without an Alarm** | **Cases With an Alarm** | ***P*** |
| Door open per case, min | 14.45±3.3 | 10.81±2.3 | <.001 |
| Door ajar per case | 8.65%±1.5% | 6.63%±1.6% | <.001 |
| Door openings per minute, No. | 0.53±0.1 | 0.42±0.1 | <.001 |
| Time per door opening, s | 9.84±0.6 | 9.35±0.6 | <.001 |
| Time per case, min | 167.68±25.1 | 165.98±24.6 | .733 |

Following placement of the door counter, the rate of door openings per minute decreased by 1% per day (the multiplicative factor was exp[ß]=0.99; 95% confidence interval, 0.979-0.999) during the preintervention period. However, the activation of the alarm clearly had an effect, resulting in a significant decrease in door openings. A likelihood ratio test of the alarm and no alarm study day variables together was highly significant (chi-square[2]=49.6, $P<.001$). The greatest effects were seen immediately after installation of the alarm, when the rate decreased by 19% (exp[ß]=0.81; 95% confidence interval, 0.692-0.947). However, door openings gradually increased at a rate of 1% every day (exp[ß]=1.01; 95% confidence interval, 1.000-1.020) thereafter. Despite this, door-opening rates remained lower in the postintervention group than in the preintervention group throughout the study period.

## Discussion

Periprosthetic joint infection remains a catastrophic and dreaded complication, occurring after 1% to 2% of all total joint arthroplasties. Furthermore, the incidence of PJI is expected to rise in coming years, mirroring the dramatic projected increases in demand for total joint arthroplasty.[13] Operating room traffic is associated with increased risk of PJI. Studies have shown that up to one-third of door openings and room traffic are for nonessential purposes, such as social visits and future planning.[3] Currently used methods of reducing room traffic are limited and largely ineffective, necessitating the development of novel strategies to deter nonessential foot traffic into the operating room. This study assessed the efficacy of a door alarm as a potential means of limiting unnecessary intraoperative door openings and foot traffic.

This study found that implementation of a door alarm significantly decreased the frequency of door openings during total joint arthroplasty cases for a period of time. Prior to the intervention, the authors found that door openings occurred a mean of 0.53 times per minute from incision until close. Following implementation of the door alarm, door openings decreased significantly, to 0.42 openings per minute. There are few studies available with which to compare these results. Panahi et al[5] examined door openings occurring during all arthroplasty procedures. They reported frequencies of 0.65 and 0.84 door openings per minute occurring during their primary and revision arthroplasty procedures, respectively.[5] More recently, Bédard et al[14] also used door openings to measure room traffic during only primary joint arthroplasty cases. They reported an average rate of 0.64 door openings each minute, with 0.84 openings per minute occurring before incision and 0.54 openings per minute occurring after incision.[14] These results are consistent with the current preintervention results, supporting the efficacy of the door alarm intervention.

Bédard et al[14] also observed the type of personnel responsible for each door opening. They found nursing staff to be responsible for 52.2% of total door openings, followed by anesthesia staff at 23.9% and orthopedic staff at 12.7%.

A second goal of the current study was to assess whether implementation of a door alarm would decrease the duration of time that the door remained open after opening. Again, few studies have examined the effect of prolonged door opening time during total joint arthroplasty. Mears et al[11] investigated the effects of door openings on air flow patterns in rooms with vertical laminar flow. They found that, on average, the door remained open for 9.6 minutes per case, or 8.5% of the total surgical time following incision. They also found that, in 77 of 191 cases, the door was opened long enough to overcome the positive pressure, allowing transient air flow reversal from the corridor into the operative theater.[11] In the current study, the authors observed a significant decrease in the mean total duration of time that the door was left open during the case, from 8.65% to 6.63% of the total surgical time from incision to close. These results are consistent with those from previous studies.

Interestingly, the authors observed that, over time, the reduction in door openings when the alarm was active gradually diminished. This receding effectiveness suggests that the alarm may be subject to habituation. The authors have observed this effect previously with various signs, notifications, and other passive deterrents. Surprisingly, although the alarm provided an audible reminder, this tolerance still appeared to be present. Therefore, although the door alarm was effective in the short term, the degree of long-term benefit remains uncertain.

Several limitations of this study deserve to be mentioned. The cases were not randomized to each intervention condition. This was done to allow preintervention data to be collected without the staff knowing they were being monitored, although Parikh et al[6] reported that surveillance did not affect operative traffic. During the study, the counter device remained visible and was likely noticed by the staff. (This may account for the decrease over the preintervention period.) To the authors' knowledge, however, no staff member was made aware of its true purpose. This supposition is supported by the authors' data, which are consistent with door-opening rates reported in previous studies on room traffic in total joint arthroplasty. Traffic was only monitored via the substerile door; thus, traffic occurring via the exterior corridor doors would have gone unrecorded. These doors are closed and screened off after the patient enters the room. Data collection was limited to the period between incision and closure. The authors do not believe that this affected their results. Revision cases were excluded from the study because they require additional equipment and instrumentation and have been shown to require additional room traffic. Finally, although the authors infer that reducing door openings will decrease infection risk, the low incidence of PJI would necessitate a much larger study to evaluate for an association between door openings and deep infections.

## Conclusion

The reduction of operating room traffic following the placement of a door alarm suggests there is a significant portion of operating room traffic that is unnecessary and can be reduced. This study also showed that the use of an alarm can decrease the frequency and duration of door openings during total joint arthroplasty; however, this efficacy may be subject to tolerance and may not result in a permanent reduction of unnecessary operating room traffic. Limiting room traffic presents many difficulties, and few effective measures exist to selectively deter unnecessary foot traffic. Although locks and barriers are effective, they present patient and workplace safety concerns and also prevent the passage of the essential foot traffic needed to obtain necessary equipment or reach needed representatives or providers for expert consultation. Door signs and notifications often go unnoticed or unheeded by busy staff members. Room traffic also often consists of members of many disciplines, including nursing, anesthesia, and orthopedics, medical students, and at times, industry representatives or members of the ancillary staff.[14] This further complicates the differentiation of essential from nonessential traffic. Strategies are needed to limit nonessential room traffic, but few such measures have been proposed.

Regardless of the long-term success of the authors' alarm, this study indicates the need for further measures to decrease unnecessary operating room traffic. The numbers reported in this study are consistent with those reported in the literature and likely represent a large amount of unnecessary door openings. Despite the limited long-term effect of this alarm, it should bring further attention to excessive operating room traffic. Continuing education and awareness may be necessary to maintain the results found in this study.

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