

Door Opening Affects Operating Room Pressure During Joint Arthroplasty

SIMON C. MEARS, MD, PHD; RENEE BLANDING, MD; STEPHEN M. BELKOFF, PHD, MPH

abstract

Many resources are expended to ensure a sterile operating room environment. Efforts are made to prevent exposure of patients to personnel and to achieve positive room pressure to keep out airborne contaminants. Foot traffic into and out of the operating room during surgery can undermine these efforts. The authors investigated the number and duration of operating room door openings during hip and knee arthroplasty procedures and the effect of the door openings on room pressure. They tested the hypothesis that door openings defeat positive pressure, permitting air flow into the room. Room pressure and door status were monitored electronically during 191 hip and knee arthroplasty procedures. Operating room staff were unaware that data were being collected. The authors evaluated the data with regression analysis to determine whether the number and duration of door openings had an effect on room pressure. Significance was set at $P < .05$. Doors were open, on average, 9.5 minutes per case. In 77 of 191 cases, positive pressure was defeated, allowing air flow to reverse into the operating room. Total time with the door open significantly affected the minimum pressure recorded in the room ($P < .02$), but did not significantly affect average room pressure ($P = .7$). This finding suggested that the loss of positive pressure was a transient event from which the room recovered. The number and duration of door openings showed a significant association with length of surgery. Door openings threaten positive pressure, potentially jeopardizing operating room sterility. The causes of excessive operating room traffic must be evaluated to identify ways to reduce this traffic and the associated risks. [*Orthopedics*. 2015; 38(11):e991-e994.]

The authors are from the Department of Orthopaedic Surgery (SCM, SMB), the Department of Anesthesiology and Critical Care Medicine (RB), and the International Center for Orthopaedic Advancement (SMB), Johns Hopkins Bayview Medical Center/The Johns Hopkins University, Baltimore, Maryland.

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Correspondence should be addressed to: Stephen M. Belkoff, PhD, MPH, Department of Orthopaedic Surgery, Johns Hopkins Bayview Medical Center/The Johns Hopkins University, 5210 Eastern Ave, Alpha Center, 3rd Fl, Baltimore, MD 21224 (editorialservices@jhmi.edu).

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Maintaining a sterile field in the operating room is crucial to successful outcomes in joint arthroplasty. Heating, ventilating, and cooling systems are designed to maintain elevated air pressure in the operating room relative to the adjacent hallways and rooms (positive pressure). When an operating room door is opened, positive pressure forces air out of the room, preventing airborne contaminants from entering. Another factor that may adversely affect this sterility is a high level of operating room foot traffic,¹ which has been related to higher bacterial counts in the operating room.^{2,3}

The authors investigated the number and duration of operating room door openings during hip and knee arthroplasty procedures and the effect of the door openings on operating room pressure. To meet facility standards, operating room pressure must be positive, that is, greater than the surroundings, such that air flows out of the operating room.⁴ The authors' primary hypothesis was that door openings reduce room pressure. They also hypothesized that the number of door openings during a case is a function of the type of case, length of surgery, and surgeon. Understanding the factors that affect door openings could lead to proposed interventions for decreasing foot traffic in the operating room, potentially reducing the risk of infection.

MATERIALS AND METHODS

Institutional review board approval was obtained for this study. The authors retrospectively identified all primary hip (n=91) and knee (n=100) arthroplasty procedures performed at their academic teaching institution from March through June 2011.

The authors obtained data on door openings and operating room air pressure during these cases from the heating, ventilating, and air conditioning monitoring system that was installed to record the physical environment in the operating

rooms as part of an infection control initiative. Each operating room door was instrumented with a sensor (GI-4400A; George Risk Industries, Kimball, Nebraska) that reported changes in door status (open to closed, closed to open). The time point of each status change was recorded, and the number and duration of door openings per case were calculated. Each change in room pressure of 0.01 inches H₂O, referred to herein as a pressure change, was recorded. Maximum, minimum, and average room pressures per case were also recorded, as was the average rate of air change during each case. The date, time, type of operation, surgeon, and operating room number were obtained from the medical records. Heating, ventilating, and air conditioning system data were matched with the time stamps in the case information from the electronic medical records. Data were analyzed from cut-to-close, that is, when the surgical site was open and most at risk for contamination. The surgeons and staff involved in the operative cases were unaware that door openings were being recorded. Infection data were obtained from hospital infectious disease monitoring records. Only deep infections were considered for this study.

To test their primary hypothesis, the authors used linear regression analysis to assess the association of minimum room pressure with the number of door openings per case with Stata version 10 statistical software (StataCorp, College Station, Texas). To test the secondary hypothesis, the authors performed 2 linear regressions of the number and duration of door openings, respectively, on the type of surgery, cut-to-close operative time, and surgeon. Significance was set at $P<.05$.

RESULTS

For 77 of the 191 cases, the doors were open long enough for positive room pressure to be defeated, causing air to flow into the operating room. Total door-open time significantly affected the minimum pressure recorded in the

room ($P<.02$) but did not significantly affect the average room pressure ($P=.7$), suggesting that the loss of positive pressure was a transient event from which the room recovered.

Doors were open during approximately 8.5% of the total cut-to-close operative time (1825/21,482 minutes). On average, the doors were open for 9.6 minutes (95% confidence interval, 8.3-10.3) per case. Mean cut-to-close times per surgeon ranged from 82 to 182 minutes. Then number and duration of door openings were significantly associated with the duration of surgery (Table). For each 2.5-minute increase in operative cut-to-close time, doors were opened 1 additional time and for approximately 6.9 additional seconds (95% confidence interval, 5.9-7.9). The duration of surgery varied significantly by surgeon.

There was no significant effect of door-open time on air changes, which held steady, on average, at 21.0 changes per hour (95% confidence interval, 20.4-21.6).

There was no significant difference between knee and hip cases in terms of the number or duration of door openings. On average, the doors were opened 1.1 (95% confidence interval, -2.3 to 4.5) fewer times during knee cases than during hip cases and for 36 seconds less time (95% confidence interval, -26 to 98).

Infection occurred in 1 knee case and in no hip cases. The knee case that became infected was unremarkable compared with the other cases. The cut-to-close time during this case was 103 minutes, and the mean number of air exchanges was 23 per hour. The room pressure never became negative, and the doors were open for a total of 10.3 minutes.

DISCUSSION

Data from this study supported the authors' hypothesis that door opening affects room pressure. As might be expected, the longer the duration of door opening, the greater the decrease in room pressure, to the extent that, in some instances, the

Table

Cut-to-Close Time, Door Openings, and Operating Room Pressure During Hip and Knee Arthroplasty Procedures, by Surgeon

Parameter	Surgeon					
	1	2	3	4	5	6
Knee arthroplasty						
Cases, No.	2	35	14	0	31	18
Cut-to-close time, mean (95% CI), min	181.5 (174.5-188.5)	89.9 (82.7-97.0)	77.1 (66.6-87.7)	NA	180.4 (174.4-186.5)	182.2 (154.6-209.8)
Door openings, mean (95% CI), No.	77 (67-87)	43 (39-47)	35 (28-43)	NA	50 (46-54)	75 (64-85)
Duration door opened, mean (95% CI), min	17.2 (15.2-19.2)	8.6 (7.8-9.4)	6.8 (5.3-8.3)	NA	10.1 (8.4-11.8)	15.8 (11.5-20.2)
Room pressure, mean (95% CI), inches H ₂ O	0.015 (0.012-0.019)	0.015 (0.014-0.016)	0.011 (0.010-0.012)	NA	0.011 (0.010-0.011)	0.016 (0.015-0.018)
Cases with ≤0 pressure, No.	0	9	6	NA	14	9
Hip arthroplasty						
Cases, No.	4	52	34	1	0	0
Cut-to-close time, mean (95% CI), min	172.8 (135.2-210.3)	81.4 (75.8-87.0)	88.6 (82.6-94.6)	82	NA	NA
Door openings, mean (95% CI), No.	90 (61-119)	40 (36-44)	41 (37-44)	51	NA	NA
Duration door opened, mean (95% CI), min	20.1 (14.4-26.0)	8.3 (7.3-9.2)	8.0 (7.4-8.7)	11.4	NA	NA
Room pressure, mean (95% CI), inches H ₂ O	0.014 (0.012-0.016)	0.016 (0.016-0.017)	0.012 (0.011-0.013)	0.015	NA	NA
Cases with ≤0 pressure, No.	2	18	18	1	NA	NA

Abbreviations: CI, confidence interval; NA, not applicable (ie, surgeon did not perform knee or hip arthroplasty).

pressure dropped below the pressure in the adjacent corridor, suggesting that air flow reversed into the operating room. The primary concern about defeating the positive pressure system is the potential increase in risk of infection. Door openings have been shown to be a predictor of high bacterial counts.³ In the current study, only 1 infection occurred. It is not possible to infer that this infection was associated with operating room traffic or door openings. Because infection rates are low during hip and knee arthroplasty (typically <4%⁵), a very large sample size would be required to reach sufficient power to show significant differences in rates of infection associated with decreases in pressure.⁶

This study raises the question of why there is so much operating room traffic. It is unclear why the operating room door

was opened, on average, once every 2.5 minutes of surgery. The frequency of door openings is not unique to the authors' institution.⁷ Distraction of operating room staff is a concern⁸; in addition, excessive operating room traffic may indicate logistical and personnel management inefficiencies.

The data supported the authors' hypothesis that the surgeon and the operating time affected the number and duration of door openings, but did not support the hypothesis that there were differences by type of surgery. Although there appeared to be an effect of surgeon on the number and duration of door openings, after adjustment for the duration of surgery, analysis suggested that the effect was related to the length of surgery and not to the surgeon per se (ie, the effect of sur-

geon was related to the length of time it took the surgeon to complete the case and not necessarily the surgeon's tolerance for operating room traffic). The average time between door openings in this study was 2.5 minutes, slightly longer than the times of 1.2 to 1.7 minutes reported in previous studies.^{9,10} A report on cardiovascular surgery showed findings similar to those of the current study.¹¹

Limitations

This study had several limitations. First, unlike other studies, it did not record data on the reasons for door openings^{9,12} because the authors did not want the operating room staff to know that their activities were being monitored. However, this concern may have been unfounded. Parikh et al¹⁰ reported that

awareness of being monitored apparently did not affect operating room traffic. Follow-up investigations should be conducted to identify the reasons for the door openings, to determine whether they are necessary, and to identify ways to minimize them. Lynch et al¹² reported that most door openings occur because of a need for information and that those door openings occur during the preincision period. Second, this study evaluated only the cut-to-close time, assuming that infection risk would be greatest when the patient was openly exposed to the operating room environment. Third, Lynch et al¹² also reported that the number of door openings increased exponentially with the number of people in the operating room. The current study did not track the number of room occupants. Fourth, although this study monitored room pressure, it did not monitor air quality.³ Laminar flow has been shown to decrease the effect of door openings on bacterial counts within the room.⁷ It is possible that laminar flow may protect against the pressure changes that occur with door openings.

CONCLUSION

This study showed a significant relationship between operating room door openings and room pressure. Additional research is needed to determine whether postoperative infections are related to door openings and loss of positive pressure. This is the first report of alterations in room pressure because of door opening.

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