Traffic in the operating room during joint replacement is a multidisciplinary problem

Martin Bédard, MD
Rémi Pelletier-Roy, BSc
Mathieu Angers-Goulet, BSc
Pierre-Alexandre Leblanc, BSc
Stéphane Pelet, MD, PhD

Accepted for publication
Feb. 24, 2015

Correspondence to:
M. Bédard
CHU de Québec
Hôpital de l'Enfant Jésus de Québec
1401, 18e rue
Québec QC G1J 1Z4
martinbedard@videotron.ca

DOI: 10.1503/cjs.011914

Background: Door openings disrupt the laminar air flow and increase the bacterial count in the operating room (OR). We aimed to define the incidence of door openings in the OR during primary total joint arthroplasty (TJA) surgeries and determine whether measures were needed and/or possible to reduce OR staff traffic.

Methods: We recorded the number of door openings during 100 primary elective TJA surgeries; the OR personnel were unaware of the observer's intention. Operating time was divided into the preincision period, defined as the time from the opening of surgical trays to skin incision, and the postincision period, defined as time from incision to dressing application.

Results: The mean number of door openings during primary TJA was 71.1 (range 35–176) with a mean operative time of 111.9 (range 53–220) minutes, for an average of 0.64 (range 0.36–1.05) door openings/min. Nursing staff were responsible for 52.2% of total door openings, followed by anesthesia staff at 23.9% and orthopedic staff at 12.7%. In the preincision period, we observed an average of 0.84 door openings/min, with nursing and orthopedic personnel responsible for most of the door openings. The postincision period yielded an average of 0.54 door openings/min, with nursing and anesthesia personnel being responsible for most of the door openings.

Conclusion: There is a high incidence of door openings during TJA. Because we observed a range in the number of door openings per surgery, we believe it is possible to reduce this number during TJA.

Contexte : Les ouvertures de porte perturbent le flux laminaire et accroissent la numération bactérienne au bloc opératoire. Nous avons voulu mesurer l'incidence des ouvertures de porte au bloc opératoire durant les chirurgies pour prothèse articulaire totale (PAT) et déterminer si des correctifs étaient requis ou s'il était possible de réduire la circulation du personnel au bloc opératoire.

Méthodes : Nous avons dénombré les ouvertures de porte durant 100 chirurgies électives primaires pour PAT; le personnel du bloc opératoire n'était pas au courant de l'intention de l'observateur. Le temps opératoire a été subdivisé en une période pré-incision, définie par l'intervalle entre l'ouverture des plateaux chirurgicaux et l'incision chirurgicale, et une période post-incision, définie par l'intervalle entre l'incision et l'application du pansement.

Résultats : Le nombre moyen d'ouvertures de porte par intervention pour PAT primaire a été de 71,1 (entre 35 et 176) et la durée moyenne des interventions a été de 111,9 (entre 53 et 220) minutes, pour une moyenne de 0,65 (entre 0,36 et 1,05) ouverture/minute. Le personnel infirmier était responsable de 52,2 % du nombre total d'ouvertures de porte, suivi du personnel d'anesthésie avec 23,9 % et du personnel d'orthopédie avec 12,7 %. Durant la période pré-incision, nous avons observé une moyenne de 0,84 ouverture de porte/minute, le personnel infirmier et d'orthopédie ayant été responsable de la majorité des ouvertures de porte. La période post-incision a donné lieu à une moyenne de 0,54 ouverture de porte/minute, le personnel infirmier et d'anesthésie ayant été responsable de la majorité des ouvertures de porte.

Conclusion : On observe un nombre important d'ouvertures de porte durant les interventions pour PAT. Étant donné que ce nombre varie, nous croyons qu'il est possible de le réduire.

Infection following total joint arthroplasty (TJA) remains a disastrous complication for both the patient and surgeon. The total cost for a prosthetic joint infection (PJI) has been calculated by Sulco[1] to be as high as $50 000–$60 000 per case. Revision following PJI is 2.8 times more expensive than revision for loosening and 4.8 times more expensive than primary TJA.[2] The incidence of PJI, 1%–2% for primary TJA, is a major concern and warrants a concerted effort to reduce patient morbidity and improve global health care efficacy.

Patient-related and environmental factors[3] have been studied in order to reduce PJI. The number of staff in the operating room (OR) is exponentially linked to the incidence of door openings during surgical interventions.[4] Door opening is believed to disrupt the laminar flow[5] and could thus lead to more bacteria and contamination over the wound and possibly lead to intraoperative infection.[4,6–11] Thus far, only 1 study has measured the incidence of door opening during TJA.[11] Other studies defining OR traffic patterns were either not specific to orthopedic procedures or had a very limited number of orthopedic cases.[3]

In order to reduce the infection rate in our centre, we sought to define the incidence of door openings in the OR during primary TJA and to determine whether measures were needed and/or possible to reduce staff traffic.

Methods

In a 2-month period beginning in August 2013, 100 consecutive TJAs (59 total knee [TKA] and 41 total hip [THA] arthroplasties) were performed at our institution and were included in this study. At our institution, TJAs are performed simultaneously in 3 different ORs, with each room having 2 doors, 1 opening in a sterile corridor (internal) and 1 opening in a nonsterile corridor (external). Anesthesia equipment is located close to the external door and surgical equipment close to the internal door. There is agreement at our institution that the external door should be locked during TJA immediately after the patient's arrival in the OR. Every room is equipped with a vertical laminar air flow. Patient positioning is performed by OR attendants. For standard cases, sales representatives are usually not present and come on an as-needed basis.

Three observers (R.P.R., P.A.L. and M.A.G.) were responsible for recording every door opening on a standardized sheet; 1 observer was present during each surgery. The OR staff were blinded to the real intention of the observers and were told the observers were medical school students on an observational arthroplasty rotation. This strategy was implemented in order to reduce any impact the observers could have on the behaviour of OR staff and thus on the true incidence of door opening. Also, none of the observers participated in any door opening as they were on site well before the trays were opened and after the closure of the surgical site. Surgeries were performed by a group of 10 orthopedic surgeons practising TJA at our institution. Data were recorded using a Microsoft Excel spreadsheet.

The primary data recorded were the number of door openings for both OR doors (internal and external). Door opening was defined as the opening of the door itself, regardless of how many people passed by or how long the door remained open. Every door opening was then classified by 2 other characteristics: the time period in which it occurred (preincision or postincision) and by the type of OR personnel who opened the door. The preincision period was defined as the time from the opening of surgical trays to skin incision, and the postincision period was defined as the time from incision to dressing application. The personnel categories were orthopedic, nursing, anesthesia, sales representative, radiology and other. The OR attendants were classified as "other." In the case of multiple types of staff entering the OR at the same time, the opening was attributed only to the person who opened the door. The observers also collected secondary data, including date, preparation time, duration of surgery, case number, type of surgery (TKA or THA) and body side, surgeon's name and the number of staff present for each specialty. Preparation and operating duration were recorded to allow us to determine a door opening rate per minute.

Statistical analysis

Using the descriptive data recorded, we performed a univariate analysis. The arithmetic mean was the central tendency method used to describe the number of door openings, the duration of each period (preincision, postincision and total duration of surgery) and the number of staff per personnel type present in the OR. The specific door opening rate ratios were obtained by dividing the mean number of door openings per period by the mean duration of each period. The statistical dispersion of the data is shown according to its range. We used frequency tables and a histogram to represent the frequency distribution of door openings per period, per door type and per personnel type. Data analysis was performed using Microsoft Excel.

Results

A total of 7110 door openings were recorded for 100 primary TJA surgeries. With an average total duration of surgery of 111.9 (range 53–220) minutes and an average number of door openings of 71.1 (range 35–176), the average rate was 0.64 (range 0.36–1.05) door openings/min (Table 1). The door opening rate for all TJA surgeries was 0.84 (range 0.42–1.76) door openings/min during the preincision period and 0.54 (range 0.19–0.89) door openings/min during the postincision period. For THA surgeries alone, the rate was 0.82 (range 0.47–1.73) door openings/min in the preincision period, 0.58 (range 0.32–0.89) in the postincision period and 0.66 (range 0.37–1.05) for both periods. For TKA surgeries alone, the

rate was 0.87 (range 0.42–1.76) door openings/min in the preincision period, 0.51 (range 0.19–0.87) in the postincision period, and 0.62 (range 0.36–0.93) for both periods. The difference in the rate of door openings between THA surgeries and TKA surgeries was not statistically significant ($p = 0.60$).

The internal door accounted for 95.6% of the openings, while the external door accounted for 4.4%. A total of 40.4% of the door openings occurred during the preincision period compared to 59.6% in the postincision period (Table 2). The preincision period lasted an average of 34.1 (range 16–94) minutes, for a rate of 0.84 door openings/min was calculated. The postincision period lasted an average 77.8 (range 35–161) minutes, with 0.54 door openings/min. The difference in the absolute number of door openings can be explained by the duration of these 2 periods (Table 3).

Different door opening patterns were observed in the OR with respect to a specific time period or door type. Nursing staff were responsible for 52.2% of total door openings during primary TJA cases. Anesthesia personnel came second with 23.9% of total door openings and 69% of external door openings. Orthopedic staff contributed to 12.7% of total door openings and 30% of internal door openings during the preincision period (Table 4).

There was an average of 12 (range 7–19) people in the OR for each performed TJA. Nursing personnel were a mean of 4 (range 2–9) people and were responsible for a mean of 37.1 (range 11–104) door openings, for a mean of 10.0 door openings per nurse per case. Anesthesia personnel were a mean of 3 (range 1–8) people and were responsible for a mean of 17.0 (range 1–46) door openings, for a mean of 5.2 door openings per anesthesia personnel per case. Orthopedic surgery personnel were a mean of 3 (range 2–6) people and were responsible for a mean of 9 (range 2–22) door openings, for a mean of 3.3 door openings per orthopedic personnel per case. Although sales representatives are not frequently present for routine TJA cases at our institution, they were responsible for an average of 8.0 door openings per case. Table 5 depicts further details about OR personnel population and average door openings by individual.

Discussion

Door opening is thought to disrupt the positive laminar flow system of the OR, possibly introducing more bacteria into the OR and potentially contributing to contamination of the wound. Furthermore, the number of people in the OR is known to be one of the most important factors related to the bacterial count in the OR and has been found to be exponentially linked to the number of door openings.[3,6,12] With the combination of these 2 factors, OR traffic could be associated with a higher infection rate, although this link has not yet been proven. With infection rates close to 1% for primary TJA and occurrence of infection depending on many variables, a study designed to measure the direct influence of OR traffic on PJI would require an enormous study population and would be technically difficult to realize. The main objective of our study was to define the incidence of door openings in the OR during primary elective TJA.

Table 1. Rate of door openings for total joint arthroplasties

	Period, door openings/min, mean (range)		
Procedure	Preincision	Postincision	Total duration
THA	0.82 (0.47–1.73)	0.58 (0.32–0.89)	0.66 (0.37–1.05)
TKA	0.87 (0.42–1.76)	0.51 (0.19–0.87)	0.62 (0.36–0.93)
Overall	0.84 (0.42–1.76)	0.54 (0.19–0.89)	0.64 (0.36–1.05)

THA = total hip arthroplasty; TKA = total knee arthroplasty.

Table 2. Door openings by door type and time period

	Period, mean (%) [range]		
Door type	Preincision	Postincision	Total duration
Internal	26.4 (37.1) [9–55]	41.6 (58.5) [10–134]	68.0 (95.6) [24–167]
External	2.3 (3.3) [0–26]	0.8 (1.1) [0–13]	3.1 (4.4) [0–31]
Total	28.7 (40.4) [10–81]	42.4 (59.6) [12–134]	71.1 (100) [35–176]

Table 3. Variables used to calculate the rate of door openings per period

	Period, mean (range)		
Variable	Preincision	Postincision	Total duration
No. of door openings	28.7 (10–81)	42.4 (12–134)	71.1 (35–176)
Duration	34.1 (16–94)	77.8 (35–161)	111.9 (53–220)
Door opening/min	0.84 (0.42–1.76)	0.54 (0.19–0.89)	0.64 (0.36–1.05)

The rate of door openings recorded in our study was 0.64 door openings/min. This represents an extremely high incidence of door openings during TJA even though such a procedure is known to need a particularly aseptic environment. The high variation of door openings for the same operation duration (range 0.36–1.05 door openings/min) shows that reduction of the OR traffic should be possible.

Some specialties were more frequently involved in door openings during a specific time period or for a particular door. Whereas nurses accounted for more than half of the door openings (52% for both the pre- and postincision periods), anesthesia staff were responsible for more than 69% of the external door openings. Orthopedic staff were responsible for about 28% of the door openings in the preincision period. Although we did not record the reasons for door openings in this study in order to preserve confidentiality, some of the reasons included leaving to retrieve a necessary instrument or implant, staff rotation for breaks, checking with OR staff to confirm that the surgery can proceed, talking with colleagues in the corridor, and coordinating nursing and anesthesia personnel. Some of these reasons are justified, while others represent bad behaviours that offer an opportunity to reduce the number of door openings during surgery.

A previous study[11] reported a door opening rate of 0.65 door openings/min for primary TJA, which is similar to the rate of 0.64 door openings/min found in our study. The weakness of the previous study was a change during the investigation regarding counting start time, which could have modified their true rate of door openings per minute. Lynch and colleagues[3] compared OR traffic in different surgical subspecialties and found a rate of 19–50 door openings/hr. A rate of 0.32 door openings/min was found to be unacceptable in cardiac surgery (average of 19.2 door openings/hour).[9] These data confirm that OR traffic is alarmingly high and that this situation is present not only in our particular OR, but also in other institutions. Unfortunately, the few published articles on this topic do not allow for the creation of a norm regarding OR personnel traffic.

Limitations

There were some limitations to our study. Classification of door opening by specialty was ambiguous when different staff was entering the OR at the same time. We attributed the opening to the first person going through the door, but this could be a hazardous classification. In addition, we did not report the reason for each door opening in order to avoid the OR personnel becoming aware of the nature of our study. While in some instances the reason was obvious, at other times it was not. In these latter cases, we would not have been able to inquire about the reason for the door opening without raising the suspicions of the OR personnel and risk revealing the goal of our study. One variable that was not taken into account was the cumulative time for which the door remained open. Instead of opening the door 2 times to leave and return, OR staff would sometimes hold the door open. This was recorded as only 1 door opening, while it could have been more damaging than 1 or even 2 shorter door openings. In addition, the speed at which the door was opened could

Table 4. Contribution to door openings by each personnel type by door type (internal v. external) and time period

	Preincision, %			Postincision, %			
Personnel	Internal	External	Total	Internal	External	Total	Total duration
Orthopedic	30	6	28	2	0	2	12.7
Anesthesia	14	66	18	27	72	28	23.9
Nursing	34	18	33	66	15	67	52.2
Representative	0.5	0	0.5	1.6	0	1.6	1.1
Radiology	0	7	0.6	0.5	12	0.7	0.7
Others	21.4	3	20	2.3	1.4	2.3	9.5

Table 5. Details of operating room staff population and average number of door openings per individual by category

Personnel	No. staff, mean (range)	No. door openings, mean (range)	No. door openings per individual, mean
Orthopedic	2.7 (2–6)	9.0 (2–22)	3.3
Anesthesia	3.3 (1–8)	17.0 (1–46)	5.2
Nursing	3.7 (2–9)	37.1 (11–104)	10.0
Representative	0.1 (0–2)	0.8 (0–26)	8.0
Radiology	0.2 (0–2)	0.5 (0–16)	2.5
Others	1.9 (0–5)	6.7 (0–21)	3.5
Total	11.8 (7–19)	71.1 (35–176)	6.0

not be recorded in this study. It is known that the faster the door opens, the more air displacement occurs in the OR.[13] Having 3 different observers could have introduced an interobserver bias, so the data to be collected were deliberately simple to classify. Omitting the more complex variables (eg, multiple staff entry, time and speed of door opening) was standardized by a protocol sheet provided to every observer to reduce such possible error.

While we recognize that reducing the number of door openings to zero is not reasonable, we believe that the number of unnecessary door openings can be greatly reduced to achieve a cleaner operating environment. First and foremost, decreasing the number of door openings requires better education of all OR personnel, as personnel from several disciplines were involved in the high rate of door openings recorded at our institution. Personnel should be made aware of the potential link between OR traffic and infection rates. They should also be made aware of the alarmingly high rate of door openings and how this disrupts air flow in the OR, potentially introducing microbes into the surgical site. More specifically, OR staff need to be educated about their own personal implication with regards to which door they opened during which period and for what reason. We propose suggestions that may further reduce the number of unnecessary door openings. Locking the external door immediately after the entry of the patient into the OR should be emphasized. Staff schedule should be organized in such a way that staff rotation during each TJA is minimized and ideally reduced to zero. Rotation of scrubbed staff should not be tolerated. Having attendants specifically assigned to a particular OR could potentially decrease the incidence of door openings, especially in the preincision period. Bad behaviours, such as opening the door to check if the case is ready for the surgeon or getting more anesthetic supply for the next case should be eliminated. If someone's presence in the OR does not directly benefit the patient, this person should not enter.

Although education is the best way to make personnel aware of the problem of high OR traffic, monitoring OR traffic may be a method of discouraging staff from entering or leaving the OR unnecessarily. This could be achieved either by video-recording personnel entering and leaving the OR during surgery or by installing automatic meters that record who enters and leaves the OR during surgery. While it would seem that personnel might alter their behaviour knowing that their entering and leaving the OR was being monitored, 1 study reported no difference in the time between door swings and no difference in the maximum or minimum number of people in the OR during surgical procedures when OR personnel knew their movements were being monitored.[8]

Conclusion

There is a high incidence of door openings during TJA. This situation can increase the risk of PJI. High variations in door openings for the same duration of surgery show that reduction of the OR traffic is feasible and should be a priority. Education of OR personnel is the key to reducing door openings during TJA and potentially help decrease associated PJI.

Affiliations: From the Department of Orthopedic Surgery, CHU de Québec, Hôpital de l'Enfant-Jésus, Québec, Que. (Bédard, Pelet); and the Faculty of Medicine, Université Laval, Québec, Que. (Bédard, Pelletier-Roy, Angers-Goulet, Leblanc, Pelet).

Competing interests: None declared.

Contributors: M. Bédard and S. Pelet designed the study. R. Pelletier-Roy, M. Angers-Goulet, P.A. Leblanc and S. Pelet acquired the data, which M. Bédard, R. Pelletier-Roy and S. Pelet analyzed. M. Bédard and R. Pelletier-Roy wrote the article, which all authors reviewed and approved for publication.

References

1. Sculco TP. The economic impact of infected total joint arthroplasty. *Instr Course Lect* 1993;42:349-51.
2. Bozic KJ, Ries MD. The impact of infection after total hip arthroplasty on hospital and surgeon ressource utilization. *J Bone Joint Surg Am* 2005;87:1746-51.
3. Lynch RJ, Englesbe MJ, Sturm L, et al. Measurement of foot traffic in the operating room: implication for infection control. *Am J Med Qual* 2009;24:45-52.
4. Hanssen AD, Rand JA. Evaluation and treatment of infection at the site of a total hip or knee arhroplasty. *Instr Course Lect* 1999;48:111-22.
5. Smith EB, Raphael IJ, Maltenfort MG, et al. The effect of laminar air flow and door openings on operating room contamination. *J Arthroplasty* 2013;28:1482-5.
6. Ritter MA. Operating room environment. *Clin Orthop Relat Res* 1999;369:103-9.
7. Pulido L, Ghanem E, Joshi A, et al. J. Periprosthetic joint infections: the incidence, timing, and predisposing factors. *Clin Orthop Relat Res* 2008; 466:1710-5.
8. Parikh SN, Grice SS, Schnell BM, et al. Operating room traffic: Is there any role of monitoring it? *J Pediatr Orthop* 2010;30:617-23.
9. Young RS, O'Regan DJ. Cardiac surgical theatre traffic: time for traffic calming measures? *Interact Cardiovasc Thorac Surg* 2010;10:526-9.
10. Evans RP. Current concepts for clean air and total joint arthroplasty: laminar airflow and ultraviolet radiation: a systematic review. *Clin Orthop Relat Res* 2011;469:945-53.
11. Panahi P, Stroh M, Casper DS, et al. Operating room traffic is a major concern during total joint arthroplasty. *Clin Orthop Relat Res* 2012; 470:2690-4.
12. Scaltriti S, Cencetti S, Rovesti S, et al. Risk factors for particulate and microbial contamination of air in operating theatres. *J Hosp Infect* 2007; 66:320-6.
13. Wilson DJ, Kiel DE. Gravity driven counterflow through an open door in a sealed room. *Build Environ* 1990;25:379-88.