Original Article

Glove Perforation in Orthopaedic Surgery: Pattern and Predictors

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Abstract

Background: Intact surgical gloves prevent transmission of pathogens between the surgeon and the patient. However, gloves may be breached during surgical operations with risk of cross-transmission of pathogens between the surgeon and the patient. This study aimed to determine the incidence, nature and predictors of glove perforations in orthopaedic surgery. **Methods:** Gloves worn by the surgeon, their assistants and the scrub nurse were tested. Number, position and nature of perforations were recorded and analysed. Binary logistic regression was used to assess the impact of six possible predictors on the likelihood of glove perforation. **Results:** The operative glove perforation rate was 72.2%. Perforations occurred more on the nondominant hand (62.4%) and on outer gloves (85.8%). They were more common among surgeons and their assistants than scrub nurses and in trauma and implant operations than other surgeries. Only 27.1% of glove perforations were detected intraoperatively. The status of operative personnel and duration of surgery were predictive of glove perforation. **Conclusions:** Glove perforation is common in orthopaedic operations and was predicted by status of the surgeon and the duration of surgery. Double gloving provides a better barrier to contamination of surgeon's skin by patients' body fluids than single gloving; however, sometimes, the barrier can still fail. We recommend that double-gloving be routinely used in orthopaedic surgery, especially where complex instrumentations are employed.

Keywords: Blood-borne pathogens, double gloving, Glove perforations, orthopaedic operations, single gloving, surgical site infection

Introduction

Since surgery is an invasive procedure, both the patient and the surgeon are at risk of transmitting pathogens to each other. For the patient, this can result in surgical site infection which may prolong their admission in the hospital and lead to other complications.[1,2] The surgeon is also at risk of being infected with patient's blood-borne pathogens, with hepatitis B and HIV being the most frequently reported.[3-5]

In most open surgeries, the part of the surgeon that most frequently comes in contact with the patient's wound is the hand. The intact glove prevents the surgeon's skin from coming in contact with the patient's open wound, so that pathogens are not transferred between the patient and the surgeon. However, gloves are often breached in surgeries when they are torn or perforated by instruments or bone fragments or when they become abraded from wear and tear.[6-8]

The incidence of torn gloves depends on the nature of the surgery. Orthopaedic operations have the highest rate of glove perforation because they involve drilling, sawing and manipulation of sharp bone fragments as well as handling of metallic implants.[9,10] The objectives of this study were to determine the incidence and nature of perforation of gloves and identify factors that predict glove perforation in orthopaedic surgery.

Methods

This prospective descriptive study covered a 6-month period from May 2018 to October 2018. It was performed at the Surgical Operating Suite of LAUTECH Teaching Hospital,

Access this article online

Quick Response Code:

Website: www.njotonline.org

DOI: 10.4103/njot.njot_16_20

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How to cite this article: Ajibade A, Oluwadiya KS, Olaitan PB, Ogunlusi JD. Glove perforation in orthopaedic surgery: Pattern and predictors. Niger J Orthop Trauma 2020;19:49-53.

Submission: 18.05.2020 **Revision:** 07.06.2020
Acceptance: 10.08.2020 **Web Publication:** 15.12.2020

Osogbo after obtaining clearance from the Research Ethics Committee of the hospital. Seventy-two consecutive orthopaedic operations were studied. Implant and non-implant operations were included in the study, while operations that lasted <30 min were excluded. Gloves worn by the surgeon, their assistant or assistants and the scrub nurse were tested. The number of assistants was determined by the complexity of the surgeries and availability of personnel. The gloves were donned in routine manner. Two brands of gloves, Dana and Neomedic, were in use in the hospital at the time of the study. The choice of which to use for any operation was dictated by the brand provided for the operation. The operations were performed by all consultant surgeons and residents in the orthopaedic unit of the hospital.

After surgery, the user washed the gloved hand with water and then dried it by rubbing it on a clean part of his gown. Each glove was labelled to indicate the designation of the user (surgeon/assistant/scrub nurse), the side on which it was worn (right/left) whether double or single gloved, and in the case of the former, its position (outer or inner). The gloves were then put in a nylon bag and sealed.

To test the gloves for perforations, the nylon bag was opened and the information on the labels was entered on the glove form. Each glove was then filled with 1000 ml of water and checked after 2 min to detect leaks. To detect perforations in the fingers, it was sometimes necessary to gently distend the individual fingers of the gloves. The numbers of perforations in the gloves were noted, and the position and nature of each perforation were recorded.

Two forms were used for the study. The first (Form I) was a general form containing information relating to the surgery itself. It had a Surgery Identification Number (SIN) with which it was linked with the second form. It also contained information about the nature of surgery, dominant hand of each member of the team, gloving method (double/single), designation of the surgical team and the total number of gloves used in the surgery. One general form was filled for each surgical procedure.

The second form (Form II) was filled for each torn glove. It was linked to Form I by the SIN. It contained information about the position, type of perforations (puncture or tear) and whether or not the user was aware of the perforation during the surgery. Since each Form II was linked to its parent Form I, it was easy to identify the number of gloves torn in each surgery. For example, if an assistant surgeon had a glove torn and the surgeon had two torn, three Form IIs-one for each torn glove-would be filled, but only one Form I would be filled. All 4 forms would bear identical SIN and would be stapled together.

Statistical analysis

We used Chi-square statistics to assess the association between glove perforation and a number of categorical variables. Both the Kolmogorov–Smirnov test of normality ($P < 0.001$) and normality curves showed that duration of surgery had a nonnormal distribution; therefore, we used Mann–Whitney U test to assess the difference between duration of surgery in the perforated and intact glove groups. Finally, we performed binary logistic regression to assess the impact of six predictors on the likelihood that gloves would be perforated. The predictor variables were status of the surgical team (Surgeon/Assistant/Scrub Nurse), duration of surgery in minutes, brand of glove, type of surgery (Emergency/Elective), instrumentation and tissue type (bone/soft tissue). These predictor variables were added based on literature review and some of the variables that were significantly associated with glove perforation in the crosstab procedure. A backward selection was done to fit the model and standard techniques for model checking were done. Six models were tested by SPSS IBM SPSS Version 25 (IBM SPSS, Chicago, USA). Models 1–3 had only one significant variable, model 4 had two, but the Hosmer-Lemeshow Goodness of Fit test was 0.031, indicating that the model did not fit. Model 5 had two significant variables and was also found to fit the data ($P = 0.482$). We chose Model 5. The model explained between 23.3% (Cox and Snell R square) and 31.6% (Nagelkerke R square) of the variance in glove perforation and correctly classified 68% of the cases. We inferred statistical significance for all the tests at $P < 0.05$.

Results

The median duration of the 72 orthopaedic operations was 125 min (interquartile range = 128 min). Mann–Whitney U test showed that surgeries where perforations occurred (median = 150 min) were longer ($P < 0.001$) than those with no perforations (median = 55 min). There were at least one surgeon, one assistant and one scrub nurse per procedure making a total of 230 personnel who took part in all the procedures. All surgeons and first assistants double-gloved for all the operations, but only 70.4% of scrub nurses and 95.7% of second assistants wore double gloves. The total number of gloves worn per surgery ranged from 6 to 26 (median = 15.5 gloves). Overall, 1089 gloves were used in all the procedures: 578 as outer/single gloves and 511 as inner gloves.

In the 72 surgeries, we identified 119 perforated gloves worn by 85 operative personnel in 52 surgical operations. This gives an overall operative perforation rate of 72.2% (52/72) and an overall glove perforation rate of 10.9% (119/1089). However, the glove perforation rate ranged from 3.1% in inner gloves to 19.1% in outer gloves. The overall perforation rate among

Table 1: Rate of glove perforation among surgical team members ($P<0.001$)

Status	Number of observed perforations (%)					Total
	None	1	2	3	4-7	
Surgeons	27 (38.0)	25 (35.2)	11 (15.5)	2 (2.8)	6 (8.5)	71
Assistants	53 (60.2)	29 (33.0)	6 (6.8)	0	0	88
Scrub nurse	65 (91.5)	6 (8.5)	0	0	0	71
Total	145 (63.0)	60 (26.1)	17 (7.4)	2 (0.9)	6 (2.6)	230

the surgical team was 37.0% (85/230). As Table 1 shows, this rate ranged from 8.5% among scrub nurses to 61.9% among surgeons.

Only 23 (27.1%) of the 85 team members who had perforations detected the perforations intra-operatively. They had to change their gloves intraoperatively. Majority of these breaches were detected because the gloves were visibly torn, but two were detected because the person felt a needle prick. Sixty team members had one glove perforation and the remaining 25 had multiple perforations ranging from two to seven. Five (20%) of the multiple perforations were detected in more than one glove. The outer glove only was perforated in 73 (85.8%) cases, both gloves were perforated in six (7.1%) cases, and the inner glove alone was perforated in the remaining six (7.1%) cases. Fifty-three (62.4%) of the 85 team members whose gloves were perforated had the perforations in the gloves on the left hand, which was also the nondominant hand. The index finger and the thumb were the most perforated parts of the gloves [Figure 1].

As shown in Table 2, the perforation rate for surgeons was about 7 times the rate for scrub nurses and almost two times the rate for assistants ($P < 0.001$). Similarly, implant and prosthetic surgeries where special instrumentations were used had a significantly higher glove perforation rate than surgeries where no instrumentations were used ($P = 0.001$). Trauma surgeries had significantly higher rate of perforations than paediatric orthopaedic or general orthopaedic surgeries. The brand of gloves also seemed to affect the rate of perforation, as Dana Brand produced a significantly lower rate of perforations than Neomedic gloves. However, neither the limb operated, nor nature of surgery (emergency/elective), nor the type of tissue (soft/bone) resulted in significantly different glove perforation rates.

As shown in Table 3, only status of the team member and the duration of surgery made statistically significant contribution to the binary logistic regression model. Surgeons were 20 times, and assistant surgeons 7 times more likely to have their gloves perforated than scrub nurses. Similarly, for every 1-min increase in operation time, the likelihood of glove perforation increased by 1.007.

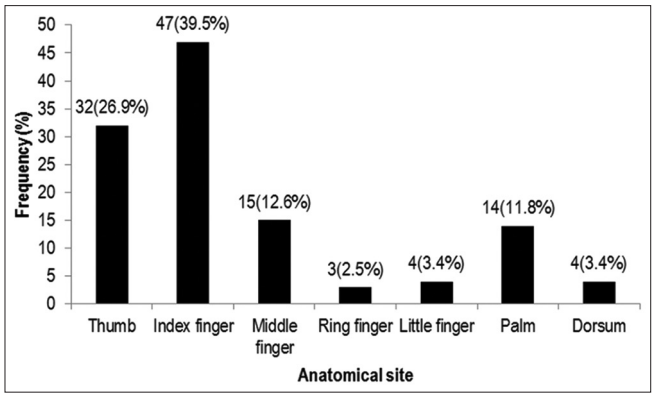

Figure 1: Puncture sites in gloves

Discussion

At 10.9%, and for a study limited to orthopaedic surgery, the overall glove perforation rate in this study is rather low. It falls within the lowest 10th percentile of the 8%–50% reported in the literature.[9,11-13] The relatively low overall perforation rate is probably because >90% of the surgical team members were double-gloved for the surgeries: the outer glove perforation rate of 19.1% was pared down by the inner glove perforation rate of 3.1%. However, the operative perforation rate was 72.2%; that is, almost three out of every four operations had at least one incidence of glove perforations where the surgical team members were at significant risk of exposure to patients' body

Table 2: Relationship between glove perforation and some selected parameters

Operation parameter	Perforation of one or more team member's glove		*P*
	Perforation detected (%)	No perforation detected (%)	
Team member's status			
Surgeon	44 (62)	27 (38)	<0.001
Assistant	35 (39.8)	53 (60.2)	
Scrub nurse	6 (8.5)	65 (91.5)	
Nature of surgery			
Emergency	10 (30.3)	23 (69.7)	0.392
Elective	75 (38.1)	122 (61.9)	
Instrumentation used?			
Yes	72 (43.9)	92 (56.1)	0.001
No	13 (19.7)	53 (80.3)	
Tissue type			
Soft tissue	5 (26.3)	14 (56.1)	0.316
Bone	80 (37.9)	131 (62.1)	
Limb operated			
Lower limb	77 (37)	131 (63)	0.096
Upper limb	8 (50)	8 (50)	
Both	0	6 (100)	
Subspecialty			
Trauma	65 (43.9)	83 (56.1)	0.011
General orthopaedics	12 (27.3)	32 (72.7)	
Paediatric orthopaedics	8 (21.1)	30 (78.9)	
Brand			
Dana	32 (28.3)	81 (71.7)	0.008
Neomedic	53 (45.3)	64 (54.7)	

Table 3: Logistic regression for prognostic factors for glove perforation

Predictor	OR	CI	*P*
Status			
Scrub nurse	Reference		
Assistant surgeon	7.268	2.736-19.310	<0.001
Surgeon	20.139	7.193-56.38	<0.001
Duration of surgery	1.007	1.002-1.011	0.004

OR: Odds ratio, CI: Confidence interval

fluids. The glove perforation rate among the surgical team members was also 33%, meaning that one out of every three members of the surgical team had their gloves perforated. These two high values showed that there was a need for greater precautions against glove perforations among the orthopaedic surgical crew in our study. Orthopaedic surgeries are inherently prone to perforation of gloves because a lot of drilling, sawing and manipulation of hard, sharp-edged bone is done.[9,10] In our own setting, this was worsened by the fact that sometime the appropriate instrumentations were unavailable, so alternate instrumentations were used. This may lead to longer operation time and increased possibility of glove perforations and injuries because of the increased clumsiness of using inappropriate instruments.

The finding of perforated inner gloves without concomitant outer glove perforation in 6 team members might have resulted from glove fatigue or pre-existing perforations in the inner gloves. Four of the surgeries in which only inner gloves were perforated lasted longer than 2 h. Studies have shown that gloves may develop spontaneous perforations from abrasions when surgeries lasted more than 2 h.[1] On the other hand, the isolated tears in the inner gloves may have been due to preexisting perforations that were not detected by the usual inspections which were mostly perfunctorily done at donning. We, therefore, recommend that surgeons inspect gloves for tears and perforations before and after donning.

Only 23.7% of those who had their gloves perforated were aware of the perforation during surgery and consequently changed the damaged gloves. The remaining 76.3% did not know that their gloves were perforated until after surgery. This indicates that for operators who were not double-gloved, more than three out of every four with perforated gloves were exposed to patients' body fluids for significant length of time. Studies have shown that the extent of the danger posed by pathogens such as hepatitis and HIV is dependent on the time patients' body fluid is in contact with the skin of the surgeon and other surgical team members.[10] To limit this, surgeons must be encouraged to wear double gloves with the perforation indicator system.[1,14] A study reported intra-operative perforation detection rate of 90.2% when indicator gloves were used.[15]

Most previous studies showed the left hand and the index finger and thumb of the nondominant thumb to be the most commonly perforated parts of surgical team's gloves.[9-11] This agrees with the findings in our study in which the combined incidence of injuries to the index finger and the thumb was 66.4% and 62% of the perforations occurred in the left gloves. This is because the non-dominant hand is clumsier and are more prone to injuries.[10] In addition, being the "holding" hand in most situations, the nondominant hand is exclusively at risk of needle and drill punctures.[8]

Our study also indicated that some brand of gloves might be better than others at preventing glove perforations. In this study, Dana brand appears to have a lower incidence of glove perforations than Neomedic brand. It is therefore important for hospital administrators to take the quality of brands into consideration when purchasing surgical gloves. Hwang *et al*. tested four brands of gloves and concluded that the quality of surgical gloves in terms of perforations, handling and allergy differs from brand to brand.[16] They advised that government and hospitals should take the responsibility of monitoring the quality of surgical gloves to ensure the safety of patients and healthcare workers.

Our study showed the status of the surgical team was a significant predictor of glove perforations. Surgeons were twenty times more likely to have their gloves perforated than scrub nurses were. They were also seven times more likely to have their gloves perforated than assistant surgeons were. This is in agreement with results from similar studies from all over the world and is because surgeons carry out most of the active manipulations and almost exclusively do all intra-operative suturing, while the assistants are mostly occupied with retracting and holding tissues. The perforation rate among scrub nurses is low in our study.[7,10,17] Yinusa *et al*. reported a higher perforation rate among scrub nurses (11.7%) compared to surgeons (10.1%) in their study.[9] They attributed this unusual finding to the "significant handling of instruments by nurses in instrumented procedures." The scrub nurses in our studies did not assemble the instruments for the surgeons. They only identified and handed over instruments and implants to surgeons who assembled them, and so they were probably not doing any "significant" handling. This may explain the lower rate of glove perforations among the scrub nurses in our study.

Duration of surgery was the second significant predictor of glove perforation in our study. For every 1-min increase in operation time, the likelihood of glove perforation increased by 1.007. This meant that the odds of a glove perforating during surgery were increased about 57% for every hour increase in operating time. At 2 h, the odds were more than doubled. Therefore, we recommend that surgeons should routinely inspect their gloves for perforations after an hour and mandatorily change the gloves after 2 h of surgery. The later will be in keeping with recommendations from other authors.[1,14]

One limitation of our study is the mere routine inspection of gloves for perforation before and after donning by surgical team members. Consequently, tiny perforations might have been missed. This may account for the observation of perforated inner gloves in the presence of intact outer gloves. We also did not capture information on whether appropriate instrumentations were used for the operations or not. Inappropriate instrumentations may therefore be a confounder in our study as the procedural difficulty that attends their use can increase the risk of glove perforation as well as prolong the duration of surgery which in itself is associated with higher glove perforation rate.[6,7]

Conclusions

Glove perforation is common in orthopaedic surgical procedures. This rate was affected by the status of the surgeon and the duration of surgery. While double gloving provides a better barrier to contamination of surgeon's skin by patients' body fluids than single gloving, there are still instances when the barrier will fail. We therefore recommend that double-gloving should be routinely used in orthopaedic surgery especially where complex instrumentations are employed.[14]

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Misteli H, Weber WP, Reck S, Rosenthal R, Zwahlen M, Fueglistaler P, *et al*. Surgical glove perforation and the risk of surgical site infection. Arch Surg 2009;144:553-8.
2. Kojima Y, Ohashi M. Unnoticed glove perforation during thoracoscopic and open thoracic surgery. Ann Thorac Surg 2005;80:1078-80.
3. Naver LP, Gottrup F. Incidence of glove perforations in gastrointestinal surgery and the protective effect of double gloves: A prospective, randomised controlled study. Eur J Surg 2000;166:293-5.
4. Tanner J, Parkinson H. Double gloving to reduce surgical cross-infection. Cochrane Database Syst Rev 2006;3:CD003087.
5. Thomas S, Agarwal M, Mehta G. Intraoperative glove perforation – Single versus double gloving in protection against skin contamination. Postgrad Med J 2001;77:458-60.
6. Thanni LO, Yinusa W. Incidence of glove failure during orthopaedic operations and the protective effect of double gloves. J Natl Med Assoc 2003;95:1184-8.
7. Maffuli N, Capasso G, Testa V. Glove perforation in elective orthopaedic surgery. Acta Orthop Scand 1989;60:565-6.
8. Walczak DA, Pawelczak D, Grobelski B, Pasieka Z. Surgical gloves – Do they really protect us? Pol Przegl Chir 2014;86:238-43.
9. Yinusa W, Li YH, Chow W, Ho WY, Leong JC. Glove punctures in orthopaedic surgery. Int Orthop 2004;28:36-9.
10. Laine T, Aarnio P. How often does glove perforation occur in surgery? Comparison between single gloves and a double-gloving system. Am J Surg 2001;181:564-6.
11. Arowolo OA, Agbakwuru EA, Obonna GC, Onyia CU, Akinkuolie AA, Olaogun JG. Safety of the surgeon: 'Double-gloving' during surgical procedures. South Afr J HIV Med 2014;15:144-7.
12. Makama JG, Okeme IM, Makama EJ, Ameh EA. Glove perforation rate in surgery: A randomized, controlled study to evaluate the efficacy of double gloving. Surg Infect (Larchmt) 2016;17:436-42.
13. Palmer C. Major trauma and the injury severity score – Where should we set the bar? Annu Proc Assoc Adv Automot Med 2007;51:13-29.
14. Caillot JL, Paparel P, Arnal E, Schreiber V, Voiglio EJ. Anticipated detection of imminent surgeon-patient barrier breaches. A prospective randomized controlled trial using an indicator underglove system. World J Surg 2006;30:134-8.
15. Laine T, Aarnio P. Glove perforation in orthopaedic and trauma surgery. A comparison between single, double indicator gloving and double gloving with two regular gloves. J Bone Joint Surg Br 2004;86:898-900.
16. Hwang JS, Mehta AD, Yoon RS, Beebe KS. From amputation to limb salvage reconstruction: Evolution and role of the endoprosthesis in musculoskeletal oncology. J Orthop Traumatol 2014;15:81-6.
17. Palmer JD, Rickett JW. The mechanisms and risks of surgical glove perforation. J Hosp Infect 1992;22:279-86.