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Perforation of Surgical Gloves during Lower Extremity Fracture Surgery and Hip Joint Replacement Surgery

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Purpose: To assess the frequencies and sites of surgical glove perforations in lower extremity fracture surgery and hip joint replacement (HJR) surgery. Additionally, we also studied the usefulness of an indicator system glove.

Materials and Methods: We assessed surgical glove perforations in 30 cases of lower extremity fracture surgery and 18 cases of HJR surgery conducted by one right handed 1st operator from April 2013 to July 2013. We assessed frequencies and sites of perforation in 152 gloves; 95 used in lower extremity fracture surgery and 57 used in HJR surgery. We studied the perforation rates and sites according to participants and operation types. Using the Biogel indicator system glove, which is well known as a fast indicator of glove perforation, we were also able to assess the time difference between operative participant detection of perforation and inspector nurse detection while observing in the operative field.

Results: There were 18 of 30 cases in lower extremity fracture surgeries and 12 of 18 cases in HJR surgeries which had more than one surgical glove perforation event. Of all 152 gloves used, perforation occurred in 15 of 57 gloves (26.3%) in HJR surgery and 23 of 95 gloves (24.2%) in lower extremity fracture surgery. Perforation occurred more frequently in operators than assistant doctors or scrub nurses. The most frequent perforation site was the second digit of the left hand. On average, the time difference between operative participant notice of perforation and inspector nurse notice of perforation was 20.6 seconds.

Conclusion: The perforation of surgical gloves happened in approximately one out of every four persons. Importantly, we noted a 37.0% prevalence of glove perforation in 1st operators. Considering that glove perforation is a critical factor responsible for intra-operative infection, surgeons must be conscious of the risk of surgical glove perforation and use double gloving regularly. Furthermore, indicator double gloving is recommended for fast detection of outer glove perforation.

Key Words: Perforation, Double glove, Fracture surgery, Hip joint replacement surgery

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INTRODUCTION

Various efforts have been made to maintain aseptic conditions for surgeries, yet constant risks of infection remain. Although there are multiple causes of infection, those spreading from surgical operators (e.g., surgeons, assistant surgeons, and scrub nurses), are known to be among the most frequent causal factors. Thus, surgical infection has been prevented via requiring all surgical operators to perform surgical hand scrubbing using antiseptic agents followed by the wearing of sterilized surgical gloves in order to control potential infections at surgical sites. Despite surgical hand scrubbing, surgical operators often possess pathogens on their hands; hence, the occurrence of surgical glove perforations may collapse infection control barriers and transfer pathogens to patients via surgical sites. The frequencies of surgical glove perforations of have been reported in many types of surgeries, ranging from about 8% up to 61%[1-5]. It is interesting to note that the perforation occurrence rate in orthopedic surgeries was shown to be even higher than that observed for other types of surgeries[6,7].

In the present study, we analyzed surgical glove perforation rates during hip joint replacement surgeries and lower extremity fractures which required invasive reduction as well as internal fixation. Our hypothesis was that there would be a greater likelihood of perforation compared to other orthopedic surgeries, and that serious medical consequences, such as surgical infections, would result. To test our hypothesis, the numbers of surgical glove perforations were recorded for all surgeries. In addition, we prospectively analyzed differences in perforation rates between the types of surgeries (i.e., hip joint replacement surgery vs. lower extremity fracture surgery), the rates of perforation in surgical operators (i.e., a surgeon, assistant surgeons, and scrub nurses), as well as the sites of the surgical glove perforations. Furthermore, we used Biogel indicator system gloves (powder-free; Mölnlycke Health Care, Kulim, Malaysia) which provide faster recognition of perforation in order to assess the difference in the amount of time between the operative participant detection of perforation and the detection of the occurrence by an inspector nurse in order to investigate whether these gloves were effective in reducing the time required to detect perforations.

MATERIALS AND METHODS

1. Materials

Surgeries for a total of 48 patients (i.e., 30 cases of lower extremity fracture surgeries requiring invasive reduction as well as internal fixation, and 18 cases of hip joint replacement surgeries) were evaluated with regard to the perforation rate from April 2013 through July 2013. Surgeries were conducted by a right handed surgeon and surgical glove perforations that occurred for a surgeon, assistant surgeons, and scrub nurses were investigated (Table 1). The operative participants were all right handed. The Biogel gloves were double gloves with green colored inserts so that exposure to blood through a perforation of the outer glove changed the color of the inner glove to indicate the occurrence. For the outer gloves, general latex gloves were utilized as depicted in Fig. 1.

2. Methods

A total of 152 gloves were used for 48 surgeries in the study. Upon notice of the perforation, gloves were replaced, while suspicious gloves were initially changed and subsequently tested via water-leak examination after the surgery. Gloves were not replaced during surgeries in which glove perforation were not suspected; however, all gloves were also tested for perforations using the water-leak examination after the surgeries. For our analysis, we investigated how many perforations were found in all gloves used for surgeries, if there was a difference between perforation rates based on the types of surgeries (i.e., fracture surgeries vs. hip joint replacement surgeries), whether operation participants (i.e., a surgeon, assistant surgeons, and scrub nurses) displayed different perforation rates, and which sites on the

Table 1. Types of Surgeries

Type of surgery	Case (n)
Fractures of lower extremity	30
Inter-trochanteric fracture	19
Proximal tibia fracture	7
Total hip replacement periprosthetic fracture	1
Distal femur fracture	3
Hip joint replacement surgeries	18
Primary bipolar	12
Primary total hip arthroplasty	6

surgical gloves were most frequently perforated.

As previously described, Biogel indicator system gloves were used in order to recognize glove perforations. It has been reported that the length of time required for recognition of double glove perforations is generally shorter than for single gloves; however, little information is available regarding the time required for noticing perforations during surgeries. Thus, we assigned nurses to the operation rooms who were solely present to monitor the perforation of surgical gloves. The time point at which the nurse noticed a perforation was considered as the onset time of the perforation. The inspector nurse was informed to stop the operation if operation participants did not notice the perforation after one minute from onset time of the perforation.

3. Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics software, ver. 19.0 (IBM, Armonk, NY, USA). Statistical significance was tested using the Pearson's X^2-test. *P*-values <0.05 were considered to be statistically significant.

RESULTS

Amongst the 30 cases of fracture surgeries, 18 cases of perforation were found, while 12 perforations were noted in 18 cases of hip joint replacement surgeries. Fifteen (26.3%) and 23 (24.2%) gloves were perforated out of the 57 and 95 gloves used in hip joint replacement surgeries and fracture surgeries, respectively. As a result, we did not find any statistical difference in the rates of perforation between the types of surgeries (*P*=0.082; Table 2).

The rate of perforation was found to be the highest for the surgeon (20 perforations out of 54 gloves; 37.0%) followed by assistant surgeons (9 perforations out of 50 gloves; 18.0%), and scrub nurses (9 perforations out of 48 gloves; 18.8%). As expected, the surgeon had the highest perforation rate, which was approxi-mately 2.1-fold higher than rates found for assistant surgeons and scrub nurses. The differences between the surgeon perforation rate and the rates found for assistant surgeons and scrub nurses were statistically significant (*P*=0.006 and *P*=0.007, respectively; Table 3).

We further evaluated the number of glove perforations. A total of 46 perforations were observed in the

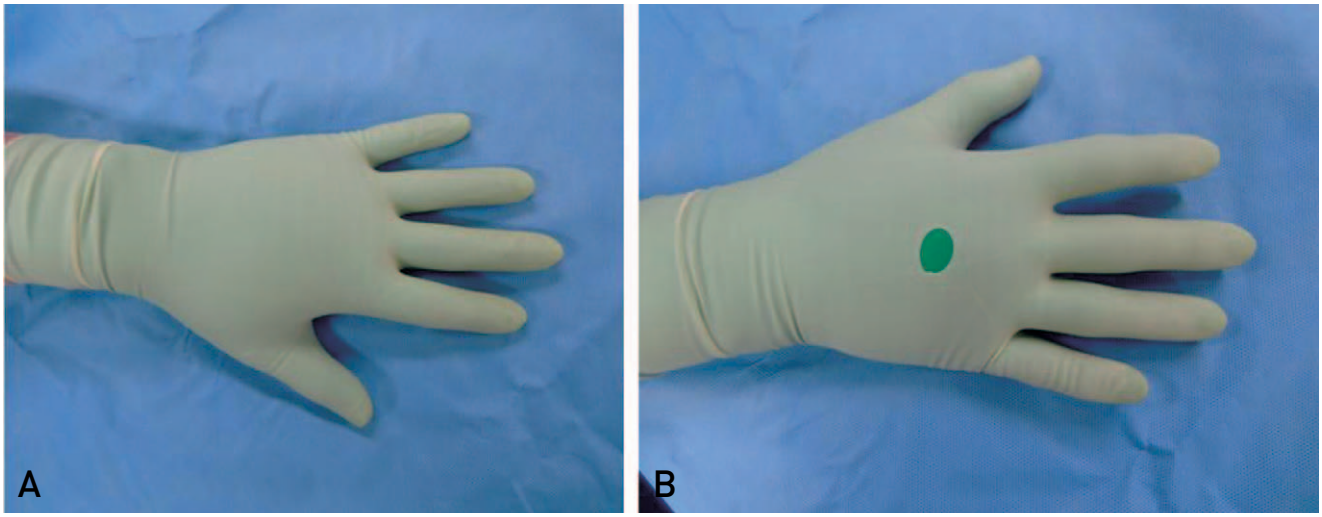

Fig. 1. Perforation of indicator system glove. (**A**) Before perforation (white color), (**B**) after perforation (green color).

Table 2. A Comparison of Cases of Surgical Glove Perforation per Type of Surgery

Type of surgery	Gloves with perforation	Gloves without perforation	Total
Fracture surgery	23 (24.2)	72 (75.8)	95
Hip joint replacement surgery	15 (26.3)	42 (73.7)	57
Total	38 (25.0)	114 (75.0)	152

Values are presented as number (%).

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Table 3. Comparison of Glove Perforation Occurrence Rates according to Operation Participant Roles

Operation participants	Gloves with perforation	Gloves without perforation	Total
Surgeon*	20 (37.0)	34 (63.0)	54
Assistant surgeons	9 (18.0)	41 (82.0)	50
Scrub nurses	9 (18.8)	39 (81.3)	48
Total	38 (25.0)	114 (75.0)	152

Values are presented as number (%).
* All surgeries were performed by a right handed surgeon.

Table 4. Distribution of Glove Perforation Sites

Perforation site	Perforation, n (%)
1st digit of left hand	7 (15.2)
2nd digit of left hand	21 (45.7)
3rd digit of left hand	3 (6.5)
1st digit of right hand	2 (4.3)
2nd digit of right hand	8 (17.4)
3rd digit of right hand	5 (10.9)
Total	46 (100)

38 gloves. Thirty gloves had only a single perforation while eight gloves had two perforations. Sixteen gloves had perforations on the second digit of the left hand, while five gloves had perforations on the second digit of the left hand as well as either the first digit of the left hand, the second digit of the right hand, or the third digit of the right hand, indicating that the second digit of the left hand was the most common site of perforation (21 cases of perforation; 45.6%), followed by the second digit of the right hand, and the first digit of the left hand (eight [17.3%] and seven cases [15.2%] of perforation, respectively; Table 4).

As previously mentioned, the time point at which the inspector nurse noticed a perforation was considered as the onset time of perforation. We assessed the differences in the time taken for recognition of perforations between the inspector nurse and the operation participants. The average time difference was shown to be 20.6 seconds, with a range of two to 60 seconds. The average time taken to recognize the first perforation was 20.9 seconds, whereas it took an average of 19.8 seconds to find the second perforation. All cases of perforations were found in the outer gloves; no perforations were noted in the inner gloves.

DISCUSSION

Previously, surgical glove perforation rates were reported to vary, ranging from 8-61%[2-5]. It has been demonstrated that orthopedic surgeries, fracture surgeries, and cardiothoracic surgeries in particular, represent higher rates of perforation occurrence, possibly due to a greater likelihood of perforation from sharp fractures and thorax bone structures[6,7]. In contrast, endoscopic surgeries have relatively low rates of perforations[8]. In the present study, we evaluated the rate of perforation that occurred during orthopedic surgeries, specifically lower extremity fracture surgeries and hip joint replacement surgeries, using the double glove system with indicative functions. As a result, a 25.0% rate of perforation occurrence was found. It should be noted that the occurrence rate of lethal infection has been demonstrated to be approximately 1% after arthroplasty surgeries. Furthermore, the rate of perforation was shown to be 26.3% after arthroplasty surgeries in the present study, indicating that more attention is required by operation participants with regard to surgical hand scrubbing based on the potential for glove perforation and subsequent post-operative infections.

The occurrence of surgical glove perforation may collapse infection control barriers between operation participants' hands and patients' surgical sites, thereby resulting in infection through surgical wounds. Furthermore, it is also possible that viral and pathogenic organisms can be transferred to operation participants. In cases where surgical gloves have perforations, operation participants are not only exposed to blood on their hands, but also may be exposed to patients' blood via sharp needles or surgical tool wounds. According to Laine and Aarnio[9], only 0.5% of operation participants were exposed to patients' blood when more than one glove (i.e., a double glove system) was used, and increased up to 7.4% for those using single gloves. Similarly, Naver and Gottrup[8] also reported a perforation rate of 51% when only one glove was used; however, the rate was reduced to 7% for a double gloving system. The results from a number of other studies have consistently

indicated that the double gloving system may reduce the rate of infection that can occurr during surgeries[10-12]. Thus, it is likely that using more than one glove may reduce the likelihood of operation participants' hand exposure to patients' blood. In support of this assertion, we did not find any inner glove perforations in the present study, although a few perforations were found on the outer gloves via the double glove system.

When perforation of surgical gloves occurs, patient infection risks may be elevated; however, proper measures may not be pursed due to a lack of awareness of perforations. Therefore, it is important to take timely actions with regard to perforations on surgical gloves. It was previously reported that surgeons recognized perforations on gloves earlier/faster by wearing green under the gloves, which provided indications of perforation[9,13,14]. Additionally, when comparing the rates of perforation of double-gloving systems, those with indicative functions had lower rates of perforations on inserts compared to those with normal gloves[6,7,15]. In the present study, the average time difference between inspector nurse detection of a perforation and operative participants detection of a perforation was 20.6 seconds when the Biogel indicator system gloves were used. Given that no perforations were found on the inner gloves, the Biogel indicator system gloves may be effective in preventing the perforation of inserts via early recognition.

We also found that the second digit of the left hand had the most frequent perforations (45.6%), followed by the second digit of the right hand (17.3%), and the first digit of the left hand (15.2%), which is in agreement with the results from other previous studies reporting the second digit of the left hand as the most frequent site of perforation[3,5], followed by first digit of the left hand[6]. Possible explanations for the higher rate of perforations on the second digit of the left hand may be that many surgeons hold surgical tools in their right hand while using the left hand to hold body tissues, thereby making it more likely to be exposed to sharp fractured bones or the solid edge of inserts. Another possibility is that needle holders are often controlled using the right hand, and hence there is a greater chance for needle perforations on gloves worn on the left hand. In our hospital, all operation participants were right handed, and therefore surgical maneuvers were conducted using the left hand, which may explain the higher frequency of left glove perforations. Additionally, no perforations were noted in 10 cases of intertrochanteric fracture surgeries, as well as in two cases of proximal tibia fractures, which may have been due to the relatively simple nature of these fracture surgery operations.

In order to avoid potential problems caused by surgical glove perforations, glove replacement on a regular basis has been recommended[16,17]. For example, Kojima and Ohashi[18] recommended changing gloves every two hours given that the occurrence rates of surgical glove perforations are significantly increased after two hours of use. In the present study, we did not study the effects of time of operation on perforation. Therefore, surgical gloves were not changed regularly.

When examining the difference in perforation rates with regard to the roles of the operation participants, the surgeon had the highest rate (37.0%) while assistant surgeons only experienced 18.0% of perforations. Similar trends have also been demonstrated in other studies including those by Caillot et al.[19] and Marín-Bertolín et al.[11]. This may be due to assistant surgeons' use of surgical tools in order to provide better surgical sights, rather than the utilization of surgical knives or suture needles. Additionally, the occurrence rate of perforation in scrub nurses was found to be similar when compared to that of assistant surgeons (18.0%), whereas it was reported to be much higher in a study by Hollaus et al.[3] (i.e., 40%). Perforations that occurred in the gloves of srcub nurses may have been due to their preparation of sharp surgical tools (e.g., surgical knives or suture needles), in addition to their direct involvement of surgeries.

The present study had a few potential limitations of. First, although it seems clear that perforation may play an important role in infection, it is difficult to estimate the exact magnitude of the effects of perforation on postoperative infections considering the multitude of factors involved (e.g., patient factors, environmental/operation room factors, operation times, and procedures). Additionally, we defined the time point at which the inspector nurse noticed a perforation as the onset time of perforation in order to measure the time required to recognize the perforation by the operating participants. It may, however, be difficult for the inspector to accurately confirm perforations due to the necessity for a clear view during surgeries.

CONCLUSION

On average, we found that one of every four operation

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participants experienced perforation in their surgical gloves while performing lower extremity fracture surgeries and hip joint replacement surgeries. In particular, surgeons were observed to have a perforation rate of 37.0%. Considering the clinical significance of surgical glove perforations with regard to post-operative infections, there is an obvious need for heightened awareness of the possibility of perforation, and the need for double-gloving systems. Additionally, a double gloving system with indicative functions may be recommended for faster detection of perforations of the outer glove.

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