ORIGINAL ARTICLE

Incidence of Microperforation for Surgical Gloves Depends on Duration of Wear

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BACKGROUND. The use of sterile gloves is part of general aseptic procedure, which aims to prevent surgical team members from transmitting infectious agents to patients during procedures performed in an operating room. In addition, surgical gloves also protect team members against patient-transmitted infectious agents. Adequate protection, however, requires that the glove material remain intact. The risk of perforations in surgical gloves is thought to correlate with the duration of wear, yet very few prospective studies have addressed this issue.

METHODS. We prospectively collected 898 consecutive pairs of used surgical gloves over a 9-month period in a single institution. After surgical team members wore the gloves during surgical procedures, the gloves were examined for microperforations using the watertight test described in European Norm 455, part 1. The gloves were analyzed as a pair; if 1 glove had a perforation, the pair was considered to be perforated. In addition, we evaluated the use of a hand cream that contained a suspension of cornstarch and ethanol to determine its potential influence on the rate of microperforation.

RESULTS. Wearing gloves for 90 minutes or less resulted in microperforations in 46 (15.4%) of 299 pairs of gloves, whereas wearing gloves for 91–150 minutes resulted in perforation of 54 (18.1%) of 299 pairs, and 71 of (23.7%) of 300 pairs were perforated when the duration of wear was longer than 150 minutes ($P = .05$). Subgroup analysis revealed no significant difference in the rates of microperforation for surgeons (56 [23.0%] of 244 pairs of gloves perforated), first assistants (43 [19.0%] of 226 pairs perforated), and surgical nurses (53 [20.5%] of 259 pairs perforated). Of 171 microperforations, 114 (66.7%) were found on the left hand glove (ie, the glove on subjects' nondominant hand), predominantly on the left index finger (55 [32.3%]). The use of the hand cream had no influence on the rate of microperforation.

CONCLUSION. Because of the increase in the rate of microperforation over time, it is recommended that surgeons, first assistants, and surgical nurses directly assisting in the operating field change gloves after 90 minutes of surgery.

Infect Control Hosp Epidemiol 2009; 30:409-414

Since the end of the 19th century, surgeons have been wearing gloves during surgical procedures to prevent the transmission of infectious agents both to and from the patient.[1,2] Because surgical gloves are an essential medical device, in Europe the qualities and properties they are required to have are regulated in European Norm 455.[3] This standard is divided into 3 parts that cover the requirements and testing standards for determining whether the gloves are free of holes and for evaluating the gloves' physical and biological properties.

A recent meta-analysis has postulated that there is no direct evidence that the use of gloves reduces surgical site infections.[4] However, the potential influence of microperforations in surgical gloves on the results of this retrospective analysis has not yet been evaluated.

The barrier function of surgical gloves depends primarily on the integrity of the glove material. Studies have demonstrated that 18% of surgical gloves had undetected microperforation after surgical procedures, and there was a perforation rate of 4.2% even when double gloving was used.[1,5] A number of trials have indicated that the risk of perforations increases with the duration of glove wear; for example, in a study of obstetricians, the practice of changing of surgical gloves after delivery of the placenta resulted in a decrease in the number of wound infections after cesarean delivery.[6] Therefore, the Working Group Hygiene in Hospital and Practice of the Association of the Scientific Medical Societies of Germany (Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften e.V) recommends that gloves be

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Received March 14, 2008; accepted December 8, 2008; electronically published March 31, 2009.

 0899-823X/2009/3005-0001$15.00. DOI: 10.1086/597062

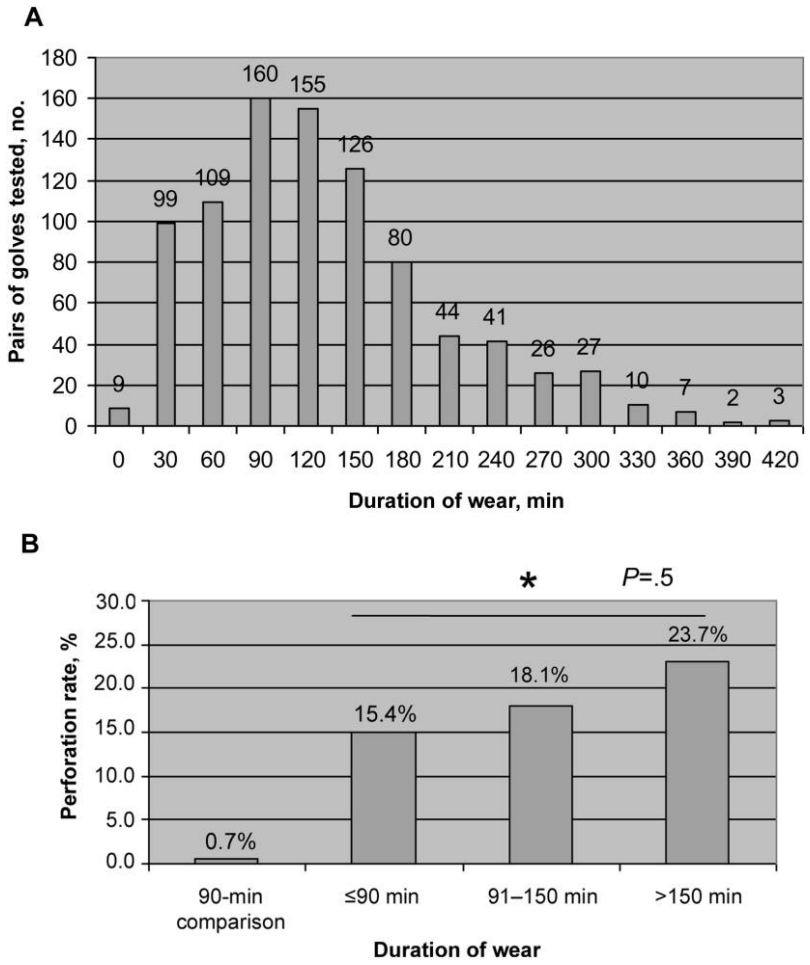

FIGURE 1. Duration of glove wear and microperforation rate. *A,* Duration of wear for all gloves tested; *B,* Microperforation rate stratified by duration of wear.

changed every 2–3 hours during surgery to preserve the barrier function of the glove.[7] These recommendations, however, are often not followed in practice.

It is also known that the risk of perforation depends on the type of surgery performed, ranging from 6.6% in urological surgery to 65% in cardiac surgery.[8-15] The present study aimed to evaluate the incidence of microperforation during different types of surgical procedures in relation to the duration of glove wear, with the goal of providing evidence-based recommendations for the timing of glove changes during surgery. In addition, we evaluated the incidence of microperforation with regard to the potential influence of a hand cream that contains a suspension of cornstarch and ethanol, an agent commonly used by members of the surgical team to facilitate the application of gloves.

METHODS

In a prospective study conducted from May 2005 through January 2006, all surgical gloves worn in the Department of General Surgery at the Ernst-Moritz-Arndt University, Greifswald, Germany, were collected and examined (898 pairs of gloves). All participating surgeons ($n = 18$) and surgical nurses ($n = 10$) were right handed. The gloves were separated into 1 of the following 3 groups, according to duration of wear: 1–90 minutes, 91–150 minutes, and more than 150 minutes. We also recorded the randomized use of a hand cream containing a suspension of cornstarch and ethanol that is emulsified with polyoxyethylen-(1,5)–cocosalkylamin and contains carbopol as a thickening agent (Biosorb; Johnson & Johnson). This cream is a sterile product applied after scrubbing to reduce and absorb any excess moisture that remains on the hands. It was used by the wearers of 449 pairs of gloves (50% of all gloves collected). In addition, for each pair of gloves, we recorded the type of surgery performed, an anonymized identifier for the wearer, his or her position on the surgical team, and the amount of time the gloves were worn.

The surgical interventions were compared according to the level of mechanical exposure or stress involved, the kind of instruments used, and the tissue that was operated on. We divided the procedures into the following groups: laparos-

TABLE 1. Baseline Parameters for the Study of Glove Microperforation

Wearer used hand cream	No. of pairs of gloves tested, by duration of wear		
	⩽90 min	91–150 min	>150 min
No	150	149	150
Yes	149	150	150

NOTE. The hand cream contained a suspension of cornstarch and ethanol. For details about its formulation, see Methods.

copic procedures (eg, biliary duct surgery, appendectomies, and hernia repairs), minor abdominal surgery, moderate abdominal surgery, major abdominal surgery, vascular procedures, and cardiothoracic surgery.

The gloves used comprised Peha-taft comfort powder-free (Paul Hartmann), Peha-taft syntex (Paul Hartmann), Peha-micron plus (Paul Hartmann), Biogel (Molnlycke), and DermaPrene Ultra (Ansell Healthcare Europe). Microperforations were evaluated by use of the watertight test, in accordance with European Norm 455, part 1.[3] The gloves were analyzed as a pair; if 1 glove had a perforation, the pair was considered perforated. Furthermore, to compare the perforation rate for gloves worn during work that involved mechanical stress with the perforation rate for gloves not exposed to mechanical stress, we analyzed an additional 150 pairs of surgical gloves worn by students during a 90-minute lecture.

The statistical significance of the differences between groups was analyzed using the χ^2 test. In addition, the Fisher exact test was used, as appropriate. Associations between duration of wear and the percentage of gloves that was perforated were defined by correlations and partial correlations (Spearman ρ, controlling for the team member's function). The odds of perforation and the odds ratios (and 95% confidence intervals) for perforation given different durations of wear were calculated for each group. A difference was considered statistically significant if the P value was less than .05.

RESULTS

We analyzed 898 pairs of surgical gloves (Table 1). The mean duration of wear was 130 minutes (range, 3–420 minutes) (Figure 1*A*). A total of 171 surgical gloves (19.0%) were found to have undetected microperforations. The use of the hand cream had no influence on the perforation rate ($P = .889$) (Table 2).

TABLE 2. Influence of the Use of Hand Cream that Contained Cornstarch and Ethanol on Glove Microperforation Rate

Use of hand cream	No. of pairs of gloves perforated/ no. of pairs not perforated[a]
Yes	85/364
No	86/363
Total	171/727

NOTE. For details about hand cream formulation, see Methods.
[a] $P = .889$.

As the duration of glove wear increased, an increase in the rate of microperforation was observed. The rate increased from 15.4% (46 of 299 pairs perforated) when duration of wear was 90 minutes or less to 18.1% (54 of 299 pairs perforated) when the duration of wear was 91–150 minutes, and it increased further to 23.7% (71 of 300 pairs perforated) when the duration of wear was longer than 150 minutes (Figure 1*B*). There was a positive correlation between perforation rate and duration of glove wear ($P = .05$).

The rate of microperforation for gloves worn by surgeons was 23.0% (56 of 244 pairs perforated). The rate for first assistants was 19.0% (43 of 226 pairs perforated), and the rate for surgical nurses was 20.5% (53 of 259 pairs perforated). The difference between the 3 groups with respect to perforation rate was not statistically significant ($P = .167$) (Figure 2*A*). The odds of perforation depending on the team member's role in the operating room and the duration of glove wear were calculated (Tables 3 and 4). Overall, the mean rate of microperforation showed a dependence on time. Among first assistants and among surgical nurses, a correlation between perforation and duration of wear was observed (Spearman ρ, 0.017 and 0.032, respectively). However, we

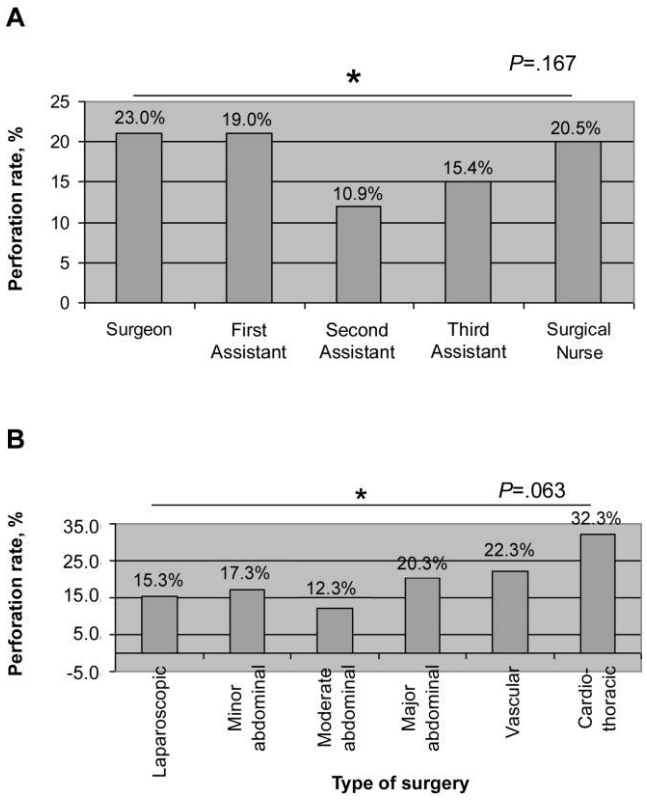

FIGURE 2. Glove microperforation rate stratified according to the surgical team member's role during the surgical procedure *(A)* and according to the type of procedure *(B)*.

TABLE 3. Odds of Perforation Stratified by Role of Surgical Team Member During Procedure and Duration of Wear

Role, duration of wear	Total no. of pairs of gloves	No. of pairs of gloves perforated/no. of pairs not perforated	Odds of perforation
Surgeon			
⩽90 min	112	20/92	0.22
91–150 min	83	24/59	0.41
>150 min	49	12/37	0.32
First assistant			
⩽90 min	91	14/77	0.18
91–150 min	78	11/67	0.16
>150 min	57	18/39	0.46
Second or third assistant			
⩽90 min	37	3/34	0.09
91–150 min	59	6/53	0.11
>150 min	73	10/63	0.16
Surgical nurse			
⩽90 min	59	9/50	0.18
91–150 min	79	13/66	0.20
>150 min	121	31/90	0.34
Mean			
⩽90 min	299	46/253	0.18
91–150 min	299	54/245	0.22
>150 min	300	71/229	0.31

observed no correlation between perforation and duration of wear for the second and third assistants or for surgeons (Spearman ρ, 0.177 and 0.079, respectively). Most of the perforations occurred during cardiothoracic surgical interventions (290 [32.3%] of 898) (Figure 2*B*), whereas moderate abdominal surgeries had the lowest incidence of perforation (110 [12.3%] of 898).

Subgroup analysis revealed that 20 (17.9%) of 112 pairs of gloves worn by surgeons and 14 (15.4%) of 91 pairs of gloves worn by first assistants had microperforations after the gloves had been worn for 90 minutes or less ($P = .638$). Surgical nurses experienced the same rate of glove perforation as first assistants (9 [15.3%] of 59 pairs of gloves perforated) ($P = .982$). Of 171 microperforations, 114 (66.7%) occurred in the left hand glove. The distribution of perforations on the left hand was as follows: index finger, 55 (32.2%); palm, 21 (12.3%); middle finger, 16 (9.4%); thumb, 14 (8.2%); ring finger, 5 (2.9)%; and little finger, 3 (1.8%). On the right hand, where 57 (33.3%) of the perforations occurred, the perforations were distributed as follows: middle finger, 20 (11.7%); thumb, 12 (7.0%); index finger, 11 (6.4%); palm, 8 (4.7%); ring finger, 3 (1.8%); and little finger, 3 (1.8%) (Figure 3).

In the comparison group of students who wore gloves that were not subjected to mechanical stress, only 1 (0.01%) of 150 pairs had a microperforation.

DISCUSSION

Surgical gloves must have an intact surface if they are to maintain the protective barrier between patients and surgical staff during surgical interventions. The results from our study clearly indicate an increase in the rate of microperforation, and consequently, a lack of protection when gloves are worn for longer than 90 minutes. Thus, periodic glove changes are

TABLE 4. Odds Ratio (OR) for Glove Perforation: Comparison of Various Periods of Wear, Stratified by Role of Surgical Team Member During Procedure

	OR (95% CI) for perforation		
Role	⩽90 min : 91–150 min	91–150 min : >150 min	⩽90 min : >150 min
Surgeon	0.53 (0.27–1.05)	1.25 (0.56–2.81)	0.67 (0.30–1.51)
First assistant	1.11 (0.47–2.35)	0.99 (0.42–2.30)	1.05 (0.47–2.34)
Second or third assistant	0.78 (0.18–3.33)	1.02 (0.35–3.00)	0.80 (0.21–3.12)
Surgical nurse	0.78 (0.31–1.97)	1.02 (0.50–2.10)	0.80 (0.35–1.82)

NOTE. CI, confidence interval.

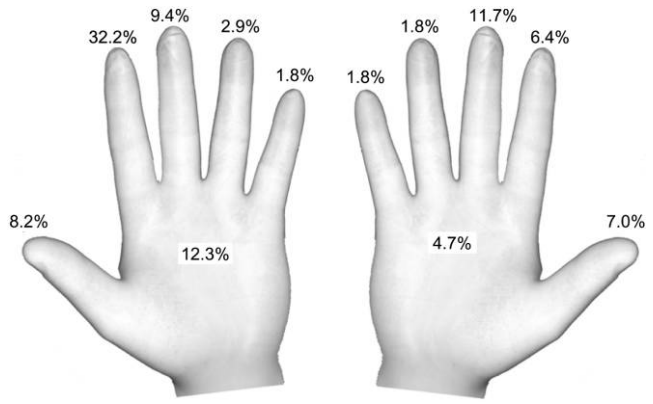

FIGURE 3. Distribution of glove microperforations on the hands of glove wearers.

crucial to minimize the risk of undetected microperforations and the potential transmission of infectious agents.

We observed a similar incidence of microperforation in gloves worn by surgeons and gloves worn by first assistants, which can be explained by the similar mechanical stress to which these gloves are exposed during surgery. Surprisingly, surgical nurses also had a similar risk of glove microperforation, which is attributable to the handling of sharp surgical instruments. These results are supported by findings published by Chapman et al.[8] Conversely, other studies suggest that the perforation rate for surgeons is higher than that for first assistants.[10,16,17] However, these trials addressed only specific types of surgery, such as cardiothoracic, pediatric, orthopedic, and oral surgery, which may explain the difference in findings, given that our trial included a broad variety of surgery types.

Data from trials performed recently have shown that the majority of glove perforations occur in the glove on the nondominant hand, which is generally the left hand.[8,13] This happens because the dominant hand holds the surgical instruments during the procedure, and the glove on the nondominant hand, which was the left hand for all participants in the present study, is particularly at risk for perforation while that hand is holding tissue or unloading a needle holder. The results of our study support these findings; we found that 67% of all perforations occurred in the left-hand glove, the index finger of which was at the highest risk for microperforation—31.3% of all left-hand perforations occurred there. Given these findings, it appears that it would be reasonable to improve the glove material, either by making it thicker or by making it more resistant to perforation. This is especially true for the glove worn on the nondominant hand, with special emphasis on the fingers that are most exposed, which are the left index finger and the right middle finger.

The results for the comparison group, who wore surgical gloves during a lecture and whose gloves were thus not subject to mechanical stress, showed only 1 perforation after 90 minutes of wear. We can therefore can deduce that all microperforations observed in the gloves of surgical team members occurred intraoperatively and were not the result of material fatigue. The result for the comparison group also provides evidence that the gloves used in this study were of good quality prior to use and that simply wearing the gloves was not associated with a statistically significant rate of perforation. Given that after 90 minutes of surgery, 46 (15.4%) of 299 pairs of gloves already had microperforations, it seems that it would be reasonable to suggest that gloves be changed sooner than after 2–3 hours of surgery, which is the wear time that has recently been recommended.[7] An earlier glove change would help to ensure that the medical staff and the patient are adequately protected against the transmission of infectious agents. The recommendation to change gloves appears to be particularly relevant for the surgeon, the first assistant, and the surgical nurse, given that in these 3 groups, microperforations caused by mechanical stress were detected after less than 90 minutes of glove wear (the microperforation rates for these 3 groups at this time point were 17.9%, 15.4%, and 15.3%, respectively). For second assistant and third assistants, we recommend a glove change after 150 minutes because our findings indicate that their gloves are exposed to less mechanical stress.

Double gloving is an alternative to improving the glove material and/or changing gloves after 90 minutes. Wearing a second pair of surgical gloves results in a statistically significant reduction in the incidence of microperforation in the innermost gloves.[4,18,19] Furthermore, a colored indicator glove could be used, so that a change in color could signal perforation and, if necessary, the glove could then be changed.[20]

In addition, we were able to show that the application of a hand cream that contained a suspension of cornstarch and ethanol had no significant influence on the rate of microperforation ($P = .890$). Therefore, the use of such creams cannot be supported as a means to prevent perforation. Further research, however, will reveal whether the application of this type of cream prior to donning surgical gloves might help reduce the concentration of microorganisms on the hands of the medical staff and thus indirectly reduce the risk of bacterial transmission to the surgical site via microperforation.

On the basis of the results presented here, we recommend that surgeons, first assistants, and surgical nurses directly assisting in the operating field change their gloves after 90 minutes of surgery. Given the lower rates of microperforation observed for second and third assistants, a glove change after 150 minutes of surgery seems to be sufficient for these groups to maintain a proper protective barrier. Improvement of the glove material should be considered for the specific parts of the glove that are at highest risk for microperforation, and double gloving remains an alternative to improving the glove material.

ACKNOWLEDGMENTS

Potential conflicts of interest. All authors report no conflicts of interest relevant to this work.

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