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Perforation rates in double latex gloves and protective effects of outer work gloves in a postmortem examination room

A STROBE-compliant study

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Abstract

Medical staff face the risk of exposure to blood-borne infectious agents during postmortem examinations. This study investigated the effectiveness of non-slip work gloves worn over 2 layers of surgical latex gloves (outer and inner gloves) as a means of reducing hand and finger injuries. Complete sets of outer and inner gloves worn during postmortem examinations were collected from participating forensic staff. Latex gloves were categorized into 2 groups based on the users' actions during the examination: the wearing group if the wearer wore their work gloves continuously without interruption, and the taking-off group if the wearer removed them at least once. Perforation rates, locations, and shapes were compared between these groups. Outer-glove perforation occurred significantly more often in the taking-off group (n = 102 pairs) than in the wearing group (n = 91 pairs) (30.4% vs 3.8%, $P < .001$). Inner-glove perforation occurred at rates of 2.0% and 0.5% ($P = .38$), respectively. The wearers did not incur hand or finger injuries. Perforation rates were similar between the dominant and non-dominant hands ($P = .18$). Regarding location, gloves were punctured most frequently at the thumb, followed by the index finger. Most examiners (85.6%) did not notice the perforation when the damage occurred. Therefore, we could not confirm that a specific operation within a set of plural operations affected the rate of perforation. Additionally, we could not prove a relationship between glove perforation and each operation performed with/without work gloves. The perforation appearances varied greatly in shape and size, suggesting multiple causes of perforation. The continuous (i.e., uninterrupted) wear of work gloves during postmortem examinations reduced the incidence of perforations in both latex glove layers and thus reduced the risk of hand and finger injury.

Abbreviations: AIDS = acquired immunodeficiency syndrome, AQL = acceptable quality limit, HBV = hepatitis B virus, HCV = hepatitis C virus, HIV = human immunodeficiency virus.

Keywords: double latex gloves, glove perforation, postmortem examination, risk of infection, work gloves

1. Introduction

Medical staff are exposed to a variety of biohazards during postmortem examinations, including blood-borne infectious agents. Notably, hepatitis B and C virus (HBV, HCV) carrier rates are higher in Japan than in other developed countries, with respective estimates of 0.9% to 1.1% and 1.5% to 1.8%.[1] Moreover, the rates of human immunodeficiency virus (HIV) infection and acquired immunodeficiency syndrome (AIDS) may be increasing (combined prevalence of 0.024% as of December 31, 2017).[2] Infections occurring during autopsy procedures frequently go unnoticed by medical examiners because the diseases require an incubation period ranging from a few months to several years until symptom onset. In some cases, these infections may even be fatal.

Gloves are the best way to prevent blood-borne infections. Surgical rubber gloves were introduced in 1889 by Dr. William Halsted.[3,4] After decades of use, however, medical staff noted the risk of glove perforation during both surgery[5,6] and postmortem examinations.[7,8] Double gloving refers to the practice of wearing 2 pairs of latex gloves for additional protection. Many studies have compared perforation rates between single and double gloving in general surgery, orthopedic surgery, and obstetrics/gynecology operation rooms. While single gloves and outer double gloves have similar perforation rates, inner double gloves are punctured significantly less often, which supports the recommendation of double gloving.[9–13] However, no previous studies have investigated perforation rates among multiple glove layers in postmortem rooms.

Our institution has long adopted double latex gloving as a standard infection control measure and also supports the practice

Editor: Babak Abdinia.

This research received no specific grants from funding agencies in the public, commercial, or not-for-profit sectors and was supported by research funds from the Kyoto Prefectural University of Medicine.

We presented data from 106 glove samples (53 pairs) at the 103rd Congress of the Japanese Society of Legal Medicine in 2016. The conference paper was published in Japanese but is not available online in any language. We confirm that this paper is not being submitted to any other journal.

The authors declare no conflicts of interest.

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Medicine (2019) 98:27(e16348)

Received: 16 January 2019 / Received in final form: 21 May 2019 / Accepted: 16 June 2019

http://dx.doi.org/10.1097/MD.0000000000016348

of wearing work gloves over latex gloves to enhance grip and prevent slippage. However, some of our staff occasionally remove the work gloves during postmortem examinations and claim that these gloves reduce their manual sensitivity and dexterity. We wondered whether work gloves simply impede the wearer's manual dexterity or also reduce the risk of physical injury to the hands and fingers to some extent. Therefore, we aimed to investigate whether work gloves actually provide benefits. In this study, we compared the outer- and inner-latex glove perforation rates between users who continuously wore work gloves throughout postmortem examinations and those who removed them at some point. Furthermore, we observed the shapes and locations of perforations to determine the procedure (s) or device(s) associated with a higher risk of perforation.

2. Materials and methods

The subjects were forensic pathologists and support staff involved in consecutive postmortem examinations in our department from September 2015 to March 2016. Each staff member wore 1 pair of work gloves (10-gauge, polyester, and cotton-poly blend) over 2 pairs of disposable latex gloves (Kimtech Pure G3, Kimberly-Clark Professional, Roswell, GA) during each examination (Fig. 1). The autopsies were performed in the conventional manner, and the participants were advised not to change the normal frequency with which they removed their work gloves. In the conventional manner, only 1 pathologist cut the organs with a long knife, while 2 support staff (usually non-pathologists, although a pathologist may perform this role in the absence of available non-pathological staff) shaved hair using a safety razor and opened the skull with a scalpel, raspatory, electric saw, and T-shaped chisel. Many other operations could be handled by either the operator or the support staff, including incising the skin and subcutaneous tissue with a scalpel, fastening the skin or organs with forceps, cutting ribs with a rib shear, removing organs with scissors or scalpels, trimming organs with scissors, cutting the intestinal lumen with scissors, opening the spine with electric saw and manual suturing with an S-shaped needle. Latex gloves worn during the procedure were collected immediately if the user noticed a perforation; if not, they were collected after the procedure was completed. All gloves were labeled by hand (left and right) and layer (outer and inner). Gloves were tested for punctures by submerging them in water and checking for any air leakage and the locations, as reported by Guo et al and Katz et al.[14,15] We did not use the water leakage test because in a pilot study, this test revealed the presence or absence of perforations in gloves but could not distinguish individual but closely associated perforations. The perforation sites were marked, and the gloves were cut into ~1-cm squares centered around each perforation. These squares were sandwiched between 2 glass slides and examined using optical microscopy to confirm the sizes and shapes of the perforations.

Figure 1. Work gloves and latex gloves.

Subjects were also surveyed immediately after each autopsy about whether they had removed their work gloves at any point. If so, they were additionally asked when and why they did so and whether they took off the left, right, or both gloves. Subjects were also asked whether they noticed any perforations during the procedure and, if so, under what circumstances. Ethical approval was waived because it was a study on the collected gloves after routine work. The personal conventional manner of autopsy was not intervened, and they immediately changed the perforated gloves as usual when they noticed them.

Fisher exact test was used for all comparisons. The statistical significance was set at a P value <.05. Microsoft Excel 2013 (version 2.21; Microsoft Corp., Redmond, WA) was used for the statistical analysis.

3. Results

3.1. Numbers of postmortem examinations and subjects

Of the 66 consecutive postmortems available for analysis, 63 examinations performed by a total of 6 individuals—3 forensic pathologists, and 3 support staff (4 right-handed, 2 left-handed) —were observed during the study period. Three postmortems were excluded from the analysis because the researcher was absent from the examination proceedings. In total, 193 sets of latex gloves were collected (386 pairs of outer and inner gloves; 772 in total) from all staff involved.

3.2. Numbers of perforations

Perforations were observed in 69/386 outer gloves (17.9%) and 5/386 inner gloves (1.3%), with respective totals of 97 and 5 holes (inner-glove perforations in the absence of damage to the corresponding outer gloves were excluded from the count, assuming that the perforations were not sustained as a direct result of the autopsy procedure). Wearers noticed 14/97 (14.4%) of the outer-glove perforations and attributed the damage to surgical equipment (scissors, scalpels, suture needles, vulsellum forceps, raspatory, corner of a ruler) and jagged bone spurs. The events causing the remaining 85.6% of perforations could not be confirmed. No participant experienced a hand or finger injury during the study period.

For analysis, the 193 sets were classified into 2 groups based on their wearers' actions during the exam: a wearing group in which members wore their work gloves continuously without interruption (n=91, 47%), and a taking-off group in which members removed one or more work gloves at least once (n=102, 53%). Individuals cited hair shaving, cutting of the intestinal lumen, and skin suturing as specific procedures that prompted glove removal. The following reasons were cited for the removal of work gloves: the presence of numerous shaved hairs that were stuck to the gloves, could not be washed away, and would contaminate the fields; a sense that it would be difficulty to wash the work gloves after cutting the bowel; and a sense that work gloves dull the senses in the hand and increase the difficulty of suturing. Therefore, the participants stated that they always removed their work gloves during the above-described operations.

Table 1 presents the perforation data by glove layer and group. Outer gloves were perforated at a significantly higher rate in the taking-off group than in the wearing group (30.4% vs 3.8%: $P<.001$). Inner gloves were perforated more frequently in the taking-off group, although this difference was not significant ($P=.38$). Outer gloves from the taking-off group contained as many as three perforations per glove, whereas those from the wearing group had a maximum count of one perforation per glove. Table 2 presents perforation data stratified by operators and support staff. In both groups, outer gloves were perforated at a significantly higher rate when removed ($P<.001$).

Seven of the 69 perforated outer gloves with a total of 7 holes belonged to the wearing group (mean, 1.0/glove). The remaining 62 gloves with a total of 90 holes belonged to the taking-off group (mean, 1.5/glove). Perforated inner gloves had an average of 1.0 hole/glove in both groups.

Table 1

Number of perforations of outer and inner gloves.

a) Outer gloves

Perforations	Wearing group (n=182)	Taking-off group (n=204)	P value*
No	175 (96.2%)	142 (69.6%)	<.001
Yes	7 (3.8%)	62 (30.4%)	
One perforation	7	40	
Two perforations	0	16	
Three perforations	0	6	

b) Inner gloves

Perforations	Wearing group (n=182)	Taking-off group (n=204)	P value*
No	181 (99.5%)	200 (98.0%)	.38
Yes	1 (0.5%)	4 (2.0%)	
One perforation	1	4	

* Fisher exact probability test.

3.3. Location of perforations in outer gloves

There was no significant difference in the perforation rate between outer gloves worn on the staff members' non-dominant hands and those worn on the dominant hands (40/193 vs 29/193, $P=.18$). Gloves worn on the non-dominant hand had an average of 1.4 holes (54 holes/40 gloves), compared with 1.5 holes on the dominant hand (43/29). On both hands, outer gloves were punctured most frequently at the thumb, followed by the index finger (Fig. 2).

3.4. Appearances and sites of perforations

Eighty-five perforations were observed using optical microscopy. The mean (±SD) and median diameters were 2.5 ± 3.4 and 1.3

Table 2

Number of perforations of outer gloves in operators and support staff.

a) Operators

Perforations	Wearing group (n=104)	Taking-off group (n=16)	P value*
No	103 (99.0%)	10 (62.5%)	<.001
Yes	1 (1.0%)	6 (37.5%)	

b) Support staff

Perforations	Wearing group (n=78)	Taking-off group (n=188)	P value*
No	72 (92.3%)	132 (70.2%)	<.001
Yes	6 (7.7%)	56 (29.8%)	

* Fisher exact probability test.

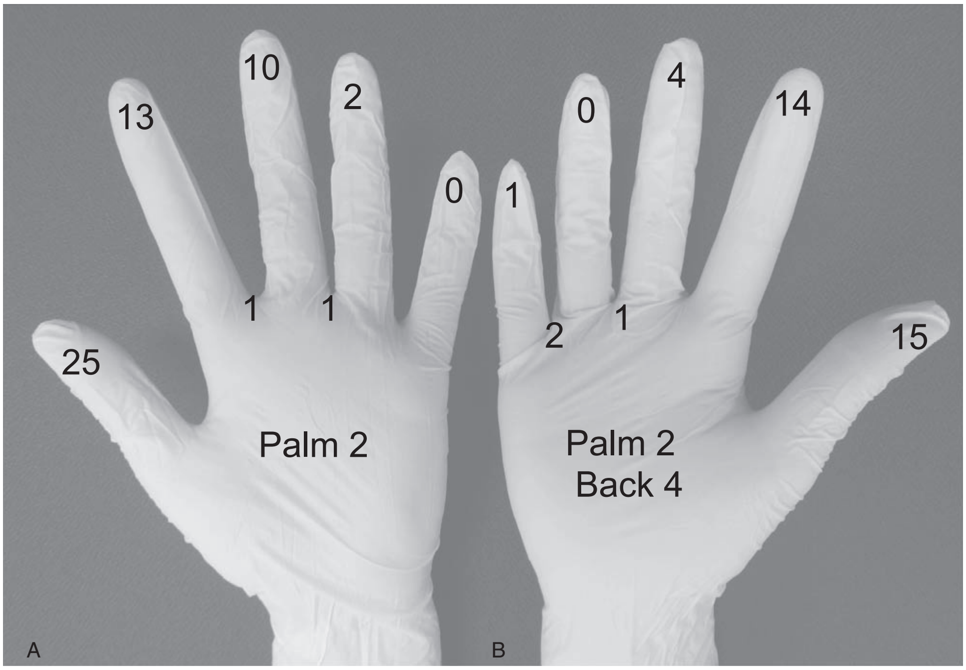

Figure 2. Location of perforations in outer gloves. A. Non-dominant hand. B. Dominant hand. Dominant hands of right- and left-handed people were counted in B.

mm, respectively. Perforations were grouped according to a novel classification scheme based on hole shape and margin appearance (e.g., jagged, smooth), and the sites are shown in Fig. 3. The perforation rates in categories IV and VI were higher on the dominant hand. Figure 4 shows typical punctures for categories I–VIII. As mentioned above, inner-glove perforations in the absence of outer-glove damage were not included in the above counts. However, we still evaluated these perforations visually and grouped them into an additional category for reference (IX).

4. Discussion

Our investigation found that outer gloves were perforated at a significantly higher rate in the taking-off group than in the

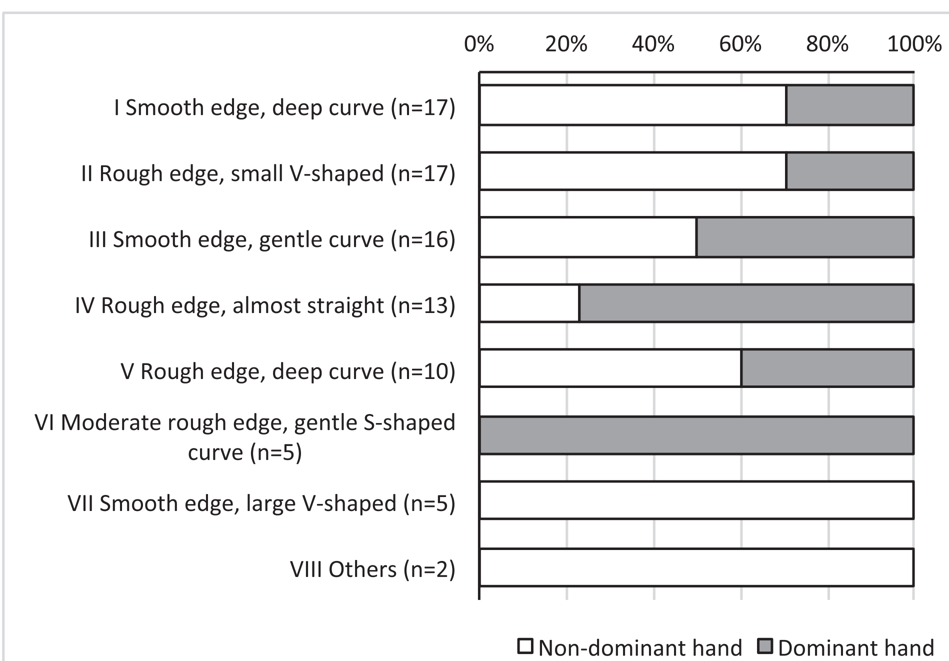

Figure 3. Appearances and sites of perforations in the outer gloves.

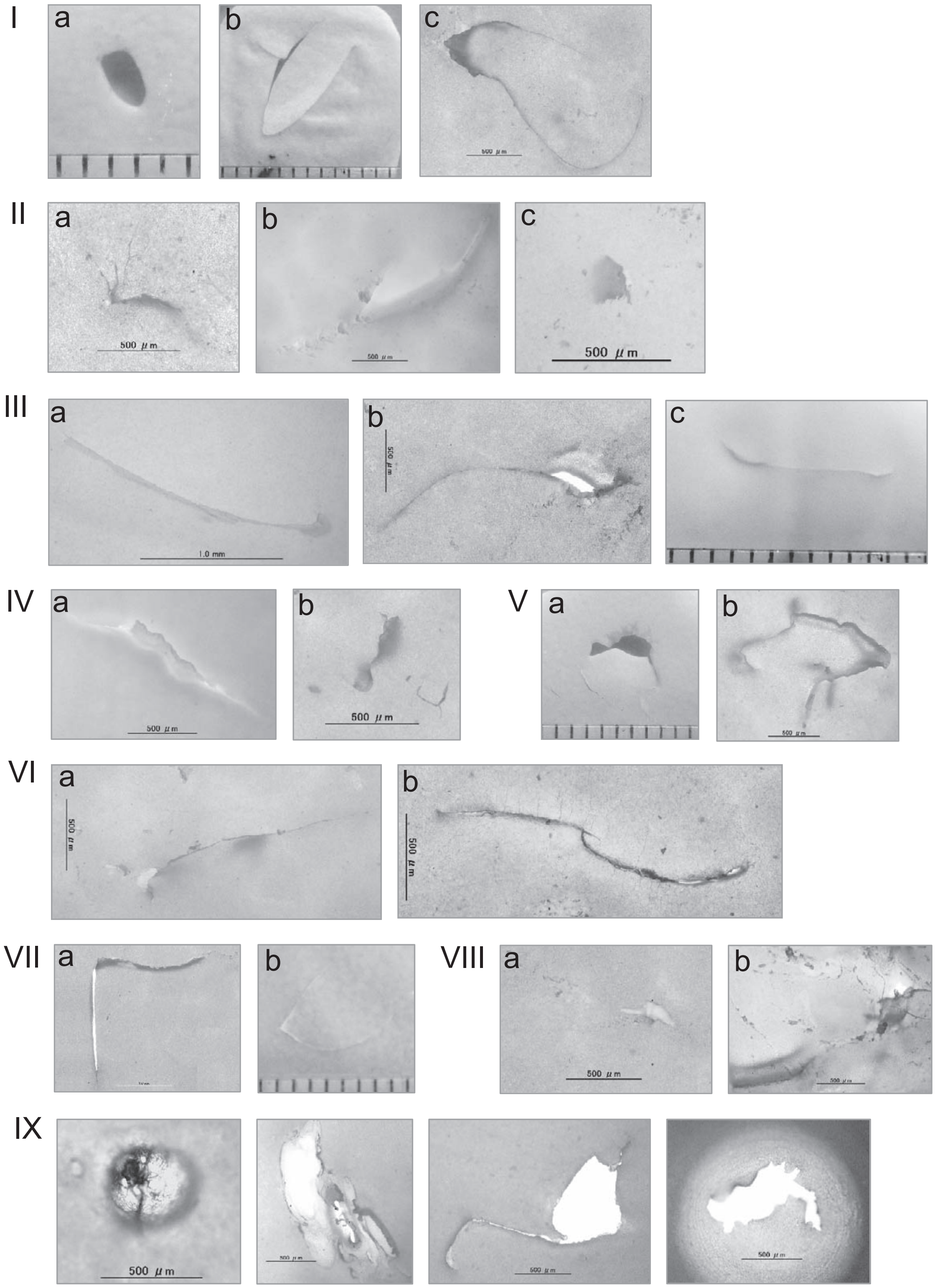

Figure 4. Representative appearance of each perforation in outer gloves. One interval of the scale in I, III, V, and VII represents 1 mm. The scale in IIIa and VIIa represents 1.0 mm. All other scales represent 500 μm. I. Smooth edge, deep curve. II. Rough edge, small V-shaped. III. Smooth edge, gentle curve. IV. Rough edge, almost straight. V. Rough edge, deep curve. VI. Moderate rough edge, gentle S-shaped curve. VII. Smooth edge, large V-shaped. VIII. Others. IX. Excluded perforations in inner gloves without simultaneous perforations in outer gloves.

wearing group ($P < .001$). Inner-glove perforations tended to occur more frequently in the taking-off group, although the difference was not significant. Moreover, the number of perforations per glove was higher in the taking-off group. The perforation rates were significantly higher among both operators and support staff in the taking-off group, possibly because most procedures were performed by both groups, and few tasks were group-specific. Initially, we aimed to confirm the relationships between glove perforation and each operation performed with/without work gloves. However, the participants failed to notice 85.6% of the glove perforations, and therefore the specific event that caused a perforation during a plural operation could not be confirmed. It also remained unclear whether the glove was perforated by the wearer or via the actions of another staff member. The small sizes of the perforations are a likely factor impeding their detection. Several clinical reports have stated that glove perforations go unnoticed in approximately 82% to 90% of cases.[10,16,17]

Therefore, we thought the shape and size might be useful for determining when and how the perforations occurred. After the study period, we punctured unused latex gloves using a variety of surgical instruments and other means as a basis for comparison. These mock perforations could be categorized by cause according to our novel classification scheme as follows: Ia-b, scissors; IIa-b, suturing needles; IIc, bone spurs; IIIa, thin-bladed tools (long knives, scalpels); IIIb, thicker-bladed scalpels; IVa-b, bone spurs; Va, vulsellum forceps; VIa, scissor blades and long knives; VIb, scissors; VIIa, scissors; VIIb, raspatory; VIIIa, suturing needles; and VIIIb, vulsellum forceps. Type Ic and Vb perforations could not be reproduced. While the cause of a given puncture could be roughly inferred based on its shape, this could not be differentiated in all cases. Figure 3 demonstrates higher IV and VI perforation rates in the dominant hand. Damage to non-dominant gloves was likely caused by surgical instruments held in the dominant hand, whereas damage to dominant gloves was likely due to incidental contact (e.g., with sharp tools or bone spurs) when moving the dominant hand. Goyal and Singh[18] found that non-dominant gloves worn during surgeries were punctured most often at the thumb and index finger and citing the holding of needles by hand as the most common cause. In our sample, although non-dominant gloves were punctured more than dominant gloves, this difference was not significant. Our findings may have been influenced by several considerations specific to postmortem examinations. For example, medical examiners directly retrieve and pick up scissors, scalpels, and other sharp instruments. This differs from operating rooms, where instruments are handed to surgeons by assistants. Moreover, wounds are never covered with towels during autopsies, whereas surgeons in operating rooms tend to cover the edges of wounds to prevent infection and hand damage.

We also considered the possibility that some perforations could have been caused by factors unrelated to the postmortem examination procedure itself. Quality control standards typically use the metric of acceptable quality limit (AQL), defined as the highest permissible ratio (%) of defective items in a sample. Many global standards prescribe an AQL of 1.5% for surgical latex gloves. For a concrete example, up to 3 defective gloves would be permissible in a sample of 200 gloves (100 pairs/operations). All gloves examined here were Kimtech Pure G3 latex gloves, which are medical grade (AQL 1.5). Prior to the study, we subjected 80 unused gloves (40 pairs) to a leakage test and noted perforation in only one; this defect rate (1.25%) was within the permissible range. Our study sample included 386 inner gloves, so the corresponding upper bound would be 5.8 holes. However, we still found 11 inner-glove perforations in the absence of outer-glove damage after the postmortem examinations (2.8%), which exceeded the acceptable range. Such damage could have been caused by wearers pulling too strongly on the gloves when putting them on or the catching of fingernails on the material. Essentially, this finding means that autopsy staff are exposed to an additional perforation risk when putting on latex gloves that exceeds the 1.5% defect rate permitted by quality-control specifications.

Inner gloves were perforated more frequently in the taking-off group, although this difference was not significant. However, the lack of significance might be attributable to the small number of perforations (e.g., 1 or 4). Perforations in inner gloves could allow infectious fluids to reach the bare skin directly, leading to a risk of infection. Various estimates place the risk of infection from a single needlestick or cut at 0.1% to 0.36% for HIV, 2.7% to 10% for HCV, and 30% for HBV.[19–21] Measures to prevent HBV infection include vaccines; however, approximately 10% of people do not respond to vaccination.[22] There have been scattered cases of HCV infection among healthcare workers both in Japan and abroad.[23–28] Moreover, 1 pathologist reportedly died from HIV infection in 2003.[29,30] The potential socioeconomic loss resulting from an infection cannot be ignored; once a medical staff member is infected, the disease will undermine their health in both the short and long terms and, in the worst cases, may lead to death. Some expenditures should be considered to prevent infection. Evidence from many clinical studies in operation rooms strongly supports the practice of double gloving for infection prevention.[9–13,30] The present study did not seek to compare single versus double latex gloving. Nonetheless, our observations of perforations even on the inner gloves in both groups suggest that double gloving should remain the preferred approach during postmortem examinations. However, the practice of double gloving lacks international consensus.[31] Double gloving is not the only measure available to reduce the risk of hand and finger injuries. Replacing gloves midway through a procedure, using dark-colored inner gloves, and using gloves made of cut-resistant materials are all recommended approaches to this end.[8,32–35] However, these measures can also be effectively combined with other, non-glove-related approaches, including placing sharp instruments in a sharps container immediately after use, not releasing spare scalpel blades by hand, handwashing after an examination, and ensuring examiners have been vaccinated for HBV.

The reasons cited by our subjects for removing their work gloves included contamination of the operative field by large amounts of hair or feces clinging to the work gloves and reduced working efficiency when suturing due to reduced sensation in the fingers. The former issue could be addressed by having the wearers replace their soiled work gloves with new ones. In the latter case, although the removal of work gloves allegedly increased the examiners' digital sensitivity and improved dexterity, no corresponding reduction in perforation rate to outer latex gloves was observed.

This study had several limitations. First, we did not record the duration of time that the gloves remained off during the examinations. Second, our analysis did not differentiate examinations based on cadaver or operation characteristics (e.g., adult vs child, multiple trauma vs none, and examination time). Third, we did not examine how wearing work gloves might have hampered working efficiency (e.g., prolonging the procedure). Fourth, we did not perform a cost/performance evaluation to compare glove prices with infection risks or related socioeconomic losses.

Our findings demonstrate that removing work gloves worn over 2 pairs of surgical gloves during a postmortem examination, even temporarily, increases the incidence of perforations to both the outer and inner latex gloves. Although the number of perforations noticed by staff was too small to enable a confirmation of when and how most perforations occurred during plural operations, differences in the shapes and sizes of the perforations suggested multiple causes of perforation. Accordingly, we strongly recommend the practice of double gloving during postmortem examinations and suggest that wearers should not remove their work gloves at any time during the procedure.

Acknowledgments

The authors are grateful to the support staff who participated in the study.

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