

Comparison of blood transmission through latex and nitrile glove materials

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Aims	To compare blood transmission through nitrile, single and double layer latex glove materials in simulated needlestick injuries.
Methods	Experiments involved nitrile, single and double layer latex gloves. A cutting suture needle was dipped into a specimen of blood and then immediately jabbed through the glove material into a cell containing saline. This process was repeated using the same blood specimen with different glove materials, plus a control experiment with no glove material. Other factors, including the angle, speed and depth of needle penetration, were controlled through the use of a testing machine. Following needle punctures, samples were taken from the suspension contained in each cell and examined under blind conditions. Median red blood cell (RBC) count was used as a measure of the quantities of blood transmitted through the different gloves.
Results	Nitrile glove material was associated with reduced transmission of RBCs compared to single layer latex. Double layer latex gloves provided better protection than single layer latex or nitrile gloves.
Conclusions	These findings suggest that in protecting against blood transmission in the context of needlestick injuries, single layer nitrile gloves are superior to single layer latex gloves, but double gloving with latex gloves provides better protection than either single layer latex or nitrile.
Key words	Blood-borne pathogens; health care worker; gloves; needlestick injuries; surgical.

Introduction

Blood-borne viruses (BBVs) are a recognized occupational hazard in different professions, particularly in health care workers (HCWs). Transmission of BBVs to HCWs is most commonly associated with percutaneous exposure to contaminated blood [1].

In managing the risk of BBV exposure, personal protective equipment, including medical gloves, plays an important role [2]. The 'wiping effect' of the glove material reduces the volume of blood inoculum during needlestick injury [3–5]. This reduces microbial transmission and consequently diminishes the risk of occupational infections [6,7].

To date, limited work has been undertaken and published to evaluate the wiping effect of medical gloves. A literature review indicates that the few studies that have been published are often of limited reliability owing to small numbers of measurements undertaken [3–5,8–10]. To address this paucity of information, this study

was conducted with the aim of comparing blood transmission through nitrile, single and double layer latex materials in needlestick injury.

Methods

Standardized methods were adopted to simulate needlestick injury and measure the protective effects of glove materials. Test gloves were selected from commonly used latex and nitrile gloves produced by the same manufacturer. 'Bodyguard®' powder-free latex examination gloves and Bodyguard® blue nitrile powder-free examination gloves were used as latex and nitrile test materials. The minimum thickness of the palm of both glove products reported by the manufacturer is 0.13 mm. Experiments were undertaken in a laboratory setting at the Surgical Materials Testing Laboratory (SMTL), Bridgend, UK.

Reproducible needle movements were achieved using a universal testing machine (Instron® model 3345), calibrated for angle, range and speed of harmonic motions.

A widely used straight cutting suture needle (Syneture SL643) was used. To carry out the tests, a needle was cut from the suture and mounted in the testing machine. All experiments were performed with the suture needle perpendicular to the glove material. The position and angle of the needle to the crosshead of the machine was checked using a mechanical guide. A new needle was used for each simulated needlestick injury.

In relation to glove tension, it has been proposed that biaxial stretch between 0 and 20% does not have a significant effect on wiping quality of glove material [5]. In this study, glove materials were stretched in two dimensions by 20% to represent operator use. This was achieved by the use of a mechanical frame with clips (Figure 1). Glove materials were labelled with pairs of parallel lines, vertically crossing in the centre of the test material. The distance between the lines was measured to ensure the glove material was equally stretched by 20% in both axes.

After stretching, the glove material was tightly clipped to the frame, which was then placed over a microbiology cell plate. The testing machine was used to drive needles into the blood specimen and then through the glove materials. The needle was dipped into a sample of anticoagulated horse blood to a depth of 5 mm. The contaminated needle was then immediately jabbed through the glove material at the desired speed and angled into a cell containing normal saline to the depth of 5 mm. The cell depth was 10 mm with a capacity of 0.1 ml. The cells were half

filled with 0.05 ml of normal saline, leaving a space between the glove and saline level. This space prevented saline from accidentally overflowing and washing the blood on the outer surface of the glove into the cell. The process was repeated using the same method and blood specimen with different glove materials, together with control experiments with no glove barrier. Simulated needlestick injuries were undertaken by the investigator and a technician who also loaded the testing machine to perform the simulations according to desired parameters.

Following needle punctures, cell plates were blinded by independent coding and then passed to the investigator (the lead author), who was trained by a microbiologist at SMTL. A standard sampling and cell counting technique was followed throughout. Two samples were taken from the suspension contained in each cell and examined microscopically using a haemocytometer slide to count red blood cells (RBCs) [11]. Cell plates were gently rotated before sampling to ensure RBCs were homogenously dispersed in the suspension. The number of RBCs were used as a surrogate measure of quantities of blood transmitted through glove materials.

A pilot study was undertaken to ensure that the needlestick apparatus performed as described above. The values observed in the pilot study were used to estimate the variation of data and to determine an appropriate statistical method of analysis.

For each glove material, 50 simulated needlestick injuries were undertaken. Each glove type was then compared

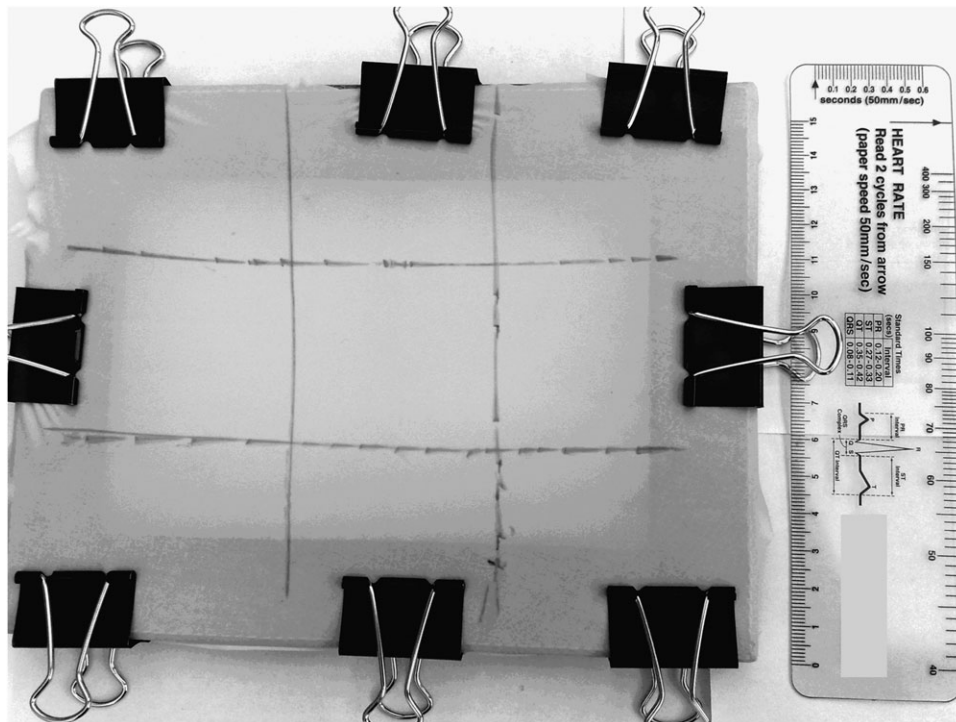


Figure 1. Glove stretching frame. The glove material is bi-axially stretched to represent the skin-tight fit to the user's hand.

with a set of 25 needlestick simulations with no glove as a control. The number of simulated needlestick injuries was determined from pilot study data to ensure that the power of the study was at least 80%.

RBCs were assumed to be randomly dispersed in normal saline, and also to be randomly scattered into the divisions of the haemocytometer slide. The Kolmogorov–Smirnov and Shapiro–Wilk tests of normality indicated that assumptions of normality were invalid and therefore non-parametric tests were undertaken.

Groups were compared using a Kruskal–Wallis non-parametric analysis of variance. Where there was evidence of a difference between groups, this was followed by Mann–Whitney rank sum tests for comparing paired independent samples. Three pairwise tests were undertaken for comparing the three glove material combinations with the controls. In addition, glove materials were separately tested against one another. RBC counts for the single layer latex material were therefore compared both with the double layer latex and the nitrile glove material. The values for the nitrile material were in turn compared to those of the double layer latex. No assumption was made as to whether one type of glove was superior to another such that two-tailed tests were used to compare each glove type against another.

In total, six pairwise comparisons were undertaken to compare different glove materials with controls and each other. The Bonferroni correction was applied to the statistical significance level in order to ensure the cumulative type 1 error remained <0.05. The standard significance level of 0.05 was divided by the number of comparisons as the criterion for significance ($0.05/6 = 0.008$) and the results of any of the six independent tests were considered significant when $P < 0.008$. When a difference was statistically significant, an approximate effect size (r) was calculated to standardize the magnitude of the effect observed. The Z score was converted into estimated effect size using the following equation in which N is number of observations [12]:

$$r = Z / \sqrt{N}$$

An estimated effect size >0.3 was considered a ‘medium’ effect, with a level of 0.5 as the threshold for a ‘large’ effect [12]. Statistical analysis was undertaken using SPSS version 15.

Results

Measures of central tendency and statistical dispersion are given in a box-whisker diagram together with the medians and interquartile ranges in Figure 2.

Table 1 summarizes minimum and maximum values observed together with interquartile range and mean rank.

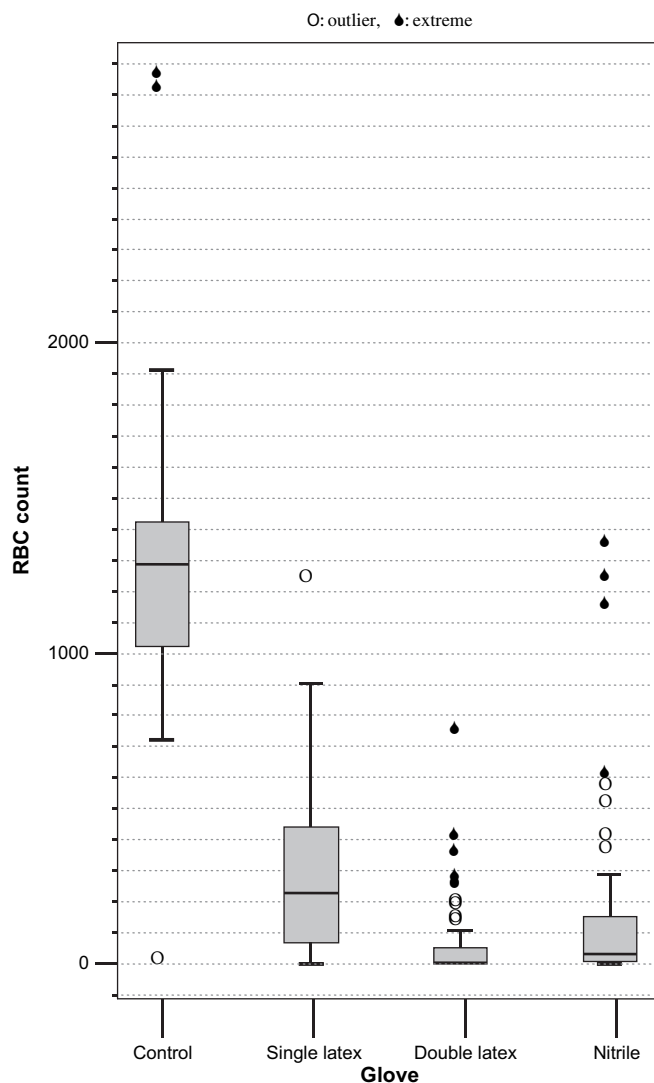


Figure 2. Box-whisker diagram of RBC counts for test gloves and controls.

Table 1. Distribution of values (RBC counts) and ranked data for glove types and controls

Glove	<i>n</i>	Minimum	Maximum	Percentiles		
				25th	50th (median)	75th
Single latex	50	0	1231	64	229.5	442.5
Nitrile	50	0	1342	6.75	33.5	156.5
Double latex	50	0	737	0	3	57
Control	25	0	2852	1081	1288	1432

The Kruskal–Wallis test (non-parametric analysis of variance) demonstrated that RBC counts were significantly different amongst the groups ($P < 0.001$).

In spite of a wide range of values, test gloves were associated with smaller medians than the control group.

All glove materials tested were associated with significant and large reductions in RBC count ($P < 0.001$, $r > 0.5$).

From Figure 1 and Table 1, the median RBC count for the nitrile material appears smaller than the median for the single layer latex material. Despite substantial variability of values, these two medians are higher than that for the double layer latex glove. Pairwise Mann–Whitney tests were carried out to investigate the difference between each glove type. Estimated effect sizes (r) were again used to compare the magnitudes of the observed differences. The findings in Table 2 can be summarized as follows:

- The observed RBC counts for the nitrile material (median = 33.5) were significantly lower than the RBC counts for the single layer latex material (median = 229.5), $U = 781.5$, $P < 0.001$. The magnitude of the effect was small to medium ($r = 0.323$).
- The values for the single layer latex material (median = 229.5) were significantly higher than that for the double layer latex material (median = 3), $U = 502$, $P < 0.001$. The additional layer of latex had a medium to large effect on reducing number of RBCs ($r = 0.518$).
- The number of RBCs for the double layer latex glove (median: 3) was significantly lower than the RBC count for the nitrile material (median: 33.5), $U = 788.5$, $P < 0.001$. The size of effect was small to medium ($r = 0.319$).

Discussion

Our study found that the wiping quality of nitrile glove material was modestly superior to single latex material and that double layer latex gloves provided better protection than single layer latex and nitrile gloves. To the authors' knowledge, this is the first experimental study using a computer-controlled system to produce simulated needlestick injury.

Nitrile is associated with promising biomechanical performance and has been recommended as an alternative to latex [13]. Nitrile is made by polymerizing monomers, which contain triple carbon–nitrogen bonds (nitrile functional group). Natural rubber latex is a diene polymer made from monomers containing carbon–carbon double

bonds which crosslink one polymer to another. This provides latex with a superior elastic character to most synthetic rubber materials. The dynamic properties of latex produce a greater ability to reseal puncture holes and significantly reduce the leakage of fluid after the material is perforated with a needle [14]. The existing evidence shows that majority of glove perforations go undetected [15]. It is therefore likely that nitrile gloves, which have less ability to reseal puncture holes, would carry a greater risk of blood transmission through perforation.

It has also been suggested that this inherent quality of latex could offer a better wiping effect. However, the findings of this study do not support this view. Due to its different characteristics, nitrile material is more resistant to abrasion and puncture than latex [13]. Besides its other physical and mechanical properties, the greater stiffness and the coarse surface of nitrile may influence the wiping effect.

Our literature search shows that there is limited published evidence on the wiping effects of latex and nitrile gloves in simulated injury. In the study by Mast *et al* [3], a limited number of observations were undertaken and the power of the study was low. Their experiments did not detect a statistically significant difference between the wiping effect of latex and of nitrile materials. In contrast, the current findings show a statistically significant difference between latex and nitrile gloves in needlestick simulations with a suture needle.

Cumulative evidence supports the practice of 'double gloving' [16]. There is also interest and debate on the selection of latex glove substitutes [17]. The difference observed in this study between single and double latex gloves in needlestick injury with a cutting suture needle is consistent with previous studies [10]. Additional protection associated with double latex was reported by Bennett *et al*. [10]. This was also supported by an experiment with an enzyme solution described by Lefebvre *et al*. [11]. However, two other studies by Bricout and Krikorian suggest double layer latex gloves offer little benefit over single layer latex gloves [5,18]. The study design and methodology of these experiments probably influenced the results. Given the mechanical characteristics of blood removal by barrier gloves, an enhanced wiping effect of double layer gloves is likely. 'Double gloving' is reportedly associated with diminished tactile

Table 2. The Mann–Whitney analysis of glove comparisons and estimations of effect size

Glove type:	Single latex versus control	Nitrile versus control	Double latex versus control	Single latex versus nitrile	Single versus double latex	Nitrile versus double latex
Mann–Whitney U	60	81	45	781	502	788
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Effect size (r)	0.73	0.71	0.76	0.32	0.52	0.32

sensation and reduced dexterity. On the basis of objective measurements, the perceived impact of double layer gloves on dexterity does not appear clinically significant [16].

This study has a number of strengths. First, the computer-controlled system provides reproducible simulated needlestick injury with controllable parameters. Second, the large number of observations for each experimental condition provides sufficient statistical power to control type II errors and detect differences between glove materials.

We acknowledge that this study has some limitations. Firstly, in the present work, only non-sterile gloves were tested. Although it is plausible to extrapolate the results of the present paper to sterile gloves of comparable thickness, the wiping effect of sterile gloves may be an area that deserves further investigation.

Secondly, this study used a specimen of horse blood as an available alternative to human blood for the test contaminant and made use of RBC count as a surrogate marker of viral transmission. Comparisons have shown similarities between haematocrit and whole blood viscosity in horses and humans [19], which are expected to influence its adherence to a needle or glove [9]. Moreover, in the present study, comparisons were made using the same sample of blood throughout the experiment and it is therefore considered unlikely that the use of horse blood significantly influenced the results. Experiments using human blood with techniques for measuring BBV transmission are recommended for future studies.

Free viruses such as hepatitis B virus and hepatitis C virus are randomly dispersed in samples of blood from infected patients. HIV viruses can be carried in infected circulating cells (e.g. T cells), which are also distributed at random in a blood specimen. It is therefore reasonable to conclude that the volume of blood inoculum transmitted correlates with the number of viral particles, which is a major determinant of the risk of infection.

From the findings of this experiment, greater protection is expected with two layers of latex compared to one layer latex or nitrile gloves, supporting the practice of double gloving in high risk medical procedures.

Existing evidence tends to suggest that nitrile gloves have less ability to reseal puncture holes and in theory, this would make the use of nitrile gloves less advantageous [14]. However, the present study indicates that the wiping quality of nitrile glove material is modestly superior to single latex material.

Future studies should attempt to represent actual needlestick injuries in clinical practice with methods measuring viral burden of BBVs transferred. Further investigations with double nitrile gloves are recommended to indicate whether these are equivalent or superior to double latex material.

Key points

- There is limited evidence to assess the effectiveness of different glove materials in reducing the risk of transmission of blood-borne viruses associated with needlestick injury.
- In the context of protecting against blood-borne viruses transmission in needlestick injuries, single layer nitrile gloves seem to be modestly superior to single layer latex gloves.
- Double gloving with latex gloves provides better protection against red blood cell transmission in needlestick injuries than either single layer latex or nitrile.

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