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Risk assessment of accidental exposure of surgeons to blood during orthopedic surgery. Are we safe in surgical gloves?

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Abstract

Aim. To analyze tears in sterile surgical gloves used by surgeons in the operating theatre of the Trauma and Orthopedic Surgery Department, Copernicus Memorial Hospital, Łódź, Poland

Materials and Method. This study analyzes tears in sterile surgical gloves used by surgeons by ICD-9 and ICD-10 codes. 1,404 gloves were collected from 581 surgical procedures. All gloves were tested immediately following surgery using the test method described in Standard EN455–1 (each glove was inflated with 1,000 ± 50 ml of water and observed for leaks for 2–3 min.).

Results. Analysis of tears took into consideration the role of medical personnel (operator, first assistant, second assistant) during surgical procedure, the type of procedure according to ICD-9 and ICD-10 codes, and the elective or emergency nature of the procedure. The results of the study show that these factors have a significant influence on the risk of glove tears. Significant differences were observed in tear frequency and tear location depending on the function performed by the surgeon during the procedure.

Conclusion. The study proved that the role performed by the surgeon during the procedure (operator, first assistant, second assistant) has a significant influence on the risk of glove tearing. The role in the procedure determines exposure to glove tears. Implementing a double gloving procedure in surgical procedures or using single gloves characterized by higher tear resistance should be considered.

Key words

Surgical gloves, glove tears, orthopedic surgery, double gloving

INTRODUCTION

Glove defects are the subject of research in various disciplines, ranging from agriculture [1] to healthcare. Surgical gloves offer effective protection against infections as long as their protective layer remains intact. The US Centers for Disease Control and Prevention (CDC) publishes data on medical personnel infected with HIV [2]. The need to protect medical personnel against blood-borne infections has been discussed in some publications [3, 4, 5]. Double gloving is recommended in the case of high-risk procedures involving patients with confirmed HIV, HCV, or HBV virus infection, as a damaged single glove may lead to infecting a member of the surgical team [6]. Some authors have also analyzed glove defects in the context of preventing surgical infections [7, 8]. Suttie and Al-Ani consider HIV-, HBV- and HCV-positive patients to be high-risk patients and recommend using a separate procedure for them [9, 10]. Papuas et al. analyzed the influence of a single blood-borne disease on the risk of exposure of medical personnel [11]. Most research on glove failure concentrates on punctures [12, 13, 14]. There is very little work done on glove tears [15], a type of glove failure occurring during some orthopedic procedures. The surgeons working at the Trauma and Orthopedic Surgery Department wear gloves both to minimize the risk of infecting the patient and for their own protection.

MATERIALS AND METHOD

The study was conducted between 1 October 2012 – 31 November 2013 in the operating theatre of the Trauma and Orthopedic Surgery Department, Copernicus Memorial Hospital in Łódź, Poland. All the surgeons and surgical assistants expressed their consent to take part in the study. All medical personnel participating in the study (n=20) were right-handed. A water leak test was performed immediately after surgical procedures by doctors who were directly involved in them.

Surgical teams consisted of an operator and a varying number of assistants, depending on the type and complexity of a given procedure. All the gloves used by the surgeons (operators, first, second, and third surgical assistants) during surgical procedures in the operating room of the hospital in Łódź.

The gloves used in the Łódź hospital investigated in this study were CE-certified and purchased through a tendering procedure. The gloves were manufactured by Sempermed

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or Mercator Medici. The study was open and prospective. Randomization was carried out at the point of issuing gloves to the team. The hospital did not implement a double gloving procedure for high-risk surgical procedures. Wearing double gloves was an individual decision made by the surgical personnel.

During the study, it was noted whether a given pair of gloves was the initially worn pair or a replacement pair used because of damage or defect of the initially worn pair. Analysis took into account the manufacturer and type of gloves; assistant or operator work time; type of procedure; duration of procedure (under or over 2 hours); elective or emergency nature of the procedure; role of the surgeon (operator or assistant), work experience, complications during the procedure, and other factors. Analysis also included information about whether a glove tear (perforation) was noticed during surgery or not. In order to obtain accurate data, gloves were collected and tested immediately following surgery and the results were recorded. Throughout the study, 1,404 gloves were collected (56 double and 1,348 single pairs from 581 surgical procedures). 93 latex gloves were excluded from the water leak test because of tears made during the procedures, which left 1,367 gloves available for analysis. All gloves were tested immediately following surgery using the test method described in the Standard EN455–1 (each glove was inflated with 1,000 ± 50 ml of water and observed for leaks for 2–3 minutes) [16].

The new elements in the presented study included analysis of tears by ICD-9 and ICD-10 codes and the role of medical personnel (operator, first and second assistant). The number of tears was recorded and their location marked on a diagram. As a control, unused gloves of each type were inflated with water in the manner described above, and monitored for defects (100 unused gloves from each manufacturer were tested as a control group).

Ipsilateral tears of single or double gloves (internal or external) leading to blood contamination were regarded as significant. Any type of skin contamination with blood was called an exposure. If a glove was noticed to be perforated or torn, it was immediately replaced with another glove of the same type. The size of gloves worn (whether single or double) depended on the individual preferences of the surgical team members.

All calculations were carried out using R for Windows, version R-2.15.3. P values of 0.05 or less were considered significant.

Data. Data on the type of and nature of surgical procedures, the number of operated patients, number of doctors, assistants, gloves, punctures and tears, duration of procedures, tears and puncture locations, names of doctors performing surgery, etc., were gathered on a spreadsheet.

The study analyzed 581 orthopedic procedures with the following structure by ICD-9 and ICD-10 codes (Tab. 1).

This paper presents tear rates by ICD-9 and ICD-10 codes only for procedures performed more than 10 times during the period of study (Tab. 2).

Table 1. Percentage share of the first 10 procedures in accordance with ICD-9

ICD-9	Description	No. of procedures	Percentage share	Percentage share of the first 10 procedures
79.15	Closed reduction of fracture with internal fixation, femur	92	15.83%	15.83%
81.51	Total hip replacement	37	6.37%	22.20%
80.26	Arthroscopy of knee	36	6.20%	28.40%
78.62	Removal of implanted devices from bone. humerus	35	6.02%	34.42%
79.36	Open reduction of fracture with internal fixation. tibia and fibula	31	5.34%	39.76%
81.54	Total knee replacement	30	5.16%	44.92%
79.32	Open reduction of fracture with internal fixation; radius and ulna	26	4.48%	49.40%
04.43	Release of carpal tunnel	22	3.79%	53.18%
81.52	Partial hip replacement	22	3.79%	56.97%
79.16	Closed reduction of fracture with internal fixation. tibia and fibula	14	2.41%	59.38%

Table 2. Percentage share of the first 10 procedures in accordance with ICD-10

ICD-10	Description	No. of procedures	Percentage share	Percentage share of the first 10 procedures
S72	Fracture of femur	127	21.86%	21.86%
S82	Fracture of lower leg. including ankle	72	12.39%	34.25%
M23	Internal derangement of knee	47	8.09%	42.34%
M16	Osteoarthritis of hip	35	6.02%	48.36%
S52	Fracture of forearm	35	6.02%	54.39%
S42	Fracture of shoulder and upper arm	32	5.51%	59.90%
M17	Osteoarthritis of knee	32	5.51%	65.40%
T84	Complications of internal orthopedic prosthetic devices. implants and grafts	25	4.30%	69.71%
G56	Mononeuropathies of upper limb	22	3.79%	73.49%
D16	Benign neoplasm of bone and articular cartilage	19	3.27%	76.76

DISCUSSION AND RESULTS

In contrast to studies by [17], where the results were given separately for major and minor surgeries, this study presents its findings by ICD-9 and ICD-10 codes. This allowed for more exact comparison of the presented results with other studies on glove punctures and tears. Additionally, 3 categories of surgical assistants (first, second, and third assistants) were utilized because of the differences in tear rates between them.

581 orthopedic surgeries were involved, out of which 34.94% (n_1=203) were elective and 65.06% (n_2=378) were emergency, and identified 93 glove tears: 35 in elective procedures and 58 in emergency procedures (Tab. 3).

In the population analyzed, no tears or punctures were found in the case of third surgical assistants, whereas statistically significant differences in glove tear rates were observed between operators performing emergency and elective procedures. The results of the presented study are similar to those obtained by Korniewicz et al. [18], who reported a 6.8% defect rate in latex gloves during orthopedic procedures. Laine and Aarnio observed an 8.54% glove puncture rate during trauma and orthopedic surgeries [12].

Table 3. Tear rates by type of procedure (elective / emergency) and role of medical personnel

Type of procedure	Number of procedures	Structure of procedures [%]	Tear rates [%] Total	Operator	I Assistant	II Assistant	III Assistant
Emergency	378	65.06%	6.76%	12.43%	2.93%	0.00%	0.00%
Elective	203	34.94%	6.41%	10.84%	5.42%	2.13%	0.00%
Total	581	100.00%	6.62%	11.88%	3.8%	1.27%	0.00%

The above difference may be the result of a different structure of surgical procedures examined in those studies.

The structure of the gloves used was as follows: 356 Sempermed gloves and 1,048 Mercator Medical gloves. The overall tear rate was 6.62% (93/1404), the tear rate for elective surgeries was 6.41%, and that for emergency surgeries 6.76% (Tab. 4).

Table 4. Structure of glove tears, by manufacturer

Type of procedure	Structure of gloves used, by manufacturer [%] Mercator Medical	Sempermed	Glove tear rates, by manufacturer [%] Mercator Medical	Sempermed
Emergency	76.46%	23.54%	7.16%	5.45%
Elective	71.79%	28.21%	5.36%	9.09%

A higher tear rate was observed in Sempermed gloves during elective surgeries. The tear rates by manufacturer are as follows: Mercator Medical – 6.49% and Sempermed – 7.02% (68 and 25 gloves, respectively). In terms of the nature of procedures, 546 gloves were used in elective surgeries and 858 gloves in emergency surgeries.

Table 5 shows tear rates by the nature (elective or emergency) and length of procedure. Because there were not many cases of procedures that took more than 2 hours, only data for those lasting up to 2 hours are presented in the Table.

Table 5. Tear rates by manufacturer and nature of procedure (elective or emergency) for procedures lasting up to 2 hours

Manufacturer	Elective [%]	Emergency [%]
Mercator Medical	4.83%	6.37%
Sempermed	7.20%	4.89%

The data in Table 6 were aggregated by ICD-9 code to 2 decimal places. In the process of aggregation, all 3-digit ICD-9 procedures were taken into account, including those in which tears did not occur.

Because of the small number of procedures performed (less than 10), the following ICD-9 groups (in which glove tears occurred) are not included in the Table: 00.70, 00.80, 77.56, 77.42, 77.63, 78.42, 79.06, 79.13, 79.31, 79.35, 81.81, 83.85, 84.86, 86.22, 97.18.

Table 7 presents glove tears by ICD-10 code and the role of medical personnel during the procedure.

Note: ICD-10 codes include only those procedures where glove tears occurred and which were performed more than 10 times

The structure of glove tears (n=93) was as follows: 69 tears occurred in operators' gloves (74.19% of all tears), 22 in first assistants' gloves (23.66%), and only 2 in second assistants' gloves (2.15%). The tear rate was higher in the case of emergency surgeries – 6.76%, and lower in elective surgeries – 6.41%.

Table 6. Tears by ICD-9 code and the role of medical personnel

ICD-9 code	ICD-9 description	Glove tear rates irrespective of the role of medical personnel [%]	Glove tear rates – Operator [%]	Glove tear rates I Assistant [%]	Glove tear rates II Assistant [%]	No. of procedures
78.24	Limb shortening procedures. carpals and metacarpals	15.38%	15.38%	15.38%	0.00%	13
78.62	Removal of implanted devices from bone. humerus	4.29%	5.71%	2.86%	0.00%	35
79.11	Closed reduction of fracture with internal fixation. humerus	4.17%	8.33%	0.00%	0.00%	12
79.15	Closed reduction of fracture with internal fixation. femur	8.70%	13.04%	4.40%	0.00%	92
79.16	Closed reduction of fracture with internal fixation. tibia and fibula	14.29%	21.43%	7.14%	0.00%	14
79.32	Open reduction of fracture with internal fixation; radius and ulna	9.62%	19.23%	0.00%	0.00%	26
79.36	Open reduction of fracture with internal fixation. tibia and fibula	11.11%	19.35%	3.23%	0.00%	31
79.39	Open reduction of fracture with internal fixation; other specified bone	15.00%	35.71%	7.69%	0.00%	14
81.51	Total hip replacement	6.08%	18.92%	5.41%	0.00%	37
81.52	Partial hip replacement	5.68%	13.64%	9.09%	0.00%	22
81.54	Total knee replacement	10.00%	20.00%	10.00%	0.00%	30

Of the 56 double gloves used, 18 were torn, and 12 of these cases involved both internal and external tears.

The highest tear rate, irrespective of the role performed by the doctor on the surgical team, was observed for following procedures: Fracture of shoulder and upper arm – 12.31%, Fracture of lumbar spine and pelvis – 11.90%, Acquired deformities of fingers and toes – 11.11%, and Osteoarthritis of knee – 10.53% (Tab. 7). In fractures of the lumbar spine and pelvis surgery, the operator's gloves were torn in 28.57% of the cases, which means that in one out of 4 procedures the operator's hands came in direct contact with the patient's blood. A significantly higher tear rate was observed in procedures lasting longer than 120 minutes: 29.03% for Mercator Medicinale and 14.89% for Sempermed. The tear rate was high in operators and first

Table 7. Glove tears by ICD-10 code and role of medical personnel during the procedure

ICD-10 code	ICD-10 description	Glove tear rates irrespective of the role of medical personnel [%]	Glove tear rates – Operator [%]	Glove tear rates I Assistant [%]	Glove tear rates II Assistant [%]	No. of procedures
D16	Benign neoplasm of bone and articular cartilage	4.65%	10.53%	0.00%	0.00%	19
M16	Osteoarthritis of hip	5.00%	17.14%	2.86%	0.00%	35
M17	Osteoarthritis of knee	10.53%	18.75%	9.38%	3.23%	32
M20	Acquired deformities of fingers and toes	11.11%	11.11%	11.11%	0.00%	18
S32	Fracture of lumbar spine and pelvis	11.90%	28.57%	7.69%	0.00%	14
S42	Fracture of shoulder and upper arm	12.31%	21.88%	3.13%	0.00%	32
S52	Fracture of forearm	8.57%	17.14%	0.00%	0.00%	35
S72	Fracture of femur	7.64%	13.39%	4.76%	0.00%	127
S82	Fracture of lower leg. including ankle	10.34%	15.28%	5.56%	0.00%	72
T84	Complications of internal orthopedic prosthetic devices. implants and grafts	6.67%	4.00%	12.00%	7.69%	25

Note: ICD-10 codes include only those procedures where glove tears occurred and which were performed more than 10 times

assistants wearing Mercator Medicinale gloves – 45.45% (5 tears in 11 procedures) and 36.36% (4 tears in 11 procedures), respectively. The corresponding statistics for Sempermed gloves were 33.33% for operators and 13.33% for first assistants. Due to the small number of these procedures, more data should be obtained and the results verified.

The most frequent tear location was the index finger – 34 tears for the right hand and 26 for the left. The second most frequent tear location was the right thumb – 25 tears. As many as 54.84% of tears were observed on the non-dominant right hand and 39.78% on the left hand. In 2 cases (5.38%), tears occurred on both hands of the operator or first assistant.

The model used to present glove tears was developed by Ersozlu *et al.* for punctures [17]. In the presented study, the Table proposed by him was extended with additional columns to include ICD-9 and ICD-10 codes and the role of medical personnel during the procedure. Table 8 presents tear locations for operators.

Table 8. Tear locations in operators' gloves

	Number of tears	
Tear location	Right glove	Left glove
Thumb	20	7
Index finger	25	23
Middle finger	3	5
Ring finger	0	0
Little finger	0	0
Palm	2	2

Note: some tears occurred in more than one location

Analysis of the types of procedures presented in Tables 1 and 3 shows that in some of them there were no glove tears, e.g., in 04.43 – release of carpal tunnel.

Glove tears occur frequently during orthopedic surgeries such as:

a) total hip replacement;
b) total knee replacement;
c) open reduction of fracture with internal fixation; other specified bone;
d) limb shortening procedures, carpals and metacarpals, e) closed reduction of fracture with internal fixation, tibia and fibula.

If gloves are torn during such procedures, they no longer protect the medical personnel or the patient. Changing the type of gloves or using inserts between them to protect the integrity of internal gloves should be considered. Preventive procedures concerning exposure to patients' blood should be modified according to recommendations of Centers for Disease Control and Prevention (CDC) [19, 20, 21].

CONCLUSIONS

1. The study results suggest that the role performed by the surgeon during the procedure (operator, first assistant, second assistant) has a significant influence on the risk of glove tearing. The role in the procedure determines exposure to glove tears.
2. Informing medical personnel about glove tear statistics concerning selected orthopedic procedures may increase awareness of operators and assistants performing procedures involving bones and sharp instruments, careful handling of which may decrease the glove tear rate.
3. Changing the type and thickness of gloves in procedures with the highest tear rates may decrease those rates. Furthermore, glove inserts can be tested as an additional protection for internal gloves, limiting tears in them. Analysis of tears using different models of gloves will allow choosing the model that is the most tear resistant.
4. Implementing a double gloving procedure in surgical procedures or using single gloves characterized by higher tear resistance should be considered.

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