THE JOURNAL OF BONE & JOINT SURGERY (BJ)

Glove perforation and contamination in primary total hip arthroplasty

M. Al-Maiyah,
A. Bajwa,
P. Finn,
P. Mackenney,
D. Hill,
A. Port,
P. J. Gregg

From James Cook University Hospital and University of Teesside, Middlesbrough, England

- M. Al-Maiyah, FRCS, FICMS, MSc, Senior House Officer
- A. Bajwa, MRCS, MSc, Specialist Registrar
- P. Mackenney, FRCS(Ed), Specialist Registrar
- A. Port, FRCS(Orth), Consultant
- P. J. Gregg, FRCS, Professor of Trauma and Orthopaedics

Department of Orthopaedics

- D. Hill, MRCSPath, Consultant

Department of Microbiology
James Cook University Hospital, Marton Road, Middlesbrough TS4 3BW, UK.

- P. Finn, MSc, Medical Statistician

School of Health, University of Teeside, Middlesbrough TS1 3BA, UK.

Correspondence should be sent to Mr A. Al-Maiyah c/o Mr Ports' secretary, Orthopaedic department (Ward 33), James Cook University Hospital, Marton Road, Middlesbrough TS4 3BW, UK; e-mail: mamaiyah@yahoo.co.uk

doi:10.1302/0301-620X.87B4.15744 $2.00

J Bone Joint Surg [Br] 2005;87-B:556-9.
Received 21 June 2004; Accepted after revision 1 October 2004

We conducted a randomised, controlled trial to determine whether changing gloves at specified intervals can reduce the incidence of glove perforation and contamination in total hip arthroplasty. A total of 50 patients were included in the study. In the study group (25 patients), gloves were changed at 20-minute intervals or prior to cementation. In the control group (25 patients), gloves were changed prior to cementation. In addition, gloves were changed in both groups whenever there was a visible puncture. Only outer gloves were investigated.

Contamination was tested by impression of gloved fingers on blood agar and culture plates were subsequently incubated at 37˚C for 48 hours. The number of colonies and types of organisms were recorded. Glove perforation was assessed using the water test. The incidence of perforation and contamination was significantly lower in the study group compared with the control group. Changing gloves at regular intervals is an effective way to decrease the incidence of glove perforation and bacterial contamination during total hip arthroplasty.

Restricting contamination to a minimal level is vital during joint replacement surgery as infection is a devastating complication. Glove perforation resulting in contamination during operations occurs in all surgical specialties. Studies performed in other specialties have reported an incidence of perforation ranging from 10% in ophthalmic surgery to 50% in general surgery.[1-4] In orthopaedic surgery, the incidence has been shown to vary depending on the type of surgery ranging from 14% during paediatric procedures to 57% during hip fracture operations.[5,6] Studies in other specialties have reported an increased incidence of perforation and contamination associated with longer duration of surgery.[7,8] The widespread use of double-gloving has increased the awareness of surgeons to the possibility of glove perforation. However, unnoticed perforation remains a problem and may only be discovered upon later inspection of the gloves.[9]

The prevalence of glove contamination during preparation and draping for joint replacement varies from 20% to 28%.[10] Potential sources of contamination within the operating theatre are the patient's own skin flora as well as airborne infection from theatre personnel and environment.[11,12] The use of ultra-clean laminar flow ventilation, sterile hoods and a body-exhaust system has significantly reduced airborne contamination.[13] Waterproof gowns are considered to be more effective against the transfer of organisms between the patient and the surgeon.[14] Contamination of gloves and wound by the patient's own skin flora as well as the surgeon's hands is still a problem. In current practice, surgeons may change gloves two to three times during total hip replacement operations. Gloves are usually changed after draping and before cementing the acetabular and femoral components.

The aims of our study were to investigate the incidence of glove perforation and contamination during primary total hip arthroplasty, determine whether changing gloves at specified intervals can reduce their perforation and contamination, and to identify the strains of contaminating bacteria.

Patients and Methods

We performed a randomised, controlled study of 50 consecutive patients undergoing primary cemented total hip replacement. All members of the surgical team wore double gloves, either Biogel or Biogel Reveal (Regent Medical Ltd, Cheshire, UK) or Reveal surgical gloves. A consultant undertook 20 operations in each group and supervised a specialist registrar in three operations and a staff grade in two. In the study group, the outer gloves were changed

Table I. Number of pairs of gloves used

	Study group	Control group
Surgeon		
Pairs of gloves	120	94
Median (range)	5 (4 to 6)	4 (3 to 6)
Assistant		
Pairs of gloves	116	88
Median (range)	5 (2 to 6)	3 (2 to 6)
Nurse		
Pairs of gloves	118	91
Median (range)	5 (4 to 6)	4 (2 to 6)

Table II. Glove perforation percentages

	Study group		Control group		
	Pairs of gloves	Pairs with perforations (%)	Pairs of gloves	Pairs with perforations (%)	p value*
Surgeon	120	5 (*4.2*)	94	11 (*11.7*)	0.04
Assistant	116	4 (*3.4*)	88	6 (*6.8*)	0.27
Nurse	118	6 (*5.1*)	91	15 (*16.5*)	0.01

* calculated using chi-squared test

after draping, either at 20-minute intervals or immediately before cementation if this occurred before the end of a 20-minute interval. In the control group, three changes of outer gloves were employed which represented the current practice in our institution: after draping and before cementation of the components. In addition, gloves were changed in both groups whenever a visible puncture was detected.

Randomisation was performed using computer-generated random numbers to form blocks of four patients each. Pre-prepared sealed envelopes were opened in the operating theatre at the time of surgery to allocate the operation to either the study or the control group.

At each operation the outer gloves of the surgeon, first assistant and scrub nurse were studied. Contamination was tested by making an impression of each gloved finger on sterile culture media (blood agar) immediately before each set of gloves were removed. Discarded gloves were collected and labelled appropriately. The culture plates were immediately sent to a microbiology laboratory for incubation at 37°C for 48 hours. A single consultant microbiologist (DH) reported the results of the culture. The number of colonies, density of growth and strain of bacteria were noted for each culture. We identified all bacterial isolates by using Gram stain, coagulase, oxidase and catalase tests.

The degree of contamination was categorised at 48 hours after incubation and divided into three grades: 1) no contamination if there was no growth; 2) low contamination where between one and five colonies were noted and 3) heavily contaminated if there were more than five colonies on the blood agar culture medium. Perforation of the gloves was tested using the water test (European standard EN 445).[15] Each glove was filled with one litre of water and the cuff twisted through 360° to increase the pressure and to test for leakage.

Data processing and statistical analysis were performed using SPSS® version 10.0 for Windows (SPSS Inc, Chicago, Illinois). The incidence of glove perforations and contamination were compared between the study and control groups using the chi-squared test and Fisher's exact test. Values for $p < 0.05$ were regarded as significant.

Results

A total of 627 pairs of outer gloves were included in the trial; 354 pairs in the study group and 273 pairs in the control group. Inner gloves were not included in the study. A summary of glove numbers is shown in Table I. The operating time was calculated as the time from completion of draping to removal of the drapes at the end of the operation. There was no difference in operating times between the study and control groups. The median operating times were 70 minutes (95% confidence interval (CI) 60 to 80) and 75 minutes (95% CI 65 to 90), respectively. The median time between each glove change was 16 minutes (95% CI 15 to 20) in the study group compared with 23 minutes (95% CI 21.5 to 25) in the control group. Thus, in all cases, the surgical teams in the study group changed gloves more frequently than in the control group.

Glove perforation. The proportion of perforated gloves was significantly lower in the study group compared with the control group for surgeons ($p < 0.05$) and scrub nurses (Table II). There was no statistically significant reduction in perforation of gloves worn by assistants.

Glove contamination. There was a significantly lower incidence of glove contamination in the study group compared with the control group (4.8% *vs* 13.9%, respectively). The results for glove contamination are shown in Table III. In the study group, gloves of all members of the surgical team remained free from contamination in 56% (14 of 25) of operations compared with 24% (6 of 25) for the control group ($p = 0.02$).

The effect of regular glove changes on contamination for each member of the surgical team are presented using the

Table III. Incidence of glove contamination

Contamination*	Study (%)	Control (%)	p value
Operation			
None	*56.0*	*24.0*	
Low/heavy	*44.0*	*76.0*	0.02†
Surgeon			
None	*68.0*	*36.0*	
Low	*32.0*	*36.0*	
Heavy	-	*28.0*	0.01‡
Assistant			
None	*80.0*	*52.0*	
Low	*20.0*	*36.0*	
Heavy	-	*12.0*	0.07‡
Nurse			
None	*76.0*	*56.0*	
Low	*24.0*	*24.0*	
Heavy	-	*20.0*	0.06‡

* contamination was considered as being heavy if at least one pair of outer gloves showed heavy contamination; low otherwise. Gloves of each surgical team in each operation considered as one unit for calculation
† calculated using chi-squared test
‡ calculated using Fisher's exact test

Table IV. Details of the 106 isolated bacteria

Bacteria	Total (%)
Coagulase-negative staphylococci	73 (*68.9*)
Staphylococcus aureus	7 (*6.6*)
Micrococcus	13 (*12.3*)
Diphtheroids	10 (*9.4*)
Coliforms	1 (*0.9*)
Pseudomonas	2 (*1.9*)

percentage of operations in which gloves of surgeons, assistants and scrub nurses were either not, lightly or heavily contaminated (Table III). Glove contamination was lower in the study group in all cases, but this reduction was only statistically significant for the surgeons.

We found 106 bacterial isolates, the details of which are shown in Table IV. The majority of isolates were coagulase-negative staphylococci (CNS), followed by *micrococcus* species and diphtheroids. *Staphylococcus aureus* represented 6.6% of the total number of isolates, of which only two isolates were methicillin-resistant *Staphylococcus aureus*, MRSA. There were also two isolates of *Pseudomonas* species and one isolate of *E.coli*.

Discussion

The surgical glove is an important barrier between the hands of the surgeon and the patient. It remains a significant factor in the protection against contamination and infection for both parties. The incidence of glove perforation has been investigated in most surgical specialties with reported incidences of 12.7% in general surgery,[4] 13.3% in obstetric surgery[16] and 21.5% in plastic surgery.[17] In orthopaedic surgery, previous studies have reported an overall incidence of perforation of 26% in elective orthopaedic procedures[18] and up to 57% in hip fracture surgery.[5] The incidence of perforation in our study was lower with the highest perforation rate found for scrub nurses in the control group (16.5%). The overall results of the control group resemble those of McCue, Berg and Sanders[19] in which the incidence of outer glove perforation in total joint arthroplasty was 13%. Their study used the same protocol for changing gloves as the control group in our study.

In this prospective study, we have shown that regularly changing gloves decreases the incidence of perforation. The median time for changing gloves was 16 minutes (95% CI 15 to 20) in the study group and 23 minutes (95% CI 21.5 to 25) in the control group. This was associated with a significant reduction in the incidence of glove perforation for surgeons ($p = 0.04$) and nurses ($p = 0.01$). The overall incidence of perforation for assistants was low, which may be because assistants are less involved in the handling of sharp instruments than are surgeons and scrub nurses.

The rationale for wearing gloves during operations is to prevent contamination of surgical wounds and possible infection by the operator's skin organisms and is a well-described practice.[20,21] Currently, there is increased attention being paid to the role of gloves as a barrier to protect the surgical team against infection by hepatitis B and C viruses and HIV. It has been estimated that 13% of operating team staff have pre-operative skin damage which significantly increases the risk of infection.[22] Many measures have been introduced to reduce glove perforation, such as the use of Biogel Reveal (Regent Medical Ltd) double-gloving, taper-point needles[23] and glove reinforcement,[24] yet unnoticed perforations may be discovered on later inspection.[9] For these reasons, we recommend that changing gloves at regular intervals during surgery would minimise the period in which a potentially perforated glove was in use.

Glove contamination has been studied in many surgical subspecialties, and has often been investigated alongside the perforation of gloves. Reported incidences of contamination are 33% in vascular surgery,[25] 29% in neurosurgery[26] and 62.9% in cardiac surgery.[27] In general surgical procedures, Bukhari et al[7] reported that gloved fingertips became contaminated in 52% of operations. They also found that glove contamination and bacterial counts increased over the duration of surgery.

During joint replacement, Davis et al[10] reported that 28.7% of gloves used for preparation were contaminated. In the study by McCue et al,[19] the incidence of outer glove contamination was 12%, however, gloves from only ten operations were included in the study. In our study, the overall incidence of glove contamination in the study group was significantly lower than in the control group (4.8% *vs* 13.9% respectively).

The clinical implications of these findings are potentially of great importance. A simple regime of regular glove changing has significantly reduced the incidence of perforation and contamination. It therefore has the potential to decrease the rates of wound infection and to reduce the risk to surgeons of inoculation by infectious diseases.

Coagulase-negative staphylococci were the commonest contaminants in our study and have been identified as a regular contaminant by others.[10,17] Cultures taken during revision arthroplasty operations from New York hospitals were positive for coagulase-negative staphylococci in more than one third of cases.[28] Other studies from the United Kingdom[29,30] and elsewhere have reported similar findings. Further studies are required to formally establish a causal link between contamination during surgery and infected prostheses.

We conclude that glove changing at regular intervals is effective in decreasing the incidence of glove perforation and contamination during hip arthroplasty.

This study has been funded from Professor P. J. Gregg research fund and the bacteriological studies were conducted in Microbiology Department, James Cook University Hospital.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

1. **Albin MS, Bunegin L, Duke ES, Ritter RR, Page CP.** Anatomy of a defective barrier: sequential glove leak detection in a surgical and dental environment. *Crit Care Med* 1992;20:170-84.
2. **Chapman S, Duff P.** Frequency of glove perforation and subsequent blood contact in association with selected obstetric surgical procedures. *Am J Obstet Gynecol* 1993; 168:1354-7.
3. **Brough SJ, Hunt TM, Barrie WW.** Surgical glove perforations. *Br J Surg* 1988; 75:317.
4. **Dodds RDA, Guy PJ, Peacock AM, et al.** Surgical glove perforation. *Br J Surg* 1988;75:966-8.
5. **Eckersley JR, Williamson DM.** Glove punctures in an orthopaedic trauma unit. *Injury* 1990;21:177-8.
6. **Maffulli N, Capasso G, Testa V.** Glove perforation in pediatric orthopaedic surgery. *J Paediatr Orthop* 1991;11:25-7.
7. **Bukhari SS, Harrison RA, Sanderson PJ.** Contamination of surgeons' gloves fingertips during surgical operations. *J Hosp Infect* 1993;24:117-21.
8. **Hollaus PH, Lax F, Janakiev D.** Glove perforation rate in open lung surgery. *Euro J Cardiothorac Surg* 1999;15:461-4.
9. **Nicola P, Aldham CH, Allen PW.** Increased awareness of glove perforation in major joint replacement: a prospective randomized study of Regent Biogel Reveal gloves. *J Bone Joint Surg [Br]* 1997;79-B:371-3.
10. **Davis N, Curry A, Gambhir AK, et al.** Intraoperative bacterial contamination in operations for joint replacement. *J Bone Joint Surg [Br]* 1999;81-B:886-9.
11. **Ha'eri GB, Wiley AM.** Total hip replacement in a laminar flow environment with special reference to deep infections. *Clin Orthop* 1980;148:163-8.
12. **Howorth FH.** Prevention of airborne infection during surgery. *Lancet* 1985;1:386-8.
13. **Charnley J.** Postoperative infection after total hip replacement with special reference to air contamination in the operating room. *Clin Orthop* 1972;87:167-87.
14. **Scheibel JH, Jensen I, Pedersen S.** Bacterial contamination of air and surgical wounds during joint replacement operations: comparison of two different types of staff clothing. *J Hosp Infect* 1991;19:167-74.
15. **European Communities.** Commission communication in the framework of the implementation of Council directive 93/42/EEC of 14 June 1993 in relation to medical devices and Directive 98/79/EC of the European Parliament and of the Council of 27 October 1998 on in-vitro diagnostic medical devices. *Official J Eur Communities* 2001;44:C319/13.
16. **Serrano CW, Wright JW, Newton ER.** Surgical glove perforation in obstetrics. *Obstet Gynecol* 1991;77:525-8.
17. **Cole RP, Gault DT.** Glove perforation during plastic surgery. *Br J Plast Surg* 1989;42: 481-3.
18. **Maffuli N, Capasso G, Testa V.** Glove perforation in elective orthopaedic surgery. *Acta Orthop Scand* 1989;60:565-6.
19. **McCue SF, Berg EW, Saunders E.** Efficiency of double gloving as a barrier to microbial contamination during total joint arthroplasty. *J Bone Joint Surg [Am]* 1981;63-A: 811-13.
20. **Lowbury EJL, Lilly HA.** Disinfection of the hands of surgeons and nurses. *Br Medical J* 1960;5184:1445-50.
21. **Hanon KN, Korniewicz DM, Hexter DA, Kornilow JR, Kelen GD.** Loss of glove integrity during emergency department procedures. *Ann Emerg Med* 1998;31:65-72.
22. **Palmer DJ, Rickett WS.** The mechanisms and risks of surgical glove perforation. *J Hosp Infec* 1992;22:279-86.
23. **Wright KU, Moran CG, Briggs PJ.** Glove perforation during hip arthroplasty: a randomised prospective study of a new taperpoint needle. *J Bone Joint Surg [Br]* 1993; 75-B:918-20.
24. **Alrawi SJ, Houshan I, Zanial SA, et al.** Cardiac surgical procedures and glove reinforcements. *Heart Surg Forum* 2002;5:66-8.
25. **Zdanowski Z, Danielsson G, Jonung T, et al.** Intraoperative contamination of synthatic vascular grafts: effect of glove change before graft implantation: a prospective randomised study. *Euro J Vasc Endovasc Surg* 2000;19:283-7.
26. **Savitz SI, Bottone EJ, Savitz MH, Malis LI.** Investigations of the bacteriological factors in clean neurosurgical wounds. *Neurosurgery* 1994;34:417-20.
27. **Goldsmith I, Lip GY, Khan F, Patel RL.** Contamination of the surgeon's bare and gloved fingertips in cardiac operations. *Int J Clin Pract* 1998;52:529-32.
28. **Brause BD.** Infections with prostheses in bones and joints. In: Mandell GL, Bennett JE, Dolin R, eds. *Principles and practice of infectious diseases.* Vol. 1. Fifth ed. Edinburgh: Churchill Livingstone, 2000:1196-200.
29. **Mohanty SS, Kay PR.** Infection during total hip replacements: why we screen MRSA when MRSE is the problem? *J Bone Joint Surg [Br]* 2004;86-B:266-8.
30. **James PJ, Butcher IA, Gardner ER, Hamblen DL.** Methicillin-resistant Staphylococcus epidermidis in infection of hip arthroplasties. *J Bone Joint Surg [Br]* 1994; 76-B:725-7.