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ORIGINAL STUDY

Infection risk analysis of orthopaedic surgical team Double glove cuff interface moisture

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Moisture droplets can accumulate at the paired surgical glove interface during long-duration orthopaedic surgery cases. The sterility of this moisture is unknown. This prospective study at an urban university-based level I trauma center analyzed moisture droplets sampled from the double glove cuff interface for bacterial contamination.
Moisture droplet samples were collected from 15 unique orthopedic surgery team members during 15 non-contaminated surgeries of ≥ one-hour duration.
After ≥ 72 hours incubation (32° C), all negative controls (opened, unused sterile gloves in operating room environment) displayed no bacterial growth. All positive controls (unwashed surgeon wrists) displayed bacterial growth. All samples collected from beneath the outer cuff of the double glove cuff interface were also negative for bacterial growth.
Moisture that accumulates at the paired surgical glove interface during orthopaedic surgery cases is not a source of bacterial contamination.

Keywords: surgical gloves ; sterile technique ; infection risk ; bacterial culture.

INTRODUCTION

Surgical site infections account for nearly 300,000 infections in the United States annually *(2,17)*. Approximately 35,000 of these infections occur after orthopedic surgery. This represents nearly 20% of all healthcare-associated infections, contributing to over 8,200 deaths in the United States each year *(11,18)*. To reduce the rate of surgical site infections, national and international organizations have developed patient treatment guidelines *(4,9,10,13,22)*. Despite these guidelines, studies have identified surgical site infections as a primary readmission factor following surgery, prolonging hospitalization time, doubling readmission rates, and increasing the cost of an episode of care by more than 300% *(6,21)*. Other reports have estimated that surgical site infections increase United States healthcare system costs by $5.7-$10 billion dollars annually *(2,16-18)*.

Surgical site infection causes are multi-factorial, including patient, surgeon, hospital, and procedure-

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related factors. Although many surgical risk factors are not modifiable, procedure-related factors such as sterile technique are. To decrease infection risk, orthopedic surgeons often don two pairs of surgical gloves, changing outer or "top" gloves prior to inserting implants and when dressing the wound *(1,3,12,20)*. During orthopaedic surgical procedures, moisture droplets from the surgeons' forearms or hands can accumulate in the proximal glove cuffs where the top glove extends past the under glove (Fig. 1) *(20)*. Since the sterility of this moisture is unknown, it may represent a source of surgical field contamination. The purpose of this prospective study at an urban university-based level I trauma center was to analyze the infection risk of moisture droplets sampled from the double glove cuff interface of orthopedic surgical team members.

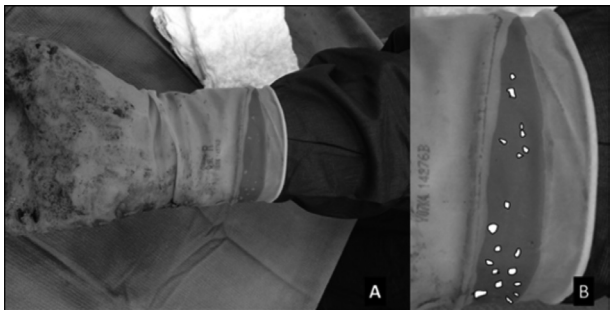

Fig. 1. — Visible moisture droplet accumulation at the interface of the two surgical gloves at the one hour mark during open reduction internal fixation of a proximal humeral fracture (A) and close-up (droplets highlighted in white) (B).

MATERIALS AND METHODS

Institutional review board approval was obtained from the medical study review committee prior to study initiation. Informed consent was obtained from all study participants. The primary investigator identified "non-contaminated" orthopedic surgery cases with the assumption that no infection or bacterial contamination was present at the time of surgery. Only cases where the surgical case duration was expected to be greater than or equal to one hour were included in this study. At a minimum one-hour surgical case time, a single investigator used a sterile cotton-tipped applicator to collect visible moisture droplet samples bilaterally beneath the outer glove cuff at the interface with the inner glove of 15 different orthopedic surgery team members. One team member was sampled during each surgical case. This convenience sample included attending surgeons, fellows, residents, medical students, and surgical technicians. Of the 15 orthopedic surgery cases that contributed to this study, 11 involved upper or lower extremity fracture fixation using plates or nails, two involved ankle/foot fusion procedures and two represented exploratory procedures to alleviate sciatic nerve entrapment.

Moisture droplet samples were collected in the following order. First, samples were collected from the unwashed wrists of five attending surgeons prior to scrubbing. These samples represented the positive control group. Next, samples were collected from the surgical glove cuff interface of orthopaedic surgery team members during actual surgical cases. Lastly, samples were collected on the same day of surgery from a pair of unused sterile gloves two hours after they had been removed from packing and left in the open air in an adjacent, unused operating room. These samples served as the negative control group. Each collected sample was taken directly to a university microbiology laboratory for culturing and bacteria colony forming unit analysis by a medical technologist who was blinded to sample source. Using standard university microbiology protocols, specimen blood agar, MacConkey, chocolate agar, and colistin naladixic acid (CNA) agar growth medium cultures were incubated at 32° C and monitored for aerobic and anaerobic bacterial growth over a $\geq$ 72-hour period. Group bacterial growth differences were statistically compared using a Fisher's Exact Test with an alpha level of $P \leq 0.05$ to indicate statistical significance (IBM SPSS Version 21.0, Armonk, NY).

RESULTS

Seventy cultured specimens were analyzed. This represented 30 sterile glove swabs (negative control), 30 experimental samples (Table I), and 10 swabs from unwashed, orthopedic surgeon wrists (positive control) (Table II). Average surgical time was 1.5 hours (range = 1- 2 hours) when

Table I. — Orthopedic surgical team member, surgical procedure, characteristics and culture Results (IM = intra-medullary; ORIF = open reduction, internal fixation).

Subject	Title	Procedure	Side	Glove Wear Duration (hr:min)	Culture Results
1	Attending	Foot Fusion	R	2:00	N
			L	2:00	N
2	Resident	Foot Fusion	R	2:00	N
			L	2:00	N
3	Fellow	Tibial IM Nailing	R	1:45	N
			L	1:45	N
4	Medical Student	Tibial IM Nailing	R	1:45	N
			L	1:45	N
5	Resident	Tibial Plafond ORIF	R	2:00	N
			L	1:00	N
6	Technician	Tibial Plafond ORIF	R	2:00	N
			L	2:00	N
7	Attending	Sciatic Nerve Exploration	R	1:30	N
			L	1:30	N
8	Technician	Sciatic Nerve Exploration	R	1:30	N
			L	1:30	N
9	Resident	Distal Radius ORIF	R	1:00	N
			L	1:00	N
10	Resident	Distal Radius ORIF	R	1:00	N
			L	1:00	N
11	Resident	Proximal Humerus ORIF	R	1:00	N
			L	1:00	N
12	Fellow	Femoral IM Nailing	R	1:00	N
			L	1:00	N
13	Resident	Distal Radius ORIF	R	1:15	N
			L	1:15	N
14	Resident	Tibial Plateau ORIF	R	1:30	N
			L	1:30	N
15	Attending	Tibial Plateau ORIF	R	1:30	N
			L	1:30	N

rounded up to the nearest 15 minute interval. Following specimen culture incubation, neither the negative control group nor the experimental group displayed any bacterial growth. The positive control group displayed positive bacterial growth in all specimens. The bacterial growth that was observed in the positive control group represented a variety of different strains, with coagulase-negative Staphylococcus being the most prevalent (Table II). No specimen culture displayed any evidence of methicillin-resistant Staphylococcus aureus. Fisher Exact Test analysis revealed no statistically significant frequency differences between the experimental and negative control groups ($p > 0.9$).

Table II. — Culture results from unwashed hands of orthopedic surgeons.

Subject	Side	Culture Results
1	R	Positive for rare growth coagulase-negative Staphylococcus; 2 types
	L	Positive for rare growth coagulase-negative Staphylococcus
2	R	Positive for rare growth coagulase-negative Staphylococcus ; 2 types
	L	Positive for 1 colony coagulase-negative Staphylococcus
3	R	Positive for rare growth coagulase-negative Staphylococcus ; 2 types
	L	Positive for rare growth coagulase-negative Staphylococcus ; 2 types
4	R	Positive for rare growth coagulase-negative Staphylococcus ; 2 types
	L	Positive for 1+ mixed organisms: coagulase-negative Staphylococcus and Bacillus species
5	R	Positive for rare growth mixed coagulase-negative Staphylococcus
	L	Positive for rare growth coagulase-negative Staphylococcus ; 2 types and rare growth Viridans streptococcus

DISCUSSION

Visible moisture droplets were identified at the interface of paired surgical glove cuffs for each orthopedic surgical team member that was sampled. This phenomenon has been recently evaluated *(20)*; however, its clinical significance and its sterility has not been confirmed. In this prospective study of an urban, university-based orthopedic surgery team, no evidence of bacterial culture-positive moisture was detected in the experimental group. These results suggest that moisture from the double surgical glove cuff interface does not represent a significant bacterial contamination source.

Using 5-micron-diameter powder and an ultraviolet light detection system, Fraser et al. *(7)* studied glove-gown interface sterile field breaching during simulated lower extremity total joint arthroplasty. They concluded that the surgical gown-glove interface was a common contamination site when positive-pressure surgical helmet systems were used during orthopedic surgery *(7)*. In addition to double gloving, many orthopedic surgeons routinely change gloves to decrease surgical site contamination risk *(5,8,14,19)*. In a prospective study of palmar surface surgical glove bacterial contamination during 29 total hip arthroplasty cases, Beldame et al. *(3)* reported that in 53.6% of these procedures, at least one glove was contaminated. Routine outer surgical glove changes decreased the incidence to 20% *(3)*. In a randomized controlled study involving 50 total hip arthroplasty cases, Al-Maiyah et al. *(1)* reported that the overall glove contamination frequency was lower when the outer gloves were changed at regular intervals compared to when outer gloves were only changed after draping and prior to implant cementing. All members of the surgical team remained free from contamination in 56% (14 of 25) of operations in which regular outer glove changes were performed compared with 24% (6 of 25) for the control group ($p = 0.02$).

Other factors such as orthopedic surgeon and surgical team experience, gown material and design may also contribute to surgical contamination rates *(12,20)*. In prospectively evaluating surgical glove fingertip working surfaces immediately after draping for total hip or knee arthroplasty procedures, Makki et al. *(12)* reported that contamination was more likely to occur at the index finger and thumb of the dominant hand of less experienced orthopedic surgeons. In comparing contamination rate differences between cloth and paper surgical gowns among 102 orthopedic surgical team members, Ward et al. *(20)* reported a four-fold greater contamination frequency among subjects who wore cloth gowns (31% cloth vs. 7% paper) [odds ratio (95% confidence interval): 4.64 (1.72-

12.53); p = 0.0016]. Their work suggested that gown material might be an important surgical contamination predictor.

This study has several limitations. Since infections occur in approximately 1.5-2% of orthopaedic surgery cases *(15)*, to adequately, power a prospective study using surgical site infection rate as the outcome measurement would have required a study sample of approximately 10,000 subjects. Rather, like a previous report *(15)*, this study relied on contamination frequency as measured by bacterial colony forming units as being predictive for having a greater likelihood for developing a surgical site infection. The study had sufficient a priori statistical power to detect differences between the negative control and the experimental group had they existed. Study strengths include use of a prospective research design with both positive and negative control groups, use of a single examiner to collect all samples, and culture bacterial growth analysis performed by an experienced medical technologist who was blinded to sample source and who used the standard institutional protocol.

CONCLUSION

Visible moisture droplets at the surgical glove cuff interface of double-gloved orthopedic surgical team members displayed a sterility profile similar to unused gloves. Therefore, accumulation of this moisture does not represent a significant surgical site infection risk. Additional studies with increased subject numbers during other, longer duration orthopedic surgery cases are recommended.

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