

# Do Longer Surgical Procedures Result in Greater Contamination of Surgeons' Hands?

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## Abstract

**Background** A surgical site infection is a substantial cause of complications in patients. Different methods are being used to decrease surgical site infections; however, these infections still can cause complications, especially in patients undergoing longer operations (> 3 hours). There is evidence that the efficacy of the scrubbing material fades after 3 hours. However, we do not know the longevity of hand cleanliness after application of scrubbing materials in a long operation. It can be postulated that if the surgeon's

scrubbed hands are recolonized after a certain time, they may serve as a progressive source of contamination during surgery.

**Questions/purposes** We asked: (1) Is there a correlation between surgical duration and hand contamination at the end of surgery? (2) At what point during surgery does hand contamination reach or exceed prescrub levels?

**Methods** Three spine surgeons using the same scrubbing technique and materials consisting of chlorhexidine gluconate 1% solution and ethyl alcohol 61% w/w were enrolled in our study. Between December 2014 and April 2015, spine procedures of 3 hours or more, which were the

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Each author certifies that his or her institution approved the human protocol for this investigation that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This study was done at Scripps Clinic and the San Diego Center for Spinal Disorders, La Jolla, CA, USA.

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first case of the day, were selected for this study (20 cases). Cases in which glove changing occurred (perforations, repressing, and redraping) or cultures obtained after scrubbing were positive (indicative of insufficient hand sanitization) were excluded (0% of cases). Twenty cases (100% enrollment) were analyzed. Surgeons' hands were swabbed with sterile cotton tip applicators and 5 mL sterile phosphate-buffered saline before hand scrubbing (prescrub), immediately after hand scrubbing (postscrub), and immediately after surgery (postoperative). Results were reported in colony-forming units per milliliter. The correlation between duration of surgery and hand recontamination was tested by regression analysis of time versus colony-forming units per milliliter. Receiver-operating characteristic curve tested the cutoff point, where recontamination occurred.

**Results** With a longer duration of surgery, more colony-forming units are recovered from gloved hands at the end of surgery ( $R = 0.94$ ,  $R^2 = 0.89$ ,  $p = 0.005$ ). The receiver-operating characteristic curve suggested that 5 hours is the cutoff point for hand recolonization. At 5 hours, contamination reached or exceeded prescrub levels (area under the curve, 0.66; 95% CI, 0.23–1.0), whereas before 5 hours, there was no contamination detected at the end of surgery.

**Conclusions** Our results show that duration of surgery correlates with hand recontamination and at 5 hours, recolonization of a surgeon's hands become detectable. Recolonization may have started even earlier than 5 hours. However, these levels are not detectable in the laboratory at earlier times.

**Clinical Relevance** Based on this pilot study, rescrubbing is highly recommended before the fifth hour of an operation, ideally at some point between the fourth and fifth hours.

**Future** We also recommend the surgical site infection rates in operations using rescrubbing should be compared with those from surgeries with just the conventional single-scrubbing technique, in a randomized controlled trial, to determine the effectiveness of this novel rescrubbing method.

## Introduction

Despite substantial advances in infection control during the past 150 years [1, 3], surgical site infections remain a major cause of morbidity and mortality [7, 9, 20]. Identification of surgical-site risk factors allows for implementation of more effective avoidance strategies [16]. One of the intraoperative risk factors for surgical site infections is the duration of the operation [23], with longer operations having higher rates of infection [6]. Some authors have reported that the number of surgical site infections increase with operations lasting

longer than 5 hours [9, 10, 21]. However, the increased rate of surgical site infections in longer cases historically has been attributed to higher blood loss, use of instrumentation, and more soft tissue injury [4, 8, 15, 20]. To our knowledge, no one has questioned whether a surgeons' hands are a potential source of surgical site infection in longer operations (> 3 hours). A common misconception among healthcare professionals is that surgical scrubbing before surgery and use of sterile gloves eliminate their hands as a potential source of a surgical site infection. However, operative site contamination transmitted from the hands of healthcare professionals despite adhering to scrubbing protocols has been reported [18]. Interestingly, evaluation of hand-scrubbing materials has shown a loss of efficacy more than 3 hours from the initial cleaning [10]. Although the duration of scrubbing has been studied, there are no published data assessing the longevity of hand cleanliness after the initial scrubbing during prolonged surgery.

We therefore asked: (1) Is there a correlation between surgical duration and hand contamination at the end of surgery? (2) At what point during surgery does hand contamination occur, or reach or exceed prescrub levels?

## Materials and Methods

### Subjects

Three spine surgeons (GMM, RE, AN) from one institution participated in this study, which received institutional board approval. All three surgeons (100%) met the inclusion criteria and none (0%) was excluded. The dominant hand of each surgeon was determined so that sampling could be taken from that extremity consistently. Twenty sets of samples at different times during the surgery were collected between December 2014 and April 2015. The distribution of sample sizes in each group was as follows: 3 hours ( $n = 2$ ), 4 hours ( $n = 6$ ), 5 hours ( $n = 6$ ), 6 hours ( $n = 3$ ), 7 hours ( $n = 2$ ), and 8 hours ( $n = 1$ ).

### Inclusion and Exclusion Criteria

The inclusion criteria were (1) spinal operations lasting at least 3 hours, and (2) use of the same surgical undergloves by each surgeon. The exclusion criteria were: (1) cases in which the surgeon changed undergloves during the operation owing to underglove perforation and penetration, or for personal comfort reasons; (2) skin conditions, abnormal disorders, or skin injuries on the tested hand; (3) use of antibiotics during the 3-month period before study onset;

and (4) cases where postscrub cultures were positive, indicative of insufficient hand sanitization.

### Surgical Scrub Technique

The standard scrubbing protocol for the first case of the day was used. It consisted of cleaning the fingernails with brushes but no use of brushes for skin surfaces to prevent skin abrasions and injuries, followed by thorough scrubbing with chlorhexidine gluconate 1% solution and ethyl alcohol 61% w/w for at least 3 minutes from the elbow and below. Sterile nontouch technique for gowning and gloving with the help of a surgical assistant was used. All of the used gloves in this study were the same standard brands used at our institution on a daily basis. In addition, all three participating surgeons used the same brand of gloves.

### Sample Collecting

We used a modification of the method described by Williamson and Kligman [24]. With this method, the dominant hand was cupped and 5 mL of 0.075 mmol/L phosphate-buffered saline pH 7.9 containing 0.1% Triton™ X-100 (Teknova Inc, Hollister, CA, USA) was used to wash the palm with a sterile cotton swab for 60 seconds until 1 mL of rubbing solution was collected in the sterile universal bottle and transferred to the laboratory for culturing within 30 minutes of sampling.

### Sample Collection Times

Samples were collected at three times for each case: before hand scrubbing (prescrub), immediately after hand scrubbing (postscrub), and immediately after surgery (postoperative). We used the postscrub culture results as an exclusion criterion, where a positive postscrub culture could be the evidence of insufficient hand sanitization. To avoid a second scrub before operating and to not affect the care and safety of the patient, the postscrub samples were collected after the operation (after the postoperative sampling), after the surgeon scrubbed, simulating the preoperative time.

### Culturing Technique

Each plastic calibrated loop was removed from its package aseptically. A 0.001-mL loop was inserted vertically in the liquid in the universal bottle to allow it to adhere to the loop. Next, a loopful of liquid was spread on the surface of a blood agar plate; the inoculation procedure then was

repeated for MacConkey agar using the same loop. Plates were incubated at least 18 hours at  $35^{\circ} \pm 2^{\circ} \text{C}$  in a  $\text{CO}_2$  or a non- $\text{CO}_2$  incubator. Next, the same laboratory technician (KG) who performed the preceding technique, counted the colonies. The number of colony-forming units (CFUs) was multiplied by 1000 because the 0.001-mL loop was used to determine the number of CFU/mL in the original specimen.

### Statistical Methods

Linear regression test was used to identify the correlation between duration of the operation and level of hand recontamination. Results were reported as R and  $R^2$ , indicating coefficient of correlation and coefficient of determination respectively with a 95% CI.

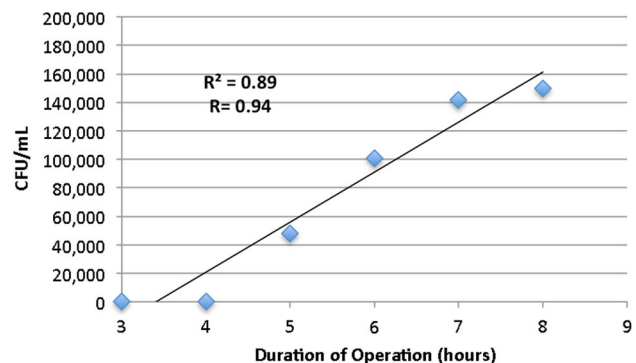
Receiver-operating characteristic (ROC) analysis was used to define the recolonization cutoff point. Area under the curve (AUC) also was evaluated and reported with 95% CI.

Postoperative culture results were compared with those of the prescrub time using a paired t test. The significance level was set at a probability less than 0.05.

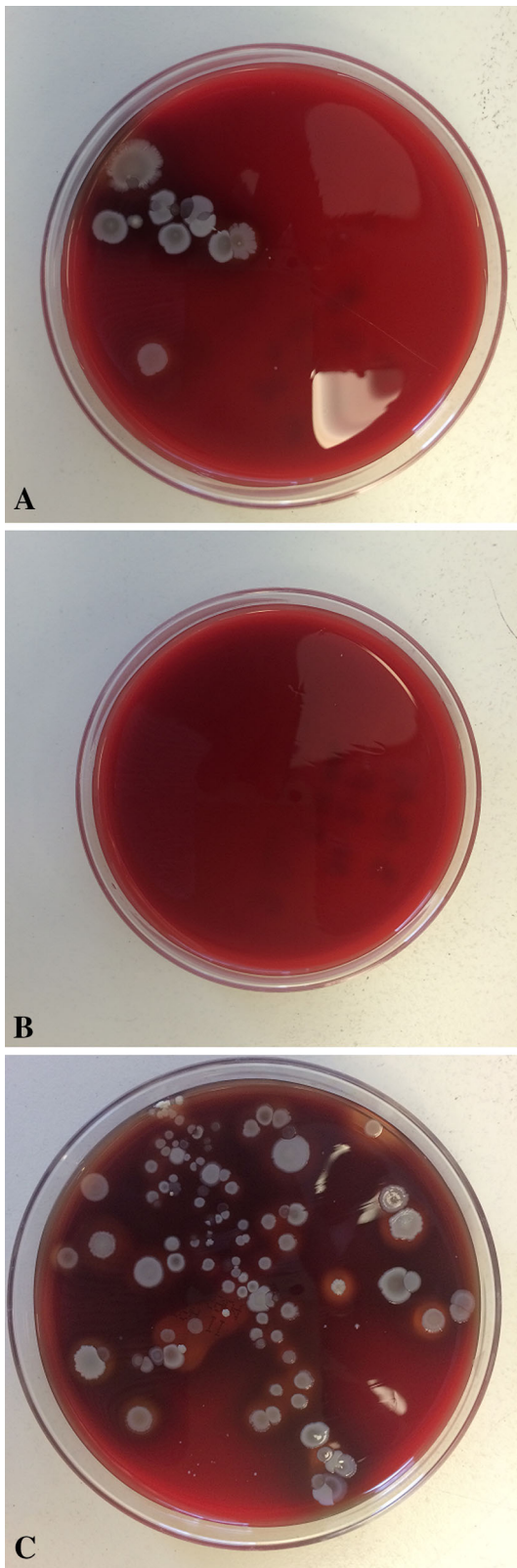
## Results

### Correlation of Hand Contamination with Surgical Duration

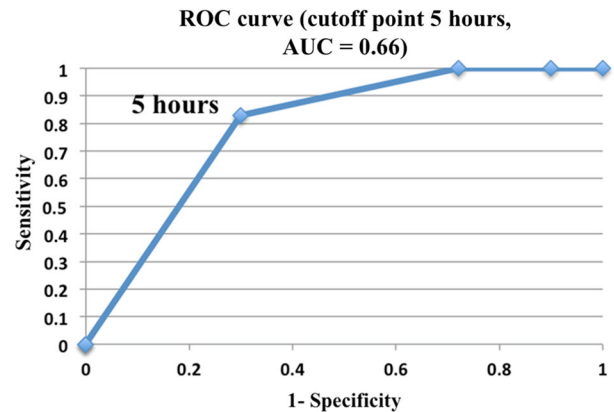
With a longer duration of surgery, more CFUs are recovered from gloved hands at the end of surgery ( $R = 0.94$ ,  $R^2 = 0.89$ ,  $p = 0.005$ ) (Fig. 1). An example of recolonization in an 8-hour case is shown (Fig. 2).



**Fig. 1** The correlation between duration of the operation and hand contamination is shown. There is a linear correlation with  $R = 0.94$  and  $R^2 = 0.89$ . CFU = colony forming units.



**Fig. 2A–C** (A) A blood agar dish from the prescrub time in an 8-hour case shows some mixed Gram-positive bacterial growth. (B) The blood agar dish at the postscrub time shows no growth at this time, which indicates efficient hand scrubbing. (C) The postoperative blood agar dish shows even more growth with mixed Gram-positive bacteria compared with the prescrub dish.



**Fig. 3** The receiver operating characteristic (ROC) curve and its corresponding area under the curve (AUC) are shown. Five hours appears to be the cutoff point for recolonization, with an AUC of 0.66.

#### When Does Hand Contamination Reach or Exceed Prescrub Levels

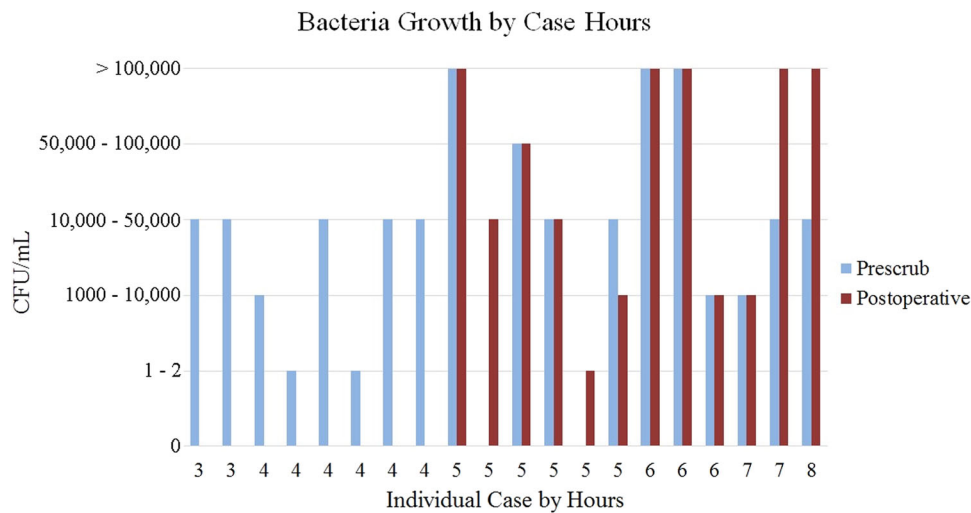
The ROC curve suggests that 5 hours is the cutoff point for hand recolonization. At 5 hours, contamination reached or exceeded prescrub levels (AUC, 0.66; 95% CI, 0.23–1.0) (Fig. 3), whereas no contamination was detected at the end of operations that were less than 5 hours (Fig. 4). Postscrub results were compared with those from prescrub times by a paired *t* test. It appeared that 5 hours was the first cutoff point that the difference in results was not statistically significant ( $p = 0.989$ ) (Table 1).

#### Other Findings

All cultured bacteria in all samples were mixed Gram-positive.

#### Discussion

Operations lasting longer than 5 hours have been reported as an independent risk factor for infection [9, 22]. The increased risk in longer operations has been attributed to factors like higher blood loss, use of instrumentation, and



**Fig. 4** The levels of contamination in CFU/mL for the durations of the operations are shown. The blue bars represent the prescrub times, and the red bars represent the postoperative times. The postscrub times are not presented as there was no growth in any case. CFU = colony forming units.

**Table 1.** Average hand contamination at three times

Duration of operation (hours)	Average prescrub CFU/mL ± SD (range)	Average postscrub CFU/mL	Average postoperative CFU/mL ± SD (range)	p value
3	30,000 ± 0.00* (10,000–50,000)	0.00	0.00	**
4	15,800 ± 12,500 (1–50,000)	0.00	0.00	0.033
5	47,500 ± 45,800 (0–150,000)	0.00	48,300 ± 45,100 (1–150,000)	0.989
6	102,000 ± 48,300 (1–150,000)	0.00	103,000 ± 94,700 (1–150,000)	0.998
7	17,500 ± 14,500 (1–50,000)	0.00	142,100 ± 142,100 (1–150,000)	**
8	30,000 ± 0.00*#	0.00	150,000*#	**

\* SD = 0.00 owing to similarity of all results; CFU = colony forming units; \*\*unable to measure owing to similarity of results between samples at different times or small sample size; #no range because n = 1.

more soft tissue injury [4, 8, 15, 20]. It is of great importance to know that wearing surgical gloves does not provide complete protection against acquisition of infections caused by some organisms such as hepatitis B and herpes simplex virus [14, 19]. The barrier integrity of gloves varies based on the type and quality of glove material, intensity of use, length of time used, and manufacturer [5, 10–12]. In a study by DeGroot-Kosolcharoen and Jones [5], only four brands of sterile latex surgeons’ gloves proved nonpermeable to water and blood. Other brands showed leakage that ranged from 1% to 52%. Their findings affirm that gloves can be regarded only as a means of reducing the risk of gross soilage from blood or body fluids. Healthcare professionals should be educated that gloves do not provide absolute protection against hand contamination.

In a case report by McNeil et al. [17], it was shown that *Pseudomonas aeruginosa* was transmitted from the hands of the operating room nurse to the operation site despite proper routine surgical scrubbing and gloving. There are several mechanisms by which the gloves might have failed

during this incidence. The most obvious would be breaks in the gloves [13]. It also has been shown that the porous nature of natural rubber latex gloves allows uptake of aqueous fluids into the latex membrane and increases permeability to viruses and chemicals that can cause glove failure [2, 12].

Considering the above-mentioned data, if surgeons’ hands get recolonized during longer operations they can become a continuous source of contamination despite proper scrubbing and gloving. Therefore we aimed to find a correlation between the duration of an operation and hand recontamination, and second, to find the cutoff point where the hands get recontaminated. Our study was designed accordingly, and showed that there is a correlation between duration of the operation and recolonization of surgeons’ hands. In addition, we found that at 5 hours after the initial scrub, the hands are equally or even more contaminated compared with before scrubbing.

Our study has numerous limitations. First, the sample size was small. This was a pilot study and, to our

knowledge, there are no previously published data regarding longevity of hand cleanliness. Consequently, we had no threshold to run the power analysis to determine required sample size. Our limited budget also played a major role in the study design, however the decision to accept 20 samples was based mainly on achieving consistent positive results in longer operations even with a small sample size.

A second limitation was that this study was done at one center and involved a single-surgical-subspecialty (spine surgery). It would be interesting to perform the study with different hospitals and different subspecialties to test the effects of various approaches and various scrubbing techniques on the final results. However, as a pilot study, we accept that this study is from a single center and is a single-subspecialty design.

A third limitation was that we did not take postscrub samples immediately after scrubbing, nor did we culture glove surfaces during the operations, so as not to affect patient care. Based on institutional review board requirements, we did not want to interfere with care of the patients without solid evidence supporting benefits for the patients.

Finally, we tested only chlorhexidine gluconate 1% solution mixed with ethyl alcohol 61% w/w as it is one of the most commonly used scrubbing solutions in the United States. Therefore, generalization of the findings of this study to all types of scrubbing materials requires more investigation.

This study showed hand contamination increases with longer surgical duration. Several studies have shown that longer surgical duration increases surgical site infections owing to higher blood loss, use of instrumentation, and more soft tissue injury [4, 8, 15, 20]. However, we believe this is the first time that a study has examined surgeons' hands as a potential source of contamination after successful conventional single-scrubbing techniques in longer operations.

In addition, we also found that after 5 hours, hand contamination levels reached or exceeded prescrub levels. There was no detectable recolonization at 4 hours, which means that detectable recolonization occurred between the fourth and fifth hours of the operation, indicating rescrubbing should be done during this interval. Interestingly, there were several postoperative samples in our study that showed greater numbers of CFUs than their prescrub counterparts. These findings suggest bacterial migration from within the skin pores.

Although our study showed that there is a correlation between the duration of an operation and hand recolonization and the cutoff point for this phenomenon is 5 hour after the initial scrub, we did not aim to provide a rescrubbing technique as a single solution for prevention of surgical site infections in longer operations. A surgical site infection is a multifactorial problem. Accordingly, a

multifaceted approach including the newly proposed rescrubbing technique at 4- to 5-hour intervals and other recommendations such as antibiotic prophylaxis, attempts to decrease blood loss, less manipulation of soft tissues, and thorough sterilization of instruments are needed to avoid these infections.

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