

Does Extent of Skin Preparation Influence Contamination During Direct Anterior Total Hip Arthroplasty? A Fluorescent Tracer Proof-of-Concept Study

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ABSTRACT

There is currently no evidence-based consensus regarding the optimal extent of skin preparation when performing total hip arthroplasty (THA) through the direct anterior approach using dedicated anterior-approach draping systems (DAA Drapes).

The purpose of this study was to evaluate the contamination risk associated with different disinfection and draping strategies for anterior-approach THA using a proof-of-concept contamination model.

Six commonly used skin preparation protocols were evaluated using a standardized fluorescent contamination model. Protocols ranged from extensive bilateral lower-limb preparation to limited ipsilateral preparation excluding the foot or distal leg. After draping, the operative field was assessed under ultraviolet light for contamination. Contamination rates and distances from the surgical field were recorded and analyzed using non-parametric statistics.

No contamination was observed in the four most extensive preparation strategies. Contamination occurred in 28.6% of trials when the ipsilateral foot and ankle were excluded from preparation and in 57.1% of cases when preparation was limited to above the knee. Lifting the leg to disinfect the posterior aspect and disinfecting the contralateral limb did not reduce contamination risk.

In this proof-of-concept study, limited skin preparation of the ipsilateral lower limb—particularly omission of the foot and distal leg was associated with a substantially increased risk of surgical field contamination. More extensive measures, such as lifting the leg or disinfecting the contralateral limb, did not confer additional benefit.

These findings should be considered hypothesis-generating and require validation through microbiological and clinical outcome studies.

Keywords: Direct anterior approach, Total hip arthroplasty, Draping, Skin preparation, Contamination model, Fluorescent tracer.

INTRODUCTION

Periprosthetic joint infection (PJI) remains one of the most devastating complications following total hip arthroplasty (THA). Despite its relatively low incidence, the clinical, psychosocial and economic burden of PJI is substantial^{5,8}.

Multiple preventive strategies have been investigated, including perioperative antibiotics, operating room protocols, surgical attire and patient optimization^{1-4,6,7,9,-13,25}.

However, surprisingly little evidence exists regarding optimal skin preparation protocols and draping techniques. Only one previous article addressed the importance in prepping the foot before

putting the stockinette when draping for a total hip replacement in a posterior approach to the hip¹⁴.

We found no studies that confirm the efficacy of various skin preparation protocols and draping techniques currently used in the anterior approach to the hip.

The increasing adoption of direct anterior THA has been accompanied by the introduction of dedicated anterior approach draping systems (DAA drapes). Although these systems are widely used, no evidence-based recommendations exist regarding the extent of skin preparation required before draping. Current practice varies considerably between surgeons and institutions and is often based on personal preference rather than scientific evidence.

Manufacturers have suggested that the use of DAA suites makes draping more efficient, less time consuming and more ergonomic. However, there is no peer reviewed data to confirm these statements to date.

The aim of this proof-of-concept study was to evaluate surgical site contamination (SSC) risk associated with different skin preparation protocols for direct anterior THA using a standardized fluorescent contamination model.

We hypothesized that progressive reduction of the prepared skin surface would increase contamination risk during draping for direct anterior total hip arthroplasty.

METHODS

Mimicking contamination

Fluorescent powder (Glo Germ™, Moab, UT, USA) was used as a visual contamination tracer. This technique has previously been used by Vles et al to mimic contamination in their study looking into the importance of a ‘clean phase’ when performing two stage revisions¹⁵. This technique was also used by Fraser et al, Chen et al and Makovicka et al to visualize contamination¹⁶⁻¹⁸.

To improve transferability and reproducibility, Glo Germ™ powder was mixed with ultrasound gel (Parker Aquasonic 100 Ultrasound Gel™, Parker Laboratories Inc, Fairfield, New Jersey, United States), creating a standardized contamination medium that could be applied consistently to predefined non-prepared anatomical regions. The model was designed to create a standardized worst-case contamination scenario. It was not intended to simulate bacterial contamination or predict infection risk, but rather to allow comparison between different preparation strategies.

Study setups

Six distinct skin preparation protocols were evaluated using a standardized contamination model. Fluorescent marker (Glo Germ™, Moab, UT, USA) was used to simulate microbial contamination and was consistently applied to all non-sterile zones, defined as anatomical regions and contact surfaces not included in the disinfection field for each respective setup.

Glo Germ™ was applied to all non-prepared anatomical regions, the operating table surface, and all contact areas between the patient and table corresponding to non-disinfected zones.

All experiments were conducted with the subject in a supine position on a standard operating table, with both arms abducted. The umbilicus served as the proximal anatomical landmark. The ipsilateral side was defined as the operative side.

Disinfection technique, duration, and solution were standardized across all setups. “Leg lifted” refers to elevation of the limb to allow circumferential access, including posterior surfaces.

The six different setups are depicted in Table I and Figure 1.

Study subjects

For this study we used 45 supine anterior hip draping suits produced by Mölnlycke (Mölnlycke Health Care Group nv, Berchem, Belgium).

Three drapes were used for initial testing of the setup. Subsequently, seven drapes were utilized in each of the six test conditions.

Seven test subjects were available. Each of them was prepped and draped in sequential fashion from setup one to six. Between each test, the examiner screened the operative field for contamination using an UV light. If contamination was detected, this was

Table I. — Overview of disinfection protocols.

Setup	Disinfection Level	Laterality	Leg Position	Prepared Regions	Non-Prepared (Glo Germ™)
1	Maximum	Bilateral	Lifted	From umbilicus distally (both legs)	Abdomen above umbilicus, table, posterior contact surfaces
2	Maximum	Bilateral	Not lifted	Same as Setup 1 (anterior only)	Posterior legs, abdomen above umbilicus, table
3	Intermediate	Bilateral incomplete	Not lifted	Ipsilateral leg + abdomen; contralateral to knee	Contralateral below knee, posterior surfaces
4	Maximum	Unilateral	Not lifted	Ipsilateral abdomen + leg	Contralateral side, posterior surfaces
5	Intermediate	Unilateral	Not lifted	Ipsilateral leg excluding foot/ankle	Foot/ankle, contralateral side
6	Low	Unilateral	Not lifted	Ipsilateral thigh only	Lower leg, contralateral side

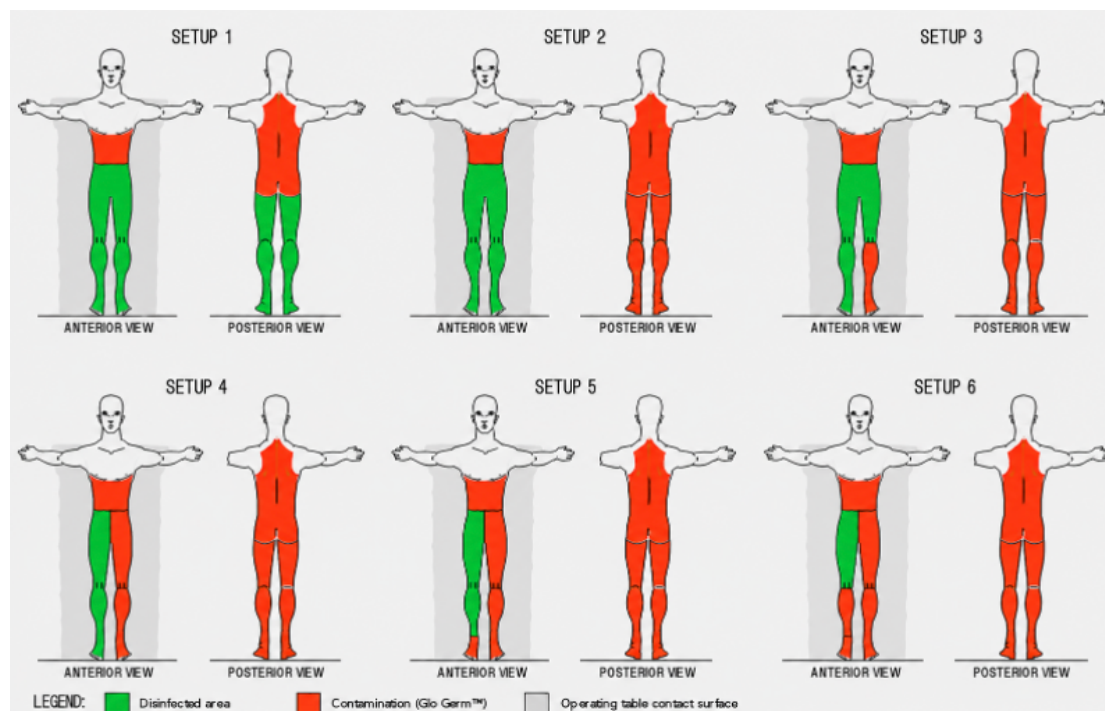


Fig. 1 — Schematic representation of the six experimental setups. Green indicates disinfected areas, red indicates contamination (Glo Germ™), and grey indicates operating table contact surfaces. Each setup includes anterior and posterior views.

removed with clear alcoholic prep. Glo Germ™ was re-applied as necessary to keep lubrication and as required for the setup.

Test subjects were nude except for the genital area, which was covered with a cotton towel. In all settings Glo Germ™ was applied to the covered genital area.

Draping was performed by three examiners: One at the feet of the patient to hold and lift both legs, one for the ipsilateral side and one for the contralateral side.

After draping, three examiners screened the operative field for contamination using the UV light. The field was deemed contaminated if 2 of three examiners found and confirmed a positive marking.

Subsequently the drapes were carefully removed top to bottom and the inner side of the drapes were inspected for the following aspect (Figure 2):

1. Closest contaminated distance superior to field in centimeters.
2. Closest contaminated distance posterior to field in centimeters.
3. Closest contaminated distance anterior to field in centimeters.
4. Closest contaminated distance inferior to field in centimeters.

All findings were marked in an Excel (Microsoft™, Redmond, Washington, United States) file for processing (Supplement: Table II).

RESULTS

This was an exploratory proof-of-concept study and no a priori sample size calculation was performed.

Categorical outcomes were compared across conditions using a chi-square test of independence. Effect size was expressed as Cramér's V. Continuous measures were compared using the Kruskal–Wallis test with epsilon-squared (ϵ^2) as a non-parametric effect size. Pairwise comparisons were performed using Mann–Whitney U tests with Holm correction for multiple testing. Distal distance was compared only between settings 5 and 6.

Statistical analyses were performed using non-parametric methods appropriate for small sample sizes. A p-value < 0.05 was considered statistically significant.

Contamination by Draping Condition

Contamination rates differed significantly across conditions. No contamination occurred in settings 1–4 (0/28, 0%). Contamination occurred in 2 of 7 trials (28.6%) in setting 5, and 4 of 7 trials (57.1%) in setting 6 (fig. 3).

A chi-square test demonstrated a significant association between draping condition and contamination ($\chi^2(5) = 16.33$, $p = 0.006$, with a large effect size (Cramér's V = 0.62)).



Fig. 2 — Evaluation of the contamination distance after removal of the drape.

This indicates that less extensive prepping conditions were associated with substantially higher contamination risk.

Distance Comparisons Across Conditions

Median distances in the proximal, posterior, anterior, and distal directions varied across conditions, but none of the differences reached statistical significance: (Supplement: Table II)

- Proximal: $H = 4.46$, $p = 0.485$, $\epsilon^2 = 0.00$
- Posterior: $H = 7.95$, $p = 0.159$, $\epsilon^2 = 0.08$
- Anterior: $H = 10.00$, $p = 0.075$, $\epsilon^2 = 0.14$

Although anterior distance demonstrated the largest effect size and trended toward significance, the study was underpowered to confirm this finding.

Distal Distance (Settings 5 vs. 6 Only)

Distal distance did not differ significantly between the two applicable conditions (Mann–Whitney U, $p > 0.05$).

Effect of lifting vs not lifting the legs (Setting 1 vs Setting 2), and disinfecting or not disinfecting the contralateral side (Settings 1,2 vs Settings 3,4)

No statistical difference could be shown for contamination or distance measurements between these settings.

Power Considerations

A post hoc power analysis for the chi-square test (using Cramér's $V \approx 0.62$ and $N = 42$, $\alpha = 0.05$) yields an

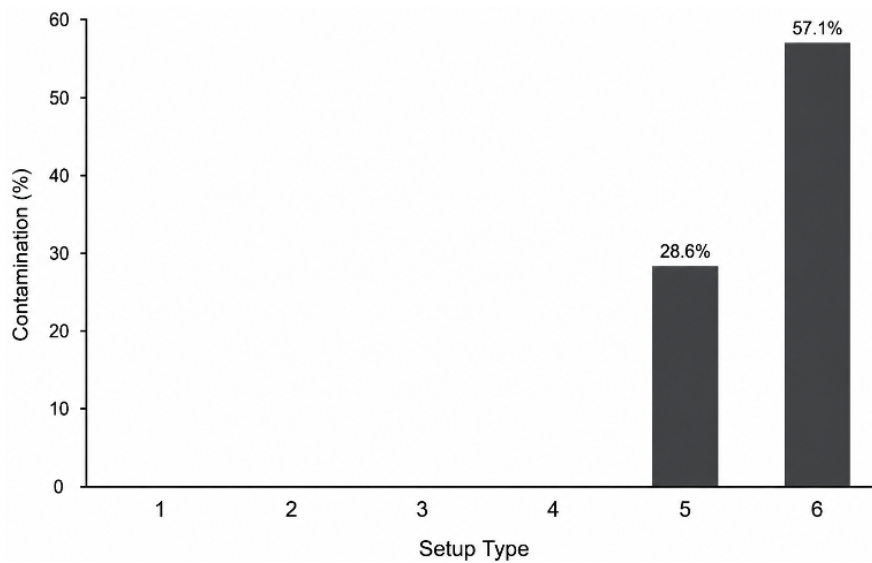


Fig. 3 — Contamination rate according to surgical setup.

estimated power of approximately 0.79. This means the study was reasonably well powered to detect the large observed association between each setup and contamination.

In contrast, the non-significant Kruskal–Wallis tests for distance measures likely suffer from low power. With only seven observations per group, the study has limited sensitivity to detect small or moderate differences in distances between each setup.

Summary of Key Findings

Contamination risk was negligible in widely prepped configurations (settings 1–4).

Less extensive skin preparation protocols to the ankle or below-knee level increased contamination risk dramatically (Settings 5 and 6) (Fig. 3).

Measured distances between drape boundaries and the surgical field did not differ meaningfully across conditions and did not explain contamination events.

DISCUSSION

The most important finding of this study is that omission of the ipsilateral foot and distal leg substantially increased contamination risk during draping.

In contrast, extending preparation to the contralateral side or lifting the limb to disinfect posterior surfaces did not provide measurable benefit within the constraints of this experimental model (Figure 3).

These results have clinical relevance for surgeons: expanding the sterile field may offer a simple, practical method to reduce contamination risk. These findings raise concerns regarding the reduction of the disinfected area to a local field on the operated leg.

The results showed that disinfection of the contralateral side had no added value. Furthermore, lifting of the operative side to disinfect the posterior aspect had no added value.

From this proof-of-concept study, the findings support preparation of the entire ipsilateral leg, without lifting to disinfect the posterior side. The study suggests this might limit the risk for SSC (setup 4).

Measured distances between setups proximally, anteriorly and posteriorly did not predict contamination. This suggests that the qualitative boundary of preparation, rather than precise spatial parameters, plays a predominant role in preserving the sterile field.

Notably, contaminated margins were frequently found in close proximity to the surgical field after removal of the DAA drapes (Fig. 2). Therefore, we have adopted the practice of applying 3 extra small sterile drapes at the edges of the surgical field: at the end of the surgical table, at the anterior border and at the posterior border of the surgical field. This is a speedy and cost-effective process, which might increase safety by protecting the sterile margins before applying the DAA drape (Supplement. Fig. 4).

It is important to emphasize that this method is not supported by the study findings and that future research should validate this.

Among the contamination-free protocols, setup 4 may represent a pragmatic compromise between preparation extent and efficiency. This can be taken into account as time management has become more important in current surgical practice^{19,20}.

It should be noted that the unnecessary disinfection of large areas of the body, might have a negative effect on patients. Alcoholic preps can lead to irritation,

allergic reactions and burn wounds²²⁻²⁴. It seems advisable to look for optimization between safety and unnecessary overuse of disinfectant.

Despite the widespread use in daily practice, to our knowledge our pilot study is the first to investigate contamination risk associated with different skin preparation protocols when using DAA draping systems and the first to offer a guideline for intra-operative use.

Only one previous study was found, looking at draping technique in a posterior approach for total hip replacement. Abbott et al investigated the best practice in draping for total hip replacement using the posterior approach. They found that not disinfecting the foot led to a higher risk for SSC¹⁴. This finding is in line with our own findings for the anterior approach.

The present study does not demonstrate a relationship between contamination and surgical site infection. Instead, it identifies contamination pathways that may be relevant during draping and provides a rationale for future microbiological validation studies.

The present study has several limitations:

First, this was a proof-of-concept study using a fluorescent contamination model rather than microbiological testing. Although fluorescent tracers have previously been used to investigate contamination pathways, the model cannot be considered a surrogate for bacterial contamination or infection risk.

Second, the contamination medium consisted of Glo Germ™ mixed with ultrasound gel. While this improved reproducibility and transferability between experiments, it does not represent physiological contamination encountered during surgery.

Third, the study evaluated contamination during draping only and did not investigate intra-operative wound contamination, bacterial cultures or clinical infection outcomes.

Finally, the small sample size limited the power for distance-based analyses. Because the same volunteers were sequentially tested in all six conditions, observations cannot be considered fully independent and contamination events may have been influenced by repeated testing. Consequently, the results should be interpreted as hypothesis-generating and should serve as a basis for future clinical and microbiological investigations.

CONCLUSIONS

In this proof-of-concept contamination model, exclusion of the ipsilateral foot and distal leg was

associated with a marked increase in contamination events during draping for direct anterior THA.

More extensive preparation strategies, including contralateral preparation and posterior disinfection obtained by lifting the limb, did not demonstrate additional benefit.

These findings should be considered hypothesis-generating and warrant further validation using microbiological and clinical outcome studies.

According to local regulations, formal ethical committee approval was not required. The study involved only healthy adult investigators acting as study subjects. No patients were involved, and no personal health data were collected.

Acknowledgments: DAA drapes were provided by Mölnlycke (Mölnlycke Health Care Group nv, Berchem, Belgium). The company was not involved in the proceedings of the study or the analysis and reporting of the results.

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For clinical trials: N/A.

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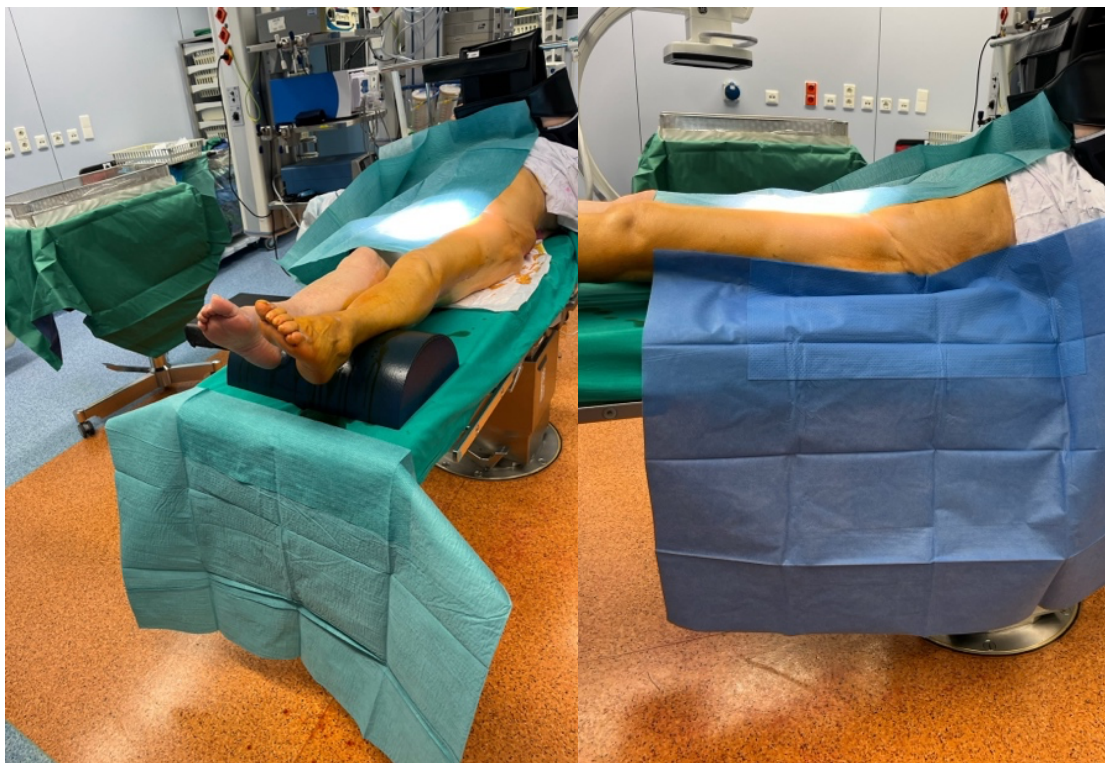
SUPPLEMENTS

Supplementary table II. — Reporting of all test conditions.

	subject number	Contamination	Distance proximal	Distance posterior	distance anterior	distance distal
setting 1: max prep both legs lifted	1	0	10	11	4	NA
	2	0	8	10	6	NA
	3	0	12	8	8	NA
	4	0	15	7	11	NA
	5	0	14	11	9	NA
	6	0	8	10	5	NA
	7	0	11	8	5	NA
Mean		0	11,14 (SD 2,73)	9,29 (SD 1,6)	6,86 (SD 2,54)	NA
setting 2: max prep both legs non lifted	1	0	12	8	5	NA
	2	0	17	12	7	NA
	3	0	12	14	4	NA
	4	0	10	10	6	NA
	5	0	9	8	7	NA
	6	0	14	7	4	NA
	7	0	12	12	11	NA
Mean		0	12,28 (SD 2,63)	10,14 (SD 2,61)	6,29 (SD 2,43)	NA
setting 3: company advisory	1	0	12	12	11	NA
	2	0	12	17	15	NA
	3	0	10	8	9	NA
	4	0	17	8	12	NA
	5	0	16	11	8	NA
	6	0	13	9	11	NA
	7	0	16	12	6	NA
Mean		0	13,71 (SD 2,63)	11 (SD 3,16)	10,29 (SD 2,93)	NA
setting 4: unilateral full non lifted	1	0	10	10	6	NA
	2	0	8	8	4	NA
	3	0	12	8	4	NA
	4	0	15	7	8	NA
	5	0	15	8	6	NA
	6	0	13	9	12	NA
	7	0	11	11	9	NA
Mean		0	12 (SD 2,58)	8,71 (SD 2,38)	7(SD 2,89)	NA

Supplementary table II. — Reporting of all test conditions — continued.

setting 5: unilateral to ankle	1	0	12	13	9	15
	2	1	12	9	12	6
	3	0	16	7	6	6
	4	0	8	9	5	12
	5	1	14	14	7	4
	6	0	15	18	10	25
	7	0	15	11	4	20
Mean		28,6%	13,14 (SD 2,73)	11,57 (SD 3,74)	7,57 (SD 2,88)	12,57 (SD 7,91)
setting 6 unilateral to below knee	1	1	15	9	4	2
	2	1	9	11	5	4
	3	0	18	13	7	9
	4	1	16	15	9	3
	5	0	11	9	6	5
	6	1	11	12	4	0
	7	0	14	13	3	7
Mean		57,1%	13,43 (SD 3,21)	11,71 (SD 2,21)	5,43 (SD 2,07)	4,29 (SD 3,04)



Supplementary Fig. 4 — Current preferred setup.

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