Research Article

Contamination of Irrigation Fluid During Primary Total Knee Arthroplasty

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All patients provided consent to be included in this study.

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Abstract

Purpose: During surgical procedures, some amount of irrigation fluid leaks from the surgical site and accumulates on the sterile drapes. Whether these fluid collections show bacterial contamination over time in primary total knee arthroplasty remains unclear.

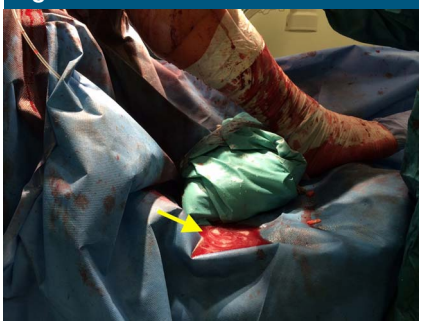
Methods: In this study, we included 100 patients. We collected the samples of irrigation fluid before skin incision and every 30 minutes after the start of surgery. In addition, at the end of surgery, we evaluated the suction tip for bacterial contamination. After 3 months, we clinically evaluated all patients for periprosthetic joint infection.

Results: Although the drapes were found to be sterile after 30 minutes, fluid residues on the surgical drapes show a contamination rate of 22% after 60 minutes and thus a marked correlation between advanced duration of surgery and bacterial contamination. The suction tip was contaminated with bacteria in 22% of cases. The spectrum of pathogens typical of periprosthetic joint infection could be demonstrated.

Conclusion: Fluid surgical drape reservoirs were abacterial during the first 30 minutes but showed marked bacterial contamination over time. For total knee arthroplasty, we recommend regular replacement of the suction tip every 30 minutes. In addition, irrigation fluid reservoirs should not be withdrawn by suction 30 minutes after skin incision.

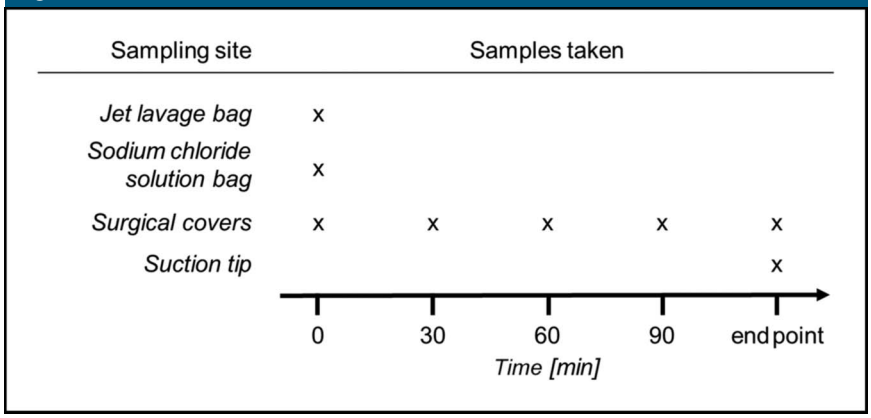
For most patients with osteoarthritis of the knee, total knee arthroplasty (TKA) results in a marked improvement in quality of life.[1] However, periprosthetic joint infection (PJI) after TKA represents a considerable problem for the individual patient and the healthcare system. Many studies have shown that TKA infections are often associated with prolonged course of illness, revision procedures, and lifelong consequences for the health of patients.[2] To prevent infections, surgery of TKA requires a sterile environment. Despite additive preventive measures such as the use of iodine foils to cover the skin in between the surgical drapes or of sterile space-suit technology for the surgeon and assistant, the infection rate in primary total joint replacement remains between

Figure 1



Photograph showing the surgical field with the fluid reservoir (yellow arrow) on the surgical drape during total knee arthroplasty.

Figure 2



Schematic showing the documentation of the sampling schedule according to the sampling site and time point. Counting (zero minute) starts with skin incision.

0.7% and 3% of the cases.[3,4] Several potential intraoperative contamination sources are reported in the literature, such as surgical gloves, air flow, suction tips, and splash basin fluid.[5-11] One basic measure for intraoperative prophylaxis against PJI is repeated irrigation of the surgical field with sterile crystalloid solutions. In animal models, intensified lavage of contaminated wounds achieved a clear reduction in the microbial load.[12] In addition, there is minimization of intra-articular bone fragments and cement particles in correlation with the amount of irrigation fluid used.[13] Nevertheless, in general, the total amount of irrigation fluid is not sucked from the wound into the suction device. Thus, fluid residues on the surgical drapes emerge (Figure 1). These fluid residues might not consist of used irrigation fluid, blood, and debris but could also represent a potential niche for bacteria. It was already shown that the intraoperative retention of irrigation fluid in open containers leads to a bacterial contamination rate of 62% at the end of orthopaedic interventions.[6] Suction devices, commonly used to remove accumulating irrigation fluid, showed substantial bacterial contamination for primary total hip arthroplasty (THA).[10,11] However, to what extent the fluid reservoirs on the surgical field remain sterile over the course of primary TKA and thus represent a potential infection focus remains unclear. In addition, whether there is a time-dependent contamination rate of the fluid reservoirs over the course of primary TKA is unknown. For this reason, the objective of the current study was to investigate whether pathogenic microbes can be identified in irrigation fluid during primary TKA and to determine the potential time points of contamination.

Methods

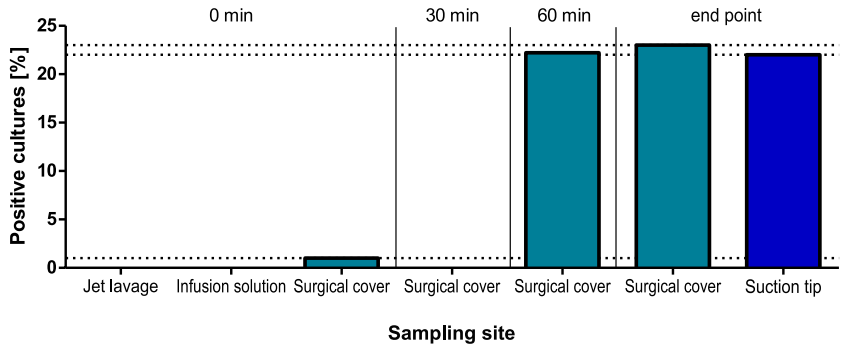
In this prospective, single-center study, we included 100 patients who underwent primary TKA. The inclusion criterion was a minimum age of 18 years, and written informed consent was obtained from patients to participate in the study. The exclusion criterion was previous knee surgeries with residual internal fixation devices. Four experienced, high-volume surgeons at the senior level, who performed a minimum of 80 annual primary TKAs each, performed the procedures between March and June 2016. The patient population comprised 64 women and 36 men with an average age of 68.9 years (SD, 10.2 years) and an average body mass index of 29.5 (SD, 4.7). In 95 patients, TKA was due to primary knee osteoarthritis. In five patients, nonsurgically treated posttraumatic osteoarthritis was the

Dr. Pfitzner or an immediate family member is a member of a speakers' bureau or has made paid presentations on behalf of Aesculap/B. Braun, DePuy, and Smith & Nephew and serves as a paid consultant to DePuy. Dr. Kopf or an immediate family member is a member of a speakers' bureau or has made paid presentations on behalf of Karl Storz and Smith & Nephew; has received research or institutional support from Karl Storz; and serves as a board member, owner, officer, or committee member of *Knee Surgery, Sports Traumatology, Arthroscopy*. Dr. Hommel or an immediate family member is a member of a speakers' bureau or has made paid presentations on behalf of Smith & Nephew. None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Fuchs, Dr. von Roth, and Dr. Sass.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The study is registered in the German Clinical Trials Register (no. DRKS00009696).

reason for joint replacement. After inpatient admission, all patients underwent preoperative shaving of the surgical site with a disposable razor the day before surgery. Standard preoperative skin scrubbing of the patient's lower extremity was performed using an antiseptic solution (Softasept N; B. Braun). For skin disinfection of the surgical site, it was washed four times with an antiseptic solution (Braunol; B. Braun) for at least 10 minutes. Patients received single-shot perioperative antibiotic prophylaxis (cefuroxime 1.5 g intravenously 30 minutes before skin incision). In the event of cephalosporin intolerance, 1 g of vancomycin was administered intravenously 2 hours before skin incision. The median parapatellar approach was used as the standard surgical approach. After defined time intervals during surgery, irrigation fluid was collected and tested for bacterial contamination (Figure 2). Crystalloid sodium chloride solution (500 mL NaCl 0.9%; B. Braun) was used as irrigation solution with a 50-mL syringe and a fluid irrigation device (Pulsavac; Zimmer). At the beginning of surgery, two samples were taken from the two irrigation containers (one jet lavage bag and one 500 mL 0.9% sodium chloride bottle) to exclude initial contamination. Sterile draping was performed following a routine protocol, with a two-layer sterile covering towel. Before skin incision, approximately 50 mL of irrigation fluid was poured onto the surgical covers. Of these, 3 to 5 mL fluid residues were immediately collected from the surgical drapes with a sterile 10-mL syringe for microbiologic evaluation. Every 30 minutes and at the end of surgery, 3 to 5 mL of fluid from the surgical drapes were investigated. All samples were injected into blood culture bottles (Bactec Peds-Plus; BD). In addition, at the end of surgery, the disposable suction tip (Dahlhausen) was retained for subsequent microbiologic testing. After surgery, all samples were sent to a microbiologic institute where they were incubated for 14 days. In case of contamination, bacterial species were identified and resistograms were established.

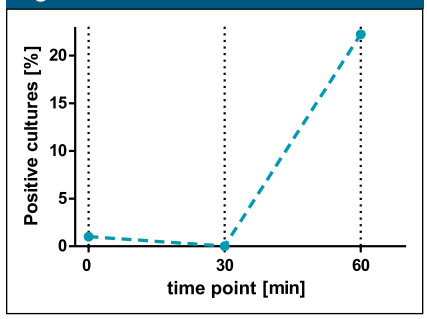
Figure 3



Graph showing microbial detection over time. Positive microbial cultures at the respective testing time points: jet lavage (zero), sample from the irrigation fluid bag of the jet lavage at the start of surgery; infusion solution (zero), sample from the irrigation fluid bottle at the start of surgery; surgical covers (zero), irrigation fluid sample from the surgical covers at the start of surgery; surgical covers (30/60/end point), irrigation fluid sample from the surgical covers 30/60 minutes after the start of surgery and at the end of surgery; suction tip (end of surgery), testing of the suction tip at the end of surgery.

All 100 patients underwent cemented TKA (61 Journey II Bi-Cruciate Stabilized Knee System and 39 Journey II Cruciate Retaining Knee System; Smith & Nephew). The average duration of surgery was 66 minutes (SD, 7.2 minutes). The procedures were performed in the same surgical theater, in which 98% of the surgeries are endoprosthetic interventions. No wound drains were used in the patient population. All patients received 1 g of tranexamic acid systemically during the surgical procedure and 2 g intra-articularly after closure of the joint capsule. There was a laminar airflow and outwardly directed excess pressure during the entire surgical preparation and procedure. The surgeons wore sterile, disposable operating room clothing. No postoperative antibiotics were given in any of the evaluated cases.

Figure 4

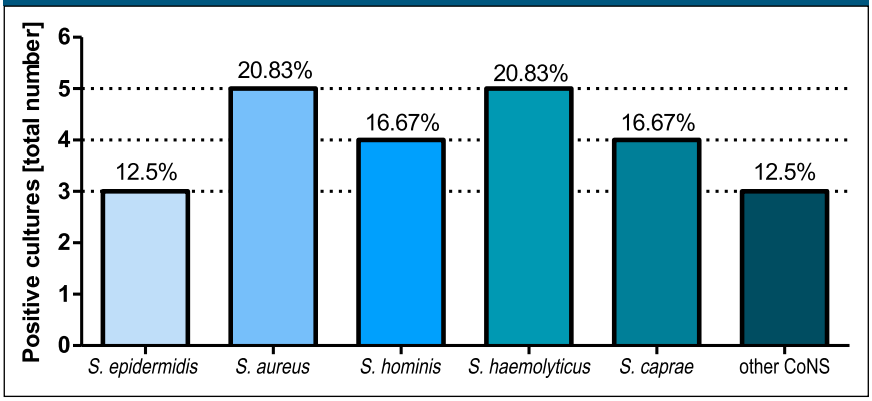


Graph showing positive bacterial cultures of the surgical cover; percentage of microbiologically positively tested samples from irrigation fluid depending on the duration of surgery.

Patients with confirmed irrigation fluid contamination were summoned to the outpatient department after 1 and 3 months and examined for clinical signs of PJI such as persistent redness, swelling, and wound healing disorders.

The study was approved by the local ethics committee (no. S20a/2015) and declared in a clinical trial register (DRKS00009696). All statistical analyses were performed with SPSS Statistics V22.0 (IBM).

Figure 5



Graph showing microbial identification; number and percentage of microbial differentiation of all positive final microbiological findings. CoNS = coagulase-negative staphylococci

Results

Samples of the fluid bags for irrigation and jet lavage were not contaminated. At the beginning of surgery, in one patient, *Staphylococcus hominis* was detected on the surgical cover. Culture-positive microbiological findings were not seen after 30 minutes. After 60 minutes, the samples of 22 patients (22%) were contaminated with bacteria. At the end of surgery, a culture-positive finding was seen in 23 cases (23%) in 23 patients. The suction tip investigation at the end of surgery showed bacterial contamination in 22% (Figure 3).

A very strong correlation ($R^2 = 0.89$) was found between the advanced duration of surgery and the number of positive microbial findings of the irrigation fluids between the time period of 30 minutes and the end of surgery (Figure 4). In all cases, microbiologic evaluation confirmed contamination with staphylococci. In three cases, other coagulase-negative staphylococci were detected without further differentiation of the bacterial strain (Figure 5).

In 87% of all positive microbial findings of the irrigation fluids, a threefold positive pathogen finding (60 minutes, end of surgery, and suction tip) was seen. In three patients (13%), two positive cultures each were observed at different time points. In two cases, a positive culture was found exclusively in the irrigation fluid samples. Here, two positive microbiologic findings each per patient were seen after 60 minutes and at the end of surgery. In all other samples tested, the respective microbes were detected both in irrigation fluid and on the suction tip. The mean surgical time did not differ between patients with and without positive culture results. No difference was noted in pathogen characteristics or bacterial contamination of irrigation fluid and suction tip regarding the two different antibiotic treatments. Over the follow-up period of 3 months, no clinical or laboratory evidence of PJI was seen in the patient cohort. No wound-healing disorders were observed. Intra-articular hematoma developed in two patients, with a limited knee joint flexion <90° on the sixth postoperative day, which did not require surgical intervention within the follow-up period. These symptoms disappeared within 4 weeks and were not present at the first follow-up examination at our outpatient department.

Discussion

The objective of this study was to microbiologically investigate the irrigation fluid reservoir in 100 patients undergoing primary TKA, in order to define potential infection sources at different time points. We are not aware of any comparative studies on this subject. Our data suggest that retained irrigation fluid reservoirs on the surgical covers show increasing bacterial contamination over time in primary TKA. The surgical site was sterile at 30 minutes, but 22% of the cases already showed bacterial contamination 60 minutes after skin incision. The typical bacterial strains known from PJI such as *Staphylococcus epidermidis* and *Staphylococcus aureus* were cultured.[14,15] A strong correlation was seen between the advanced duration of surgery and the number of positive microbiological findings.

As a result of the devastating consequences of PJI, its early diagnosis and the best possible prevention are the constant subject of scientific discourse.[5,16-20] Different studies have produced new perspectives and recommendations concerning the improvement of intraoperative PJI prophylaxis. Previous studies have focused on bacterial colonization of splash basin fluid in relation to the duration of surgery.[7,8,21] Anto et al[7] investigated contamination in 21 patients with primary hip or knee arthroplasty over an average surgical duration of 96 minutes. In five surgeries (24%), they demonstrated contamination with pseudomonads or coagulase-negative staphylococci. As a recommendation for improved intraoperative infection prophylaxis, the authors proposed that the used surgical instruments should remain on the instrumentation table and should not be placed in a splash basin. By means of microbiologic tests on surgical gloves in primary THA, Al-Maiyah et al[5] showed that

an increased number of contaminations occurred over the chronological course of surgery. The authors recommended a regular change of surgical gloves every 20 minutes to reduce potential contamination of the surgical field.

One study is available that deals with the contamination of irrigation fluid in relation to its open intraoperative storage. In 13 of 21 cases (62%), Andersson et al[6] demonstrated contamination with staphylococci or corynebacteria by direct microbiologic analysis from the irrigation fluid storage container at the end of the procedures, with a minimum operating time of 60 minutes. The authors concluded that open intraoperative storage of irrigation fluid represents a potential source of infection.

Other studies directed their focus to the contamination of intraoperatively used suction tips.[9-11] Greenough et al[10] demonstrated bacterial contamination of disposable suction tips used for primary THA in 11 of 30 patients (37%) at the end of surgery. In 31 additional THA procedures, exclusively, the suction tips that were used during femoral preparation were investigated. Only in one case, a positive microbial culture (*S epidermidis*) was obtained. The authors concluded that the contamination of the suction tip is correlated with the duration of its use and recommend its replacement before femoral preparation. Givissis et al[9] also evaluated the contamination of intraoperatively used suction tips in 50 orthopaedic trauma surgeries ranging from open reduction and internal fixation of the upper and lower extremities to spinal decompression and posterior stabilization. The authors demonstrated bacterial contamination in 27 cases (54%). Contamination with staphylococci was found in 21 cases (77.8%) of the positive microbial findings. In 26 of 27 (96.3%) of all positive microbial findings, surgery lasted at least 60 minutes.

Comparing our results with those of the previously mentioned authors, we can confirm their observations on the basis of our data. Most importantly, the connection between the contamination load and duration of surgery has to be emphasized. The rate of positive cultures was much higher in the study by Givissis et al[9] at 54% compared with our results (22%). This fact may be attributable to the large proportion of traumatologic interventions, within the context of which preoperative patient conditioning is much more difficult than in elective TKA. In both studies, there were a smaller number of patients compared with the current study. In addition, the heterogeneity regarding the surgical procedures must be mentioned, as primary TKA patients were not included in the patient population in either of the two publications. Nevertheless, on the basis of the current data, it may be concluded that the suction tip is subject to substantial bacterial contamination with increasing duration of surgery.

Andersson et al[6] demonstrated a high bacterial contamination rate of irrigation fluid with respect to its open intraoperative storage. The approximately threefold higher contamination rate compared with our data may be attributable to the fact that it was conducted in 1984. Since then, numerous preventive measures for optimization of microbial reduction have been implemented. Furthermore, this publication shows a different study design, as the authors focused exclusively on the analysis of irrigation fluid in relation to the intraoperative storage. In addition, there are a small case number of 21 evaluated operations. Nevertheless, with regard to the open storage of solutions in use, their data deserve attention.

We do notice that the results of our study and the observations by the cited authors show much higher bacterial contamination rates than rates of diagnosed PJI. First, it is possible that most potential PJIs in those patients were successfully prevented by perioperative antibiotic patient protection. Second, the previously mentioned fact illustrates that we might have to change our understanding of PJI etiology. In this context, the question arises whether there is certain immunologic resilience, which leads to pathogen elimination in the case of a low bacterial infection load. Additional studies seem to be necessary to clarify the question whether there are specific patient-related endogenous immunologic skills, which gain the potential to contain a certain threshold of pathogens inducing PJI.

A limitation of our study is that the 100 interventions were performed by four different surgeons. In this respect, factors possibly influencing our results may be attributable to interindividual differences. This limitation may result in different surgical times, which, in turn, correlate with the contamination rate. However, because the average duration of surgery of 66 minutes (SD, 7.2 minutes) was documented, this aspect is of little relevance. There was no evaluation of potential microbial contamination or culture sample preservation from the instruments and surgical gloves. In addition, the short follow-up period of 3 months must be mentioned. This aspect is particularly important for low-grade infections because they are diagnosed after a longer follow-up period, and thus, the true rate of PJI cannot be reliably determined.

Conclusion

This study shows increasing bacterial contamination of irrigation fluid reservoirs on the surgical drapes over time for primary TKA. Regular lavage continues to be considered an important

measure for cleaning the surgical field. On the basis of our observations and to ensure that surgeries are performed in the best possible sterile environment, we recommend replacement of the suction tip every 30 minutes. In addition, we recommend that the collected irrigation fluid reservoir is no longer withdrawn by suction 30 minutes after skin incision. With this study, we hope to add a new aspect of intraoperative infection prophylaxis to the current scientific discussion.

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