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Outcome following deep wound contamination in cemented arthroplasty

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Abstract Infection remains a devastating complication of joint replacement surgery causing a significant burden to both patient and surgeon. However, despite exhaustive prophylactic measures, intraoperative contamination still occurs during cemented arthroplasty with current infection rates of 1–2%. A study was undertaken to determine the incidence of perioperative contamination in cemented arthroplasty patients, to identify contaminating organisms, to identify contaminated regions within the operative wound, to identify factors associated with increased contamination, and finally to assess the medium-term clinical outcome in patients with confirmed intraoperative wound contamination. Eighty consecutive patients undergoing hip and knee cemented arthroplasty were prospectively enrolled over a 6-month period. All scrubbed personnel wore total body exhaust isolation suits and procedures were carried out in ultra-clean air theatres. Of 441 samples, contamination was identified at 21 sites (4.8%) representing a cohort of 18 patients (22.5%). Longer duration of surgery predisposed to higher contamination rates while lower contamination rates were significantly related to fewer gowned personnel within the ultra-clean system, and fewer total personnel in theatre during the procedure. None of the patients developed clinical evidence of deep prosthetic infection at follow-up. We noted a high incidence of intraoperative contamination despite standard prophylaxis. However, this was not reflected by a similar rate of postoperative infection. This may be due to a small bacterial inoculum in each case or may be due to the therapeutic effect of perioperative intravenous antibiotic prophylaxis.

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Résumé L'infection reste une complication grave de la chirurgie de remplacement articulaire et, en dépit des mesures prophylactiques, la contamination opératoire existe encore durant les arthroplasties cimentées avec un taux d'infection de 1 à 2%. Le but de ce travail était de déterminer l'incidence de cette contamination, d'identifier les micro-organismes en cause et les régions contaminées au sein du champ opératoire, de préciser les facteurs associés favorisant et enfin d'étudier le devenir à moyen terme des patients avec une contamination opératoire confirmée. Quatre-vingt patients consécutifs, opérés pour une arthroplastie cimentée de hanche ou de genou, étaient enrôlés prospectivement pendant une période de 6 mois. Tout le personnel habillé chirurgicalement portait un scaphandre isolant et l'opération se déroulait dans une enceinte à air ultra filtré. A partir de 441 échantillons une contamination était identifiée sur 21 sites (4,8%), représentant un groupe de 18 patients (22,5%). Une plus longue durée opératoire prédisposait à un plus grand taux de contamination. Un faible taux de contamination était significativement en relation avec un moindre nombre de personnes à l'intérieur de l'enceinte ultra-filtrée et avec un moindre nombre de personnes dans la salle d'opération pendant la réalisation de l'arthroplastie. Aucun patient n'avait développé d'infection profonde au dernier recul. Le taux élevé de contaminations opératoires malgré les précautions prophylactiques ne se retrouve pas dans un taux similaire d'infections post-opératoires. Ceci est peut-être due à la petitesse de l'inoculum bactérien dans chaque cas ou encore à l'effet thérapeutique de l'antibiothérapie prophylactique intra-veineuse.

Introduction

Infection remains a devastating complication of joint replacement surgery causing a significant burden to both patient and surgeon. Over the past three decades, infection rates have decreased through meticulous attention to aseptic technique in the perioperative period. Charnley [4] highlighted the hazards of contamination during

arthroplasty surgery, striving to improve high early infection rates. One of the most significant advances in the reduction of contamination was the introduction of ultra-clean air-flow theatre systems [4]. This was further improved with the use of sterile hoods and body-exhaust systems, multiple instrument trays and a scrubbed, gowned leg holder. In developing these intraoperative practices, Charnley and Eftekhar [5] reported a dramatic decrease in postoperative wound infection from 9 to 1%. Lidwell [20] reported a reduction in infection rates from 3.4 to 1.7% with the use of clean-air theatres, to 0.4% with the addition of prophylactic antibiotics, and to 0.2% with a combination of clean-air theatres, antibiotics and occlusive clothing.

However, despite exhaustive prophylactic measures, intraoperative contamination still occurs during cemented arthroplasty with current infection rates of 1–2% [11, 19]. Davis et al. [7] demonstrated a high incidence of bacterial contamination in the allegedly sterile theatre environment, with an overall contamination rate of 63% being noted. Their data revealed that 29% of gloves, 17% of gowns and 14.5% of light handles were contaminated by the end of procedures within a laminar flow system. Examination of instruments used at the direct site of implantation during total hip arthroplasty revealed 6% contamination rates for acetabular and femoral broach samples [22].

The main sources of contamination appear to be from the skin of the patient and airborne particles from theatre personnel [15, 21]. Brown et al. [3] reported bacterial air counts more than four times higher during preparation and draping of the leg using an unscrubbed, ungowned leg holder than intraoperatively. Using a scrubbed, gowned leg holder, air counts during draping were reduced, but were still twice greater than during the operation itself. Other factors implicated in contamination include duration of the procedure [12], the number of personnel in theatre [2], the type of gowns and drapes used [24] and contamination from splash bowls and suction tips [16]. Changing gloves at regular intervals has been found to be effective in decreasing the incidence of glove perforation and potential bacterial contamination by the surgical team [1]. The benefits of changing from skin blade to deep blade to reduce wound contamination are still debated [6], but Davies et al. [7] reported contamination rates of 9.4% for skin blades and 3.2% for inside blades used during surgery.

A study was undertaken to determine the incidence of perioperative contamination in cemented arthroplasty patients, to identify contaminating organisms, to identify contaminated regions within the operative wound, to identify factors associated with increased contamination, and finally to assess the medium-term clinical outcome in patients with confirmed intraoperative wound contamination.

Materials and methods

Eighty consecutive patients undergoing hip and knee cemented arthroplasty were prospectively enrolled in the study over a 6-month period. Primary total hip replacement was carried out in 55 patients and total knee replacement in 23 patients. Two further patients underwent revision hip and knee arthroplasty for aseptic loosening. Exclusion criteria included those with evidence of active joint, prosthetic or systemic sepsis on radiological and biochemical investigations. All patients underwent standard medical and dental pre-assessment.

Preoperative wound site preparation included a chlorhexidine shower on the morning of surgery. All anaesthetic procedures took place in a dedicated room leading into the operating theatre while surgical procedures took place in clean-air laminar flow theatres (Ultra Clean Ventilation System, Weiss Technik, Wrexham, UK). Prophylactic intravenous cefuroxime (1.5 g) was administered at induction as per hospital protocol and continued every 8 h postoperatively for 24 h. In cases of penicillin allergy, erythromycin (1 g) was administered intravenously. Skin hair was removed by clipping in the induction room immediately prior to surgery. Non-scrubbed personnel wearing sterile gloves painted and draped the surgical site in the induction room. A second preparation and draping was performed in the operating room by the scrubbed surgical team. Scrubbed personnel included the scrub nurse, surgeon and two assistants, one designated as the scrubbed leg-holder. In some cases, extra scrubbed personnel were involved for training purposes. All wore total body exhaust isolation suits with a double gloving technique. Outside gloves were changed by all after draping and by the surgeon prior to cementing the prosthesis in position. Gloves were also changed should inadvertent contamination occur or if the material was breached in some way. All cement used was gentamicin-impregnated (Palacos) cement.

Bacteriological samples were taken with sterile swabs from the skin at the incision site preoperatively, from the proximal femoral neck at 30-min intervals, after closure of the fascia, and from the suture line prior to closure. Swabs were placed in sterile containers while still in the laminar flow zone. Suction tips and inside and skin blades were also sent for analysis. Samples were cultured on Columbia blood agar and incubated at 37°C, 5% CO_2 for 48 h. Any cultures obtained were typed by morphology.

Results

A total of 441 intraoperative samples were collected from 80 patients. Contaminated samples were identified at 21 sites (4.8%) representing a cohort of 18 patients (22.5%). Single-site contamination occurred in 16 patients while two patients had more than one contaminated sample (Table 1). The most commonly contaminated swab was that from the skin after preparation and before application of the plastic adhesive incision drape (Table 2). The contaminating organisms were all skin commensals with *Staphylococcus epidermidis* cultured from 15 out of 21 samples (Table 3). Only two patients developed clinical symptoms postoperatively: one of the non-contaminated group developed a serous discharge from a drain site, which resolved without treatment, and patient B (Table 1) became pyrexial

Table 1 Patients with more than one contaminated site

	Contaminated sites	Contaminating organism	Sequelae
Patient A	Skin swab Inside blade	*Staphylococcus epidermidis*	
Patient B	Skin swab	*Staphylococcus epidermidis*	Pyrexia 36 h postoperatively; Gram-negative bacillus on blood culture; settled after appropriate antibiotics
	Skin blade Inside blade	Gram-negative bacillus	

36 h postoperatively. Blood cultures revealed a Gram-negative bacillus as the causative organism and the patient settled on appropriate antibiotic treatment with no further complications.

Patients undergoing total hip replacements showed higher levels of contamination than those undergoing total knee replacements (14 patients [25%] vs. four patients [16.6%]). Longer duration of surgery predisposed to higher intraoperative contamination rates (<90 min, 17% contamination rate vs. >90 min, 33% contamination rate). However, these differences were not statistically significant. Furthermore, contamination rates were not significantly affected by surgeon seniority, surgical approach, or use of Turkish towels intraoperatively. Lower contamination rates were significantly related to fewer gowned personnel within the ultra-clean system, and fewer total personnel in theatre during the procedure (Student's *t* test, $p<0.03$).

Patients were followed up for a mean of 49.6 months (±3.2 months, 95% CI). Of the original 80 patients enrolled in the study, ten patients (12.5%) were lost to follow-up and eight patients (10%) had died from causes unrelated to their surgery. Of the remaining patients, 98% were happy with their functional outcome and none of the patients had developed clinical evidence of deep prosthetic infection in the medium term.

Table 2 Sites of contamination

	Total specimens	Contaminated specimens	Percentage
Skin swabs	56	10	17.8
Femoral neck swabs			
30 min	64	1	1.6
60 min	68	2	2.9
90 min	24	1	4.1
Skin blades	66	2	3.0
Inside blade	75	1	1.3
Suction tip	43	2	4.6
Suture line	45	2	4.4
Total	441	21	4.8

Table 3 Contaminating organisms

Organisms cultured	Positive samples	Percentage
Staphylococcus epidermidis	15	71.4
Gram-negative bacillus	2	9.5
Streptococcus spp	1	4.7
Mixed contaminants	3	14.4

Discussion

Deep infection following arthroplasty condemns the patient to multiple wash-out and revision procedures, protracted courses of expensive and potentially toxic antibiotics, and prolonged hospital stays with immobilisation and isolation. Revision surgery for infection is a major challenge to the surgical team and requires adherence to stringent ward and theatre protocols to avoid spread of infection to susceptible patients. The cost of treating an infected prosthesis has been estimated as being four times greater than a primary procedure [8].

Recent work has identified coagulase-negative staphylococci as being most commonly cultured from infected orthopaedic prostheses [25]. *Staphylococcus epidermidis* occurs as normal flora of the skin and mucous membranes. However, in the presence of immunosuppression, neutropenia, in-dwelling catheters, mechanical heart valves and orthopaedic prostheses, it can become an opportunistic pathogen. It was the most common contaminating organism identified in this series, and is recognised as one of the most important agents of hospital-acquired infection with multi-resistant strains emerging.

Skin commensals were identified as the primary contaminating organisms in this series of cemented arthroplasties. Despite chlorhexidine showers and preparation and draping in both the induction room and in theatre, 17.8% of skin swabs were contaminated. It had previously been suggested that it is not surface bacteria that cause wound contamination, but those lying deeper in the sebaceous glands and hair follicles exposed by the surgical incision. Fairclough et al. [10] demonstrated that 15% of surgical wounds were contaminated by organisms present on the skin prior to disinfection. They further showed that iodophor-impregnated plastic adhesive drapes applied to the operation site 24 h prior to surgery reduced wound contamination from 15 to 1.6%. Plastic incision drapes were used during all of our procedures, but only six were impregnated with iodine; thus, significant conclusions cannot be drawn regarding their use. However, it has been suggested that isopropyl alcohol should be used to "de-fat" the skin prior to painting with an iodine preparation to ensure adherence of plastic incision drapes throughout the procedure [14].

Higher intraoperative contamination rates were found with prolonged operative times. At 30 min, 1.6% of samples were contaminated increasing to 2.9% and 4.1% at 60 and 90 min respectively. In concurrence with previous reports [2], significantly lower contamination rates were

related to fewer gowned personnel scrubbed for each procedure, and fewer total personnel in theatre during the procedure.

Transient immunosuppression is a worrying finding in patients undergoing arthroplasty surgery. Intraoperative blood loss appears to result in a reduced frequency of natural killer cell precursors and decreased interferon gamma postoperatively [13]. It has also been suggested that immunosuppression following intra-articular injections of steroid may interfere with asepsis in subsequent arthroplasty surgery [18]. Preoperative co-morbidities that could potentially result in immunosuppression, due to the disease itself or its treatment, were noted in seven patients, including rheumatoid arthritis, non-insulin-dependent diabetes mellitus, psoriatic arthritis, and ulcerative colitis. One patient on chronic steroid management of rheumatoid arthritis had a single contaminated specimen of *Staphylococcus epidermidis* with no short- or medium-term clinical sequelae.

James et al. [17] reported a 9% rate of contamination of donated femoral heads at primary hip arthroplasty. *Staphylococcus epidermidis* was isolated in 77% of the positive cases. There was no significant difference in complication or revision rates in donor patients whose femoral heads had a positive culture compared with those with sterile femoral heads, at a minimum follow-up of 1 year. A high incidence of intraoperative contamination of cemented arthroplasties was noted in our series, with 18 patients exposed to noteworthy intraoperative contamination. However, this was not reflected by a similar rate of postoperative infection at medium-term follow-up, suggesting that an interdependent relationship must exist between bacterial virulence, patient immune status and wound environment. The small bacterial inoculum in each case may account for the lack of clinical sequelae. Alternatively, the therapeutic effect of perioperative intravenous antibiotic prophylaxis may be responsible. Previous studies have demonstrated the absence of systemic antibiotic prophylaxis as one of the major risk factors for the development of infection in primary hip arthroplasties [9]. Also, the ability of bacteria to attach to various biomaterials has been shown to differ, with the lowest colony-forming units of *Staphylococcus epidermidis* being associated with stainless steel and cobalt chrome implants [23]. All of the implants used in this study comprised cobalt chrome alloys.

The majority of contamination in this study of patients undergoing cemented arthroplasty surgery was localised to the skin. Exhaustive preoperative skin preparation did not remove all organisms. Further measures, including use of ultra-clean air theatre systems, total body isolation suits, complex disinfection, draping and glove changing regimes still does not eliminate contamination from arthroplasty. Measures to reduce operative times, reduce the number of personnel in the operating room and prevent transfer of organisms from adjacent skin into the wound may help reduce intraoperative contamination rates. Further awareness of intraoperative sources of contamination and the relationship between bacterial virulence, patient immune status and wound environment may guide changes in practice to further improve infection rates.

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