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Ultrasonic Debridement in Infected Knee Prosthesis an Innovative Approach to Infection Management

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Abstract

Between April 2022 and June 2023, a group of 11 patients with periprosthetic knee infection were treated with ultrasound debridement with Bone Scalpel and Sonic One O.R. (Misonix), an innovative technique that uses high-frequency sound waves to remove necrotic tissue and bacterial biofilm from the bone surface and periprosthetic tissue. Throughout the procedure we wash the surgical field with saline plus iodopovidone diluted in these amounts 500 ml saline + 18 ml iodopovidone for a total of 6 Liters of Solution. All patients showed positive outcomes, with clinical and lab resolution of infection. The approach proved effective in reducing bacterial load and improving tissue healing, representing a promising therapeutic option in the management of periprosthetic knee infections.

Keywords: Periprosthetic Joint Infection (PJI), Ultrasonic Debridement, Knee Prosthesis, Biofilm Removal, Infection Management, Bone Scalpel

Introduction

Periprosthetic infections are one of the most feared and difficult to manage complications after knee prosthesis. The presence of bacteria, often organized in resistant biofilms, makes infections particularly insidious, requiring complex and prolonged treatments that may include antibiotics, surgical revisions, or even removal of the prosthesis itself. In this context, ultrasonic debridement is emerging as an innovative and promising technique to improve the effectiveness of periprosthetic infection treatment [1-5].

What is Ultrasonic Debridement?

Ultrasonic debridement is a surgical technique that uses high-frequency ultrasound waves to remove infected, necrotic, or damaged tissue in a precise and minimally invasive manner. Ultrasound generates micro vibrations that disrupt necrotic tissue and disturb bacterial biofilms, facilitating their removal without damaging surrounding healthy tissue.

In the treatment of periprosthetic knee infections, traditional debridement may be insufficient to completely remove bacteria encapsulated in biofilms, especially in hard-to-reach areas. Ultrasonic debridement, however, offers a significant advantage: the ability to penetrate and disrupt the biofilm, making the bacteria more susceptible to antibiotics and improving the overall effectiveness of the treatment.

Ultrasonic debridement can be performed either during a surgical revision or in combination with joint lavage and replacement of the mobile components (DAIR) of the prosthesis (such as polyethylene). This technique allows for more thorough cleaning of the surgical site, reducing the bacterial load and promoting better control of the infection [6].

The main benefits of ultrasonic debridement in the management of periprosthetic infections include:
Improved biofilm removal: Ultrasound can disrupt biofilm

Reduced risk of damage to healthy tissue: The selectivity of ultrasound allows infected tissue to be removed without compromising healthy tissue, reducing the risk of further complications.

Less invasiveness: Compared to traditional debridement techniques, the use of ultrasound is less traumatic and can reduce post-operative recovery times.

Increased efficacy of lavage solutions and antibiotic treatment: Removal of biofilm and infected tissue allows greater penetration of lavage solution and antibiotics, improving the chances of eradicating the infection.

Materials and Method

Between April 2022 and June 2023, we treated 11 patients affected by knee PJI. Infectious counseling was performed in all patients based on the examination of the aspirate found 9 patients positive for Staphylococcus Aureus and in 2 patients for Staphylococcus Epidermidis. Antibiotic therapy set with teicoplanin or gentamicin and levofloxacin for 8 to 12 weeks [7, 8].

The average PCR values recorded in each individual patient were high (average 88mg/L) as was the ESR whose average recorded values of 123 mm/h. The mean procalcitonin and presepsin values were 1.2 ng/ml and 652 pg/ml, respectively. No patients presented with fever. Locales of infection such as redness, edema, pain and prolonged leakage were present in the four patients undergoing DAIR. In the patients undergoing two-stage revision, the only clinical symptom was spontaneous pain.

Four patients with acute knee prosthesis infection (< one month) were successfully treated using the DAIR (debridement, antibiotics, and implant retention) procedure. This technique consists of surgical cleaning of the infected area, keeping the prosthesis in situ substituting all mobile components, combined with targeted antibiotic therapy.

Seven patients with chronic infection (> one year) were treated by two-stage revision, an approach considered the gold standard for the management of this complication. The first stage involves removal of the infected prosthesis, followed by insertion of an antibiotic-impregnated spacer to fight the infection. We use in all cases Hoffman technique. After 8-12 weeks of antibiotic treatment and monitoring to confirm eradication of the infection, patients underwent the second stage, which involves implantation of a new knee prosthesis [9].

In the cases described, DAIR and two-stage revision, debridement was performed carefully to remove necrotic tissue and reduce the bacterial load with Sonic One O.R. (Misonix) for perisprosthetic tissue and Bone Scalpel with diamond tip (Misonix) for bone tissue, while antibiotic administration was tailored according to the results of microbiological cultures and preoperative infectivological evaluation. Throughout the procedure we wash the surgical field with saline plus iodopovidone diluted in these amounts (500 ml saline + 18 ml iodopovidone). We recommend that 6-9L of irrigation solution, including saline or antiseptic solution such as sterile dilute povidone- iodine. The SonicOne® O.R. takes advantage of the movement longitudinal motion of a tip at a frequency of 22.5 kHz. The repeated sequence of impacts causes in our case the rupture of biofilm while leaving adjacent soft tissues unharmed in case of accidental contact. Ultrasonic debridement takes advantage of the cavitational effect produced by a titanium tip constantly irrigated for effective removal of necrotic tissue while leaving healthy tissues unharmed adjacent tissues.

The age of subjects ranged between 62 and 82 years old (mean age 78.3), 3 are male and 8 females. Clinical and radiographic follow-up was done 1-4-12 months after surgery. Radiographic set included standard anteroposterior and lateral x-rays, anteroposterior and lateral x-rays on weight bearing in monopodalic or bipodalic standing position, patella axial view (Merchant view). An accurate radiological study permits to recognize the grade of osteolysis, the bone stock and axial defects which, all together, represent essential elements for presurgical planning in order to calculate the level of tibial osteotomy and implant size, allowing a correct positioning of components and preventing eventual technical difficulties which every kind of revision could present [10].

Patients, during hospitalisation, undergo a rehabilitative evaluation and start a personalized rehabilitative program focused on restoring muscular strength, articular mobility and proprioceptive functions of knee, hip and ankle in order to obtain a faster post-surgical recovery. Rehabilitative program starts early with isometric exercises and passive motion, continues with the gradual recovery of orthostatic position and walking using walkers since the first day after surgery. Average post-surgical hospitalization time is around 5-8 days and after a radiographic examination patient are discharged home or to rehabilitation center in order to start a specific rehabilitative treatment. At the beginning they start with a partial weight bearing with two canes; one cane is abandoned 30 days after surgery (on average) after the first post-surgical clinical and radio-graphic evaluation. Free walking starts on average 60 days after surgery. At an average follow-up of 12 months, we examined 11 subjects for a total of 11 implants. All subjects undergo a clinical and radiographic evaluation immediately after surgery, then 1, 6, 12 months after surgery; for clinical evaluation we refer to the parameters of International Knee Score, together with common subjective parameters as pain and limp. For radiographic evaluation we use the Knee Society radiographic evaluation form, assessing the presence of radiolucency lines, components' positioning and implant alignment. Average follow- up for the group of patients is about 12 months, during this period nobody presented superficial or deep infections. PCR, ESR, Procalcitonin, and Presepsin values at all follow-ups were within the physiological range.

Discussion

Biofilm is a major contributor to the recurrence of infection, as it provides protection to encapsulated organisms against conventional antimicrobial agents and the host immune system. Therefore, biofilm management is critical to control PJI [11].

The use of ultrasound to increase the antibacterial activity of antibiotics was first introduced in 1994 by Pitt et al, who demonstrated that low-intensity pulsed ultrasound increased the antibiofilm activity of antibiotics in vivo. In addition, ultrasound was found to increase the antibiofilm activity of disinfectants such as ozone in vitro.

The biological impact of ultrasound on microorganisms is attributed to acoustic cavitation, which effectively removes extracellular polysaccharides and proteins present in microbial

biofilms. In addition, ultrasound can change the structure of proteins that constitute extracellular polymeric substances, which initially act as barriers against chemical disinfectants. Based on previous studies, we believe that the combination of ultrasound debridement and our solution of saline and povidone iodine can effectively eliminate biofilms.
Solution of saline and povidone iodine has been recommended for the control of PJI in the context of the DAIR procedure, as stated by the International Consensus Meeting on PJI [12].

Several studies have explored the efficacy of ultrasonic debridement in managing periprosthetic knee infections (PJI). Devecioğlu, A. G., et al investigated the effectiveness of a piezoelectric ultrasonic scalpel in removing methicillin-resistant Staphylococcus aureus (MRSA) biofilms from orthopedic implant materials, including titanium alloy, stainless steel, and ultrahigh molecular weight polyethylene (UHMWPE). The results demonstrated a four-log reduction in colony-forming units per milliliter (CFU/mL) with piezoelectric ultrasonic scalpel, compared to a two-log reduction with pulse lavage (PL), indicating that piezoelectric ultrasonic scalpel is significantly more effective than PL in biofilm removal.

Singh, R., et al. evaluated the short-term outcomes of non-contact low-frequency ultrasonic debridement in treating PJI. The findings suggested that this method is effective in managing infections, although the study emphasized the need for further research to confirm long-term efficacy.

Jones, T. R., et al. has highlighted the potential benefits of novel ultrasonic cutting devices that selectively apply high strain to hard tissues while allowing soft tissues, such as ligaments and nerves, to be deflected without damage. These devices may enhance the effectiveness of surgical debridement in PJI cases [13].

O'Donnell et al in an in vitro study, demonstrate that a one-minute exposure to 0.35 percent povidone iodine reduced MRSA biofilm by 88% after 72 hours of incubation. Premkumar et al found that 10% povidone iodine showed the highest efficacy against biofilm-based bacteria in vitro, outperforming 0.3% povidone iodine and other commercial antiseptics after a three-minute exposure, regardless of the toxicity of high povidone iodine solution concentrations. In contrast, Sweet et al in an in vivo study showed that 0.35% povidone iodine solution as prophylaxis for a three-minute exposure did not change the infection rate.

Limitations and Considerations

Despite its many advantages, ultrasonic debridement is not without its limitations. The technique requires specific equipment and adequate training of medical personnel. 11 patients certainly does not make literature but it is definitely a good start. In our treatment protocol of infected TKA, ultrasound debridement still occupies a key role. Furthermore, its success depends on proper patient selection and integration with other therapeutic strategies, such as use of solution of saline povidone iodine and targeted antibiotic therapy [14].

Conclusions

All four patients treated with DAIR and seven patients treated by two stage revision showed significant reduction in infectious symptoms and improvement in joint function.

Ultrasonic debridement represents a promising innovation in the management of periprosthetic knee infections. Although further clinical studies are needed to evaluate its long-term efficacy, this technique offers significant potential to improve patient outcomes, reduce complications, and improve quality of life. In a complex field such as prosthetic infections, every technological and therapeutic advance is crucial to offer patients the best chance of recovery and healing [15].

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