One-stage revision of an infected cementless total hip replacement

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Keywords
Silver, single stage revision, resistant infection, total hip replacement, canine, dog

Summary
A two-year-old, 44 kg dog with a right Helica cementless total hip replacement (THR) was radiographically diagnosed with implant loosening eight months after the index total hip replacement procedure. Subsequent synovialcentesis and synovial fluid culture revealed a methicillin-resistant coagulase-negative Staphylococcus spp infection of the right THR. A one-stage revision using a hybrid BFX cementless acetabular cup and CFX cemented femoral stem was performed. Vancomycin and micro-silver antimicrobial powder impregnated cement were used in the revision. At re-evaluation 27 months following the revision procedure, the patient did not exhibit any signs of lameness. Radiographic images confirmed stable implants, with bone ingrowth into the cup and no signs of implant loosenning. Our report demonstrates the success of a one-stage THR revision when faced with a multi-drug resistant perioperative infection, when combined with the use of micro-silver antimicrobial powder and culture-based antibiotic impregnated cement therapy.

Clinical report
A 44 kg, two-year-old spayed female Akita dog was evaluated in December 2012 for the complaint of a several month history of right pelvic limb lameness. A right cranial cruciate ligament rupture was diagnosed by the referring veterinarian in August 2012, and was initially managed with carprofen (100 mg orally, Q12 hours as needed) and tramadol (100 mg orally, Q12 hours as needed). The dog had a previously corrected right thoracic limb angular limb deformity in March of 2011, a left tibial tuberosity advancement in December 2011, and a right THR with a Helica pro-

References
(1–5) Implant treatment recommendations include exchange (85% and 90% respectively) as well as when comparing cementless and those fixed with antibiotic loaded cement (85% and 90% respectively) (13).

Successful one-stage total hip revision in a septic joint using the addition of vancomycin and silver to the bone cement has not been reported in the dog. Massat and colleagues reported a case of a septic one-stage revision in 1998, though that case involved replacement of an experimental smooth-surfaced, carbon composite cementless femoral endoprosthesis with a cementless porous-coated anatomic stem (14). The organism cultured in that report was a non-resistant Staphylococcus intermedius (14). Our report describes a clinical case of septic acetabular cup loosening following Helica cementless hip implantation and the subsequent one-stage revision using a BioMedtrix BFX cementless cup and CFX cemented femoral stem with vancomycin and micro-silver impregnated cement, including long-term follow-up.

Introduction
Total hip replacement (THR) is a successful treatment modality used in people and dogs for moderate to severe clinical signs of pain and reduced limb function secondary to coxofemoral pathology (1–5). Implant related complications have been well described with infection reported to be the third most common reason for revision of both human and canine total joint replacements in the United States (6-10). With both septic and aseptic hip loosening, treatment recommendations include explantation or implant revision. Implant revision has traditionally been a two-stage process in North American human patients with greater than 90% infection eradication rates (11). Two-stage revision has also been performed in dogs, however disadvantages of two-stage revision include subjecting the patient to two major surgical procedures, increased cost, and increased risk of intra-operative and postoperative complications such as fracture and dislocation (3, 12, 13). Recently, similar success rates were observed when comparing one- and two-stage revision of infected total hip replacement in human patients (88% and 85% respectively) as well as when comparing cementless and those fixed with antibiotic loaded cement (85% and 90% respectively) (13). Successful one-stage total hip revision in a septic joint using the addition of vancomycin and silver to the bone cement has...
thesis in March 2012 after the dog failed to respond to six months of medical management. All previous procedures were performed at another facility. On physical examination there was a marked weight-bearing lameness in the right pelvic limb and signs of moderate to severe discomfort on extension of the right coxofemoral joint. The right stifle was mildly uncomfortable with medial buttress and positive cranial tibial thrust. The left stifle had a good range of motion, though a bidirectional patellar luxation (both lateral and medial) was noted with the stifle in full extension. The left coxofemoral joint was non-painful with a normal range of motion. Survey radiographs of the right stifle and pelvis were obtained under sedation one week later using hydromorphone (0.1 mg/kg intramuscularly [IM]), acepromazine (0.04 mg/kg IM), and dexamethasone (3 mcg/kg intravenously [IV]). Orthogonal radiographs of the right stifle revealed increased soft tissue opacity and mild degenerative changes. Radiographic views of the pelvis revealed signs of a smoothly marginated, irregular lucency at the implant bone interface of the acetabular component. There was irregular periosteal reaction along the cranial aspect of the acetabulum and lateral aspect of the right ilial shaft with ilial trabecular sclerosis (Figure 1A). A smoothly margined lucency was evident at the implant bone interface of the collar of the femoral component, and bone ingrowth was present surrounding the threaded shaft of the femoral component. The radiographic diagnosis was loosening of the acetabular component and right stifle osteoarthritis that was probably secondary to cranial cruciate ligament rupture. There was a strong suspicion of infection based on the irregular appearance of the new bone formation adjacent to the ilial body and cranial to the acetabulum.

Two weeks after the initial consultation, synoviocentesis of the right coxofemoral joint was performed under sedation with a 22-gauge spinal needle. Red-tinged synovial fluid was obtained and submitted for aerobic culture and susceptibility. A methicillin-resistant coagulase-negative Staphylococcus species was cultured. Susceptibility included clindamycin, doxycycline, marbofloxacin, and trimethoprim combined with sulfadimethoxine. The patient was treated with clindamycin (5 mg/kg orally, Q12 hours). A right tibial plateau levelling osteotomy was performed following the method described by Slocum (15). Follow-up examination and radiographs of the right stifle were performed six weeks later; gait evaluation revealed a mild improvement in weight bearing. The right stifle was negative for cranial tibial thrust and had a good range of motion, though signs of moderate discomfort of the right coxofemoral joint remained. Radiographs revealed complete tibial osteotomy healing with no evidence of implant complications. The administration of clindamycin was continued for treatment of the right coxofemoral implant infection.

The patient returned three months later for continued right pelvic limb lameness. Four weeks following completion of antibiotic medication, and 16 weeks from initial aspiration and culture, the right coxofemoral joint was re-aspirated and samples submitted for culture had no growth detected. Radiographic findings were similar to the previous findings, except that osseous changes on the right ilium had improved slightly. The treatment options of explantation of the total hip prosthesis, a one-stage revision, or a two-stage revision were discussed with the...
owner; the owner elected a one-stage revision.

Fourteen months following the index total hip replacement procedure, the patient was again premedicated with acepromazine (0.04 mg/kg IM) and morphine (0.5 mg/kg IM), then induced with ketamine (5 mg/kg IV) and diazepam (0.25 mg/kg IV). Epidural anaesthesia was performed with preservative-free morphine (0.2 mg/kg) and anaesthesia was maintained with isoflurane in oxygen. Cefazolin (22 mg/kg IV) was administered preoperatively and every 90 minutes until recovery from anaesthesia. A cranialateral surgical approach to the right coxofemoral joint was performed through a new cranial skin incision. A partial deep gluteal tenotomy was performed and the joint capsule was sharply incised and reflected from the femoral neck. The prosthetic femoral head was luxated from the acetabular component and the vastus lateralis was reflected from the femoral neck. Soft tissue present between the stem and head was removed and submitted for culture. The femoral prosthesis was exposed and both neck flanges removed. The stem component was difficult to remove and required an additional lateral approach to the proximal right femoral shaft to expose the portion of the stem that protruded from the lateral femoral cortex. Using an air-drill burr and osteotome, cortical bone was removed from the threads of the stem, which was then loosened and removed using a mallet while grasping the neck of the stem with vise-grips. During the process of removing the stem, the greater trochanter fractured. Remaining soft tissue at the fracture site was excised from the greater trochanter to expose the femur at the level of the medial acetabular wall. Four 2.5 mm bone tunnels were drilled circumferentially around the acetabular bed into the cancellous bone of the ischium (n = 1), dorsal acetabular rim (n = 2), and ilium (n = 1). Another tunnel was drilled centrally within the preparation site through the medial acetabular wall. Small strips of gelatin sponge were soaked in 1 g of vancomycin, then rolled cylindrically, and placed into the bone tunnels. A 32 mm BFX cup was placed. The femoral canal was prepared for the insertion of a new femoral component by reaming using progressively larger reamers and finally prepared using a combination of rasps and broaches. A cement plug was inserted into the medullary cavity, 40 g of polymethyl methacrylate (PMMA) bone cement mixed with 1 g of vancomycin powder and one dose (0.25 g) of silver additive was injected into the canal, and a size 9 CFX stem was placed. A 14-hole, 3.5 mm limited contact dynamic compression plate was contoured and applied with three proximal and four distal 3.5 mm bone screws to the lateral surface of the femur and over the proximal aspect of the greater trochanter. A 2.0 mm braided cable was applied around the proximal femur for added stability in the area of the proximal femur where bone screws could not be placed due to the presence of the femoral stem. A plus-3 17 mm head was placed, and reduced. The surgical site was thoroughly lavaged with sterile saline and a closing sample was obtained for culture. The joint capsule was closed using interrupted cruciate suutures of 4.0 metric polydioxanone suture and the deep gluteal tendon was repaired using a double baseball stitch pattern of 4.0 metric polydioxanone. The deep and superficial muscular fascia was closed with 3.5 metric polydioxanone, and the subcutaneous tissues with 2.0 metric polydioxanone. The skin was closed with skin staples. Postoperative radiographs revealed good implant placement, with an angle of lateral opening of approximately 45 degrees and 14 degrees of retroversion of the acetabular component. The stem was well-aligned with slight valgus (3 degrees) and slight cranial to caudal tipping (2 degrees) with a complete cement mantle and good intrusion of the cement into the subtrochanteric cancellous bone (Figure 2A).

The patient was discharged two days later with instructions to the owner to administer tramadol (3 mg/kg Q8 hours), carprofen (2.2 mg/kg Q12 hours for 10 days), and clindamycin (5 mg/kg orally, Q12 hours for a total of 8 weeks). The results of both intra-operative cultures were negative for growth. At the two-week postoperative re-examination, the incision had healed without complications and the patient had a mild weight-bearing lameness on the right hindlimb. There was good range of motion and the implants were stable on palpation. No signs of discomfort were evident during palpation of the right femur. Subsequent re-examination at six and 16 weeks revealed continued improvement of lameness with good range of motion in the right coxofemoral joint with a subtle weight-bearing lameness of the right pelvic limb at week 16.

Follow-up radiographs at both six and 16 weeks revealed stable implants, with normal osseous remodelling and bone ingrowth into the acetabular component. The greater trochanter was progressively healing at six weeks, and was almost fully healed at 16 weeks. The periosteal reaction lateral to the ilial bone was resolving radiographically with only subtle bone changes visible at 16 weeks (Figure 2B). There was no evidence of implant complications with the right tibial plateau levelling osteotomy or left-sided tibial tuberosity advancement.

Fifteen months after the total hip replacement revision, the owner reported an acute lameness in the left hindlimb. A left

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Meniscal tear was diagnosed based on radiographs and physical examination. The right coxofemoral joint had good range of motion with mild discomfort and no visible lameness observed on gait analysis. Radiographs showed no change in the right total hip replacement prosthesis when compared to previous views. The owner elected medical management in the form of physical therapy, non-steroidal anti-inflammatory medication, and weight loss. An acute right hindlimb lameness developed two months later and on physical examination a moderate weight-bearing lameness was noted in the right pelvic limb with discomfort on palpation and flexion of the stifle. A right meniscal tear was suspected. The right hip range of motion was normal with no evidence of femoral shaft discomfort with deep palpation. The right tibial plateau levelling osteotomy implants were removed one week later and a meniscal release was performed. The patient recovered well following this procedure and had no visible lameness in either pelvic limb at re-examination 22 months after the revision procedure. In August 2015 (27 months following the revision), the patient was evaluated at the Cummings Veterinary Medical Center for re-examination and pelvic radiographs. There was a mild left hindlimb lameness referable to the left stifle and normal right hindlimb function. Radiographs revealed stable total hip implants with normal bone remodelling (Figure 2C).

Discussion

Although two-stage prosthesis revision has been advocated as the gold standard for the treatment of infected THR in human patients, this case demonstrates that infected, loose THR can be successfully revised in a single stage in the dog using a hybrid implant system. Long-term clinical and radiographic follow-up revealed normal hip function, stable implants, and bone ingrowth into the acetabular component with no complications at last follow-up examination. We were unable to discern if the acetabular component loosening of the original Helica implant was the result of failure of ingrowth or septic loosening of a stable component, as the original procedure was not performed at our clinic and complete radiographic follow-up was not available.

Infection is a devastating complication of total hip arthroplasty and can result in implant loosening, decreased hip function, pain and eventual removal or revision of the hip prosthesis for resolution (16, 17). Bacteria form a polysaccharide glycocalyx biofilm on the implant surface that protects the bacteria from opsonizing antibodies and antibiotics. In addition, the presence of a foreign material, such as polymethyl methacrylate (PMMA), can decrease local microbiidal capacity by depleting the local macrophage oxidative response (16). Clinical variables that increase the probability of infection include increased surgical time (>90 minutes) and an increased number of previous surgeries (1, 17). Differentiating aseptic loosening from infection with secondary loosening can be difficult. For instance, a persistent radiolucent line around the acetabular component can be indicative of either instability (aseptic loosening) or infection (septic loosening). Rapid development of a continuous radiolucent line greater than 2 mm, or severe focal osteolysis within the first year following surgery, is often associated with infection, as was the case here (18). In this case, diagnosis of septic loosening was confirmed with a positive culture of a methicillin-resistant coagulase-negative Staphylococcus species following synoviocentesis of the right total hip joint, however false negative culture results are common following synoviocentesis (19). A positive intra-operative culture result may raise the clinical suspicion of a postoperative infection; however Iriejej and others reported that positive intraoperative culture results taken at the time of joint closure were not associated with an adverse outcome (infection or other total hip replacement related complications) with a one-year follow-up evaluation (17).
The reported incidence of infection after primary total hip replacement is under one percent in most large human orthopaedic centres (20). Reports of infected total hip replacements in dogs are uncommon. Hummel and others reported a 3.7% rate of septic loosening in a retrospective study of 163 cases using the Zurich\textsuperscript{u} cementless total hip replacement system (21). Bergh and others reported a 1.3% to 1.5% infection rate after cemented total hip replacement (7). In human medicine, the most common microorganisms causing implant related infections are S. aureus, coagulase-negative staphylococci, gram-negative aerobic rod-shaped bacteria, and streptococci species (18). The outcome in people is affected by the species of microorganism isolated in cultures; positive intra-operative cultures for Staphylococcus aureus are associated with a seven-fold increase in the risk of infection (17, 22). In our case, we isolated a methicillin-resistant coagulase-negative Staphylococcus species that is a commonly reported organism in cases of periprosthetic joint infection in dogs (8, 16).

Two-stage revisions have been the gold standard in revising a septic prosthetic joint and have been well-described (23–25). Limitations of a two-stage revision include increased economic burden for the owner, subjecting the patient to two major orthopaedic procedures, increased hospitalization time, and increased antibiotic administration. One-stage exchange procedures can dramatically reduce cost and morbidity for the patient and are gaining popularity in human medicine. One recent study of 39 cases reported no recurrence of infection following a one-stage septic revision with an average follow-up of 6.6 years (26). Revisions in human medicine are influenced by guidelines recently published by the Infectious Diseases Society of America (IDSA), which provide guidelines for treatments including debridement with implant retention, one-stage exchange, two-stage exchange, resection arthroplasty, or antibiotic suppressive therapy. In the case of highly resistant infections, the IDSA recommends either a two-stage revision or permanent resection arthroplasty, unless the organism has a known sensitivity to oral antibiotic medication with excellent oral bioavailability, in which case a one-stage revision is recommended (27). The methicillin-resistant Staphylococcus spp in our case was susceptible to clindamycin, which has an oral bioavailability in dogs of 73% (28). Surgical debridement with implant retention followed by appropriate antibiotic therapy has been described for treatment of an infected cementless total hip prosthesis (29). Revisions using cement can be susceptible to failure, probably due to poor bone stock which does not provide an adequate environment for fixation (30). Turner and others demonstrated that aseptic loosening of a cemented femoral stem led to normal cortical and medullary bone and marrow being replaced with inflammatory and granulation tissue (30). This inflammatory tissue can be a source of cytokines that stimulate bone resorption and lead to decreased bone ingrowth to the implant, so thorough debridement is required at revision (30). The patient in our case had adequate acetabular bone due to the original cup size and position. This allowed reaming of infected tissue and bone to the grossly healthy cancellous bone circumferentially and the medial acetabular wall. Additionally, the location of the Helica femoral neck implant allowed adequate bone stock for femoral canal preparation and implantation of antibiotic loaded cement and a standard femoral component. Adequate acetabular bone stock allowed the implantation of a BFX acetabular component; however, the presence of a large lateral cortical defect from the Helica femoral stem, bone resorption of the calcar, and stove-pipe femoral conformation led to the selection of a cemented femoral component. The CFX femoral component also allowed for the use of antibiotic and silver impregnated PMMA in the revision. The use of vancomycin-soaked gelatin sponges in the acetabular preparation bed served as an adjunct treatment, as vancomycin-soaked gelatin sponges have been shown to release the entire drug dose in 24 hours (31).

Infection is one of the most commonly described complications of THR in dogs and the use of PMMA bone cement as a vehicle for antibiotic delivery to the site of implant infection has been well documented (1, 7, 8, 21, 32–34). With antibiotic-resistant bacterial infections becoming more commonplace (8, 16), increased attention has been given to the addition of silver particles (both with and without more traditional antibiotics) to PMMA bone cement (33–37). Alt and others showed that PMMA bone cement loaded with 1% nanosilver (silver particles between 5–50 nm) was highly effective at inhibiting proliferation of S. epidermidis, methicillin-resistant S. epidermidis (MRSE), and methicillin-resistant S. aureus (MRSA) (including formation of MRSA biofilm) in vitro, while PMMA loaded with gentamicin inhibited only S. epidermidis (33). Additionally, it has been shown that the use of gentamicin alone in bone cement can result in higher rates of infection with gentamicin-resistant bacteria when compared to plain bone cement (38). The combination of silver particles with tobramycin has been shown to increase antimicrobial activity by over 200% when compared to either agent used alone. This potentiation is likely to be due to similar mechanisms of action (silver inactivates various bacterial enzymes by binding to thiol [–SH] groups) and suggests that the combination of two agents with similar antimicrobial behaviours may be a more appropriate choice than single agent therapy (39). Cytotoxicity of silver additives has been of concern, though available studies show contradictory results (33, 40). Although previous reports have demonstrated an antimicrobial effect of silver alone or in combination with antibiotics, a recent report by Morrison and others demonstrated that microsilver (particle size 10 μm) impregnated PMMA beads had no effect on methicillin-resistant S. pseudintermedius (MRSP) biofilm formation (33, 38, 39). This is possibly due to the small surface area-to-volume ratio of the PMMA beads used in that study and suggests that the silver concentration on the surface of the PMMA could play a key role in determining its antimicrobial activity (41).

This report demonstrates the success of a one-stage total hip arthroplasty revision using a hybrid BFX cup and CFX stem fol-

\textsuperscript{u} ZCTH: Kyon Inc., Zurich, Switzerland
lowing Helica implant infection and loosening. By using culture-based antibiotic therapy combined with micro-silver (average particle size of 10 µm), we were able to successfully treat a methicillin-resistant *Staphylococcus* species infection with a one-stage revision and demonstrate excellent clinical function at long-term follow-up. There are few reports on the safety and efficacy of silver particles, but this report and other current literature has demonstrated the safe use of silver additives with very promising results (33, 40, 42-44).

**Conflict of interest**

There are no conflicts of interest to declare.

**References**