Focus On
One stage exchange arthroplasty: the devil is in the detail

The general management of periprosthetic infections after total joint replacement (TJR) remains a challenging procedure to any arthroplasty surgeon. The infection rate after primary TJR is reported to be between 0.5% and 2%, however in the field of revision arthroplasty, this might increase to over 10%.1-4

Consequently, periprosthetic infections remain a serious problem, despite modern techniques, implants and rigorous perioperative prophylaxis. The therapeutic goal in either one or more staged revisions of periprosthetic infections is, in general, defined by a complete eradication of the infection and maintenance of the joint function. While it has been widely accepted that the treatment of a late chronic infection should be undertaken with a two- or more-staged revision technique, a distinct single-staged revision approach has shown similar good results within the last 30 years in our own clinical setup.5-8

In general, both revision techniques should be available depending on the clinical situation, the local setup and the surgeon expertise. In the most frequent scenario, implant removal is followed by a defined six week or longer course of systemic antibiotic treatment and delayed implantation. In particular, the introduction of antibiotic impregnated spacers in infected total knee and hip revisions, seemed to improve the functional outcome of the two-staged approach and has gained increasing popularity within the last five to ten years.9-11

However, looking carefully at the current literature and guidelines for the treatment of infected TJRs, there is no clear evidence that a two- or more-staged procedure has a higher success rate than a one-staged approach,(Della Valle)12

Although a larger number of relevant articles6,10,13-15, describe the two-staged technique as the benchmark procedure for the eradication of infection, most of the recommendations (duration of antibiotic treatment, static vs mobile spacer, interval of spacer retention, cemented vs un cemented new implant fixation and especially overall success rates) are based on expert opinions and evidence level IV to III studies, rather than on prospective, randomised or comparative data.10,11,13-18

We consequently believe that a distinct one-stage exchange still offers certain advantages with a comparatively high success rate. The major advantages are the need for only one procedure (if no recurrence), reduced hospitalisation time, reduced overall cost and relatively improved patient satisfaction.8,19,20

Although obvious advantages exist, there are obligatory pre- and peri-operative details which need to be meticulously respected to achieve a successful one-staged revision.

Consequently this article describes the author’s experience of their current institution’s management strategies, which have been in place for over 30 years, with the one-staged approach in the revision of an infected TJR. Emphasis is given to all detailed requirements that provide the basis for a high surgical and post-operative success rate.

Etiology and Classification
Every periprosthetic infection is a foreign body associated infection and should be clearly differentiated from other bone infections.

Most micro-organisms from human bacterial flora gain access to the surface of the prosthesis during the operation and more than 90% of infections during the first year after operation are due to contamination during the procedure.21 Haematogenous infections are less frequent. In the presence of foreign bodies, a contamination as low as 100 colony-forming units (CFU) is sufficient to induce an infection. In comparison, when no foreign material is present, it takes 10 000 cfu.22 This effect is due to the diminished clearing capacity of phagocytosis by leucocytes in the presence of foreign material.23,24

Furthermore, the bacteria are adhesive to the implant surface by forming a biofilm. This biofilm blocks natural defense mechanisms. These sessile bacteria are also highly resistant to antimicrobial agents and the minimal inhibitory concentration can be elevated up to the 1000-fold within the biofilm.25

The general period between colonisation and clinically detectable infection may last for months or years and as a result, local signs of infection may occur very late. It is important to realise that periprosthetic infection does not only indicate an infection of the prosthetic interface, but also of the surrounding bone and soft tissues.

Classification
Infection can be classified in two ways; 1) acute infection - occurring within the first three post-operative weeks; 2) late infection - occurring after the third post-operative week.

Consequently we aggressively treat an acute infected TJR with a local debridement, soft-tissue revision and lavage, polyethylene liner exchange, including preservation of the initially implanted prosthesis. Systemic antibiotics are adapted to the algorithm described by Zimmerli, Trampuz and Ochsner.26 Late infection, however, is treated with complete implant removal. Independent from a one- or two-staged approach, a further re-implantation of a new prosthesis should be scheduled as soon as possible after infection eradication.

Earlier classification guidelines mostly defined stages of periprosthetic joint infection (PJI) into early, acute and late infection types. Due to the general advancements of diagnostic algorithms and further developments of systemic and local treatment options, we also adapted our classifications system to the staging system described by McPherson et al.27,28 This
includes, besides type and timing of infection, mainly the current systematic medical and immune status of the host patient, as well as the current local extremity grade based on all possible local compromising factors.

**Diagnosis**

The first symptoms of early infection usually present around four to eight days after a TJR. With the presence of purulent secretion, infection is clear. However, any prolonged wound discharge (> 12 days), continued soft-tissue swelling and induration, or wound dehiscence should be taken seriously. We suggest in these cases a pro-active and aggressive approach is taken at all times by the surgeon. If an early infection (within three weeks) occurs after the patient is discharged from the hospital, often superficial wound healing problems, hematomas and seromas are evident, which might correlate with the presence of deep infection of the implant. This however, is not always obvious and the clinical signs can be more subtle.

According to our experience, current evidence and recent clinical practice guidelines by the American Academy of Orthopaedic Surgeons, we defined the following mandatory pre-operative testing, for every case of a TJR patient with unexplained pain:12

- Laboratory monitoring of CRP and erythrocyte sedimentation rate (ESR).29,30
- Knee and hip joint aspiration with prolonged microbiologic culture time of at least 14 days, with patients being off antibiotics for a minimum of 14 days.31
- Synovial fluid analysing of white blood cell count and percentage of neutrophils.32-34
- Repeated aspiration in cases of own negative cultural results in combination with either obvious infection signs or pre-existing external positive cultural results.
- Biopsy of the knee joint in cases of persistent negative aspiration results, with obvious infections signs.35

**Joint Aspiration**

The mandatory and most relevant pre-operative diagnostic test needed in any case of a planned one-staged exchange, is based on knee joint aspiration with an exact identification of the bacteria. The presence of a positive bacterial culture and respective antibiogramm is needed for the one-staged procedure in order to define which antibiotic loaded acrylic cement is required to achieve a high topic therapeutic level of antibiotic elution.13,14,36-40

This protocol has become mandatory in our clinic for every planned TJR revision including all late or early aseptic loosening, furthermore in all other cases of unexplained pain or malfunction after primary or revision TJR.

In a previous aspiration study, we were able to show that between 4% and 7% of our patients who were initially planned to have an aseptic total hip or knee replacement revision had evidence of a subtle low grade infection, without any obvious clinical symptoms or relevant laboratory elevations as described above.41

**Imaging**

Serial conventional radiological comparison can be useful to detect obvious osseous infections signs. For the diagnosis of PJI however, we do not tend to use nuclear imaging in our setup. Although highly sensitive, bone scans, as labeled leukocyte imaging, Gallium imaging or PET imaging have shown to be non-specific with consequently only moderate reliable study data.12 Bone scans have been shown to visualise suspicious enhancements for several years following TKR and THR. Enhancements occur especially after the early phase of implantation, therefore can represent bone remodeling and may be misleading.

In addition to conventional radiological imaging of the affected joint, we recommend clinical and radiological evaluation of all other joint replacements of each PJI patient, e.g. contralateral affected THR.

**Indications**

In general we see very few arguments against a one-staged revision protocol, and are able to successfully treat over 85% of all infected cases using this technique. The mandatory infrastructural requirement is based on the evidence of the bacteria in combination with a distinct patient specific plan for the topic and systemic antibiotic treatment by an experienced microbiologist.

**Contra-indications**

We defined the following criteria to alter our one-staged approach to a two-staged procedure:

- Failure of ≥ two previous one-staged procedures
- Infection spreading to the nerve-vessel bundle
- Unclear pre-operative bacteria specification
- Non-availability of appropriate antibiotics
- High antibiotic resistance

**Pre-operative preparation and planning**

To undertake a one-stage procedure a positive bacterial culture must be present and a respective antibiogramm must exist. The proposed cemented fixation using antibiotic loaded acrylic cement is considered to be the treatment of choice in order to achieve a high topic therapeutic level of antibiotic elution from the cement.36,40 In the future, antibiotic local implant or silver coatings might be viable alternatives for the one-staged approach.

The success of a one-staged approach not only depends on the meticulous removal of all hardware material (including cement and restrictors) in combination with the antibiotic loaded acrylic cement, but also an aggressive and complete debridement of any infected soft-tissues and bone material (Fig. 1). For example, this should include a full synovectomy in the posterior aspects of the knee or radical debridement of the anterior and posterior capsule of the hip (Figs. 2 and 3).

In the knee this approach might also include sacrificing the collateral ligaments to perform a complete and radical soft-tissue resection. Thus the definitive pre-operative planning should consider the use of a of a semiconstrained or even full
contrained implant, also based on the surgeons preference and technique.

**General Pre-Operative Planning**

**Anaesthesia:**
- There should be clinical and anaesthesiological assessment of the general operative risk
- An adequate supply of available donor blood
- In the case of long exchange operations, pre-operative administration of fibrinolysis inhibitors (e.g. tranexamic acid) is recommended

**Specific risks to patients**
- The risk of recurrent or new infection between 10% and 15%
- A risk of reoperation for haematoma, wound debridement or persistent infection
- Damage to the sciatic / peroneal nerve
- Post-operative stiffness and loss of function (extensor mechanism)
- Intra- and post-operative fracture
- Increased risk of aseptic loosening

**Surgical Preparation**

**Implants and Cement:**
- The surgeon should have experience of the type of implant to be revised and be familiar with its removal and disassembly. Occasionally the use of implant-specific instrumentation will be necessary
- Pre-existing ligament deficiencies in the knee require constraint implants; however ligament deficiency may also result during intra-operative debridement – hence the need for rotating or fixed hinged implants in general. Based on our aggressive soft-tissue debridement, this is the case in over 90% of our one-staged knee revision cases
- Inadequate bone stock, possible intra-operative complications as acetabular / femoral or tibial shaft fractures, perforations of the cortex, osseous windows and tibial/femoral disintegration must be taken into consideration when choosing an appropriate implant.
- Distal femoral or proximal tibial replacement implants may have to be chosen in patients with significant bone deficiency in the knee. Bone loss is usually significantly more extensive than radiologically evident. Custom-made implants with extra-long or narrow stems may have to be ordered prior to surgery. The need for total femoral replacement implants is rare.
- Significant damage to the extensor mechanism of the knee can require an arthrodesis nail, which should be available as a last option in necessary cases (with patient consent)
- Antibiotic loaded acrylic cement with additional antibiotics in powder form to be added intra-operatively is obligatory in all cases. Invariably at least two or three mixes of cement (between 80 g and 120 g) are required. Large mixing systems and appropriate cement guns are required. In patients with a narrow diaphysis extra narrow nozzles allow for appropriate retrograde cementing technique.
- Knowledge about possible type of antibiotic loaded acrylic cement used at primary implantation, as resistance to the
previously used antibiotics must be expected.
- Often industrially pre-manufactured antibiotic loaded acrylic cement may be appropriate. However, for the success of any one-staged procedure, the antibiogramm for the final topic cement impregnation is mandatory.

**Operative Technique**

**Skin Incision and debridement:**
- Old scars in the line of the skin incision should be excised. The prior incision from the last operative approach should be used, if possible. In cases of multiple scars, the most lateral one should be considered.
- Fistulae should be integrated into the skin incision and radically excised to the joint capsule. If the need for muscular-cutaneous flaps can be anticipated, a plastic surgeon should be available.
- An anticipated operative time exceeding two hours should include an above knee tourniquet, but not inflated. The knee procedure should be started without tourniquet; consequently interfaces between infected tissue, scar and surrounding healthy bleeding soft tissue can be distinguished more clearly during the debridement. All non-bleeding tissues and related bone need to be excised very aggressively. After debridement and implant removal, maintaining the tourniquet can be helpful for the removal of intramedullary and the re-cementation.
- Biopsy material, preferably five or six samples, should be taken as a routine measure from all relevant areas of the operation site for combined microbiological and histological evaluation, after the defined antibiotics have been administered. This commonly comprises a wide spectrum cephalosporin with further antibiotic related antibiogramm.

**Implant removal and completion of debridement**
- Removing cemented implants can be easier and less invasive than removing ingrown cementless components.
- In cases of well-fixed uncemented components, cortical windows are required to gain access to the interface. High speed burrs and curved saw blades can aid removal, however, occasionally significant destruction and related loss of bone stock can occur.
- Narrow, straight osteotomes with symmetrically coned blades should be used to remove all accessible bone cement, being careful not to cause further loss of bone.
- A multiple osteotome technique should be used in the knee to drive cement from between the tibial base plate and medial and lateral component. This may be less destructive than aggressive extraction with the mallet.
- Extraction of the implant necessitates special or universal extraction instruments, if available. Otherwise general punches are required.
- Special curved chisels, long rongeurs, curetting instruments, long drills and cement taps are used to remove the cement. In the hip joint, retrograde chisels can be helpful in many cases.
- General debridement of bone and posterior soft-tissues must be as radical as possible (Fig. 1). It must include all areas of osteolysis and non-viable bone.
- Completing the debridement often exceeds the amount of resected material than seen in a two-staged approach (Figs. 2 and 3)
- We recommend the general use of pulsatile lavage throughout the procedure, however after all implant removal and completed debridement, the intramedullary canals are packed with polymeric biguanid-hydrochlorid (polyhexanid) soaked swabs. Furthermore the swabs are placed over the wound area before re-draping the patient.
- The whole team should re-scrub and new instruments be obtained for re-implantation.
- A second dose of antibiotics should be given after 1.5 hours operating time or if blood loss at this point exceeds 1.

**Reimplantation**
- Inadequate bone stock may require the use of allografts, although ideally this should be avoided. We even prefer to fill large defects with antibiotic loaded acrylic cement, and do not favour the use of any allograft.
- Alternatively the use of tantalum based acetabular wedges, femoral and tibial cones have been implemented in our regular clinical use for over four years. Variations of depth and width of those augments allow for a proper reconstruction of the resulting bone loss, including an excellent biocompatibility and related stiffness and cellular structure. Consequently a combined fixation of the cement with the prosthesis and tantalum augment becomes possible. It has been postulated that tantalum has some antibacterial potential; however this has not been clinically proven.
- The antibiotic loaded cement is prepared in the meantime, fulfilling the following criteria:
  - Appropriate antibiotic (antibiogramm, adequate elusion characteristics)
  - Bactericidal (exception Clindamycin)
  - Powder form (never liquid)
  - Maximum concentration of 10%/PMMA powder
- Antibiotics (e.g. Vancomycin) might change the polymerisation behaviour of the cement, causing acceleration of cement curing.
- Current principles of modern cementing techniques should be applied (Fig. 4). In order to achieve an improved cement bone interface, the tourniquet should be inflated prior to cementing in TKR cases.

**Post-operative antibiotics**
Associated post-operative systemic antibiotic administration is followed for 10 to 14 days (exception: streptococci). While a prolonged administration of intravenous antibiotics for six weeks is common in the two-staged approach, the rational for this prolonged period of time has not been clarified in the literature. There is, however, clear evidence of relevant systemic and organ-specific complications after prolonged antibiotic administration.
Aggressive debridement, and relatively comparable to a two-staged approach, we don’t believe that an articulating spacer, or partial or complete immobilisation of the affected joint, will result in a better functional outcome.

Although we are unable to present comparative data evaluating the functional outcome under a one- versus two-staged approach, we don’t believe that an articulating spacer, or partial or complete immobilisation of the affected joint, will result in a better functional outcome.

We consider the risk of direct damage to the sciatic or peroneal nerve and main blood vessels, as low, under the guidance of an experienced surgeon, even in such an extended aggressive debridement, and relatively comparable to a two-staged exchange. The general risk of intra- and post-operative fractures should be comparable to the two-staged exchange.

Outcome
The two-staged approach has become the method of choice for most surgeons worldwide, with reported re-infection in between 9% and 20% of cases. Although advocated as the benchmark procedure, we have established and followed the one-staged approach in our clinic for over 35 years and in over 85% of all our infected TJR patients.

Accordingly, far more studies have been published and emphasised about the two- or more-stage revision technique. Few studies evaluating the one-stage exchange and its techniques are available.

Although most reports are from our own institution, some international experience using this technique exists with rates of success between 75% and 90% depending on the time of follow up.

Besides the obvious benefit by eliminating a second major operation, further major advantage arise from the reduced duration of post-operative systemic antibiotics. This rarely prolongs more than 14 days in our setup. The rational for this has also been evaluated in a study by Hoad-Reddick et al., where the authors concluded that a prolonged course of antibiotics does not seem to alter the incidence of recurrent or persistent infection, even after a two-staged revision.

Summary
The one-staged infected TJR approach is used sparingly in the orthopaedic community. From our perspective the one-stage revision offers certain obvious advantages. The key to success is based on the well-defined and detailed intra-hospital infrastructure, including a meticulous pre-operative aspiration regime, planning, aggressive intraoperative surgical approach and post-operative specific patient care.

References
5. Kordelle J, Frommelt L, Kluber D, Seemann K. Results of one-stage endoprosthesis revision in periprosthetic infection cause by methicillin-resistant