1.3. PREVENTION: HOST RISK MITIGATION, LOCAL FACTORS

Authors: Ran Schwarzkopf, Jonathan Danoff, Arash Aalirezaie, David Choon, Peter Gold, Afshin Anoushiravani

QUESTION 1: Does a prior surgical procedure (with or without retained hardware) in the same joint as the arthroplasty increase the risk of subsequent surgical site infection/periprosthetic joint infection (SSI/PJI)?

RECOMMENDATION: Open surgical procedures with or without the use of hardware increases the risk for subsequent SSI/PJI in the same joint receiving arthroplasty. We suggest that elective arthroplasty is delayed on the affected joint that has undergone a recent (within six months) major surgical procedure.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 90%, Disagree: 6%, Abstain: 4% (Super Majority, Strong Consensus)

RATIONALE

Violation of the joint capsule by previous surgery has been found to be associated with an increased risk of subsequent PJI and SSI. Berbari et al. [1] investigated patients undergoing total hip arthroplasty (THA) or total knee arthroplasty (TKA) after a prior capsular violation in a prospective case-control study and found a significantly increased risk for PJI (hazard ratio (HR): 1.74, 1.23 to 2.47, $p = 0.002$) and for SSI (HR: 1.66, 1.16 to 2.39, $p = 0.006$). The extent of the initial index injury or procedure influences infection risk. One study found that patients with a previous fracture had an increased risk of PJI/SSI (rate ratio (RR): 5, $p = 0.04$) compared to previous soft tissue injury after conversion to TKA. Furthermore, a significantly higher infection rate was seen in patients with a prior history of open reduction internal fixation (ORIF) (31%) versus arthroscopy (3.3%) [2].

Arthroscopy has been described as a valuable tool for treating mechanical symptoms related to early arthritis. However, there is no strong evidence to suggest that the risk for PJI is higher in patients with prior arthroscopy of the hip and the knee. Some national registry retrospective studies, as well as matched case-control studies, evaluated the outcomes of total joint arthroplasty (TJA) after knee arthroscopy. Regarding the risk of infection after arthroscopy, none of these studies noted an increased risk of subsequent PJI in these patients [3–7].

The latter studies did not, however, examine the time interval between arthroscopy and the index arthroplasty. It appears that the time interval between arthroscopy and TKA may be an important issue as demonstrated by Werner et al. in a cohort study of 681 patients from a national database. They noted an increased risk of infection with an odds ratio of 2 if the TKA was performed within six months of an arthroscopy [4]. On the contrary, Viste et al. [5] found no increased risk of infection or other complications if knee arthroscopy was performed within one year and the studies by Piedade et al. [8,9] again found no correlation between arthroscopy and TKA interval with complications and failures.

The literature is more limited with regards to hip arthroscopy. Haughom et al. examined 84 patients in a matched case control study and found 1 periprosthetic THA infection each in those with and without prior hip arthroscopy at a mean 3.3-year follow-up [10]. This was consistent with other similar studies evaluating outcomes of THA after hip arthroscopy [11–15]. There is no evidence regarding the safe time interval between the hip arthroscopy and THA in order to decrease the rate of possible subsequent PJI.

Another important surgical procedure that is often performed in the knee is anterior cruciate ligament (ACL) reconstruction. Some of these patients eventually develop arthritis and may undergo TKA. The question is whether TKA in this patient population may be associated with an increased risk for PJI. TKA outcomes after ligament reconstruction have been investigated by multiple authors [2,16–19]. A retrospective review of 64,566 primary TKA from the New Zealand Joint Registry concluded that prior major surgery had a two- to three-fold increase in risk of revision for PJI at both six months ($p = 0.046$) and one year ($p = 0.01$). Prior ligament reconstruction (odds ratio (OR): 2.04, 95% 0.75 to 5.53) or osteotomy (OR: 2.72, 95% 1.33 to 5.56) were especially associated with an increased risk of subsequent PJI [2]. Hoxie et al. retrospectively reviewed TKA following ACL reconstruction and found no incidence of PJI in their small series [16]. To the contrary, Watters et al. [18] found that patients with prior ACL reconstruction (excluding patients with a history of fracture or osteotomy) had a significantly higher incidence of PJI compared to those without prior ACL reconstruction (3.3% ACL group, 0% control, $p = 0.04$). The operative time for patients with prior ACL repair was significantly longer ($p < 0.001$) as well. Pancio et al. [19] highlighted a significantly increased risk for infection at 7% after multi-ligament reconstruction (> two ligaments) versus < 1% for those without prior ligament reconstruction (OR: 9, 95% confidence interval (CI) 1–78, $p = 0.047$). Increased risk for infection after arthroscopy in which ligament reconstruction is conducted may be explained by the presence of foreign material, longer operation time, poor soft tissue integrity, increased risk for arthrofibrosis as well as the need for increased surgical dissection because of prior surgery.

THA is the treatment of choice for patients with symptomatic osteoarthritis following prior femoroacetabular impingement (FAI) surgery. The results of THA after femoroacetabular osteoplasty (FAO) surgery including the incidence of PJI/SSI has not been well-studied. However, an ongoing study at the Rothman Institute has not detected an increased risk of complications, including infection, in over 50 patients with prior FAO who have undergone THA (pending publication).

Developmental dysplasia of the hip and rotational deformities of the hip are increasingly managed with periacetabular/rotational osteotomy in the younger population. These patients may eventually need THA due to progression of arthritis. Several studies have evaluated the outcomes and technical difficulties of THA after periacetabular osteotomy/rotational acetabular osteotomy (PAO/RAO), but only a few have addressed the potential for increased PJI/SSI in this patient population. Two matched cohort reviews of patients with prior acetabular osteotomy who underwent THA did not detect an increased risk for subsequent PJI compared to controls [20,21]. Thus, based upon the available data, it appears that conversion of THA after prior arthroscopy, femorocacetabular osteoplasty or pelvic osteotomy do not appear to significantly increase the risk for subsequent PJI. One retrospective review of failed salvage hip procedures for osteonecrosis found no significant difference in the rate of PJI but detected an increased incidence of SSI (8.1%, $p = 0.005$), especially if the prior procedure was open (10%, $p = 0.003$), compared to patients with no prior surgery (0%) [22].

Fresh osteochondral allograft (OCA) transplantation is an effective treatment for osteochondral defects in the knee. However, many patients eventually require management with a TKA. The effects of prior OCA transplantation on TKA outcomes are not well-defined. Steinhoff et al. [23] retrospectively evaluated 39 TKA patients who had undergone prior OCA and found that the failure of TKA was markedly higher in this patient population at 31.4%. Of all 35 patients with at least one-year follow-up, 11 patients required a reoperation at 10 years, 2 due to infection (5.7%). These results are consistent with high failure rates (17.1%) reported by Morag et al. [24] in their case series of 35 TKAs after OCA, although no revisions were due to SSI/PJI. It appears that patients with multiple prior knee operation are more likely to experience poor outcomes following TKA including failure as a result of infection.

Retained hardware following previous open reduction internal fixation (ORIF) has been shown to increase the risk for subsequent PJI and SSI. Suzuki et al. [25] found an increased incidence of PJI in patients being converted to TKA with retained hardware (25%, OR: 26.0, CI 95% 4.5 to 151.0, $p < 0.05$) and previous ORIF (21%, OR: 7.9, CI 95% 1.1 to 57.1, $p < 0.05$). The authors suggested that compromised peri-incisional vascularity may contribute to risk of infection and they suggested the use of antibiotic cement or long-term antibiotics in this cohort of patients. However, another matched cohort study by Manrique et al. [26] did not achieve statistical significance in a similar patient population undergoing conversion to TKA. An increased incidence of SSI was seen in patients with prior hardware in situ (10.9%) versus no prior hardware (4.5%) (HR: 2.59, 95% 0.78 to 8.57, $p = 0.12$) [9].

Klatte et al. [27] retrospectively reviewed 124 patients undergoing TKA with prior history of knee surgery and pre-existing hardware. The investigators used a single-stage technique and reported one subacute infection seven months postoperatively. Similar outcomes were reported in an analogous THA patient population (109 patients, 1 infection) [28]. Archibeck et al. [29] conducted a retrospective study on 102 total hip arthroplasties (THAs) after failed internal fixation due to prior hip fracture, 12 (11.8%) of whom had early surgical complications related to the procedure, although only 50 patients were available at the two-year follow-up. The outcome of THA in patients with prior acetabular fracture has been reported to be inferior compared to primary THA [30–36]. Regarding PJI/SSI, the data is conflicting in these patients. However, a few case-control studies have reported higher rates of PJI after THA in patients with prior acetabular osteosynthesis [35,37,38].

Osteotomy is another joint preservation technique which may be employed in younger patients who are recalcitrant to nonoperative management. Nelson et al. [40] reviewed nine consecutive patients (11 knees) who had undergone varus osteotomy of the distal femur prior to TKA. Although no infections or wound complications were reported, functional and radiographic outcomes varied substantially, thereby demonstrating the increased complexity and inferior outcomes which can be expected with TKA in this population. Bergenudd et al. and Faralli et al. [41,42] demonstrated an increased risk for postoperative complications in TKA candidates following previous proximal tibial valgus osteotomy.

Removal of hardware (ROH) before TJA conversion may help to prevent PJI/SSI. When ROH after ORIF for closed intra-articular tibial plateau fractures was performed at least four months before conversion to TKA, no cases of deep infection were seen and only one diabetic patient developed a superficial infection and wound dehiscence [39]. A retrospective multicenter review evaluated the outcomes of TKA after medial opening wedge and lateral closing wedge high tibial osteotomy, in which 98.5% of patients had ROH performed. The incidence of infection was found to be 3.6% and the number of incisions needed for ROH did not influence the risk of infection.

The available literature assessing outcomes following TJA in patients with previous fractures and/or hardware is conflicting. However, given some reports in the literature, it can be inferred that a history of extensive surgery in the joint and/or retained hardware increases the complexity of a subsequent TJA and compromises the outcome, including the possibility for higher incidences of subsequent SSI/PJI.

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Authors: James Cashman, Dace Vigante, Eoin Sheehan

QUESTION 2: In patients with prior septic arthritis, what strategies should be undertaken to minimize the risk of subsequent surgical site infection/periprosthetic joint infection (SSI/PJI)?

RECOMMENDATION: Prior to elective arthroplasty, infection in the joint with prior septic arthritis needs to be ruled out using appropriate diagnostic tests. In the presence of an active infection, two-stage joint arthroplasty is recommended.

Single-stage joint arthroplasty may be considered when all diagnostic tests are normal and there is no active soft tissue involvement (such as a sinus tract or abscess).

Single-stage arthroplasty is a reasonable treatment strategy in patients with septic arthritis caused by Mycobacterium tuberculosis (TB), where anti-tuberculous medications have been commenced and in the absence of a sinus tract or extensive soft tissue involvement.

Antibiotics (no more than 5% by weight), targeted towards the prior organism, if known, should be added to cement during arthroplasty.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 88%, Disagree: 7%, Abstain: 5% (Super Majority, Strong Consensus)

RATIONALE

Systemic or active infection is an absolute contraindication to arthroplasty when an infected joint is the source of sepsis [1]. It is important to identify if a patient has an active or quiescent infection in the joint [2]. Some inflammatory serum markers are commonly measured, such as white blood cells, erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) in the evaluation of patients with septic arthritis [3]. Furthermore, joints should be considered for aspiration when patients have elevated serum inflammatory markers. A high white cell count is specific for diagnosing septic arthritis, but sensitivity is low, especially using the cutoff value of 50.0x 10^3/μL, which is the most commonly published value [4]. Bone biopsy may be of diagnostic value, in light of evidence of a quiescent intracellular *Staphylococcus aureus* [5].

Joint arthroplasty for septic arthritis has long been considered a high-risk procedure [6]. Pre-existing osteomyelitis is suggested to be more important than septic arthritis [7]. No high-quality randomized trials have assessed the effectivenesses of different treatment strategies. The majority of the published literature are case series without controls. Treatment strategies are based largely on opinion and experience with infected arthroplasties. However, the reported experience of the majority of reporting groups is similar.

Staged hip arthroplasty has been performed successfully in acute septic arthritis [8]. In one case series of 18 patients, 11 underwent two-stage hip arthroplasty, and 7 underwent single-stage hip arthroplasty. There was no recurrence of infection at a mean of 70 months follow-up [2]. In a series of 53 hip and knee arthroplasties, Bauer et al. compared acute septic arthritis treated with two-stage joint arthroplasty and quiescent "cured" septic arthritis treated with single-stage joint arthroplasty. They reported a cure rate of 87% with two-stage joint arthroplasty in active septic arthritis and 95% survivorship with single-stage surgery in cured septic arthritis. They did not identify any additional risk factors for recurrence of infection [9]. However, a further case series from 2008 reported a reinfection rate of 14% with a total complication rate of 36% [10].

Huang et al. described their case series of 14 patients with septic arthritis of the hip treated with a two-stage revision. The mean interval between stages was 12 weeks. The second stage procedure was performed with cementless implants. There were no recurrences at a mean of 42 months [8]. Romano et al. used a preformed spacer in a two-stage strategy with a mean interval of 22 weeks before implantation of cementless implants. They report a 95% survivorship with one failure due to infection at a mean follow-up of 56 months [11]. A Korean group reported on a series of nine patients at a mean follow-up of 42 months. One patient required a repeat first stage and another patient developed infection after the second stage [12].

Lee et al. reported on a series of 20 consecutive knee arthroplasties performed in patients who had a history of quiescent septic arthritis. They identified one postoperative infection at 3.5 years and recommended a single-stage revision after a judicious infection workup [13]. Nazarian et al. proposed a two-stage strategy for septic knee arthritis following their studying examining 14 patients which resulted in complete eradication of infection at a mean follow-up of 4.5 years. The interval between stages was three months [14].

The use of a spacer has been advocated as a temporizing measure due to its ability to elute antibiotics, but also to improve function between stages [15,16]. Fleck et al. reported on 14 patients who underwent two-stage hip arthroplasty, though four patients did not undergo the second stage with two reporting good function from their spacer [17].

Single-stage hip arthroplasty has been promoted for quiescent or cured infection. One series of 19 hips reported good function with no recurrence of infection using this technique. The authors recommended a thorough infection workup to ensure no evidence of active infection [18].

Two-stage joint arthroplasty has been advocated by some case series, though not randomized controlled trials [19]. In TB infection, single-stage arthroplasty appears to be a safe option [18]. However, the authors recommend prolonged anti-tuberculous medications. A series of Charnley hips from 2001 with the longest follow-up at 28 years found that 5 recurrences occurred out of 60 patients, with the failure of the acetabular component being the most common cause for revision [20]. There is a risk of postoperative infection in those patients with the untreated disease or those on corticosteroids [21]. Where sinus tracts exist, or extensive bony destruction with multiple abscesses predominate, a two-stage strategy may be recommended [22,23].

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Authors: Ran Schwarzkopf, Matthew Dietz, Afshin Anoushiravani

QUESTION 3: Does the presence of prior projectile missile/bullet fragments in a joint predispose the patient to a higher risk of subsequent surgical site infection/periprosthetic joint infection (SSI/PJI)? If so, what should be done to reduce the risk of SSI/PJI?

RECOMMENDATION: The presence of a prior projectile missile/bullet fragments in a joint, unless the joint was previously infected, does not increase the risk of subsequent SSI/PJI in patients undergoing elective arthroplasty in the same joint.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 71%, Disagree: 18%, Abstain: 11% (Super Majority, Strong Consensus)

RATIONALE

The literature regarding this injury gives few guidelines regarding the appropriate patient evaluation and subsequent risk of SSI/PJI if total joint arthroplasty (TJA) is ultimately indicated. Typically, individuals with projectile missile/bullet fragments with possible intraarticular involvement will undergo an evaluation for a traumatic arthrotomy, which may involve a joint aspiration or a saline dye load challenge [1,2]. The presence of retained ballistic fragments within the intraarticular space can cause mechanical and destructive changes due to third-body wear or the initial damage to the articular surface from trauma. The lead components of bullet fragments are soluble in synovial fluid [8] which can lead to a proliferative synovitis and destructive arthritis, which in numerous cases has led to lead arthropathy and plubism (lead poisoning) [2–9]. The concept of "autosterilization" of bullets creating an antiseptic wound has been disproven [10,11]. Tornetta et al. demonstrated that five of seven patients with low velocity intraarticular gunshot wounds without radiographic injury contained intraarticular debris (skin, clothing, bullet fragments) [12]. Therefore, the concern for secondary infection leading to septic arthritis due to retained fragments and foreign body exists [13]. However, there are a limited number of studies available describing the risk for subsequent SSI/PJI following a projectile missile/bullet injury to a lower extremity joint indicated for a TJA.

Although intraarticular gunshot wounds are uncommon, it is recommended that these injuries be managed with irrigation and debridement to prevent subsequent articular injury [1,2,14]. Accompanying fractures should undergo open reduction and internal fixation in an attempt to preserve the joint [1,2]. In small cohort, elective TJA may be indicated due to post-traumatic arthritis, chronic pain and nonunion. In a small retrospective series by Naziri et al. [15], four patients presenting with gunshot wounds to the hip, subsequently underwent elective total hip arthroplasty (THA) following their injury. All patients achieved excellent clinical and radiographic outcomes with no incidence of infection at a mean follow-up of 26 months (range 12 to 24 months). A separate study by Herry et al. [16] assessed clinical outcomes following total knee arthroplasty (TKA) in two patients who had severe ballistic injuries requiring sequential complex surgeries (e.g., management of bone defects, hinged prostheses and muscle flap). Due to their extensive bone and soft tissue injuries, both patients required revision TKA secondary to PJI. Haspl et al. [17] reported on 10 arthroplasties performed at a mean of 24 months (range 9 to 42 months) after gunshot injuries or blast injuries with retained missile fragments in the hip, knee and shoulder. Two knee arthroplasty patients were identified as having PJI where the infecting organism was *Staphylococcus aureus* at 22 and 23 months after their arthroplasty procedure. Following unsuccessful management of their infection, both patients went on to a successful arthrodesis.

There is a paucity of literature describing outcomes following projectile missile/bullet injury and the risk for SSI/PJI following TJA. Additionally, due to the nature of the studies (e.g., case series), small numbers and heterogeneous patient populations, it is difficult to independently assess the impact of projectile missiles/bullets on TJA outcomes. The clinical presentation of a destructive arthritis due to third body wear, proliferative synovitis or from the initial trauma can present similarly to an indolent infection/septic arthritis. Therefore, evaluation for presence of infection may be warranted preoperatively. Also, it can be inferred that the degree of soft-tissue injury as reported by the Gustilo Classification, Mangled Extremity Severity Score (MESS) and limb salvage index (LSI), may help identify TJA candidates at greatest risk for SSI/PJI.

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