PART VIII

SPORTS

PREVENTION

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QUESTION 1: What perioperative antibiotic prophylaxis should be used in patients undergoing arthroscopic surgery without the use of implants or grafts? What about patients with non-anaphylactic or anaphylactic penicillin allergy?

RECOMMENDATION: The literature neither supports nor refutes the use of antibiotic prophylaxis for routine arthroscopic surgeries, without the use of implants or grafts. For non-compromised, non-implant arthroscopy, antibiotic prophylaxis is not required. Patients with comorbidities which have been shown to cause higher risk for infection may benefit from antibiotic prophylaxis. A first-generation (cefazolin) or a second-generation (cefuroxime) cephalosporin can be used as first line, including for those with a non-anaphylactic penicillin allergy. For patients with an anaphylactic penicillin allergy, other antibiotics such as vancomycin, clindamycin or teicoplanin can be used.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

The overall risk of infection following routine elective arthroscopic procedures is low (for the knee it is 0.1–3.4% [1–3] and for the shoulder it is similar at 0–3.4% [4,5]). Various patient-related risk factors that are associated with higher risk of infection have been identified including the patients being young and male, conditions resulting in immunocompromised status and history of depression [1,2]. Additional risk factors that have been identified using databases include higher body mass index, history of diabetes, longer operative time and smoking [1,2]. In these patients at higher risk of infection, special consideration should be given to the use of perioperative antibiotic prophylaxis.

In a prospective study by Qi et al. there were similar infection rates in 1,326 patients irrespective of the antibiotic prophylaxis [6]. In a randomized controlled trial (RCT) by Wieck et al., administration of antibiotics did not provide additional benefit for prevention of infection in 437 patients [7]. However, it is important to note that because of the smaller cohort size, the findings may have introduced a type II error. Similarly, a recent large database study on 40,810 simple knee arthroscopies demonstrated no association between administration of perioperative antibiotics and postoperative infection [8]. Although the rate of deep infection was lower in the antibiotic group, the difference did not reach a statistical significance.

Randelli et al. reported an infection rate of 0.16% (15 infections) in their review of a series of 9,385 shoulder arthroscopies, with a significant difference in rates between patients receiving antibiotic (0.095%) and those not receiving antibiotic (0.58%) ($p = 0.01$) [4]. Conversely, Bert et al. retrospectively analyzed 3,231 knee arthroscopies (2,780 meniscectomies) and found patients who received preoperative antibiotics had an infection rate of 0.15% compared to 0.16% in those who did not ($p = 0.59$) [9].

A recent retrospective study by Pauzenberger et al. on 3,294 arthroscopic rotator cuff repairs with implants, demonstrated a reduced infection rate from 1.54% to 0.28% in patients who received no antibiotic prophylaxis compared with those who received 2 grams of cefazolin routinely, respectively. Further, those patients who received no antibiotic demonstrated a 5.53 times higher rate of infection [10].

In elective surgery, the preferred preoperative antibiotic is a first or second-generation cephalosporin (cefazolin or cefuroxime) [11]. They are broad spectrum, cost-effective and allow newer, more expensive antibiotics to be used for more resistant organisms. Cephalosporins cover gram-positive bacteria as well as clinically important aerobic gram-negative bacilli and anaerobic gram-positive bacteria. They have good distribution in muscle, bone and synovium, achieving fast bactericidal levels after administration [11].

One placebo-controlled trial evaluating prophylactic cefazolin in 2,137 total hip arthroplasty patients showed a significant reduction in infection[12] whereas another RCT of cefuroxime compared to vancomycin and fusidic acid in 435 arthroplasty patients showed no difference in infection rate, the lack of difference may have been because of the small sample size and underpowered nature of the study [13]. Alternative first line agents are penicillins including cloxacillin and flucloxacillin [11]. In known cases of anaphylactic penicillin allergy, other agents such as clindamycin, vancomycin or teicoplanin, if available, should be considered. Clindamycin is bacteriostatic and alone has poor activity against *Staphylococcus aureus* (MRSA) so other agents (e.g., levofloxacine) may need to be coadminsitered [11]. With a non-anaphylactic penicillin allergy, a second-generation cephalosporin can still be used as there is limited cross-reactivity and penicillin skin testing can assess for a true allergy [11]. Patients colonized with MRSA should receive vancomycin or teicoplanin [14]. A recent report from Europe showed that teicoplanin was the most common agent used in high-risk patients with associated comorbidities (84% of practices), but is not available in the US, Canada or China [15].

Septic arthritis post-arthroscopy remains very rare with rates of 0.009–1.1% [16]. Despite its rarity, this complication is serious as its treatment often warrants multiple surgical procedures and prolonged antibiotic treatment, with risks of significant chondral damage and patient morbidity. Despite successful eradication of infection, the joint may develop secondary osteoarthritis and functional loss [17]. Moreover, the additional short and long-term treatment costs to the patient and hospital, is a factor to consider when using antibiotic prophylaxis [18]. However, the increasing prevalence of antibiotic resistance and the occurrence of drug-related adverse events cautions its routine use [19].

Overall, the literature on antibiotic prophylaxis for knee and shoulder arthroscopy is limited. For routine elective arthroscopy without the use of implants or grafts in the healthy patient, there is no evidence to support the use of perioperative antibiotic prophylaxis. Antibiotics may be considered when implants are being used or when the patient has certain comorbidities which are considered risk factors for infection. A first- or second-generation cephalosporin antibiotic can be used as a first line agent, including in patients with a non-anaphylactic penicillin allergy. In patients with an anaphylactic penicillin allergy, other agents such as vancomycin, clindamycin or teicoplanin can be considered.

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QUESTION 2: Should routine methicillin-resistant *Staphylococcus aureus* (MRSA) screening be in place for patients undergoing elective sports procedures?

RECOMMENDATION: Routine MRSA screening is not warranted for patients undergoing elective sports procedures. Screening may be appropriate in higher-risk patients and patients undergoing more complex procedures.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Staphylococcus aureus (*S. aureus*) is the most frequent pathogen isolated from surgical site infections (SSIs) in patients undergoing orthopaedic procedures [1]. SSIs caused by *S. aureus* can be serious and difficult to treat, often requiring debridement with removal of orthopaedic implants. *S. aureus* resides on skin surfaces and asymptomatically colonizes approximately one-third of the population, most commonly the anterior nares [2]. Multiple studies have shown that *S. aureus* nasal colonization is a significant risk factor in developing *S. aureus* SSIs [3]. *S. aureus* is also found in the throat, axilla and groin [4], as well as in eczematous skin lesions [5]. Screening for and decolonization of *S. aureus* has been shown to decrease SSI rates in a variety of surgical specialties [6], but not specifically in patients undergoing sports procedures.

In some hospitals, 57% of isolates of *S. aureus* causing orthopaedic infection are resistant to methicillin [1]. Compared to methicillin-sensitive *S. aureus* (MSSA) causing SSI, patients with MRSA SSIs have been shown to have a higher risk of morbidity, mortality and greater hospital costs [7]. Indeed, one study showed that intranasal carriage of *S. aureus* was the only independent risk factor for SSIs following orthopaedic implant surgery [8].

Most studies evaluating MRSA screening and decolonization in orthopaedic patients were performed in elective total joint arthroplasty patients [9,10]. Other studies have also included spine patients (e.g., fusion) and trauma patients [11], and many did not state the specific type of elective orthopaedic patient included. These non-specific studies often had a minimum inpatient stay inclusion criterion, which therefore excludes almost all elective orthopaedic sports surgery cases.

Our extensive search of the literature identified a study by Kim et al. that evaluated patients undergoing sports procedures who screened 7,019 of 7,338 (95.6%) preoperatively for MRSA. They also included patients undergoing total joint replacement and spine surgery, with a minimum one-day inpatient stay, though no details on the types of cases or numbers were provided. There were 309 (4.4%) MRSA carriers, and these patients did have a significantly higher risk of SSI compared to non-MRSA carriers (0.97% vs. 0.14%, p = 0.0162). However, the rates of infection in the sports surgery group were not reported [3].

Given the significant lack of data on the efficacy and cost effectiveness of preoperative MRSA screening in patients undergoing orthopaedic procedures in general and those receiving sports procedures in particular, the routine practice of MRSA screening cannot be recommended. Rates of infection after sports surgery procedures are generally lower than rates after arthroplasty or spine procedures, suggesting that screening strategies may prevent fewer infections and be less cost-effective in sports surgery than in other orthopaedic procedures. Very limited data suggests that screening may be considered in sports patients who will be admitted for at least one overnight stay, particularly if implants are to be used [3]. Further studies are needed to evaluate the efficacy and cost-effectiveness of screening for Staphylococcal carriage (MRSA or MSSA) in patients undergoing sports surgery procedures.

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QUESTION 3: What perioperative antibiotic prophylaxis should be used in patients undergoing arthroscopic surgery who are methicillin-resistant *Staphylococcus aureus* (MRSA) carriers?

RECOMMENDATION: MRSA carriers should be administered vancomycin or teicoplanin as antibiotic prophylaxis prior to arthroscopic surgery involving an implant and/or a graft or for patients at higher risk of infection.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Prevalence of MRSA colonization is increasing in some community settings, even in patients who lack traditional (or any) identifiable risk factors [1]. Surveillance studies have suggested that the colonization rate in the general population varies worldwide, with methicillin-sensitive *S. aureus* (MSSA) nasal carriers making up 20–36.4% of the population, and MRSA nasal colonization composing 0.6–6% of the population [2].

When simple arthroscopy is performed (meniscal tears, articular debridement, synovectomy and microfracture), the risk of surgical site infection (SSI) is extremely low and antimicrobial prophylaxis is not routinely recommended [3–7]. However, when arthroscopic procedures involve the use of implants, grafts, placement of several surgical incisions, prolonged operative time or knee ligament reconstruction, the SSI risk is higher than in simple arthroscopy, and prophylactic antibiotic administration may be justified [8–10]. Although the efficacy of prophylactic antibiotics in reducing SSI for major orthopaedic procedures has been proven, the role of antibiotic prophylaxis in routine arthroscopy remains controversial [3,4,11,12].

Regarding arthroplasty, some studies reveal that universal MRSA decolonization is effective in reducing the overall rate of SSIs and promoting economic gains for the health system related to the downstream savings accrued from limiting future reoperations and hospitalizations [13–15]. The American Academy of Orthopaedic Surgeons (AAOS) and Surgical Care Improvement Project (SCIP) recommend first- or second-generation cephalosporins as the prophylactic antibiotics of choice for patients who are not colonized with MRSA, with vancomycin prophylaxis reserved for those who are MRSA-colonized [16]. The addition of vancomycin or an aminoglycoside to the prophylactic perioperative antibiotic regimen results in a predicted activity of 83–97% against the most common pathogens causing SSIs [17].

Thus, based on the available evidence, it is unlikely that prophylactic antibiotics are needed for simple arthroscopic procedures in the first instance and if the prophylaxis should be modified for patients who are MRSA carriers. In the absence of evidence, and due to the gravity of any SSI being caused by MRSA, we recommend that consideration be given to administration of vancomycin or teicoplanin as antibiotic prophylaxis prior to arthroscopic surgery involving an implant and/or a graft or for patients at higher risk of infection.

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QUESTION 4: What is the best method for anterior cruciate ligament (ACL) allograft sterilization to minimize the incidence of postoperative infections and mechanical weakening of the graft?

RECOMMENDATION: **The best method for ACL allograft sterilization to minimize the incidence of postoperative infection and mechanical weakening of the graft is the use of irradiation (preferably less than 1.8 Mrad). Allografts should be harvested aseptically and fresh-frozen, whenever possible.**

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

An exhaustive literature review of articles published in English was undertaken to identify studies related to allograft sterilization and the incidence of postoperative infections and graft failures. The search was performed across the PubMed, Scopus, and Cochrane databases as well as Google Scholar using the following search terms: "allograft sterilization," "infections and allografts in ACL reconstruction," "complications after allograft use for ACL" and "mechanical strength of allografts." Articles in languages other than English were not reviewed, nor were articles on non-human subjects. The articles included were from 1988 until March 2018, (Levels I-IV evidence) containing evidence of graft longevity, post-ACL infections, revision rates following use of allografts and other complications associated with allograft use. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses criteria (PRISMA) were followed.

Septic arthritis after ACL reconstruction (ACLR) is a rare event, occurring in 0.14 to 1.8% of cases [1–3]. Several studies have demonstrated a lower rate of deep infection after ACLR using allograft compared to hamstring autograft tendons and equal possibilities with the use of bone patellar tendon bone (BPTB) autograft [4–8]. The increasing use of primary allograft ACLR during the last few decades can be explained by the fact that allograft offers several advantages such as shortening operative time, reducing postoperative pain, allowing a variety of grafts to choose from and avoiding harvest site morbidity [9–11].

However, allografts bring with them an intrinsic risk of contamination, which is why every possible effort must be made in order to lower this risk as much as possible.

The American Association of Tissue Bank (AATB) has made several rules in allograft procurement, sterilization and conservation, in order to guarantee a Sterility Assurance Level, which is the probability of failing the sterilization after the whole process, lower than 1×10^{-6} [12]. The possibility of human immunodeficiency virus (HIV) transmission is one in 1,667,600 [13], but it drops to 1/173,600 for non-processed allograft [14]. In fact, there are several steps that follow a rigid protocol to ensure a lower risk of disease transmission. The donor must be checked for known disease and an examination of the body is taken to control any sign of infection or intravenous (IV) drugs stigmata [15].

Further, the donor is screened by serology tests for viral infection (i.e., HIV type I – II, hepatitis B virus (HBV) surface antigen, HBV core antibody or hepatitis C virus (HCV) antibody) [16]. Nucleic Acid Testing (NAT) is the best test for screening HIV and HCV because seroconversion occurs 15 days after the first contact with the virus [16]. Blood cultures are necessary to check for bacterial and fungal infection. Aerobic and anaerobic cultures last for a minimum of 15 days, according with the AATB and the Food and Drug Administration [17]. The successive step is the tissue retrieval, which is performed in a sterile operating room with sterile technique [18]. After that, the graft is treated with a bactericidal-antimicrobial disinfection solution. At this stage, the graft cannot yet be considered sterile [15].

There are several sterilization techniques, which can be split into irradiation and chemical sterilization. The irradiation can be based on gamma ray or electron-based radiation. The gamma radiation works by generating free radicals and directly modifying nucleic acids, leading to genomic dysfunction [19]. Unfortunately, the first effect can damage the collagen and compromise the mechanical structure of the graft in terms of strength and elasticity [20,21]. A low dose of radiation (< 25 KGy) is able to kill the bacteria, but does not have a complete effect on the virus [22–25]. In reverse, a high dose of radiation (> 35 KGy) can kill viruses, but several studies showed that at this level of radiation, the mechanical proprieties of the graft are compromised [22,26,27].

Additionally, it is necessary to consider that there is no consensus about the fact that a low dose of radiation does not damage the graft. Park et al. reviewed 21 publications and found a total of 1,453 ACLR with allograft (415 low-dose irradiated; 1,038 non-irradiated) [28]. The authors found worse functional outcomes and greater rates of re-rupture in patients receiving irradiated allograft. However, in the single publications, the result was good to excellent in both groups, and not all of the functional scores favoured the non-irradiated group as the International Knee Documentation Committee score was higher in the irradiated group [28].

There are several publications suggesting that a low dose of gamma radiation does not affect the biomechanical properties of the graft [29,30]. However, other studies find the opposite [31–33].

Furthermore, other studies suggest the efficacy of radioprotective solution (i.e., propylene glycol, dimethyl sulfoxide, mannitol and trehalose) in protecting the graft from even high doses of gamma radiation [20,34].

An alternative system is electron-based radiation, which has a lower penetration (8cmH2O vs. 30cmH2O), and a lower time is required for the sterilization (seconds vs. hours) compared to gamma irradiation. Good results have been demonstrated if used in combination with other tissue-protective measures (i.e., low temperature or carbon dioxide) [35]. Further studies are required to fully understand the effectiveness of this method.

Chemical sterilization is another option, however, some of these processes should be avoided. For example, ethylene oxide can cause post-implantation synovitis, cysts and graft failure [36,37] and iodophor rinse followed by water is not uniformly viracidal [37].

An effective solvent is paracetic acid (PAA), which does not change the strength or elasticity of the graft [38] even if it seems to be correlated with a delay in the biological remodelling, and thus can cause a reduction in early knee stability (first three months) [39].

In the absence of any definitive evidence that addresses both the mechanical strength as well as anti-infective properties in allografts, we would propose that if an allograft is the only choice available, it should preferably be fresh-frozen, aseptically harvested and subjected to less than 1.8 Mrad of irradiation. Indeed, the majority of tissue banks use combined methods (i.e., Crylife Inc., Biocleanse, Allowash, Tutoplast process, the clearant process, etc.).

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QUESTION 5: Should autograft or allograft be soaked in an antiseptic or antibiotic solution prior to implantation during anterior cruciate ligament reconstruction (ACLR)?

RECOMMENDATION: Yes, autograft tissue should be soaked in an antibiotic solution prior to implantation during ACLR.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 91%, Disagree: 9%, Abstain: 0% (Super Majority, Strong Consensus)

RATIONALE

Infection after ACLR is rare but can cause serious complications [1]. Contributing factors that may predispose to infection include diabetes, smoking, increased time of surgery and tourniquet inflation, additional or larger incisions for arthroscopic portals and the use of a drain [2].

The use of a preoperative prophylactic antibiotic has been previously established to reduce infection rates in orthopaedic surgery procedures [3]. Historically, ACL allografts have been associated with a higher risk for infection. However, a recent systematic review reported no difference in infection rates between allograft and autograft tissue for ACLR [4]. Further, hamstring autograft grafts have been reported to have a higher incidence of infection compared to both allografts and bone-tendon-bone (BTB) patellar tendon autografts [5–7].

Among the published studies, there are strong evidences that pre-soaking of hamstring grafts in topical vancomycin reduced the rate of postoperative infection when compared to intravenous (IV) antibiotics alone.

Vancomycin has been reported for its use for local antibiotic infusion into joints [8]. Vertullo et al. investigated the utility of soaking hamstring autografts with vancomycin before implementation during ACLR. In their investigation, both patient cohorts received preoperative IV antibiotics while one group additionally received a pre-soaked vancomycin graft. A statistical difference in infection rates was noted between the two patient groups as the preoperative IV antibiotic-only group reported an infection rate of 1.4% compared to a 0% rate for the group with the vancomycin-soaked allograft [9].

Pérez-Prieto et al. performed a similar study. Both patient cohorts received preoperative IV antibiotics while one group additionally received a pre-soaked vancomycin graft. However, in this series, BTB autografts were included as well. The group without vancomycin saturation of the graft had an infection rate of 1.85% while the group of patients who received systemic antibiotic prophylaxis and graft pre-soaking with vancomycin did not experience any infections (0%) [10].

Phegan et al., reporting on the use of vancomycin-soaked hamstring autografts, noted no infections in a series of 1,300 patients receiving prophylactic vancomycin pre-soaked hamstring grafts in addition to systemic antibiotics [11]. Additionally, Yazdi et al. reported using gentamicin irrigation solutions in conjunction with preoperative IV antibiotics with an infection rate of 0.57% compared to an infection rate of 2.1% in patients receiving only IV antibiotics. All patients in this series received autologous grafts [12].

Vancomycin has activity mostly against gram-positive microorganisms, while gentamicin is a broad–spectrum antibiotic targeting both gram-positive and gram-negative microorganisms [11].

Due to the high impact of literature supporting the use of soaking autograft tissue in an antibiotic solution prior to implantation during ACLR, we conclude that soaking autografts in antibiotic solution is an effective treatment in reducing infection postoperatively.

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QUESTION 6: What is the most appropriate/effective sterilization method of an anterior cruciate ligament (ACL) graft dropped on the operating room (OR) floor during ACL reconstruction (ACLR)? Should the tissue instead be disposed and alternate graft acquired?

RECOMMENDATION: **Rinsing the contaminated graft in a 4% solution of chlorhexidine gluconate is the most effective decontamination method in the event that an ACL graft is dropped on the OR floor. When a chlorhexidine gluconate solution is used for decontamination of the dropped ACL graft, the subsequent rates of infection are very low, suggesting that there is no need to dispose of the ACL graft.**

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Injuries to the ACL are among the most common injuries to the knee, with reconstruction being the preferred method of treatment when functional instability is present [1]. Autografts are frequently used for ACLR, but it has been shown that the use of autografts is associated with contamination as a result of the harvesting and manipulation process [2]. Contamination of the autograft can also occur accidentally, by dropping the graft on the OR floor or allowing it to come into contact with non-sterile surfaces. In fact, a 2008 survey showed that 75% of plastic surgeons had dropped an autograft on the OR floor at least once [3]. In 94% of those cases, the autograft was decontaminated and the operation was completed. This protocol may put the patient at risk for the development of an intraoperative infection if proper decontamination procedures are not followed. This is particularly concerning given the sheer volume of ACL autograft reconstructions done each year, which has led to a variety of case studies to attempt to identify the best method for sterilizing a dropped autograft during ACLR.

Numerous studies have shown that a contaminated autograft can be effectively decontaminated by rinsing it in a 4% chlorhexidine gluconate solution [4–8]. There is some discrepancy regarding the length of time that a graft should be rinsed in the chlorhexidine solution, with 90 seconds [8], three minutes [6,7], 15 minutes [9] and 30 minutes [4] all being recommended. Khan et al. determined that rinsing a contaminated autograft in a 4% chlorhexidine gluconate solution was the most effective decontamination technique in a systematic review of seven studies [10]. The studies included used samples from a variety of sources (fresh-frozen, autograft, cadaver) and they found that 98% of contaminated grafts soaked in chlorhexidine showed no bacterial growth [10].

Bacitracin, polymyxin B and povidone iodine were additional proposed methods of decontaminating a dropped graft, but there were conflicting recommendations regarding their use. Of note, bacitracin was shown to be highly effective in decontaminating hamstring autografts [6,7], but it did not decontaminate bone-patellar tendon-bone grafts [11]. The clinical relevance of the latter observation has not been explored further. While a povidone iodine rinse was found to be a useful method of decontamination when used on grafts dropped on the OR floor, it was ineffective on samples artificially contaminated with *Staphylococcus aureus* and *Pseudomonas aeruginosa* [12].

There is a lack of patient outcomes data and randomized control trials on the subject, as well as some discrepancy regarding the length of time a graft should be rinsed prior to implantation. However, there is agreement between numerous case studies indicating that rinsing a contaminated ACL graft in a 4% chlorhexidine gluconate solution is an effective and appropriate decontamination method.

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QUESTION 7: Does the use of a tourniquet influence the incidence of surgical site infection (SSI) following arthroscopic surgery of extremity joints?

RECOMMENDATION: No. A direct relationship between use of a tourniquet for arthroscopic surgery of the extremity joints and the incidence of SSI has not been established.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

The use of a pneumatic tourniquet during arthroscopy is a popular intraoperative measure to control bleeding, improve visualization, ease surgical procedures and possibly shorten the operative time, especially in knee procedures. For several decades, various studies have suggested that tourniquet application may result in an increased risk of postoperative pain, nerve paralysis, swelling, joint stiffness and functional weakness bringing into question the value of tourniquet use [1,2]. However, two meta-analyses found no difference in functional outcomes and general complications among patients undergoing arthroscopic surgery with and without the use of tourniquet [3,4]. Therefore, the use of tourniquets remains at the discretion of treating surgeon. A survey of the American Orthopaedic Society of Sports Medicine, Arthroscopy Association of North America and Delhi Arthroscopy Society members revealed that the majority of surgeons preferred to use tourniquet during arthroscopy surgery, thus making comparison of the outcome of these patients without the use of tourniquet somewhat difficult [5].

The potential influence of tourniquet use on the risk of subsequent SSI following arthroscopic surgery is not clear. If the tourniquet use results in a higher rate of SSI, a possible mechanism could be related to the effect of ischemia on antibiotic diffusion in the bone marrow. Administration of antibiotic while the tourniquet is inflated is unlikely to allow for proper diffusion of the antibiotics to the operated extremity and the joint. Because of the latter issue, a ten-minute delay between antibiotic administration and inflation of the tourniquet is proposed to allow the antibiotic to reach the required minimal inhibitory concentration (MIC) level in the operated joint [6].

Regarding the correlation between tourniquet use and the risk of infection after joint arthroscopy, no randomized controlled trials (RCTs) with this primary outcome were found. The available high-level studies on knee arthroscopy were underpowered due to the rarity of SSI, while no meta-analyses performed a pooled analysis of SSI events following tourniquet and non-tourniquet arthroscopic surgery [3,4]. Additionally, few single-center series of knee arthroscopies analyzed the risk factors for SSI. Sherman et al. retrospectively evaluated 2,640 arthroscopies, and did not report a direct correlation between tourniquet use and postoperative complications, including infection. However, a higher risk of postoperative complications was found only in patients older than 50 years and in a tourniquet time longer than 60 minutes [7]. Reigstad et al., focusing on SSI, reported two superficial infections after 876 simple arthroscopies (0.23%), mostly after medial meniscectomies, and failed to identify a significant correlation with tourniquet use. Rather, they rather reported a higher incidence of complications in cases of prolonged surgical time [8].

Also, Vachal et al. reported six SSIs after 908 anterior cruciate ligament reconstructions (ACLR) (0.7%), identifying previous surgeries as the only significant predictor for SSI [9]. The risk of infection has been specifically investigated in two large multi-centric series of ACLR, the Multicenter Orthopaedic Outcome Network (MOON) cohort and Kaiser-Permanente registry including 2,198 and 10,626 patients, respectively [10,11]. However, they were limited to the inclusion of tourniquet use and operative time in the multivariate logistic regression. The same limitation has been disclosed in other large multi-centric cohorts involving up to 700,000 patients undergoing knee arthroscopy [12,13].

Regarding elbow, wrist and ankle joints, few studies evaluated arthroscopic procedures without the use of the tourniquet, thus solid conclusion cannot be drawn regarding the impact of tourniquet use and SSI after ankle, elbow or wrist surgery [14–17].

Based on the available literature, no direct relationship between tourniquet use and SSI has been reported. What is clear is that there is a direct link between surgical time and the risk of subsequent infection in arthroscopic surgery of extremity joints. Thus, the use of tourniquets should be subordinated to the surgeon's preference and experience, and balanced with the patient's characteristics, comorbidities and the complexity of the procedure to limit the surgical time. When antibiotic prophylaxis is planned, the tourniquet should be inflated at least ten minutes after its administration.

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QUESTION 8: What strategies should be employed to minimize recurrent infection of a previously infected joint during subsequent joint reconstructive (non-arthroplasty) procedures?

RECOMMENDATION: We recommend that joints with remote or recent history of infection be aspirated and the synovial fluid analyzed for the presence of infection. The affected joint should not exhibit any clinical signs of infection such as erythema, swelling, warmth and others at the time of planned reconstruction.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Our extensive literature search did not reveal any studies specifically focusing on the prevention of recurrent infection in previously infected joints during reconstructive (non-arthroplasty) procedures. It is, however, well-established that previous septic arthritis is a risk factor for subsequent surgical site infection (SSI) and periprosthetic joint infection (PJI) [1–4]. Furthermore, different studies described the risk factors for developing septic arthritis, such as morbid obesity, tobacco use, inflammatory arthritis, chronic kidney disease, diabetes and hemodialysis [5–7]. Cancienne et al. reported in their case-control study of over 530,000 shoulder arthroscopies that prior steroid injection, revision surgery and malnutrition were independent risk factors for infection [8].

Multiple PJI and SSI risk mitigation strategies may be considered in a patient with remote or recent history of joint infection undergoing a reconstructive non-arthroplasty procedure [1–3,9,10]. These are discussed in further detail below.

- Medical optimization: Consider optimization of modifiable risk factors such as treatment of any systemic or local infection, correction of malnutrition, weight reduction in patients with morbid obesity (> 40 kg/m^2), treatment of vascular insufficiency, smoking cessation, correction of hyperglycemia and preoperative cessation of immune-modifying medications [10].
- Antibiotics: Administer prophylactic antibiotics to reduce the risk of recurrent infection. In patients with previous methicillin-resistant *Staphylococcus aureus* (MRSA) infection, the addition of vancomycin or teicoplanin as perioperative antibiotic prophylaxis should be considered [10,11].
- Skin preparation: Preoperative surgical site preparation using soap (antimicrobial or non- antimicrobial) or an antiseptic agent on the night before the operative day should be considered [2,10].
- Particle-free operating environment: While there is no definitive evidence for the efficacy of laminar air flow in non-arthroplasty surgery, the number of theatre personnel and operating room traffic should be minimized to reduce the risk of recurrent infection [10].
- Respect the soft tissue: Meticulous surgical technique, proper wound closure and an effort to reduce the surgical time may help minimize the risk of recurrent infection [10,12].
- Intraoperative wound irrigation: Copious intraoperative irrigation is considered an effective strategy to reduce the number of pathogens in the surgical wound [10].
- Wound management: Antimicrobial dressings may reduce the risk of SSI [10,13].

More recently, pre-soaking of hamstring tendon autograft in a vancomycin solution has been shown to reduce septic arthritis following ACL reconstruction. As such, we recommend soaking the autograft (and possibly allograft) in an antibiotic solution such as vancomycin when used in previously infected knees [14–17].

In the absence of specific literature related to the above question, we recommend that all measures are taken to ensure that infection in the affected joint is resolved, which includes absence of erythema, swelling and so on. In addition, the affected joint should be aspirated and the synovial fluid analyzed for signs of infection.

During the reconstruction of the previously infected joint, all available strategies for prevention of infection should be implemented.

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QUESTION 9: Is the surgical management of a patient with infection following anterior cruciate ligament reconstruction (ACLR) an emergency, or can the patient be optimized prior to surgical intervention? If so, what needs to be optimized?

RECOMMENDATION: Infection following ACLR is not a surgical emergency in most cases. Sepsis associated with infected anterior cruciate ligament (ACL) requires an emergency treatment. Most surgeons agree that surgical intervention should take place without delay, on a prompt basis, preferably on the same day as the clinical presentation of an ACLR infection. The patient's condition needs to be optimized prior to surgery.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Infection following ACLR is a rare event affecting up to 2.25% of patients, but it is a serious complication [1–15]. Surgical management of ACLR infections is frequently discussed in the literature, but the timing of surgical intervention is not clearly stated in the majority of these publications [3,4,6,10–12,16–18].

A few studies have addressed the issue of timing of surgery. A study by Schuster et al. stated that the surgery should be performed on the day of admission [19]. Another study by Mouzopoulos et al. also declared that the infection should be treated without delay [20]. In a review article, Wang et al. reported a summary of various studies by stating a recommendation for immediate operative treatment [21]. Torres-Claramunt et al. also reported that the generally-accepted treatment is "arthroscopic lavage, performed as soon as possible" [22]. It is known that articular cartilage degrades rapidly and loses nearly half of its glycosaminoglycan and collagen composition in the first week of a joint infection [23,24]. Therefore, a significant delay should not be experienced in the initiation of surgical treatment in patients presenting with an infection of ACL reconstruction.

The major drawback in the literature is that almost all of the studies published on infection following ACLR have been retrospective reviews. It is well-established in these studies that infection following ACLR can rarely be a life-threatening emergency. A timely and well-planned course of action based on clinical and laboratory data and microbiological findings is recommended. Graft retention has been shown as a goal along with articular cartilage protection, so lengthy delays should be avoided [1,3,6,11,13,17,18,25,26].

A protocol for patient optimization prior to surgery has not been clearly established. Clinical examination and aspiration of the knee joint is recognized as the first step in diagnosis at initial patient presentation with a suspected postoperative ACLR infection. It is also generally reported that broad-spectrum antibiotics, preferably cephalosporins, should be started as soon as possible after joint aspiration is performed [10,12,15,16,19,20,22,27]. The antibiotics should target coagulase-negative *Staphylococcus* (CNS) and *Staphylococcus aureus*, as these are the most common infecting organisms. Antibiotic therapy should be modified as soon as culture results identify the specific pathogen and the susceptibility.

Blood tests for infectious and inflammatory markers, such as white blood cell count, erythrocyte sedimentation rate and C-reactive protein, should also be conducted on the day of presentation.

This will add to the initial clinical data and offer serial information to monitor infection eradication [19–22]. Clinical records of the patient should be reviewed to identify the nature of the prior operative procedure, type of graft, method of fixation and additional meniscal or cartilage procedures, if performed [1,4,6,15,19].

As with all surgeries, comorbidities should be medically managed. This may include better control of hyperglycemia, correction of anticoagulation, correction of anemia and other conditions that may adversely influence the outcome of surgical procedure.

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Diagnosis

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QUESTION 1: Should culture samples be taken during arthroscopic treatment of a knee joint infection? If so, how many and from which area in the joint?

RECOMMENDATION: Yes, culture samples should be taken during arthroscopic treatment of a knee joint infection. We recommend that at least three culture samples from different sites be taken.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Infections of the knee joint can occur either from hematogenous spread or directly due to local trauma or a medical intervention. Infections after an arthroscopy for anterior cruciate ligament reconstruction (ACLR) or meniscal pathology are reported throughout the literature [1–18]. Infection can also occur in healthy native knees [13,19–24]. Sending intraoperative samples of synovial fluid and tissue for microbiological analysis is commonly reported in the literature [1–12,14–24], with only one study reporting no intraoperative samples for culture [13]. Two studies described the number of samples taken during the arthroscopy [11,19]. In both of the studies, five samples were taken and sent for culture. Unfortunately, no studies described an optimal area of the joint from which to take the samples.

When considering the existing research, it can be concluded that samples should be taken during arthroscopic treatment for a knee infection. However, based on the review of the literature, no conclusion can be drawn about the number of samples.

There is more research describing the number of samples to be taken during debridement in periprosthetic joint infection (PJI). In their study on 113 PJIs, Gandhi et al. concluded that the optimal number of cultures needed to obtain a positive test result was four (specificity = 0.61, sensitivity = 0.63). Furthermore, they stated that increasing the number of samples increases specificity but reduces sensitivity [25]. In the same study, the samples were collected from representative areas of the joint, including, but not limited to, synovium, intramedullary tissue, prosthetic interface and tissue from the adjacent bone [25].

During the previous consensus meeting in 2013, it was concluded that three to six samples should be obtained intraoperatively in suspected PJI cases [26]. Similarly, other authors confirmed that three to five samples should be obtained from deep tissues during surgery for suspected PJI [27,28].

There is no agreement about the area of the joint the samples should be taken from during arthroscopic treatment of septic knee arthritis. In their review, Bauer et al. reported that the samples should be taken from the deep tissue [29]. In their systematic review, Mouzopoulos et al. suggested that during arthroscopic treatment of septic ACLR, samples for culture should be taken from multiple areas, such as synovial lining, graft, femoral and tibial tunnel [30].

Based on the available data, no definitive conclusion can be drawn on the number of samples needed and the area of the joint they should be taken from during arthroscopic treatment of septic knees. Studies based on PJI were considered, as well as literature reviewed on knee septic arthritis after ACLR. Based on this data, it may be extrapolated that at least three samples should be collected during arthroscopic treatment of knee joint infection. Furthermore, they should be taken from multiple areas of the joint: graft, synovial lining and from the femoral and tibial tunnels when present. It is reasonable to also collect samples from other areas, such as the medial and lateral gutters and the suprapatellar pouch.

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QUESTION 2: What diagnostic "algorithm" should be used to diagnose infection following anterior cruciate ligament reconstruction (ACLR)?

RECOMMENDATION: The "algorithm" to diagnose postoperative infection in patients with ACLR should include clinical presentation, serological tests including C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) and analysis of the synovial fluid aspirate including gram staining and culture.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Postoperative infections following ACLR are rare, occurring in only 0.14–5.7% of cases [1–5]. As a result, clinical studies are limited and have small sample sizes. However, the general consensus is that the clinical presentation, laboratory blood tests, (specifically (CRP) and ESR) and synovial fluid aspiration analysis are essential for the diagnosis of infection after ACLR [6–13]. Magnetic resonance imaging can detect joint effusion, synovitis, edema of adjacent soft tissues and bone marrow, bone erosions, sinus tracts and soft tissue abscesses, though this has only been reported in one study [14].

Features of the clinical presentation that raise suspicion of infection include fever, malaise, sudden change in knee pain of moderate intensity, local incision drainage, local warmth, local swelling, erythema, decreased knee range of motion and inguinal lymph node enlargement, though each of these symptoms is not present in all cases [8,11,15–17].

Laboratory blood analysis should be included in the diagnosis of infection after ACLR. Interpretation of results can be challenging, as elevated levels are routinely seen postoperatively, (typically peaking by postoperative day three), as a result of the surgical trauma [3,7,13,18]. C-reactive protein levels, which increase within six to eight hours after infection, have been shown to have the highest sensitivity and specificity. Reported average C-reactive protein levels in patients after ACLR with knee infection range from 55.8 to 203 mg/L (range, 10-400 mg/L) (normal 0-0.5 mg/L) [11,15–17]. ESR levels typically rise within 24 to 48 hours [19–21]. Average ESR values in patients with knee infection after ACLR range from 57 to 76 mm/h (range, 9-108 mm/h) in the literature (normal 1-10 mm/h) [11,13,15,17,18]. Peripheral white blood cell count has also been shown to be elevated in patients with postoperative knee infection after ACLR (9.1 to 10.8 x 109/L), though this is not a consistent finding in the majority of patients [13,15,17]. Polymorphonuclear neutrophils (average 71.7%) and fibrinogen levels (average 774.7 mg/mL) have also been assessed and shown to be elevated in patients with ACLR and postoperative knee infection [13].

Gross inspection of knee joint aspiration commonly reveals turbid, yellow-green synovial fluid.[3] Microbiological analysis of synovial fluid aspirate is the most widely studied diagnostic method for septic arthritis [1,6,8,9,19,22,23]. Analysis includes gram staining, leukocyte counts, aerobic and anaerobic cultures and antibiotic sensitivities [6,13]. Positive leukocyte counts of aspirated knee fluid in knee infections after ACLR have also been reported [average 91,000 (range 64,000 to 129,000)] [6,11]. Several retrospective studies have shown that in most cases synovial fluid bacterial cultures are positive to coagulase-negative Staphylococci (*Staphylococcus epidermidis*), *Staphylococcus aureus*, *Streptococcus non-hemolytic*, *Staphylococcus schleiferi*, *Escherichia coli* or Propionibacterium in acute septic arthrosis [6,11,13,15,17–19,23,24].

Overall, there is consensus that the diagnostic algorithm for postoperative knee infection following ACLR should include sudden change in history and presentation to include change in knee pain profile, swelling and range of motion, in addition to elevated CRP and ESR blood laboratory test values and synovial fluid aspirate microbiological analysis, though due to the rarity of its occurrence and limited number of studies and sample size, the recommendation is only of moderate strength.

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Treatment

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QUESTION 1: Can arthroscopy be used for management of patients with acute sepsis of the native knee joint?

RECOMMENDATION: Yes. Arthroscopy can be used for treatment of acute sepsis of the native knee joint.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

An extensive literature search was conducted to identify all publications related to the use of arthroscopy for management of acute septic arthritis of the native knee. A total of 18 publications were identified for review and of these, 1 was excluded as the cohort included patients with periprosthetic joint infection. Three publications were not available despite all attempts to retrieve them. Fourteen papers were reviewed in full, including five publications reporting results from the pediatric population. There was one randomized controlled trial by Peres et al., and the remaining studies were retrospective reviews [1]. In the management of septic arthritis of the native knee, the two key points to address are successful clearance of infection and minimization of complications. The pediatric papers have been reviewed separately.

Adults:

Seven papers compared arthroscopic management with arthrotomy and two papers reported only on arthroscopic results.

Jeffe et al. described successful infection clearance at four months with one procedure in 75.8% (25/33) treated with arthroscopy and 80.9% (38/47) treated with arthrotomy. This difference was not statistically significant [2]. After further statistical analyses, failure in the arthroscopic group was associated with infection being caused by methicillin-resistant *Staphylococcus aureus* (MRSA) (five out of eight failures). Similar success rates were reported by Balabaud et al. accounting for 72% (16/21) for arthroscopy and 84% (16/19) for arthrotomy [3]. Böhler et al. reported significantly lower reoperation rates and significantly better functional outcomes in patients treated arthroscopically. They achieved clearance with one procedure in 95.1% (39/41) treated arthroscopically and 79.3% (23/29) treated with arthrotomy [4]. Dave et al., with follow-up of up to 7.2 years, reported success rates of 77.8% (28/36) with arthroscopy and 60% (6/10) with arthrotomy [5]. They found no relationship between using arthroscopy and the need for multiple procedures but they did report a statistically significant relationship between the number of hours between onset of symptoms and time to index procedure and the need for multiple procedures in the group as a whole [5].

Wirtz et al. had higher success rates, at 93% (25/27) with arthroscopy and 83% (20/24) with arthrotomy [6]. A large study by Johns et al. found a 2.6 times higher chance of needing further surgery in the arthrotomy group, although overall their success rates from the primary procedure were lower than other studies with a reported success rate of 50% (59/119) for arthroscopy and 29% (12/42) for arthrotomy [7].

These results support the use of arthroscopy as the initial treatment, and are backed up by the randomized controlled trial by Peres et al. with two-year follow-up reporting 100% (10/10) success rate for arthroscopy compared to 82% (9/11) for arthrotomy [1]. However, the small sample size, and the low rate of culture positivity (at 47.6%) raises concern that some of these patients may have suffered inflammatory conditions and were not truly infected.

Complications:

Complications other than reoperation were not uniformly reported in all papers. On univariate analysis by Bovonratwet et al., higher mortality and serious adverse events were associated with arthroscopy and higher transfusion rates and minor adverse events were encountered after arthrotomy [8]. On multivariate analysis, controlled for age and American Society of Anesthesiologists (ASA) grade, there was no statistically significant difference between the risk of all adverse events or readmission. Johns et al. [7] and Böhler et al. [4] reported median knee range of motion post-arthroscopy being statistically significantly higher, in contrast to other studies discussed above. However, they did report pain at 7 and 14 days being statistically significantly better in the arthroscopy group, and reported significantly more local warmth and redness in the arthrotomy group at 1 week.

Pediatric Cases:

In the management of pediatric patients with septic arthritis of the knee, the results from five retrospective reviews also supported the use of arthroscopy. However, positive culture results ranged from 48% to 62.5%, when documented. Johns et al. concluded that arthroscopy was more successful that arthrotomy in reducing return to theatre and regaining knee function earlier. However, on long-term follow-up (mean 6.9 years) they found no significant difference between the groups [7]. Success following the first procedure was reported in 11/11 (100%) for arthroscopy and 8/13 (61.5%) following arthrotomy [7]. The other four papers on managing pediatric patients only reported results of arthroscopy. Success rates were 54/56 (96%) from Agout et al. [9], 5/5 (100%) from Sanchez and Hennrikus [10], 15/16 (93.8%) from Ohl et al. [11] and 16/16 (100%) from Stanitski et al. [12].

Complications other than return to operating room were reported in all papers, but not uniformly. At 6.9 years of follow-up, Johns et al. found no difference between the Knee Injury and Osteoarthritis Outcome Score (KOOS) and Lysholm scores, range of movement, leg length discrepancy (LLD) and gait between the arthroscopy and arthrotomy groups [7]. At three weeks follow-up, Ohl et al. reported that all patients had resumed normal activities and no abnormalities on radiographs [11]. Agout et al. [9], Sanchez and Hennrikus [10] and Stanitski et al. [12] reported no pain, symmetrical range of movement, no radiographic changes and < 5mm of LLD in all patients at final follow-up.

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QUESTION 2: What type of lavage solution should be used in patients with a native knee infection being treated with arthroscopy?

RECOMMENDATION: We recommend that high volumes of saline without antibiotics should be used as the arthroscopic lavage solution for native knee infection.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Infection of the native knee can be treated surgically by open or arthroscopic methods [1–3]. Arthroscopic lavage techniques have been used widely, since the introduction of arthroscopic debridement offers the benefits of smaller incisions, decreased tissue damage and lower reinfection rates compared to open methods [1–3]. Arthroscopic treatment yields good to excellent results, though there are a limited number of comparative studies in the literature (many with small sample sizes) [1–10]. Irrigation aids in the removal of debris and decreases the intra-articular concentration of chondrolytic enzymes better than needle aspiration alone [11,12].

There is a general consensus in the literature supporting high-volume (10 to 15 L) arthroscopic lavage with saline combined with intravenous antibiotics both in pediatric and adult patients for septic arthritis [1,3,9,10,13–25]. Based on microbiological findings, lavage plus intravenous antibiotics appears sufficient to eradicate *Staphylococcus aureus*, the most common cause of septic arthritis of the native knee [7]. Two studies with larger patient numbers support saline irrigation without intra-articular antibiotics as the lavage solution of choice [2,7]. A large number of other studies described using saline lavage solution for arthroscopic treatment of knee sepsis, with an average volume of 10.1 L [6,9,17,18,20,22,26–30]. Shinjo et al. compared the effects of two common arthroscopic irrigation solutions on meniscus tissue cells, and demonstrated that Ringer's lactate solution better maintained human meniscus cell integrity than the isotonic saline [31].

Additionally, there is a lack of agreement on the use of intra-articular antibiotics despite their frequent use during arthroscopic treatment of infected native knees in clinical practice without recommendation, thus warranting further investigation [32,33]. While some are proponents of intra-articular antibiotics, others are concerned about resultant chemical synovitis and potential chondral toxicity, not mentioning the risk of increasing antibiotic resistance [5,34,35]. Only one study by McAllister et al. specifically described using an antibiotic-loaded Ringer's lactate solution during arthroscopic treatment of four postoperative septic knees following anterior cruciate ligament reconstruction. The antibiotic name was not mentioned, but they reported a 100% eradication rate for infection [17]. The use of continuous irrigation-suction drains with antibiotics added to the irrigation solution has been both supported and refuted in the literature [4,5,34,36–38]. Some studies support the use of continuous suction irrigation drains with saline, whereas others caution against their use due to concerns of secondary infection [2,4–7,13,14,14,14,34,36,39].

In conclusion, other than saline, there is limited data to support the use of other arthroscopic lavage fluids for treatment of native knee infections and further comparative clinical studies are needed.

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QUESTION 3: Should a synovectomy routinely be performed during arthroscopic treatment of an acute infection following anterior cruciate ligament reconstruction (ACLR)?

RECOMMENDATION: No. Total or partial synovectomy should be reserved for cases of severe or chronic infection.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

According to Gaechter and the proposed classification, the synovial membrane serves as a natural barrier in infection [1,2]. As a result, a primary synovectomy should be avoided in acute infections except for later stages [1,2]. The four stages of joint infection described by Gaechter were:

- Stage I: Synovitis, turbid fluid, possible petechiae
- Stage II: Fibrin clots, franc pus
- Stage III: Thickening of the synovial membrane (up to several centimeters), multiple pouches due to adhesions
- Stage IV: Pannus. Aggressive synovitis, radiographically visible changes, subchondral erosions

Klein et al. suggested a stage-oriented therapy for the treatment of bacterial joint infections in 1989, based on three stages of infection, which largely coincided with the stages I to III according to Gaechter [3].

An extensive irrigation of the joint and removal of all hematoma, fibrin deposits and partial synovectomy should be performed when synovitis is present [4,5]. In the presence of cartilage erosions in the joint or additional septa, a subtotal synovectomy is recommended [3]. Other studies advocate for a synovectomy during the first irrigation and debridement procedure, with fair results [6,7]. Zalavras et al. reported a successful outcome following a complete synovectomy [8]. More recent papers again recommend a synovectomy only in stages III and IV [9].

Prompt recognition of an infection and intervention with irrigation and debridement alone can prevent the need to remove ligament grafts and hardware. Therefore, a synovectomy should not be routinely performed during arthroscopic treatment of an acute infection following ACLR. However, this issue has not been well studied, and further studies are needed to address the influence of synovectomy in the management of infected ACLR.

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QUESTION 4: Should the graft and all hardware be removed in the treatment of patients with an acute infection following anterior cruciate ligament reconstruction (ACLR)?

RECOMMENDATION: The initial approach to an acute infection following ACLR should be arthroscopic irrigation and debridement, retention of a stable graft and hardware and intravenous antibiotic therapy.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

The incidence of septic arthritis after anterior cruciate ligament (ACL) surgery is low (0.14 to 2.25%) [1]. In acute postoperative infections, graft and hardware removal versus retention remains controversial with the goal being to eradicate the infection, preserve the articular cartilage and retain a functioning graft.

A prospective study by Abdel-Aziz et al. analyzed 2,560 ACL procedures with 24 cases of septic arthritis, with a mean follow-up of five years. In all patients, arthroscopic surgical debridement was performed (average three procedures), followed by intravenous antibiotic treatment. In all 24 cases, infection was eradicated with this protocol. No functional differences were found compared to control group according to Lysholm, International Knee Documentation Committee (IKDC) and Knee Injury and Osteoarthritis Outcome Score (KOOS) ratings [2]. Likewise, Schuster et al. reviewed more than 7,000 ACLRs, identifying a total of 36 cases of acute postoperative infections. The graft was retained in all but one case (97.2%) with a mean of 2.25 (+/-1.22 SD) procedures required to treat the infection [3].

In a meta-analysis, Kuršumović et al. reported a success rate of 85% for graft retention and infection eradication [4]. They analyzed 16 studies with a total of 147 knee infections after ACLR. Increased rates of failure were seen in cases with persistent infection requiring subsequent procedures, from 4.4% with one arthroscopic debridement, to 11.4% with two procedures, or 25% with more than three surgeries [4]. In a similar systematic review, Makhni et al. analyzed 19 studies with a total of 203 cases of septic arthritis following ACLR and reported a success rate with graft retention of 78% [5].

Wang et al. also demonstrated success after serial irrigation and debridement and intravenous antibiotics. In addition, they demonstrated a greater graft retention rate when infection was diagnosed and treated immediately (< 7 days) suggesting a crucial time constraint to treatment [1].

Therefore, the data suggests that the initial approach to acute postoperative infection after ACLR should be to attempt to retain the graft and hardware. However, there are cases in which removal should be considered, which may include presence of gross purulence, when infection is resistant to multiple irrigations and debridement, possible bony involvement of the tibia or femur and/or a nonfunctional graft [6,7].

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QUESTION 5: How many arthroscopic procedures are reasonable for the management of an infected anterior cruciate ligament reconstruction (ACLR) prior to considering graft and hardware removal?

RECOMMENDATION: Prior to considering stable graft and hardware removal, at least two arthroscopic procedures are reasonable for the management of an infected ACLR. There is evidence for successful treatment and graft retention with further arthroscopic procedures.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Septic arthritis after arthroscopic ACLR is rare with an overall frequency to be around 1% [1–4]. However, when it does occur, it is a potentially serious event with possible sequelae of osteomyelitis, arthrofibrosis and damage to the articular cartilage leading to osteoarthritis [5–7]. Although a rare occurrence, surgeons who routinely perform this procedure are likely to encounter this complication during their career [8].

Repeated arthroscopic lavage is part of the algorithm to treat infection after ACLR [4]. The number of arthroscopic procedures necessary is guided by clinical and laboratory progression as well as organism virulence and patient-related factors such as age and preexistent comorbidities [3,9]. In a study by Bostrom Windhamre et al., patients suffering from septic arthritis after ACLR underwent a mean of 3.7 interventions (range 1 to 11) [10]. Arthroscopic lavage was repeated if the patient had persistent fever, swelling and a C-reactive protein level greater than 50 mg/L. In a study of 90 cases of septic arthritis after ACLR conducted by Saper et al., arthroscopic irrigation and debridement was performed in 95.5% (86/90) of cases with an average of 1.51 procedures [2].

According to Abdel-Aziz et al., a median of three (range 1 to 6) repeated arthroscopic debridement and synovectomy procedures were required to eradicate infection [3]. In another study by Schulz et al., irrigation and debridement successfully treated the infection with a mean of 2.2 procedures with no recurrences of septic arthritis or bone infection [11]. Kim et al. presented 146 patients producing 111 (78.1%) positive intraoperative cultures. *Staphylococcus epidermidis* was identified in 46 knees (41.4%) with *Staphylococcus aureus* found as the second most common organism and presented in 38 knees (34.2%) with infection after ACLR [12]. This report differs from the previous general consensus that *Staphylococcus aureus* was the most commonly reported organism in ACLR infection [9].

In their study of 147 patients with infections of the knee, Wang et al. noted that coagulase-negative *Staphylococcus* (CNS) was the most common pathogen and represented 45.6% of the infections. *Staphylococcus aureus* was second most common and was reported to cause 23.8% of the infections [7]. The virulence of the infective organisms can affect the course of treatment, but the age of the patient appears to have some bearing on the outcome and the number of arthroscopic procedures required to control the infection. Mouzopoulos et al. reported that patients over the age of 25 years required, on average, 1.12 more procedures to control infection compared to patients under the age of 25 [9].

Immediate arthroscopic lavage and debridement should be followed by six to eight weeks of intravenous antibiotic therapy, and then two to four weeks of oral antibiotics. In cases of persistent infection, repeat arthroscopy is recommended, but serious consideration for graft removal should be considered [9]. In patients with a retained graft, McAllister et al. reported that an average of 2.75 procedures were needed to sterilize the knee joint [5]. Graft retention is important, as 30% of patients with the graft retained following surgery experienced knee instability compared to 65% of patients who had their graft removed [11,13]. Early diagnosis of infection is critical, as the literature has reported that infection diagnosed within seven days post-ACL reconstruction has a higher rate of graft salvage than those infections diagnosed beyond seven days post-op [7]. Furthermore, graft retention following infection after ACLR is a viable procedure with a reported overall success rate of 85% [14].

Upon reviewing the literature, it was found that at least two arthroscopic treatments are needed to control infection after ACLR and prior to graft and hardware removal. Despite the lack of randomized clinical trials, several retrospective studies have reported that arthroscopic lavage and debridement for infection following ACLR is an effective therapeutic intervention to minimize the severity of sequelae, including osteoarthritis, osteomyelitis and arthrofibrosis [5].

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QUESTION 6: How many arthroscopic procedures are reasonable for the management of an infected anterior cruciate ligament reconstruction (ACLR) prior to considering arthrotomy?

RECOMMENDATION: **It is reasonable to treat acute infection of the knee following ACLR with arthroscopic debridement, repeating the arthroscopy up to six times, if necessary. The use of arthrotomy in the management of infected anterior cruciate ligament (ACL) cases is not well defined.**

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

Infection following ACLR is rare but can be a potentially devastating complication. However, if early appropriate surgical intervention is performed, the functional outcome may be comparable to non-infected cases of ACLR [1].

Historically, septic arthritis of the native knee was treated with open debridement and varying degrees of synovectomy, as described by Ballard et al. [2]. More recently, Riel et al. demonstrated arthroscopic irrigation and debridement with good results and since then, they have become a routine treatment option for an infected ACLR [3]. Several subsequent studies have described arthroscopic debridement as the initial treatment of choice for the management of septic arthritis of the knee [4].

Makhni et al. conducted a systematic review on functional outcomes following surgical treatment of the infected knee following ACLR. The studies included in the analysis demonstrated that up to six arthroscopic procedures were performed for the resolution of infection and symptoms [4].

Böstrom et al. examined outcomes following infected ACLRs. They described a standard treatment protocol of repeated arthroscopic debridements, with a mean of 3.7 procedures per patient, although the range was wide (1 to 11 procedures) in all patients [5]. Another systematic review by Saper et al. concluded that arthroscopic debridement with graft retention is an effective treatment of infection following ACLR. The mean number of arthroscopic procedures per patient in these studies was 1.5 (range, 1 to 4) [6].

Interestingly, Petersen et al. used a treatment approach according to the Gaechter classification system. In their study, they reported complete resolution of infection following ACLR in all patients without arthrotomy. For Gaechter stage I and II patients, the mean number of arthroscopic debridement's was 2.5, while in stage III patients it was 3.4. There were no stage IV patients reported [7]. Similarly, Gille et al. utilized a treatment algorithm based on the stage of infection according to Gaechter [8]. In patients with stage III or IV infections, medial and lateral arthrotomy with near total synovectomy was performed after initial arthroscopy.

Torres-Claramunt et al. reported mean of 1.3 (standard deviation = 0.6) arthroscopic debridements in their study, and one patient required three procedures. The authors recommended repeated arthroscopic debridement, usually after 48 to 72 hours, if clinical and laboratory parameters do not improve [9]. Abdel Aziz et al. examined 24 patients with an infected ACLR, who required between 1 and 6 arthroscopic debridements before achieving complete resolution of infection [10].

The literature on the number of arthroscopic procedures needed prior to arthrotomy for an infected ACLR is sparse. Nevertheless, studies have shown that repeated arthroscopic procedures can give good results, although the number of procedures required varies. As a consequence, there may be no need to treat an infected ACLR with arthrotomy in most cases. However, in more severe and neglected cases (Gaechter stage IV), arthrotomy should be considered after initial arthroscopic evaluation of the joint.

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QUESTION 7: What is the optimal duration of antibiotic treatment after surgical debridement of an infected anterior cruciate ligament reconstruction (ACLR)? Should this be altered when autograft or allograft is retained?

RECOMMENDATION: Following surgical debridement of an infected anterior cruciate ligament (ACL), antibiotic treatment should be administered for four to six weeks and can be discontinued upon resolution of clinical signs and normalization of laboratory parameters. The available literature does not differentiate between retention or removal of autograft or allograft.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

ACLR surgery is an anatomically complex procedure with high success rates and low infection rates [1–3]. Nevertheless, the onset of an infection after reconstructive ACL surgery is a devastating complication that can cause, in a short period of time, a progressive degeneration of the articular cartilage, graft failure and loss of function of the knee [1–3]. A prompt diagnosis and correct management might reduce or even prevent these unfavorable outcomes [4]. The incidence of infection following ACLR ranges from 0.14% to 1.8% [5–8].

Arthroscopic debridement followed by antibiotic treatment is the preferred therapeutic approach in aiming to control the infection and save the graft. Indeed, satisfactory functional outcomes are achieved in several cases of septic arthritis following ACLR with a graft salvage rate of about 85% [9]. However, persistent infection, despite multiple arthroscopic debridements, requires graft removal and subsequent ACL revision surgery at a later stage [9]. The duration and the route of administration of antibiotic therapy, in particular when to switch from intravenous (IV) to enteral administration, remain controversial [4].

Even though the duration of antibiotic treatment can vary between 4 and 14 weeks, most authors agree that it should be administered for no less than 6 weeks [4,10–12]. IV administration is preferable for the first two to three weeks [3,8,13]. However, the microorganism cultured and the antibiogram together with the postoperative clinical and laboratory parameters dictate the precise duration of antibiotic treatment [14].

In a systematic review, Wang et al. [15] evaluated 17 articles that fulfilled the inclusion criteria of septic arthritis following ACLR. The authors found that the arthroscopic debridement with graft retention and IV antibiotics was the treatment of choice for infected ACLR in most studies, with delayed diagnosis and treatment being the greatest risk factors for graft removal and articular cartilage damage. Indeed, out of 176 patients included in all the studies, 86.9% (153/175) underwent arthroscopic debridement for septic arthritis. IV antibiotics were continued for an average period of 29.7 days [15]. IV antibiotics for an average of four to six weeks was recommended, which might then be changed to oral antibiotics as soon as the C-reactive protein (CRP) levels drop to nearly normal values (< 1 mg/mL) [3,10,11]. Oral antibiotics were then administrated for at least another 14 days until the CRP returned to normal [15].

Out of 176 patients present in all studies, 18.75% (33/175) underwent graft removal, but the optimal duration of antibiotic treatment was not clearly reported. In two studies, the revision surgery was performed 12 months or later after the infection had resolved [16,17]. However, in another study by Burks et al. the revision ACLR was performed within six weeks after the completion of the antibiotic therapy and after the laboratory values had returned to normal [18].

Mouzopoulos et al. [19] proposed the basic management protocol with graft retention based on IV antibiotic therapy over at least four weeks followed by oral antibiotic for two to four weeks. An extended IV antibiotic therapy was given only in patients who needed more arthroscopic lavages. However, the therapeutic management in case of graft removal or retention is not well distinguished.

Gobbi et al. [20] stated that serial arthroscopic lavages and IV antibiotics with graft retention remain the most effective treatment protocol, starting with empirical therapy at the time of presentation. IV antibiotics switch to culture-sensitive oral antibiotics as soon as the CRP levels have nearly normalized (< 1 mg/mL) for six weeks, or until normalization of clinical and laboratory parameters. The average duration of IV antibiotics ranges from 17.3 days to six weeks, followed by oral administration for up to 3.2 months [2,3,7,8,11,13,21–23].

Shuster et al. [24] created a detailed treatment algorithm in which the graft is preserved as long as possible. However, graft removal is considered in persistent infections after multiple revisions, in loosened fixation or in graft insufficiency. In patients undergoing debridement and irrigation, a chain of antibiotic (gentamicin) loaded beads was inserted, protruding through the wound to allow stepwise removal within approximately one week. Empiric antibiotic therapy (cephalosporin I or II combined with an aminoglycoside, clindamycin or rifampicin) is started and antibiotic treatment is re-evaluated every day and changed according to microbiological testing, if necessary. When patients show clinical improvement over five to six days with consistent and substantial decreases in CRP levels, they are discharged with oral therapy and weekly follow-up examinations. The duration of antibiotic therapy is based on the individual course of each patient and antibiotic therapy is terminated when CRP levels are within normal range (< 5 mg/L) [25]. The mean duration of inpatient treatment was 16.5 ± 8.2 days (range, 4 to 45 days). The mean duration of antibiotic treatment was 5.4 ± 2.3 weeks (range, 2.1 to 12.9 weeks). In 13 patients (36%), the duration of antibiotic treatment was < 4 weeks. A maximum of two arthroscopic irrigation and debridement procedures (mean, 1.46 ± 0.52) was necessary for eradication of the infection in these patients [25].

The available evidence does not allow for drawing a conclusive recommendation regarding the optimal duration of antibiotic treatment after surgical debridement for infected ACLR. However, the literature suggests that antibiotic treatment should be followed for four to six weeks and continued until clinical conditions are improved. Moreover, the literature is still controversial on the duration of antibiotic treatment in case of graft and hardware retention or removal, focusing mainly on the former case. Furthermore, most of the authors do not differentiate between autograft and allograft, considering and treating them in the same manner.

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QUESTION 8: Should the rehabilitation protocol be modified after surgical debridement of an infected anterior cruciate ligament reconstruction (ACLR)? If yes, what changes should be made with regards to range of motion and weightbearing status?

RECOMMENDATION: We recommend that rehabilitative treatment after surgical debridement of an infected ACLR with graft retention should not differ substantially from primary reconstruction; it should be focused on preventing stiffness and regaining motion through passive and active-assisted range of motion exercises before progressing.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

The development of an infection after ACLR can have significant complications including loss of articular cartilage, graft failure and loss of knee function [1–3]. Although there is wide agreement that treatment must be initiated as early as possible, several different treatment algorithms have been proposed [4–7]. With regards to the postoperative treatment, there are no studies directly focusing on rehabilitation protocols.

While it is well-established that a graded knee-strengthening program (including quadriceps and hamstrings strengthening) has to be started within the first postoperative days [4,8–11], there is no agreement regarding weightbearing status and range of motion parameters.

Rehabilitative treatment after surgical debridement of an infected ACLR does not differ substantially from primary reconstruction. It should be focused on preventing stiffness and regaining motion through passive and active-assisted range of motion exercises.

There are no studies suggesting an altered rehabilitation protocol in the setting of a postoperative infection. Monaco et al. [10] suggest the use of a brace locked in extension for two weeks, followed by a progressive increase in the range of movement and muscular strength. Alternatively, many authors allow immediate full range of movement under the supervision of a physical therapist [7,11]. Indelli et al. [12] and Wang et al. [3] recommend starting rehabilitation only after complete resolution of symptoms, and suggest only passive motion of the knee and the ankle in the meantime.

There is a lack of consensus on weightbearing status after treatment of an ACL infection. Torres-Claramunt et al. [4,13] suggest starting a strengthening program two weeks after surgery with progressive weightbearing after symptoms decrease. Likewise, weightbearing was gradually increased until resolution of symptoms in the rehabilitation protocol developed by Hantes et al. [14]. However, McAllister et al. [15] and Schub et al. [16], suggest beginning the weightbearing six weeks after surgery.

Overall, there is a lack of evidence to support a standardized approach to rehabilitation after the surgical debridement of an infected ACLR. High-quality controlled trials are needed to provide guidelines for this rare and difficult complication.

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QUESTION 9: When can patients safely undergo revision anterior cruciate ligament reconstruction (ACLR) following treatment for prior infection?

RECOMMENDATION: It is considered safe to perform a revision ACLR following completion of successful treatment for infection and normalization of clinical and laboratory parameters upon resolution of the infection. The literature does not suggest a specific timeframe following resolution of the infection prior to performing revision ACLR.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 92%, Disagree: 0%, Abstain: 8% (Super Majority, Strong Consensus)

RATIONALE

Infection following ACLR is rare, with a reported incidence of 0.14% to 2.25% [1,2]. When infection does occur, there are potentially significant consequences, particularly regarding patient outcomes [3]. Following allograft ACLR, there is a well-known risk of disease transmission, although a recent literature review found no difference in infection rates between autograft and allograft ACL reconstructions [4,5].

Graft retention following an infected ACLR is a viable option, as a recent meta-analysis and systematic review reported a success rate of 85% [2]. Matava et al. surveyed 61 orthopaedic surgeons and found that graft removal was not popular as the initial treatment, with only 6% and 33% of respondents removing the autograft and allograft following ACLR infection, respectively. However, in cases of persistent infection, 36% of surgeons removed the graft as part of their treatment regimen [6]. The same survey showed that the most common time frame for revision surgery was a minimum of 6 to 9 months (range, 3 to 15 months) after eradication of the infection [6].

Despite successful outcomes with graft retention, graft removal and revision ACLR remains the preferred method for some surgeons following infection [7]. In a retrospective review, Burks et al. reported on 8 infections out of 1,918 ACL reconstructions. Seven of these were treated with immediate irrigation and debridement with subsequent graft removal and administration of intravenous antibiotics for six weeks. Of those, four successfully underwent revision ACLR at a mean of three weeks (range one to six weeks) after completing antibiotic treatment [7]. In another systematic review and expected value decision analysis of 19 studies, revision ACLR, within 3 to 6 weeks after the infection, was shown to have promising results [8]. Gille et al. prospectively studied 31 patients with ACL infection where the graft was salvaged in 8 patients (26 %) and removed in 12 patients (39 %). Only two patients underwent revision ACLR at six and eight months post infection [9].

Williams et al. reported on 2,500 ACLRs with 7 infections: the graft was removed in 4 cases. One of these cases underwent successful revision ACLR one year later [10]. In a retrospective review of 3,500 ACL reconstructions, Indelli et al. identified 6 infections treated with arthroscopic debridement of which 2 grafts were removed, culminating in 1 revision ACLR and 1 total knee arthroplasty (TKA) a year later [11]. Furthermore, another study reported one patient treated with initial graft removal and successful revision ACL surgery one year after treatment [12]. Zalavras et al. also described a series of five infected ACL reconstructions treated with radical debridement and graft removal. Two patients had further procedures: 1 revision ACL reconstruction 14 months later and 1 TKA nine months later [13].

Hantes et al. reported 7 infected cases in a series of 1,242 ACL reconstructions. One patient did well with irrigation and debridement and six had a recurrence of infection, requiring subsequent graft and hardware removal. These patients were offered subsequent revision ACLR and graft reimplantation three months after the last operation. Four of the six patients underwent revision with ipsilateral bone patellar tendon bone autograft at an average of five months (range four to nine) post eradication of infection. The authors recommend revision ACLR after eradication of the infection for at least three months, with normal knee motion, no knee effusion and normal laboratory values [14].

Despite the lack of randomized clinical trials, there are several retrospective studies with low numbers of revision ACLR following treatment for prior infection. There is no consensus on the appropriate timing of revision reconstruction, with a reported range of three weeks to over a year. In general, it seems appropriate to delay surgery for a minimum of six weeks, but waiting three to six months post-eradication of infection may be optimal. Importantly, criteria such as normal knee motion, lack of knee effusion and normal laboratory markers must be considered before proceeding.

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