No Infections in 1300 Anterior Cruciate Ligament Reconstructions with Vancomycin Pre-soaking of Hamstring Grafts

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INTRODUCTION

Infection after arthroscopic anterior cruciate ligament (ACL) reconstruction is an uncommon but potentially devastating post-operative complication. Contributing factors that may lead to infection include, co-morbid diseases such as diabetes, smoking, previous surgery or concomitant open surgical procedures. Increased operative time, additional or larger incisions, long tourniquet inflation time, or use of a drain or additional instruments may also contribute [2-4,8,9,11,15,18,23,25,32,33,37,39,41,43].

Previous authors have noted an increased incidence of infection depending on the type of graft used, with a greater incidence of infection with hamstring autografts and allografts compared with patella tendon grafts [5,19,20]. This increased incidence has been attributed to intra-articular suture material [3,6], graft fixation type and/or additional soft-tissue dissection, or flash sterilization of instruments [35]. The most common source of graft contamination would appear to be from skin commensal bacteria, despite the use of prophylactic intravenous antibiotics [10,19,31].

Patients with knee sepsis after ACL reconstruction typically present with increasing pain, effusion, rising C-Reactive Protein (CRP) level, and increased intra-articular white blood cell count. Infection after ACL reconstruction can result in poorer clinical outcomes, such as reduced function, pain, arthrofibrosis, early osteoarthritis, and graft failure with later revision [3,12,17,18]. Early recognition and definitive treatment are vital, however to date no published diagnosis or management protocols exist. Serial arthroscopic lavage, synovectomy and appropriate intravenous antibiotics is the Gold Standard of treatment usually allowing for graft retention [2,21], with a similar functional outcome but a decreased return to sports [7].

Despite appropriate intravenous antibiotic prophylaxis, infection rates of between 0.14% and 2.20% have been described [6,8,9,15,18,23,32,37,39,41,43,44] after ACL reconstruction. Theoretically, the failure of antibiotic intravenous prophylaxis is due to bacterial colonisation by skin commensals of a poorly vascularized hamstring tendon with levels of intravenous (IV) antibiotic below the minimum inhibitory concentration (MIC) [20]. Similar problems of IV antibiotic prophylaxis not preventing musculoskeletal infections to the skin commensal contamination have been encountered in other medical fields. Lazar et al. [22] reported that topical Vancomycin application to sternal wounds, in addition to IV prophylaxis on patients undergoing coronary artery bypass grafting statistically reduced the incidence of post-operative wound infection.

Our hypothesis is that a reduction in the rate of septic arthrosis after ACL reconstruction would be experienced by pre-soaking the hamstring graft with an appropriate antibiotic at the time of harvest when compared to a matched cohort. Topical Vancomycin pre-soaking of hamstring grafts to reduce post-operative infection has been previously reported [38]. This controlled clinical trial reports on a larger cohort over a longer period of intervention. In addition, a diagnostic criteria and management protocol for infection after ACL reconstruction is suggested.

MATERIALS AND METHODS

This is a controlled observation trial of 1585 participants who underwent ACL reconstruction over a 13-year period from 2001 to 2014. Group 1 underwent ACL Reconstruction without topical application of Vancomycin to the hamstring graft. Data for this group of 285 patients was collected over a three-year period from 2001 to 2004. Individuals in Group 2 underwent ACL Reconstruction with topical application of Vancomycin to the

hamstring graft over the subsequent 10 years. At final follow up this group consisted of 1300 individuals. Both groups received pre-operative IV antibiotics. All patient data was recorded in a password protected searchable electronic database.

Participants

All patients underwent ACL reconstruction by the same surgeon using an identical surgical technique at the same hospital after the operating surgeon obtained informed consent. Eligibility criteria to participate included an ACL deficient knee requiring ACL reconstruction diagnosed clinically by history of a traumatic event to the knee joint, a positive Lachmann test, and a MRI confirming an ACL rupture. All participants were referred by primary care practitioners, emergency physicians or sports physicians. Systemic co-morbidity and prior surgery were recorded in all patients. Both acute and chronic ACL deficient knees were included, as were patients with concomitant chondral injuries and meniscal pathology. Exclusion criteria included those undergoing simultaneous osteotomy, revision ACL reconstruction or an ACL graft other than hamstrings tendons.

Surgical Technique

All patients were screened preoperatively on the day of surgery by the surgeon for skin scratches, skin abrasions, cutaneous or systemic infections, infected piercings and if present, surgery was delayed until the lesion or infection resolved. All skin piercings and rings on the operative limb were removed pre-surgery. Prior to surgery the operative site was removed of hair using surgical clippers and a Betadine scrub solution was applied to the operative site in pre-admission.

An identical surgical technique was implemented in each case, with Intravenous Cephalothin 2g prior to tourniquet inflation to achieve adequate plasma levels pre-incision. Alternative antibiotic was used with known allergies. Skin preparation included an iodine preparation & adherent 3M Iobane 6650 Drapes (3M, St. Paul, MN). Skin edge contact with hamstring graft during harvest was avoid with a sterile gauze. A two portal ACL Reconstruction technique was used with the anteromedial portal for femoral tunnel drilling. An EndoButton CL (Smith & Nephew Endoscopy, Andover, MA) was used for femoral fixation with an RCI screw and staple (Smith & Nephew Endoscopy) on the tibial side. Hamstring harvest occurred via a 2.5cm vertical medial tibial incision. While tunnel creation occurred, the harvested hamstring graft, still attached to the tibia, was wrapped

in protective Raytec swab (Johnson & Johnson, New Brunswick, NJ) and placed back into the harvest site deep to skin and subcutaneous fat to prevent accidental droppage [29].

Procedural variation occurred with Group 1 having a protective Raytec swab soaked in a sterile saline solution before being wrapped around the harvested graft. In Group 2 the harvested hamstring graft was similarly wrapped in a Raytec swab, with the swab pre-soaked in 5mg/mL Vancomycin solution i.e. a “Vancomycin Wrap”. Prior to insertion, the graft was rinsed with normal saline. In each case the unused Vancomycin and soaked swab was destroyed in a manner to prevent environmental contamination. Contact between the patient’s skin and the Vancomycin soaked swab was avoided to prevent skin commensal exposure to Vancomycin.

Postoperatively, patients were scheduled outpatient clinic appointments at weeks 1, 12, and 52 for review by the operating surgeon. All patients received the same postoperative rehabilitation. All patients and their referring medical practitioner were advised to notify the surgeon if they had increasing pain, swelling, or fever at any time during this period. Beyond 12 months after surgery, patients were only reviewed if they had a re-injury or an instability event. Patients were advised to avoid bacteraemia inducing invasive procedures, such as urological, gynaecological, dental or piercing procedures in the immediate post-operative phase [40].

Infection Diagnosis

Deep post-operative infection was diagnosed by the following criteria: A) Positive post-operative culture on aspiration of a painful knee or B) Negative aspiration culture with a raised or rising serial CRP, an elevated synovial white cell count $\geq 16\,200$ /uL with a painful effusion, with or without wound drainage, in the absence of a haemarthrosis. Synovial aspirates were undertaken prior to antibiotic administration.

Approval was obtained for the study from the institutional Human Ethics Committee at the Griffith University (PES/22/09/HREC).

Statistical analysis

A post hoc power analysis using G Power for Fisher's Exact Test ($\alpha = 0.0500$), revealed the sample size to be adequate ($1-\beta = 0.9100$) [12]. Statistical analysis of the study population was carried out with the χ^2 test with Yates correction and a two tailed Fisher exact test. A *P* value of 0.0500 was considered statistically significant.

RESULTS

In group 1, a total of 4 (1.4%) postoperative septic arthritis cases were documented based on the infective criteria, all presenting between 1 and 4 weeks after surgery. All 4 infections were acute and presented outside of the scheduled clinical follow-up visit, with the patient contacting the surgeon either directly or indirectly through the referring general practitioner or an emergency department physician. All infected cases occurred in males, with a mean age at surgery of 28 years, all without significant immunosuppressive comorbidity (e.g., diabetes), and none had undergone prior surgery. Sterilization procedure failure was excluded by the hospital perioperative infectious diseases review committee in all four cases. No meniscal repair or open procedure was undertaken in these infected patients; however, two underwent partial simultaneous meniscectomy.

Three of the four cases cultured coagulase-negative *S. epidermidis* after aspiration. All three presented with increasing pain, large effusions, and rising or raised CRP. The fourth case, culture negative on both aspiration and arthroscopic biopsy, presented with increasing pain, rising sequential C-reactive protein (CRP) level, and increased synovial white blood cell count ($>16\,200$ /uL). This case responded to washout and IV Flucloxacillin and Gentamicin. Of the 4 cases, one presented at 4 weeks after surgery with a nonviable graft that underwent later revision.

In Group 2, there were no cases (0%) documented based on the infection criteria after 1300 consecutive hamstring ACL reconstruction surgeries. However, three patients presented with rising sequential CRP post-operatively and underwent knee aspiration. All three had synovial WCC $< 16\,200$ /uL, and resolved with clinical observation and serial CRP testing. None of these patients were treated prophylactically with IV or oral antibiotics.

There were no reported allergies or secondary effects to staff due to the preparation of the Vancomycin. No patient had a recorded allergy to Vancomycin or an adverse event.

Statistical analysis revealed a significantly reduced post-operative infection rate in Group 2, the Vancomycin Wrap with IV antibiotics Group, compared with the IV antibiotics alone Group 1 (Fisher exact test: $P = 0.0011$; χ^2 test with Yates correction: $P = 0.0003$).

DISCUSSION

The most important finding of this study was the confirmation that pre-soaking hamstring ACL reconstruction grafts in topical Vancomycin reduces the post-surgical infection rate when compared to IV antibiotic prophylaxis alone. These findings have been recently confirmed by Pérez-Prieto et al [30]. They reported using topical Vancomycin graft soaking to reduce infection rates after ACL reconstruction with either hamstring or patella tendon autografts to zero, compared to a control group who suffered a 1.85% infection rate, despite the use of IV antibiotics.

Topical antibiotics when utilized in other areas of surgery have shown to similarly reduce infection rates. Total joint arthroplasty undertaken with bone cement containing a heat stable antibiotic, demonstrates a reduced rate of infection postoperatively [1,16,26]. Antoci et al [1] reported that the use of titanium prosthetic implants covalently coated with Vancomycin prevented bacterial adherence, proliferation, and formation of a biofilm by *S aureus*.

Antibiotic Choice

Vancomycin was chosen for this study because of its pharmacological properties and low allergenicity. It is heat stable, with a large volume of distribution and is bactericidal against skin commensals. Given Vancomycin's role as a treatment for MRSA, great care was taken to avoid skin commensal exposure to prevent the possible development of resistance. However the role of Avoparcin in cattle feed [24] inducing Vancomycin resistance genes amongst bovine *Enterococcus* strains, with then horizontal gene transfer to *Staphylococcus aureus* has been implicated in the global development of Vancomycin Resistant *Staphylococcus aureus* [27].

Vancomycin is less toxic than other alternative antibiotics, such as Tobramycin, Cefazolin, and Gentamicin, with levels above 125 micrograms/mL required before osteoblastic toxicity occurs and bone regeneration is inhibited [1]. An antibiotic concentration of at least 2 micrograms/mL is required for effective eradication of the *Staphylococcal* species, creating a wide therapeutic window to avoid toxicity to local tissues [14].

Vancomycin's interaction with collagen has recently been reported [14]. An in-vitro study that utilised bovine tendon soaked in Vancomycin, reported that the tendon continued to elute antibiotic for up to 24 hours after soaking with maximal diffusion in the first hour. This laboratory investigation suggested that the collagen fibers absorb and then slowly release the Vancomycin into the joint space. It was theorized that presoaking the

hamstring autograft in Vancomycin during ACL reconstruction surgery converted the graft from a vehicle of potential joint contamination into an alternative method of infection prophylaxis.

ACL Reconstruction Infection Algorithm

Recognition and prompt management of post-operative knee joint is imperative for improved patient outcomes [7], however diagnosis can be difficult. The usual clinical signs of infection, such as pain, effusion, warmth, reduced range of motion and difficulty weight-bearing are often present in the 1-4 weeks postoperative phase during which acute post-surgical infections also occur [10]. Other systemic symptoms such as malaise and fever [32] also can manifest either late or are absent. Clinical examination of a septic knee may also reveal wound drainage and erythema [32,41,43] even though in our series no infected patient presented with these signs.

Raised or rising CRP and ESR in the postoperative phase can be a valuable clinical utility, however until recently, normal post-operative ACL reconstruction values of CRP & ESR were not available [18,19,32,37,41].

In a retrospective review of 122 (83 non-infected and 39 infected) patient's serology after ACL reconstruction, Wang et al [42] reported that a CRP value of 41 was a more sensitive (0.941) and specific (0.976) indicator of infection than a ESR value of 32 m/h, which had a sensitivity of 91.2% and specificity of 80.5%. CRP also peaked earlier (Day 3) and responded faster as a rapid response indicator in both infected & non-infected cases than the ESR. In this series, the mean CRP for infected patients was 101.9 mg/L. There was a statistical difference between the third and fifth postoperative days for the CRP value ($P < .01$), but not for the ESR.

Synovial WCC from arthrocentesis offers an alternative diagnostic utility, however until recently its diagnostic accuracy after ACL reconstruction was poorly established. Recently, Paci et al [28] reported on 31 non-infected ACL reconstruction WCC aspiration results from a group of 151 ACL reconstruction, compared to historical controls. A WCC of 16 200/uL, in the absence of haemarthrosis, had a sensitivity of 86% and specificity of 92%, and had a positive predictive value of 95%.

A combined diagnostic and management algorithm (Figure 1) is currently used by the authors in those suffering pain after ACL reconstruction.

This algorithm uses a combination of CRP and white cell count (WCC) from knee aspiration as the two diagnostic utilities. This offers the treating clinician a diagnostic ACL reconstruction infection algorithm, while avoiding unnecessary potential joint contamination to aid prompt diagnosis. The infection algorithm is

applicable at any time in the post-operative phase. Other clinical infective parameters such as fever, peripheral WCC count, ESR, pain, effusion, ability to weight bear, erythema and wound drainage are either non-diagnostic or less accurate for joint sepsis.

In addition to cell count, aspirated synovial fluid was also sent in each case of suspected infection for culture and sensitivity. Despite recent advances in bacterial DNA testing showing improved detection rates over synovial culture alone [36], this method is currently precluded from use at our institution due to inadequately slow test processing. Recent reports of Leukocyte esterase testing [34] may offer faster diagnosis in the future rather than cell count.

Successful treatment of any infection requires copious irrigation [10] and debridement of necrotic tissue in combination with appropriate systemic antibiotic therapy. Indications for repeat arthroscopy should be based on clinical findings and reducing CRP on subsequent serial testing. Infected necrotic graft may require removal at subsequent arthroscopy [10] as infection eradication is made difficult by factors including poor graft vascularity, reduced joint antibiotic penetration and biofilm formation.

One of the limitations of the study is its observation design. Whilst all patients in both groups were operated on utilising the same technique, a possible selection bias due to increasing operator experience through the study may have resulted in the earlier patients being at a higher risk of infection. However prior to the control group of 285 patients being operated on the surgeon had undertaken similar numbers of ACL reconstruction using different techniques. Also, the distribution of patients suffering post-operative infection after ACL reconstruction was evenly distributed throughout the Group 1 cohort.

This study did not document the graft failure in the two groups, however it has been previously reported [38], that Vancomycin graft soaking does not appear to compromise the integrity of the hamstring graft or result in higher revision rates.

Both groups in this study received a single dose of IV antibiotics pre operatively, with the intervention group receiving a second dosing of antibiotic topically. This second dose may be seen as a confounder, however the topical dose of Vancomycin was too small at only 35 milligrams [14], assuming it was all absorbed, to result in an adequate systemic plasma concentration of Vancomycin to reduce infection. An adult would require at least a standard dose of 500mg of Vancomycin to achieve an adequate plasma MIC. Each patient incurred the cost of their procedure and follow up. There was no funding contributed by third parties as a source of potential

financial bias.

The treating surgeon received no financial incentive. This study was conducted using routine materials and technique. All patients were offered the same pre-surgery clinical evaluation, rehabilitation and follow up protocols. Given the statistical significance of this studies results it can be assumed that the use of this technique in everyday operating is likely to lead to a reduction in the overall incidence of infection after ACL reconstruction.

CONCLUSIONS

The use of prophylactic Vancomycin pre-soaking of hamstring grafts during ACL reconstruction reduces the rate of infection compared with systemic antibiotics alone. A post-operative infection diagnosis and management algorithm is a useful current literature based clinical pathway.

REFERENCES

1. Antoci V, Adams CS, Hickok NJ, Shapiro IM, Parvizi J (2007) Antibiotics for local delivery systems cause skeletal cell toxicity in vitro. *Clin Orthop Relat Surg* 462:200–206
2. Armstrong RW, Bolding F (1994) Septic arthritis after arthroscopy: the contributing roles of intraarticular steroids and environmental factors. *Am J Infect Control* 22:16–18
3. Armstrong RW, Bolding F, Joseph R (1992) Septic arthritis following arthroscopy: Clinical syndromes and analysis of risk factors. *Arthroscopy* 8:213–223
4. Babcock HM, Carroll C, Matava M, L'Ecuyer P, Fraser V (2003) Surgical site infections after arthroscopy: Outbreak investigation and case control study. *Arthroscopy* 19:172–181
5. Barker JU, Drakos MC, Maak TG, Warren RF, Williams RJ, Allen AA (2010) Effect of graft selection on the incidence of postoperative infection in anterior cruciate ligament reconstruction. *Am J Sports Med* 38:281–286
6. Binnet MS, Başarir K (2007) Risk and outcome of infection after different arthroscopic anterior cruciate ligament reconstruction techniques. *Arthroscopy* 23:862–868

7. Boström Windhamre H, Mikkelsen C, Forssblad M, Willberg L (2014) Postoperative septic arthritis after anterior cruciate ligament reconstruction: does it affect the outcome? A retrospective controlled study. *Arthroscopy* 30:1100–1109
8. Brown HR, Indelicato PA (1992) Complications of anterior cruciate ligament reconstruction. *Oper Tech Orthop* 2:125–135
9. Burks RT, Friederichs MG, Fink B, Luker MG, West HS, Greis PE (2003) Treatment of Postoperative Anterior Cruciate Ligament Infections with Graft Removal and Early Reimplantation. *Am J Sports Med* 31(3):414–418
10. Cadet ER, Makhni EC, Mehran N, Schulz BM (2013) Management of septic arthritis following anterior cruciate ligament reconstruction: a review of current practices and recommendations. *J Am Acad Orthop Surg* 21:647–656
11. Crawford C, Kainer M, Jernigan D, Banerjee S, Friedman C, Ahmed F, Archibald LK (2005) Investigation of postoperative allograft-associated infections in patients who underwent musculoskeletal allograft implantation. *Clin Infect Dis* 41:195–200
12. Faul F, Erdfelder E, Lang, A.G, Buchner A (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods* 39: 175-191
13. Fong SY, Tan JL (2004) Septic arthritis after arthroscopic anterior cruciate ligament reconstruction. *Ann Acad Med Singap* 33:228–234
14. Grayson JE, Grant GD, Dukie S, Vertullo CJ (2011) The in vitro elution characteristics of vancomycin from tendons. *Clin Orthop Relat Res* 469:2948–2952
15. Greenberg DD, Robertson M, Vallurupalli S, White RA, Allen WC (2010) Allograft compared with autograft infection rates in primary anterior cruciate ligament reconstruction. *J Bone Joint Surg Am* 92:2402–2408
16. Hanssen AD, Spangehl MJ (2004) Practical applications of antibiotic-loaded bone cement for treatment of infected joint replacements: *Clin Orthop Relat Res* 427:79–85
17. Hogan CJ, Fang G-D, Scheld WM, Linden J, Diduch DR (2001) Inhibiting the inflammatory response in joint sepsis. *Arthroscopy* 17:311–315
18. Indelli PF, Dillingham M, Fanton G, Schurman DJ (2002) Septic arthritis in postoperative anterior cruciate ligament reconstruction. *Clin Orthop Relat Res* 398:182–188

19. Judd D, Bottoni C, Kim D, Burke M, Hooker S (2006) Infections following arthroscopic anterior cruciate ligament reconstruction. *Arthroscopy* 22:375–384
20. Katz LM, Battaglia TC, Patino P, Reichmann W, Hunter DJ, Richmond JC (2008) A retrospective comparison of the incidence of bacterial infection following anterior cruciate ligament reconstruction with autograft versus allograft. *Arthroscopy* 24:1330-1335
21. Kohn D (1988) Unsuccessful arthroscopic treatment of pyarthrosis following anterior cruciate ligament reconstruction. *Arthroscopy* 4:287–289
22. Lazar HL, Ketchedjian A, Haime M, Karlson K, Cabral H (2014) Topical vancomycin in combination with perioperative antibiotics and tight glycemic control helps to eliminate sternal wound infections. *J Thorac Cardiovasc Surg* 148:1035-1038; 1038-1040
23. McAllister DR, Parker RD, Cooper AE, Recht MP, Abate J (1999) Outcomes of postoperative septic arthritis after anterior cruciate ligament reconstruction. *Am J Sports Med* 27:562–570
24. Mellon M, Benbrook C, Benbrook K (2001) Hogging It: Estimates of Antimicrobial Abuse in Livestock. *Union Concerned Sci*
25. Mouzopoulos G, Fotopoulos VC, Tzurbakis M (2009) Septic knee arthritis following ACL reconstruction: a systematic review. *Knee Surg Sports Traumatol Arthrosc* 17:1033–1042
26. Nelson CL, McLaren SG, Skinner RA, Smeltzer MS, Thomas JR, Olsen KM (2002) The treatment of experimental osteomyelitis by surgical debridement and the implantation of calcium sulfate tobramycin pellets. *J Orthop Res* 20:643–647
27. Noble WC, Virani Z, Cree RG (1992) Co-transfer of vancomycin and other resistance genes from *Enterococcus faecalis* NCTC 12201 to *Staphylococcus aureus*. *FEMS Microbiol Lett* 72:195–198
28. Paci JM, Schweizer SK, Wilbur DM, Sutton LG, Werner FW, Scuderi MG, Cannizzaro JP (2010) Results of laboratory evaluation of acute knee effusion after anterior cruciate ligament reconstruction: what is found in patients with a noninfected, painful postoperative knee? *Am J Sports Med* 38:2267–2272
29. Pasque CB, Geib TM (2007) Intraoperative Anterior Cruciate Ligament Graft Contamination. *Arthroscopy* 23:329–331
30. Pérez-Prieto D, Torres-Claramunt R, Gelber PE, Shehata TM, Pelfort X, Monllau JC (2014) Autograft soaking in vancomycin reduces the risk of infection after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* doi:10.1007/s00167-014-3438-y

31. Plante MJ, Li X, Scully G, Brown MA, Busconi BD, DeAngelis NA (2013) Evaluation of sterilization methods following contamination of hamstring autograft during anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 21:696–701
32. Schollin-Borg M, Michaëlsson K, Rahme H (2003) Presentation, outcome, and cause of septic arthritis after anterior cruciate ligament reconstruction: a case control study. *Arthroscopy* 19:941–947
33. Schulz AP, Götze S, Schmidt HG, Jürgens C, Faschingbauer M (2007) Septic arthritis of the knee after anterior cruciate ligament surgery: a stage-adapted treatment regimen. *Am J Sports Med* 35:1064–1069
34. Tischler EH, Cavanaugh PK, Parvizi J (2014) Leukocyte esterase strip test: matched for musculoskeletal infection society criteria. *J Bone Joint Surg Am* 96:1917–1920
35. Tuman J, Diduch DR, Baumfeld JA, Rubino LJ, Hart JM (2008) Joint infection unique to hamstring tendon harvester used during anterior cruciate ligament reconstruction surgery. *Arthroscopy* 24:618–620
36. Vandercam B, Jeumont S, Cornu O, Yombi J-C, Lecouvet F, Lefèvre P, Ireng LM, Gala J-L (2008) Amplification-based DNA analysis in the diagnosis of prosthetic joint infection. *J Mol Diagn* 10:537–543
37. Van Tongel A, Stuyck J, Bellemans J, Vandenuecker H (2007) Septic arthritis after arthroscopic anterior cruciate ligament reconstruction: a retrospective analysis of incidence, management and outcome. *Am J Sports Med* 35:1059–1063
38. Vertullo CJ, Quick M, Jones A, Grayson JE (2012) A surgical technique using presoaked vancomycin hamstring grafts to decrease the risk of infection after anterior cruciate ligament reconstruction. *Arthroscopy* 28:337–342
39. Viola R, Marzano N, Vianello R (2000) An unusual epidemic of staphylococcus-negative infections involving anterior cruciate ligament reconstruction with salvage of the graft and function. *Arthroscopy* 16:173–177
40. Waldman BJ, Mont MA, Hungerford DS (1997) Total knee arthroplasty infections associated with dental procedures. *Clin Orthop Relat Res* 343:164–172
41. Wang C, Ao Y, Wang J, Hu Y, Cui G, Yu J (2009) Septic arthritis after arthroscopic anterior cruciate ligament reconstruction: a retrospective analysis of incidence, presentation, treatment, and cause. *Arthroscopy* 25:243–249
42. Wang C, Lee YH, Siebold R (2013) Recommendations for the management of septic arthritis after ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc* 22:2136 - 2144

43. Williams RJ, Laurencin CT, Warren RF, Speciale AC, Brause BD, O'Brien S (1997) Septic arthritis after arthroscopic anterior cruciate ligament reconstruction diagnosis and management. *Am J Sports Med* 25:261–267
44. Yazdi H, Moradi A, Herbort M (2014) The effect of gentamicin in irrigating solutions on articular infection prophylaxis during arthroscopic ACL reconstruction. *Arch Orthop Trauma Surg* 134:257–261

Figure1: Infected ACLR Diagnosis & Management Flowchart