**Client assessed long-term outcome in dogs with surgical site infection following tibial plateau levelling osteotomy**

**Introduction**

Tibial plateau levelling osteotomy (TPLO) is a frequently performed surgical procedure for the management of cranial cruciate ligament (CCL) insufficiency in dogs. It is associated with an excellent functional outcome (Au and others 2010; Bergh and Peirone 2012; Gordon-Evans 2013; Nelson and others 2013; Priddy 2003; Roush and others 1993) but the reported risk of surgical site infection (0.8 to 14.3%) is high in comparison to other clean procedures (Bergh and Peirone 2012; Frey 2010; Nelson 2011). Surgical site infection (SSI) may involve soft tissues, implant-associated infection, osteomyelitis and septic arthritis; the individual contribution of these entities is not well described (Pacchiana and others 2003; Priddy 2003; Thompson and others 2011). The economic impact of SSI in TPLO has been studied (Nicoll and others 2014) but there has been little specific analysis of impact on long-term functional outcome (Weese 2008b).

Our objectives were to determine whether there was a significant association between SSI and client assessed long-term functional outcome and secondly identify predictive factors for TPLO associated SSI development and management.

**Materials and methods**

*Inclusion criteria*

Medical records (March 2007 to December 2012) at the primary author’s institution were reviewed to identify all dogs undergoing TPLO surgery for the management of CCL insufficiency. Dogs with unrelated orthopaedic disease, review surgeries or intraoperative complications with potential to alter long-term functional outcome were excluded.

*Data collection*

Data retrieved included breed, age, sex, weight, unilateral or bilateral involvement (including surgical interval), extent (complete or partial rupture), meniscal pathology, implant type, general anaesthetic and operative times and perioperative and post-operative antibiotic use. Complications were classified dependent on whether further surgical or medical treatment was required to resolve (Cook and others 2010). SSI was described according to proposed definitions of the US Centre for Disease Control (Brown 2013). For SSI, time of onset, clinical details, culture results and treatment were recorded. Clients and referring practices were encouraged to report any signs of SSI and no further fees were charged for investigation and management. With the exception of swabs (in charcoal media) from tissue sinuses, all samples for culture were submitted to an external laboratory (Finn laboratories, Diss, Norfolk, UK) in blood culture media and incubated prior to plating for culture.

Long-term functional outcome (minimum >2 year post op and minimum >1 year post SSI) was assessed using the LOAD questionnaire (Liverpool Osteoarthritis in Dogs) a previously validated clinical metrology instrument (CMI) under licence from Novartis (Camberley, Surrey, UK). LOAD was sent to all clients whose dogs developed SSI and to a randomly selected (Research randomizer; [www.randomizer.org](http://www.randomizer.org)) equivalent number that did not. Additionally, clients were asked whether non-steroidal anti-inflammatory drugs (NSAIDs) were required on an on-going or intermittent basis as a result of the operated condition.

*Procedure*

Procedures were undertaken by 1 of 3 experienced surgeons (minimum 250 TPLO procedures). Dogs were premedicated intramuscularly (IM) with 0.03mg/kg acepromazine and 0.3mg/kg methadone and 2-4 mg/kg subcutaneous (SC) carprofen. Anaesthetic induction using propofol 1%w/v was maintained following intubation using 1.5-2% isoflurane in oxygen. All dogs underwent epidural anaesthesia comprising 0.2mg/kg morphine and 2mg/kg lidocaine (without preservative). Post operatively 0.3mg/kg methadone was administered IM every 4 hours for 12 hours then 0.03mg/kg buprenorphine after a further 6 and 12 hours. Oral carprofen was continued post operatively (2mg/kg BID for 7-10 days then 2 mg/kg SID for 7-10 days). All dogs received intravenous antibiotics at induction - either cefuroxime (CEF) at 22mg/kg or clavulanate potentiated amoxicillin (CPA) at 20mg/kg; this was repeated at 90 and 180 minutes. Postoperative antibiotics were prescribed at the surgeon’s discretion.

 At sub-patellar, medial arthrotomy, remnants of the CCL were excised. The menisci were inspected and pathology was managed by partial meniscectomy. Caudal meniscal release was performed at the surgeons’ discretion. TPLO was performed according to Slocum (Roush and others 1993) with some individual surgeon and chronological variation. Only one surgeon used a jig and all three progressively reduced the extent of proximal tibial muscle dissection throughout the period of study. The osteotomy was stabilised using either a pre-contoured, non-locking Delta plate (Orthomed Ltd, Huddersfield, UK) or locking TPLO plate (Synthes Ltd, Welwyn Garden City, UK). The wound was covered for 2-3 days using a non-adherent dressing (Primapore, Smith and Nephew). Dogs were discharged after 24 hours to room confinement and limited, increasing lead exercise until follow up at 6-8 weeks demonstrated satisfactory clinical and radiographic progress. SSI cases were further re-examined 6 weeks after either antibiotic administration or implant retrieval. Joint lavage was undertaken only at the time of implant retrieval if the joint was also septic. Radiographs were obtained pre- and post implant retrieval to confirm satisfactory bone healing by demonstration of bridging bone at the caudal, lateral and cranial margins of the osteotomy.

*Statistical analysis*

Statistical analyses were performed using computerized statistical analysis software (SPSS 22.0 for Windows, SPSS Inc., Chicago, Illinois, USA) and the MLwiN statistical software package (MLwiN Version 2.20, Centre for Multilevel Modelling, University of Bristol). Variables assessed included those related to the dog (weight, sex, age, breed) and surgical procedure (general anaesthesia and surgical time, complete or partial CCL rupture, presence or absence of meniscal injury, meniscal release, implants used and details of peri- and post-operative antibiosis).

Descriptive statistics were calculated for variables where appropriate; continuous data were expressed as medians with interquartile ranges (IQR), and categorical data as frequencies with 95% confidence intervals (95% CI). Categorical variables were simplified as required by aggregation of categories. For continuous variables the functional form of the variable with respect to outcome was assessed using generalised additive models (GAM) fitted using cubic spline smoothers in the R software package (R version 3.2.0, The R Foundation for Statistical Computing). Normality of distribution was assessed using the Kolmogorov-Smirnov test.

Dog stifles were considered the unit of interest; the binary outcome for each was the presence or absence of an SSI following surgery. As some cases represented dogs undergoing bilateral staged procedures, the two resultant outcomes are not independent. Therefore data were examined using multilevel logistic regression models, accounting for within-dog clustering of stifles with a random intercept term. Amongst dogs with SSI, infection necessitating implant removal was considered as a further outcome in a separate model. All variables showing some association with SSI or implant removal on initial univariable analysis (a *P*-value <0.25) were considered for incorporation into final multivariable models. Models were constructed by a manual backwards stepwise procedures where variables with Wald and likelihood ratio test *P* < 0.05 were retained in the model. Potential confounding factors were assessed by examining parameter estimates for substantial changes following their removal. A receiver operating characteristic curve (ROC) was generated to determine whether onset of infection could predict need for implant retrieval.

The data relating to long-term outcome were not clustered, as dogs were the unit of interest. Continuous variables were compared between dogs with and without SSI using the Mann-Whitney U-test and categorical variables with the Chi-squared or Fisher’s exact tests. For all analyses significance was set at *P*<0.05.

**Results**

During the period of study, 560 dogs underwent TPLO; 5 review surgeries (failed extra-articular stabilisations), 8 with co-existent orthopaedic disease and 2 with intra-articular screw placement (immediately revised) were excluded. Five hundred and forty five dogs (683 stifles) met the study inclusion criteria. Dogs were aged between 5 and 162 months (median, 60months) and weighed between 9.2 and 84kg (median, 34kg). There were 288 males (215 neutered, 73 entire) and 257 females (199 neutered and 58 entire). Breeds with 20 or more dogs were Labradors (105; 19.3%), Crossbreeds (101; 18.5%), Golden retriever (62; 11.4%), Rottweiler (46; 8.4%), Spaniel breeds (36; 6.6%), Staffordshire bull terriers (24; 4.4%) and Boxers (20; 3.7%). There were 151 (27.7%) dogs of other breeds. Seventy-one dogs (13.0%) presented with bilateral CCL insufficiency and underwent staged TPLO (median 2.0 months; range 0.25-7.5) and 68 (12.5%) subsequently developed contralateral insufficiency (median 13.0 months; range 4-40); 406 dogs (74.5%) were affected unilaterally. The left limb was involved in 368 procedures and the right in 315. Complete CCL rupture was confirmed in 493 (72.2%) and partial in 190 (27.8%). No injuries to the lateral meniscus were identified. Injuries to the medial meniscus were identified in 179 stifles (26.2%); 154 (86%) were flap or complex tears of the caudal horn and 25(14%) were longitudinal tears of the body. Caudal meniscal release was undertaken in 3 (0.4%) stifles. The Synthes locking plate was used in 538/683 (78.2%) procedures and the Orthomed Delta plate in 145/683 (21.2%).

Complete data to report anaesthetic and operative times was available for 421/683 (61.6%) procedures. The median duration of anaesthetic time (MAT) and surgical time (MST) were 177 (IQR: 155.0-195.0) and 65 (IQR: 57.0-75.0) minutes respectively. The MAT for cases with and without SSI was 182.5 (IQR: 158.8-199.3) and 177 (IQR: 155.0-195.0) minutes. The MST for cases with and without SSI was 65.0 (IQR 59.8-77.3) and 65.0 (IQR 57.0-75.0) minutes. There was no significant difference in MAT (*P*= 0.89) or MST (*P*=0.64) between procedures that did or did not develop SSI.

Perioperative antibiotics were administered as described: 661/683 procedures received CPA (96.8%) and 22/683 CEF (3.2%). Antibiotics were continued post operatively for between 3 and 21 days (mean 7.7days) in 130 procedures (19%). There was no association between use of post-operative antibiotics and SSI (*P*=0.66).

Postoperative complications occurred in 142/545 (26.1%; 95%CI 22.5-29.9%) dogs or 149/683 (21.8%; 95%CI 18.9-25.1%) procedures. The nature, frequency and classification of post-operative complications are summarised in table 1 together with a summary of published values (Bergh and Peirone 2012). Of 149 complications, 90 (60.4%) were minor, 59 (39.6%) were major and 32 (21.5%) required surgery to resolve including 19 of 24 suspected and reported late meniscal injuries (managed by partial meniscectomy) and 1 tibial fracture. SSI occurred in 29/545 (5.3%; 95%CI 3.7-7.5%) dogs or 32/683 stifles (4.7%; 95%CI 3.3-6.5%). Time of onset, laboratory diagnostic information, treatment duration and outcome are summarised in table 2. Positive bacterial culture was obtained in 31/32 stifles (96.9%). Staphylococcus pseudointermedius was the most frequent isolate, cultured in 19/31 (61.3%); there were no multi-resistant Staphylococcal species but other multi-resistant organisms (resistant to more than three antimicrobial classes) were identified in 2 dogs. Resolution was achieved in 20/32 (62.5%) following antibiotic administration (median 6 weeks) but 12/32 (37.5%) required implant retrieval following failure of medication (median 7 weeks) to resolve. Implants were otherwise not routinely retrieved.

*Associations between independent variables and surgical site infection*

No continuous variable demonstrated a significantly non-linear relationship with the outcome considered. All were incorporated into the subsequent logistic regression analyses and only breed (*P*=0.03), gender (*P*=0.09) and implant type (*P*=0.07) showed some association (*P*<0.25) with infection on initial univariable analysis. Following construction of the final multivariable model, significant associations with the presence of infection were identified only for breed type (table 3), with crossbreed dogs showing a reduced risk of infection (odds ratio 0.10, 95%CI: 0.01-0.83, *P=*0.03).

*Associations between independent variables and infection requiring implant retrieval amongst dogs with surgical site infection*

Only time of onset of infection and the presence of joint sepsis showed some association with necessity for implant retrieval on univariable analysis, with the onset of infection variable requiring replacement of one extreme outlier result with a truncated value for the multilevel model to run. In the final model only onset of infection remained significant, with time of onset of infection significantly longer (odds ratio 1.08, 95%CI: 1.01-1.16, *P=*0.04) for dogs requiring implant retrieval (Fig. 1). The ROC curve indicated moderate predictive ability for the need to retrieve an implant, with an area under the ROC curve of 0.85 (significantly different from 0.5, *P*= 0.01). Onset of infection >14 days predicted the need for implant removal with 75.0% accuracy, sensitivity 75.0% (95% CI 42.8-93.3%), and specificity 75.0% (95%CI 50.5-90.4%). The positive and negative predictive values were 64.3% (95% CI 35.6-86.0%) and 83.3% (95% CI 57.7-95.6%) respectively. There was no association between the organism(s) isolated and necessity for implant retrieval.

*Association between SSI and long-term functional outcome*

Load questionnaires were returned for 17/32 (53%) dogs from both groups. Median follow up time was the same at 59.5months (range SSI 26-92months; unaffected 27-87months). There was no significant difference (*P*=0.7) in LOAD scores for dogs with SSI (median 7, range 0-29) and those without (median 5, range 1-31). Although 5/17 SSI dogs (29.4%) required on-going NSAID treatment compared with 2/17 (11.8%) unaffected dogs, the difference was not significant (Fishers exact test *P*=0.4). The incidence of meniscal injury necessitating partial meniscectomy was not different between the two groups (Chi-squared test *P*=0.3).

**Discussion**

The nature and incidence of post-operative complications (table 1) broadly agree with those previously summarised (Bergh and Peirone 2012) where 10 to 34% procedures experienced a complication and 2-4% required surgery to resolve. In the current study, all cases of both patellar tendinitis and fibular fracture were minor complications identified incidentally at routine clinical and radiographic re-examination between 6 and 8 weeks post operatively.

All SSI were however reported but in agreement with previous study (Pratesi and others 2015), separate analysis of clinical entities was not undertaken when evaluating outcome. In a previous study (Corr and Brown 2007) with small case numbers (n=21) and prolonged surgical times reflecting early technique experience, incidence of SSI was 14.3%. Larger studies (>100) report SSI incidence between 0.8- 8.4% (Bergh and Peirone 2012; Frey 2010; Oxley and others 2013). Factors implicated in SSI development (generally and in TPLO) include co-existent endocrinopathies, excessive soft tissue dissection, increased anaesthetic and operative time, hypothermia, increased theatre footfall, peri-operative antibiotic use, propofol for anaesthetic induction, implant presence and design, poor soft tissue coverage and use of skin staples (Brown 2013; Fitzpatrick and Solano 2010; Frey 2010; Gatineau and others 2011; Nazarali 2014; Thompson and others 2011; Weese 2008b). A recent study (Turk and others 2015) did not find TPLO a major factor but use of implants generally was associated with increased (5.6X) risk. Postoperative use of antimicrobials has been reported as protective against SSI development in some studies (Fitzpatrick and Solano 2010; Frey 2010; Gatineau and others 2011; Nazarali 2014) but was not associated with altered risk here. The use of non-locking plates in large breed dogs has recently been reported to increase SSI risk (Solano and others 2015) but there was no association between implant type and SSI development in the study population. Anaesthetic and operative time are reported as risk factors for the development of SSI in dogs (Eugster and others 2004) but in agreement with other studies (Fitzpatrick and Solano 2010; Turk and others 2015; Whittem and others 1999), they were not associated with altered risk here.

An association between breed and altered risk of SSI in TPLO has been previously reported (Fitzpatrick and Solano 2010) with Labrador retrievers having reduced risk (odds ratio = 0.29; *P*=0.01). In the current study, crossbreeds were significantly less likely to develop SSI (odds ratio = 0.10, 95%CI = 0.01, 0.84; *P*=0.03). The reason for differences in apparent susceptibility are unknown however different breeds have previously been shown to have high inter-breed and low intra-breed variation of major histocompatibility alleles and haplotypes. This is likely to have a major influence in determining the variations observed in immune response and could affect susceptibility or resistance to infection (Kennedy 2002)

Implant associated SSI is complicated by development of biofilms comprising a multi-layered structure of bacteria and extracellular matrix. Bacterial adhesion to implants is a complex process influenced by environmental factors, bacterial properties and both material surface and local tissue properties (Ribeiro and others 2012). Biofilms form within a few hours, limiting the effectiveness of the host immune response and preventing adequate local therapeutic concentrations of systemically administered antibiotics (Havard 2015). When SSI in TPLO fails to respond to prolonged appropriate antimicrobial therapy, implant retrieval is recommended and is reported necessary in 30.3 to 92% cases (Fitzpatrick and Solano 2010; Savicky and others 2013). The study retrieval rate (37.5%) is within the range reported (30.3-39.3%) by Fitzpatrick and Solano (2010).

We report a surprisingly high positive culture rate of 31/32 cases (96.9%) conflicting with rates (40-80%) for similar studies and clinical reports of joint sepsis (Fitzpatrick and Solano 2010; Marchevsky 1999; Solano and others 2015). The use of blood culture media for sample transport and incubation prior to plating is strongly recommended. This consistently achieved positive cultures in clinical cases (Marchevsky 1999) and was reported more sensitive than both direct culture of synovial fluid samples or synovial membrane biopsy in an experimental inoculation study (Montgomery and others 1989). By contrast, a recent study where the vast majority of infected synovial fluid samples were not incubated in blood culture media, reported only 44% positive cultures (Scharf and others 2015). Care should also be taken in interpreting results of samples from tissue sinuses (Brown 2013) as potential contamination with skin bacteria and the presence of secondary bacteria can occur.

As reported previously (Brown 2013), Staphylococcus pseudointermedius was the commonest organism isolated but no multi-resistant (MR) strains were identified and overall we encountered a relatively low incidence (6.25%) of MR organisms. SSI caused by bacteria that are resistant to multiple classes of antimicrobials are an important and increasing problem in veterinary medicine (Weese 2008a) and have previously been reported in up to 47.4% of canine SSI cases (Turk and others 2015). In one study, MR strains were isolated in 25.3% of TPLO SSI cases requiring implant retrieval (Savicky and others 2013). The prevalence of different pathogens is recognised to vary significantly between different geographic regions and between institutions (Weese 2008b). The nature of the population studied (otherwise healthy dogs operated and discharged within 24hours from a single discipline centre) may have contributed to the low prevalence of MR infections reported here. Although intuitively MR cases might appear more difficult to resolve, no correlation between MR status and the need for implant retrieval was observed here or in the largest TPLO case series reported to date (Fitzpatrick and Solano 2010). Retrieval is effective in resolving SSI with or without the use of post retrieval antibiosis (Gallagher and Mertens 2012; Savicky and others 2013). In the current study, onset of SSI later in the post operative period was significantly more likely to require implant retrieval. Predictive value calculation is potentially of clinical relevance and here indicated (with wide confidence intervals) that onset of infection > 14 days predicted a 64.3% chance of implant retrieval. Conversely where onset occurred < 14 days post-op, 83.3% of dogs would not require retrieval. It may be that late developing infections are more deep seated or that there is a time associated maturation / alteration in the immune protective behavior of the biofilm. As far as the authors are aware, this relationship has not been previously reported and further study including retrospective examination of data from other studies is encouraged.

TPLO results in a relatively rapid and excellent functional outcome (Nelson and others 2013), however stifle osteoarthritis (OA) is an inevitable consequence and progresses regardless of the method of surgical stabilisation (Au and others 2010). Partial menisectomy (caudal horn resection), has been shown to result in similar levels of OA seen following complete medial meniscectomy (Johnson 2004) and has the potential to alter functional outcome. To minimise the influence of either co-existent meniscal pathology and the administration of anti-inflammatory treatment on long-term outcome, we compared the incidence of meniscal injury/partial meniscectomy and requirement for NSAID medication between outcome groups; there was no significant difference.

Long-term functional outcome data in veterinary clinical studies can be difficult to obtain. Outcome (6 months to 4 years) following a variety of TPLO postoperative complications has previously been assessed using an un-validated CMI and there was no difference between dogs that did or did not suffer complication (Priddy 2003). More recently (Savicky and others 2013) used a telephone survey to assess outcome (> 1 year) following implant retrieval in TPLO surgeries that developed SSI and reported that dogs returned to ‘normal levels’ of activity.

There has only been recent recognition that although owner assessment is inherently subjective, this does not preclude its use as a valid outcome measure. If appropriate methodology is used and limitations recognised, subjective states such as level of chronic pain, stiffness and locomotor function can be reliably quantified (Brown 2014). Objective gait analysis can be time consuming, equipment dependent and reliant on relatively strict inclusion criteria. Whilst data such as changes in peak vertical force (PVF) or vertical impulse (VI) are widely used to assess the result of intervention, such analysis may not capture the more multi-dimensional and longer-term effects of some orthopaedic conditions on a patient (Brown 2007, 2014).

 In this study we report client-assessed long-term outcome over a median period of 59.5months (range 26-92months) using the LOAD Questionnaire, an owner completed, subjective, validated CMI used in the assessment of locomotor function in dogs and originally described in the assessment of elbow osteoarthritis (Hercock and others 2009), LOAD has been further validated for use in assessment of locomotor function in wider OA where weak correlation with objective kinetic data and significant moderate correlations between LOAD and other CMI’s - Helsinki Chronic Pain Index and the Canine Brief Pain Inventory have been shown (Walton 2013). LOAD has also been used in assessment of long term functional outcome following total hip replacement in dogs (Forster 2012). The instrument assesses locomotor function with a series of 13 multiple-choice questions with descriptive answers. These are given individual numeric ratings (0-4) and added to achieve an aggregate score (0-52) that reflects the degree to which mobility is impaired. Results from this study suggest that there is only mild functional impairment following TPLO with or without SSI and that client assessed functional outcome in dogs following successfully managed SSI is not significantly different from those without SSI.

*Limitations*

We acknowledge a number of important limitations to our study design. Due to the retrospective nature of the study there is reliance on both the accuracy and completeness of the medical records reviewed. Whilst there was a standardized approach to surgical preparation and anesthesia, surgical technique did vary slightly between surgeons and over time. It is accepted that increasing surgeon experience results in a reduced level of TPLO complication (Bergh and Peirone 2012); given the level of procedure experience here, surgeon effect was not evaluated.

Failure of dogs to be re-presented for examination over the study period was assumed to be due to lack of owner or referring vet concern over the possibility of a complication. Although we actively encouraged complication reporting, we cannot be certain that these were not under-reported. This is a recognized study limitation (Weese 2008b) that could only be addressed by long term direct re-examination of all study dogs which was deemed impractical. Instead and in common with many others (Fitzpatrick and Solano 2010; Oxley and others 2013; Savicky and others 2013; Turk and others 2015) indirect evidence of long-term outcome – owner telephone interview or questionnaire was relied upon. The LOAD questionnaire response rate of 53%, although positively comparable with a number of other studies (Christopher and others 2013; Corr and others 2010; Forster 2012) inevitably means that the final outcome assessment involved a relatively low number of dogs. Whilst LOAD has been validated and used previously in dogs to assess locomotor function, it has not been specifically validated for or used previously to evaluate dogs following SSI and or TPLO surgery.

Follow up times for dogs affected by SSI were not significantly different to unaffected dogs. However given the long term over which functional outcome was assessed by clients in the absence of veterinary re-examination it is possible that co-existent pathologies may have developed that had an influence on LOAD scores.

*Conclusions*

SSI following TPLO in dogs is a major complication, but when successfully resolved, there is no association between long-term functional outcome (as assessed by LOAD) and SSI. Dogs may require further surgical intervention (implant retrieval) to resolve particularly when signs of SSI develop or are recognized later in the post-operative period. Crossbreed dogs may be at lower risk of developing SSI following TPLO.

References

AU, K. K., GORDON-EVANS, W. J., DUNNING, D., O'DELL-ANDERSON, K. J., KNAP, K. E., GRIFFON, D. & JOHNSON, A. L. (2010) Comparison of Short- and Long-term Function and Radiographic Osteoarthrosis in Dogs After Postoperative Physical Rehabilitation and Tibial Plateau Leveling Osteotomy or Lateral Fabellar Suture Stabilization. Veterinary Surgery 39, 173-180

BERGH, M. S. & PEIRONE, B. (2012) Complications of tibial plateau levelling osteotomy in dogs. Vet Comp Orthop Traumatol 25, 349-358

BROWN, D. C. (2007) Development and psychometric testing of an instrument designed to measure chronic pain in dogs with osteoarthritis. AJVR 68, 631-637

BROWN, D. C. (2013) Wound infections and antimicrobial use. In Veterinary Surgery Small Animal Ed J. S. A. TOBIAS K.M, Elsevier. pp 135-139

BROWN, D. C. (2014) The Canine Orthopedic Index. Step 1: Devising the items. Vet Surg 43, 232-240

CHRISTOPHER, S. A., BEETEM, J. & COOK, J. L. (2013) Comparison of long-term outcomes associated with three surgical techniques for treatment of cranial cruciate ligament disease in dogs. Vet Surg 42, 329-334

COOK, J. L., EVANS, R., CONZEMIUS, M. G., LASCELLES, B. D., MCILWRAITH, C. W., POZZI, A., CLEGG, P., INNES, J., SCHULZ, K., HOULTON, J., FORTIER, L., CROSS, A. R., HAYASHI, K., KAPATKIN, A., BROWN, D. C. & STEWART, A. (2010) Proposed definitions and criteria for reporting time frame, outcome, and complications for clinical orthopedic studies in veterinary medicine. Vet Surg 39, 905-908

CORR, S. A. & BROWN, C. (2007) A comparison of outcomes following tibial plateau levelling osteotomy and cranial tibial wedge osteotomy procedures. Vet Comp Orthop Traumatol 20, 312-319

CORR, S. A., DRAFFAN, D., KULENDRA, E., CARMICHAEL, S. & BRODBELT, D. (2010) Retrospective study of Achilles mechanism disruption in 45 dogs. Vet Rec 167, 407-411

EUGSTER, S., SCHAWALDER, P., GASCHEN, F. & BOERLIN, P. (2004) A prospective study of postoperative surgical site infections in dogs and cats. Vet Surg 33, 542-550

FITZPATRICK, N. & SOLANO, M. A. (2010) Predictive variables for complications after TPLO with stifle inspection by arthrotomy in 1000 consecutive dogs. Vet Surg 39, 460-474

FORSTER, K. E. A. O. (2012) Complications and owner assessment of canine total hip replacement: a multicenter internet based survey. Vet Surg 41, 545-550

FREY, T. N. H., M.G. SCAVELLI, T.D. AND OTHERS (2010) Risk factors for surgical site infection-inflammation in dogs undergoing surgery for rupture of the cranial cruciate ligament- 902 cases (2005–2006). JAVMA 236, 88-94

GALLAGHER, A. D. & MERTENS, W. D. (2012) Implant Removal Rate from Infection after Tibial Plateau Leveling Osteotomy in Dogs. Vet Surg 41, 705-711

GATINEAU, M., DUPUIS, J., PLANTE, J. & MOREAU, M. (2011) Retrospective study of 476 tibial plateau levelling osteotomy procedures. Rate of subsequent 'pivot shift', meniscal tear and other complications. Veterinary and comparative orthopaedics and traumatology : V.C.O.T 24, 333-341

GORDON-EVANS, W. J. G., D.J. BUBB, C. AND OTHERS (2013) Comparison of lateral fabellar suture and tibial plateau leveling osteotomy techniques for treatment of dogs with cranial cruciate ligament disease. JAVMA 243, 675-680

HAVARD, H. M., J. (2015) Biofilm and orthopaedic implant infection. Journal of trauma and orthopaedics 3, 54-57

HERCOCK, C. A., PINCHBECK, G., GIEJDA, A., CLEGG, P. D. & INNES, J. F. (2009) Validation of a client-based clinical metrology instrument for the evaluation of canine elbow osteoarthritis. J Small Anim Pract 50, 266-271

JOHNSON, K. A. F., D.J. MANLEY, P.A. AND OTHERS (2004) Comparison of the effects of caudal pole hemi-meniscectomy and complete medial meniscectomy in the canine stifle joint. AJVR 65, 1053-1060

KENNEDY, L. J. B., A. HAPP, G.M. AND OTHERS (2002) Extensive interbreed, but minimal intrabreed, variation of DLA class II alleles and haplotypes in dogs. Tissue Antigens 59, 194-204

MARCHEVSKY, A. M. A. R., R.A. (1999) Bacterial septic arthritis in 19 dogs. Aust Vet J 77, 233-237

MONTGOMERY, R. D., LONG, I. R., MILTON, J. L., DIPINTO, M. N. & PHD, J. H. (1989) Comparison of Aerobic Culturette, Synovial Membrane Biopsy, and Blood Culture Medium in Detection of Canine Bacterial Arthritis. Veterinary Surgery 18, 300-303

NAZARALI, A. (2014) Investigation into Factors Associated with Surgical Site Infections Following Tibial Plateau Leveling Osteotomy in Dogs. In Veterinary Surgery. Ontario,Canada, Guelph. p 102

NELSON, L. (2011) Surgical Site Infections in Small Animal Surgery. Vet Clin North Am 41, 1041-1056

NELSON, S. A., KROTSCHECK, U., RAWLINSON, J., TODHUNTER, R. J., ZHANG, Z. & MOHAMMED, H. (2013) Long-term functional outcome of tibial plateau leveling osteotomy versus extracapsular repair in a heterogeneous population of dogs. Vet Surg 42, 38-50

NICOLL, C., SINGH, A. & WEESE, J. S. (2014) Economic impact of tibial plateau leveling osteotomy surgical site infection in dogs. Vet Surg 43, 899-902

OXLEY, B., GEMMILL, T. J., RENWICK, A. R., CLEMENTS, D. N. & MCKEE, W. M. (2013) Comparison of complication rates and clinical outcome between tibial plateau leveling osteotomy and a modified cranial closing wedge osteotomy for treatment of cranial cruciate ligament disease in dogs. Vet Surg 42, 739-750

PACCHIANA, P. D., MORRIS, E., GILLINGS, S. L., JESSEN, C. R. & LIPOWITZ, A. J. (2003) Surgical and postoperative complications associated with tibial plateau leveling osteotomy in dogs with cranial cruciate ligament rupture: 397 cases (1998-2001). J Am Vet Med Assoc 222, 184-193

PRATESI, A., MOORES, A. P., DOWNES, C., GRIERSON, J. & MADDOX, T. W. (2015) Efficacy of Postoperative Antimicrobial Use for Clean Orthopedic Implant Surgery in Dogs: A Prospective Randomized Study in 100 Consecutive Cases. Vet Surg 44, 653-660

PRIDDY, N. H. T., J.L. DODHAM, J.R. HORNBOSTEL, J.E. (2003) Complications with and owner assessment of the outcome of tibial plateau leveling osteotomy for treatment of cranial cruciate ligament rupture in dogs- 193 cases (1997–2001). JAVMA Vol 222, 1726-1732

RIBEIRO, M., MONTEIRO, F. J. & FERRAZ, M. P. (2012) Infection of orthopedic implants with emphasis on bacterial adhesion process and techniques used in studying bacterial-material interactions. Biomatter 2, 176-194

ROUSH, J. K., SLOCUM, B. & SLOCUM, T. D. (1993) Tibial Plateau Leveling Osteotomy for Repair of Cranial Cruciate Ligament Rupture in the Canine. Veterinary Clinics of North America: Small Animal Practice 23, 777-795

SAVICKY, R., BEALE, B., MURTAUGH, R., SWIDERSKI-HAZLETT, J. & UNIS, M. (2013) Outcome following removal of TPLO implants with surgical site infection. Vet Comp Orthop Traumatol 26, 260-265

SCHARF, V. F., LEWIS, S. T., WELLEHAN, J. F., WAMSLEY, H. L., RICHARDSON, R., SUNDSTROM, D. A. & LEWIS, D. D. (2015) Retrospective evaluation of the efficacy of isolating bacteria from synovial fluid in dogs with suspected septic arthritis. Aust Vet J 93, 200-203

SOLANO, M. A., DANIELSKI, A., KOVACH, K., FITZPATRICK, N. & FARRELL, M. (2015) Locking Plate and Screw Fixation After Tibial Plateau Leveling Osteotomy Reduces Postoperative Infection Rate in Dogs Over 50 kg. Vet Surg 44, 59-64

THOMPSON, A. M., BERGH, M. S., WANG, C. & WELLS, K. (2011) Tibial plateau levelling osteotomy implant removal: a retrospective analysis of 129 cases. Vet Comp Orthop Traumatol 24, 450-456

TURK, R., SINGH, A. & WEESE, J. S. (2015) Prospective surgical site infection surveillance in dogs. Vet Surg 44, 2-8

WALTON, B. (2013) Evaluation of Construct and Criterion Validity for the ‘Liverpool Osteoarthritis in Dogs’ (LOAD) Clinical Metrology Instrument and Comparison to Two Other Instruments. PLoS One January 2013

WEESE, J. S. (2008a) A review of multidrug resistant surgical site infections. Veterinary and Comparative Orthopaedics and Traumatology 21, 1-7

WEESE, J. S. (2008b) A review of post-operative infections in veterinary orthopaedic surgery. Vet Comp Orthop Traumatol 21, 99-105

WHITTEM, T. L., JOHNSON, A. L., SMITH, C. W., SCHAEFFER, D. J., COOLMAN, B. R., AVERILL, S. M., COOPER, T. K. & MERKIN, G. R. (1999) Effect of perioperative prophylactic antimicrobial treatment in dogs undergoing elective orthopedic surgery. J Am Vet Med Assoc 215, 212-216

Figure legend

Fig. 1 Boxplot showingtiming of onset of clinical signs of surgical site infection (SSI) associated with TPLO in dogs that did and did not required implant retrieval. The boxes represent the interquartile range and the horizontal line in the box represents the median. Range represented by the whiskers and outliers as stars. A single outlier result (300d) has been removed from the implant retrieval group.

Tables

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Complication(Classification) | Frequency(Procedures) | Frequency(%) | Previously reported range (%)\* | Number requiring surgery to resolve |
| None | 534 | 78.2 | 66 - 90 | 0 |
|  PT (minor) | 39 | 5.7 | 0.3 – 25.5 | 0 |
|  SSI (major) | 32 | 4.7 | 0.8 – 14.3 | 12 |
|  LMI (major) | 24 | 3.5 | 0.7 – 4.3 | 19 |
|  FF (minor) | 20 | 2.9 | 0.1 – 4.8 | 0 |
|  Other (3 major / 14minor) | 17 | 2.5 | N/A | 1 |
|  Seroma (minor) | 17 | 2.5 | 0.7 – 13.0 | 0 |
|  Total | 683 | 21.8 | 10-34 | 32 |

**Table 1** Nature and frequency of post-operative complications following TPLO in study dogs and previously summarised range of incidence.

*PT, patella tendinitis; SSI, surgical site infection; LMI, late meniscal injury; FF, fibula fracture.*

\*(Bergh and Peirone 2012)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SSI case** | **SSI onset (days)** | **SSI diagnosis details** | **Microbiology** | **Treatment****duration** | **Outcome** |
| 1 | 15 | SF +ve PMNs and culture | Staph. pseudintermedius | 10w | Implants retrieved 12 weeks post op. |
| 2 | 14 | SF +ve PMNs and culture | Staph. pseudintermedius | 10w | Implants retrieved 12 weeks post op. |
| 3 | 42 | SF -ve PMNs. Culture from cleaned sinus | Coag. -ve Staphylococcus | 6w | Implants retrieved 12weeks post op. |
| 4 | 21 | SF +ve PMNs and culture | Staph. aureus | 8w | Implants retrieved 12 weeks post op. |
| 5 | 10 | SF -ve. Site seroma fluid +ve PMNs and culture | Staph. pseudintermedius | 6w | Resolved |
| 6 | 16 | SF +ve PMNs and culture | E. coli | 12w | Resolved |
| 7 | 300 | SF +ve PMNs, -ve culture. Culture implants | Corynebacteria sp. | 8w | Implants retrieved 12 months post op. |
| 8 | 42 | SF +ve PMNs and culture | Staph. pseudintermedius | 6w | Implants retrieved 12weeks post op. |
| 9 | 21 | Culture from implants at retrieval | Staph. pseudintermedius | 8w | Implants retrieved 16weeks post op. |
| 10 | 17 | SF -ve. Site seroma fluid +ve PMNs and culture | Staph. pseudintermedius | 12w | Resolved |
| 11 | 7 | SF -ve. Site seroma fluid +ve PMNs and culture | Staph. pseudintermedius | 3w | Resolved |
| 12 | 6 | No SF. Culture from cleaned sinus | Pseudomonas aeruginosa | 3w | Resolved |
| 13 | 14 | SF +ve PMNs and culture | Staph. pseudintermedius | 12w | Resolved |
| 14 | 9 | SF +ve PMNs and culture | Staph. pseudintermedius | 6w | Resolved |
| 15 | 11 | SF +ve PMNs and culture | β Haemolytic Strep. | 6w | Resolved |
| 16 | 42 | No SF. Culture from cleaned sinus | Staph pseudintermedius and  Haem. Strep. | 3w | Resolved |
| 17 | 8 | No SF. . Site seroma fluid +ve PMNs and culture | Pasturella multocida | 6w | Resolved |
| 18 | 12 | No SF. Culture from cleaned sinus | Staph. pseudintermedius, Coag. -ve Staph. , P.multocida | 6w | Resolved |
| 19 | 7 | SF +ve PMNs, culture synovial membrane biopsy | Staph. pseudintermedius | 6w | Resolved |
| 20 | 14 | SF +ve PMNs and culture | Staph. pseudintermedius | 6w | Implants retrieved 10 months post op. |
| 21 | 21 | SF +ve PMNs and culture | Staph. pseudintermedius | 6w | Implants retrieved 10 weeks post op. |
| 22 | 42 | SF-ve. No culture obtained | None | 6w | Resolved |
| 23 | 7 | SF +ve PMNs and culture | Pseudomonas aeruginosa | 4w | Resolved |
| 24 | 15 | No SF. Culture from cleaned sinus | Staph. aureus | 6w | Resolved |
| 25 | 56 | SF +ve PMNs and culture | Staph. pseudintermedius | 6w | Implants retrieved 14weeks post op. |
| 26 | 4 | No SF. Culture from cleaned sinus | Staph. pseudintermedius | 6w | Resolved |
| 27 | 10 | SF -ve. Site seroma fluid +ve PMNs and culture | Coag. -ve Staph. | 6w | Resolved |
| 28 | 7 | No SF. Culture from cleaned sinus | Non lactose fermenting coliform | 6w | Resolved |
| 29 | 14 | SF +ve PMNs and culture | Staph. aureus | 6w | Resolved |
| 30 | 11 | No SF. Site seroma fluid +ve PMNs and culture | E. coli, Staph. pseudointermedius | 9w | Implants retrieved 10 weeks post op. |
| 31 | 22 | SF-ve. FNA at implant site +ve PMNs and culture | Staph. pseudintermedius | 6w | Implants retrieved 18 months post op. |
| 32 | 12 | No SF. Site seroma fluid +ve PMNs and culture | Staph. pseudintermedius | 6w | Resolved |

**Table 2** Summary of SSI case details, treatment and outcome

*SF, synovial fluid; PMNs, Polymorphonuclear leukocytes (neutrophils); Staph, Staphylococcus; Coag, Coagulase; Sp, Species; P, Pasturella*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Outcome** | **Variable** | **Category** | **Odds Ratio** | **95%CI** | ***P*-value** |
| **SSI** | Breed | Other pedigrees | (REF) | - | - |
| Spaniel | 0.98 | 0.23-4.15 | 0.98 |
| Golden retriever | 0.35 | 0.07-1.75 | 0.19 |
| Labrador | 0.80 | 0.29-2.22 | 0.67 |
| Boxer | 1.11 | 0.20-6.17 | 0.91 |
| Rottweiler | 0.45 | 0.09-2.22 | 0.33 |
| Staff Bull Terrier | 0.89 | 0.17-4.63 | 0.89 |
| Crossbreed | 0.10 | 0.01-0.84 | **0.03** |
| **SSI requiring implant retrieval** | SSI onset (days) | 1.08 | 1.01-1.16 | **0.04** |

**Table 3** Results of multilevel, multivariable analyses for associations with surgical site infection (SSI) following tibial plateau levelling osteotomy (N= 683) and SSI requiring implant removal (N= 32) *CI, confidence intervals. P-Values are from the Wald Chi-squared test*