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DVM, DACVS

Josh Zacharias
DVM, DACVS, DACVSMR

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ORIGINAL ARTICLE

Protocol changes to reduce implant-associated infection rate after tibial plateau leveling osteotomy: 703 dogs, 811 TPLO (2006-2014)

Samantha L. Stine DVM[1] | Susan M. Odum PhD[2] | W. Daniel Mertens DVM, Diplomate ACVS[1]

[1]Carolina Veterinary Specialists, Charlotte, North Carolina
[2]OrthoCarolina Research Institute, Cary, North Carolina

Correspondence
Samantha Stine, 2225 Township Road, Charlotte, NC 28273.
E-mail: samantha.stinedvm@gmail.com

Abstract

Objective: To determine the influence of a stricter aseptic protocol on implant-associated infection (IAI) rates after tibial plateau leveling osteotomy (TPLO).

Study design: Retrospective cohort study.

Sample population: Seven hundred three dogs (811 TPLO).

Methods: Medical records (2006-2014) of dogs with TPLO with a ≥18-month follow-up were reviewed. An established TPLO protocol was altered to include an iodophore-impregnated adhesive drape, cefazolin administration every 90 minutes intraoperatively and then every 4 hours until hospital discharge, orthopedic surgical gloves, triclosan-coated intradermal sutures (instead of staples), soft-padded bandage with mupirocin ointment, use of single-use gloves while handling treated dogs, and placement of an Elizabethan collar. Signalment, affected limb, protocol changes, IAI, time to explant, and culture and susceptibility results were recorded. Data were analyzed by using Fisher's exact test, Wilcoxon rank-sum test, and a multivariable logistic regression model.

Results: TPLO plates were removed from 31 dogs (8.5% prechange, 1.3% post-change) because of a suspected IAI. Bacterial culture results from an explanted screw were positive in 26 dogs (7.4% prechange, 0.94% postchange). The odds ratio (OR) of IAI in the postchange cohort was decreased by 88% (OR 0.12, 95% CI 0.05-0.33) compared with the prechange cohort, after controlling for variables. *Staphylococcus* spp. were isolated from all implants removed from IAI-positive postchange dogs, 4/5 of which were methicillin resistant. No methicillin-resistant isolates were grown from the prechange cohort implants.

Conclusion: The protocol tested here decreased IAI rates after TPLO, but most infections diagnosed after its implementation involved methicillin-resistant isolates.

Clinical significance: The protocol reported here may be used as a guide in clinics seeking to reduce their IAI rates after TPLO. Postoperative infections after implementation of this protocol should be monitored to evaluate its potential impact on the emergence of antibiotic resistance.

1 | INTRODUCTION

A surgical-site infection (SSI) is defined by the Centers for Disease Control and Prevention (CDC) as an infection of the incision, organ, or space that occurs postoperatively.[1] SSI are multifactorial, and their development results in increased patient morbidity and mortality as well as increased financial burden for clients.[2-4] In man, approximately half of all SSI can be prevented by implementing evidence-based preventative measures such as optimal timing of prophylactic antibiotherapy, use of antimicrobial-coated suture, and antiseptic prophylaxis during skin preparation.[1,2] The rising prevalence of antibiotic resistance has generated additional urgency to reduce postoperative infection rates.[1,2]

Orthopedic surgical procedures requiring placement of implants present unique challenges when treating SSI.[4] Indeed, the formation of a biofilm on a surgical implant renders medical management unproductive, and surgical removal of the implant in conjunction with debridement of the contaminated tissues is ultimately required to eradicate infection.[4] In veterinary medicine, the tibial plateau leveling osteotomy (TPLO) is one of the most commonly performed orthopedic procedures involving placement of a surgical implant. The TPLO serves to eliminate tibial thrust by establishing a more appropriate tibial plateau angle (TPA) in a cranial cruciate ligament (CrCL)-deficient canine stifle and uses an implant to stabilize the tibial osteotomy.[3-5] Complication rates associated with TPLO have been reported to be 18.8%-28%, with a postoperative implant removal rate of 2.7%-8.5% resulting from confirmed implant-associated infection (IAI).[3,5]

Although numerous studies have assessed complications in SSI in veterinary orthopedic surgery, the effectiveness of aseptic protocols followed in human orthopedics remains untested in dogs. The objective of this study was to determine the influence of several modifications in intraoperative and postoperative protocols on IAI rates after TPLO. We hypothesized that the postoperative IAI rate would drop after implementing these methods.

2 | MATERIALS AND METHODS

The database of a private veterinary referral practice (Carolina Veterinary Specialists, Charlotte, North Carolina) was searched for dogs that had undergone TPLO from April 1, 2006 through December 31, 2014. An established TPLO protocol was in place from April 2006 through April 2008. The protocol was modified with measures designed to prevent postoperative IAI and implemented from January 2011 through December 2014.

The inclusion criteria for this study required that each dog had undergone a TPLO within the aforementioned time periods (April 2006 through April 2008 or January 2011 through December 2014); each TPLO had been performed by 1 of 2 board-certified veterinary surgeons; detailed medical records were available (including surgical procedures and postoperative care); and postoperative follow-up of ≥18 months had been performed to ensure an appropriate allotment of time for IAI to develop. Dogs that had undergone bilateral, staged TPLO were included in the study, but each TPLO was counted individually. Dogs were excluded from this study if they underwent a concurrent orthopedic procedure, if the stifle had been previously surgically altered, or if any systemic disease was present.

Two groups were defined. The "prechange group" comprised dogs that underwent a TPLO from April 2006 through April 2008 prior to the revised TPLO protocol, and the "postchange group" comprised dogs that underwent a TPLO from January 2011 through December 2014 after the implementation of the revised TPLO protocol. The retrieved data included date of the procedure, breed, sex, age, weight, affected limb, prophylactic measures taken to reduce postoperative TPLO infection, the presence or absence of implant-associated postoperative TPLO infection, culture and susceptibility results, time until explantation, and other miscellaneous information pertinent to the study.

2.1 | Tibial plateau leveling osteotomy

2.1.1 | Prechange TPLO protocol

The TPLO was performed by 1 of 2 board-certified veterinary surgeons in an operating suite dedicated solely to clean, orthopedic procedures. Cefazolin (22 mg/kg IV) was administered between the time of induction and surgery, every 120 minutes intraoperatively, and every 6-8 hours postoperatively until the morning following the procedure. Occupancy of the surgery suite was limited to 3 or 4 individuals, including the surgeon, an associate veterinarian, and 1 or 2 technicians.

The dog was placed in lateral recumbency, and the affected limb was aseptically prepared by using the hanging leg technique. The affected limb was clipped, and the remaining hair was removed with a vacuum. The tissue distal to the tarsus was covered with a single-use latex glove and adhesive tape. The limb was suspended, and an initial alternating scrub preparation with an alcohol-based, 4% chlorhexidine gluconate solution and alcohol was performed 3 times in a clean surgery preparation area by a surgical technician wearing single-use gloves. The dog was moved into the designated surgical suite, and a final, sterile preparation was performed 3 times by a surgical technician wearing sterile surgical gloves using an alternating scrub preparation with an alcohol-based, 4% chlorhexidine gluconate solution and sterile saline.

Four field drapes were applied to the dog and secured with towel clamps to isolate the proximal aspect of the limb.[6] The tape suspending the unprepared distal extremity was cut by a nonsterile surgical team member while a sterile surgical team member secured the distal extremity with sterile drape material, which was then wrapped with sterile veterinary wrap.[6] The limb was placed through a fenestration in a fanfold drape and secured with towel clamps.[6]

The surgical table was routinely covered with a sterile drape and draped in.

Sterile surgical gloves were worn by the primary surgeon during each TPLO, and gloves were changed when macroperforation was seen or when microperforation was suspected. A medial approach was made from the distal 4th of the femur to the proximal 3rd of the tibia. An arthrotomy was performed at the medial aspect of the stifle to remove CrCL remnants and inspect the meniscus. If it had been damaged, the medial meniscus was debrided, and, if it remained intact, a meniscal release was performed at the discretion of the surgeon. A TPLO jig was applied to the tibia, and a Slocum (Eugene, Oregon) TPLO saw was used to perform a tibial osteotomy. Appropriate rotation of the tibial plateau was based on calculation of the TPA by using preoperative stifle radiographs. Internal fixation of the tibial osteotomy was performed with a Securos (Fiskdale, Massachusetts) or New Generation Devices (Glen Rock, New Jersey) TPLO plate.

The incision was closed in layers, and skin apposition was achieved with stainless steel surgical staples. Postoperative coaptation was performed with a modified Robert Jones bandage until the following morning. Dogs were hospitalized until the next morning, administered analgesia and cefazolin (22 mg/kg IV every 6 or 8 hours as determined by surgeon preference), and discharged the following day. Staple removal was performed 10-14 days postoperatively, and radiographs were obtained 8 weeks postoperatively to assess bone healing. An Elizabethan collar was worn for 10-14 days when dogs attempted to lick or chew the incision. An oral course of postoperative prophylactic antibiotics was not prescribed.

2.1.2 | Postchange TPLO protocol

TPLO was performed by a single board-certified veterinary surgeon in an operating suite dedicated solely to clean, orthopedic procedures. This surgeon was also 1 of the surgeons in the prechange group. Cefazolin (22 mg/kg IV) was administered between the time of induction and surgery, every 90 minutes intraoperatively, and every 4 hours postoperatively until the morning following the procedure. Occupancy of the surgery suite was limited to 3 or 4 individuals, as previously described for prechange protocol.

The dog was placed in lateral recumbency, and the affected limb was aseptically prepared by using the hanging leg technique as previously described. An iodophore-impregnated antimicrobial incise drape (Ioban 2; 3M, St Paul, Minnesota) was applied directly to the surgical limb and the surrounding drape material.[6] Orthopedic surgical gloves (Encore Latex Ortho; Ansell, Iselin, New Jersey) were worn by the primary surgeon during each TPLO procedure, and gloves were changed when macroperforation was seen or when microperforation was suspected. The TPLO procedure was performed as previously described, with the following changes. The tibial osteotomy site was secured primarily by using Securos TPLO plates; a small number of New Generation, Veterinary Implants Direct (Rancho Santa Margarita, California), Veterinary Orthopedic Implants (Saint Augustine, Florida), and Slocum TPLO plates were used, depending on the surgeon's discretion.

The incision was closed in layers by using only antimicrobial suture material consisting of triclosan-coated suture (TCS), with polydioxanone (PDS Plus; Ethicon, Johnson & Johnson Medical N.V., Belgium) for the fascial layer and triclosan-coated poliglecaprone 25 (Monocryl Plus; Ethicon, Johnson & Johnson Medical N.V., Belgium) for the subcutaneous and skin layers. An intradermal suture pattern was used to achieve skin apposition.

The radiology table was cleaned with a quaternary ammonium compound (Kennelsol; Alpha Tech Pet Inc., Littleton, Massachusetts), and radiographs were taken postoperatively to verify appropriate reduction of the osteotomy site and appropriate placement of implants. A nonadherent dressing (Telfa; Covidien, Mansfield, Massachusetts) with a strip of mupirocin and an adherent dressing retention sheet (Hypafix; BSN Medical, Hamburg, Germany) were then applied to the incision, and a modified Robert Jones bandage was placed until the next morning.

Dogs were hospitalized overnight, administered analgesia and cefazolin (22 mg/kg every 4 hours), and discharged the following day. All personnel were required to wear single-use gloves when handling hospitalized TPLO dogs to reduce contamination. Dogs were required to wear an Elizabethan collar at all times for 14 days postoperatively, with the exception of supervised leash walks. A recheck evaluation was performed 10-14 days postoperatively by the surgeon who had performed the TPLO to evaluate the incision and provide permission for removal of the Elizabethan collar. An oral course of postoperative prophylactic antibiotics was not prescribed. A summary of changes to the TPLO protocol resulting in differences between the 2 groups is presented in Table 1.

2.2 | Perioperative and postoperative incisional complications

Perioperative incisional inflammation/infection was treated empirically with oral antibiotics. Postoperative incisional complications observed in the population of dogs included superficial dermatitis, swelling, drainage, and seroma formation. Culture and sensitivity tests were performed at the discretion of the surgeon. Dogs with resolution of complications following empirical treatment were excluded from this study because they were classified with a superficial infection rather than an IAI. Dogs that had persistent lameness, continued drainage, or persistent pain underwent implant removal and culture and sensitivity testing.

TABLE 1 Summary of changes made to the TPLO protocol

Protocol change	Prechange cohort, n = 255 dogs, 282 TPLO	Postchange cohort, n = 448 dogs, 529 TPLO
Suture material	PDS and Monocryl	Triclosan-coated PDS and Monocryl
Skin closure	Stainless steel surgical staples	Intradermal suture pattern
Cefazolin administration	Every 120 min intraoperatively, every 6-8 h postoperatively	Every 90 min intraoperatively, every 4 h postoperatively
Ioban 2 use	No	Yes
Glove type used by primary surgeon	Single-layer latex surgical gloves	Ansell Encore orthopedic surgical gloves
Postoperative coaptation	Modified Robert-Jones bandage	Modified Robert Jones bandage with mupirocin applied to the incision
Patient handler required to wear single-use gloves	No	Yes
Elizabethan collar use	Used when patient showed tendency to lick at incision	Required use for 10-14 d postoperatively

TPLO, tibial plateau leveling osteotomy.

2.3 | Implant removal and bacterial culture and sensitivity testing

TPLO implant removal was based on clinical signs supportive of infection, which included lameness, incisional infection, swelling of the surgical limb, or the presence of a draining tract. Antibiotic therapy was withheld until after implant removal to preserve the accuracy of the microbial culture and sensitivity. An incision was made over the bone plate at the medial aspect of the tibia. The bone plate and screws were removed. Debridement and copious lavage of the surrounding soft tissues was performed. Microbial cultures were obtained by submitting a screw and swab for aerobic and anaerobic culture and susceptibility. The antibiotic therapy administered to treat confirmed IAI is not reported in this study because of the variability of the drug therapy prescribed in the small population of dogs.

2.4 | Statistical analysis

Data were analyzed in SAS version 9.4 (Cary, North Carolina). Standard descriptive statistics were calculated, including frequency, proportion, median, and interquartile range (IQR). All variables were used to assess whether there were any significant associations between prechange and postchange groups or between cases that became infected and those that did not become infected. Wilcoxon tests were used to determine significant differences in continuous and interval data, including age, weight, and time to explant. Fisher's exact test was used to determine associations between categorical variables, including sex and laterality. A multivariable logistic regression model was used to determine the effect of the treatment protocol change after controlling for sex, if intact, and laterality. An adjusted odds ratio (OR) with a 95% CI was calculated. An a priori α level of .05 was used to determine statistical significance.

3 | RESULTS

Seven hundred three dogs (811 TPLO) met the inclusion criteria and underwent TPLO stabilized with a bone plate from April 2006 through December 2014. The median age of the sample population was 5.5 years (IQR, 3.25-7.8), and the median weight was 32.8 kg (IQR, 26-39). Among these 703 dogs, 255 underwent TPLO from April 2006 through April 2008 (prechange cohort), and 448 underwent TPLO from January 2011 through December 2014 (postchange cohort). There were no significant differences between the groups (Tables 2, 3) with respect to age ($P = .85$), operative side ($P = .21$), gender ($P = .99$), or whether the dog was intact

TABLE 2 Demographics of cohorts depicting median age, weight, and time to explant of dogs undergoing TPLO[a]

Variable	Prechange[b]	Postchange[b]	*P*-value[c]
Age, y	6 (4-7)	5.46 (3.25-7.83)	.85
Weight, kg	34.55 (28.1-40.6)	31.95 (25.2-38.5)	.001
Time to explant, d	101 (73.5-173.5)	183 (30-766)	.62

IQR, interquartile range; TPLO, tibial plateau leveling osteotomy.
[a]Data have been calculated for both prechange (2006-2008) and postchange (2011-2014) cohorts; statistical significance was set at $P < .05$.
[b]Median (IQR).
[c]Wilcoxon test.

($P = .29$). The dogs in the prechange cohort weighed significantly ($P < .001$) more (median 34.6 kg, IQR, 28-41) than the dogs in the postchange group (median 32 kg, IQR, 25-38.5). In the prechange cohort, 33 breeds were represented; mixed breed dogs (32%, n = 89), Labrador retrievers (25%, n = 71), and golden retrievers (6%, n = 17) were the most common. In the postchange cohort, 46 breeds were represented; mixed breed dogs (40%, n = 214), Labrador retrievers (19.8%, n = 105), and golden retrievers (8.3%, n = 44) were the most common.

The overall rate of postoperative infections in the study cohort was 3.2% (26/811). The rate of IAI was significantly lower ($P < .001$) in the postchange group. Among the 282 TPLO in the prechange group, 7.4% (n = 21) had a postoperative infection compared with 0.94% (5/529) in the postchange group. Removal of the TPLO implant was performed in 8.5% (24/282) of TPLO in the prechange group, and the median time from TPLO placement to explant in this group was 101 days (IQR, 73.5-173.5). Removal of the TPLO implant was performed in 1.3% (7/529) of TPLO in the postchange group, and the median time from TPLO plate placement to explant in this group was 183 days (IQR, 30-766; Table 2).

Potential risk factors were evaluated for dogs that developed IAI, including sex (male vs female), if intact (intact vs nonintact), and time to explant (Tables 4, 5). There were no significant associations between IAI and sex ($P = .55$), age ($P = .23$), weight ($P = .15$), laterality ($P = .69$), or whether dogs were intact at the time of surgery. The implant was removed in all cases of IAI at a median of 118 days (IQR, 78-264). The implant was removed in 5 cases in the absence of infection at a median of 86 days (IQR, 22-92). The difference in time to explant was not significantly different ($P = .27$). The results of a multivariable logistic regression model indicated that the postchange cohort had nearly 88% lower odds of infection (OR 0.12, 95% CI 0.05-0.33) than the prechange cohort after controlling for age, weight, sex, if intact, or laterality (Table 6). No other factors were independently associated with increased odds of infection.

TABLE 3 Demographics of cohorts depicting number and percentage for laterality, gender, and presence of castration status of dogs undergoing TPLO[a]

Variable	Prechange[b]	Postchange[b]	*P*-value[c]
Side			
Right	124 (33)	258 (67)	.21
Left	158 (37)	272 (63)	
Gender			
Female	153 (35)	287 (65)	.99
Male	129 (35)	243 (65)	
Intact			
No	262 (35)	480 (65)	.29
Yes	20 (29)	50 (71)	
Explant			
No	258 (33)	523 (67)	<.001
Yes	24 (77)	7 (23)	

TPLO, tibial plateau leveling osteotomy.
[a]Data have been calculated for both prechange (2006-2008) and postchange (2011-2014) cohorts; statistical significance was set at $P < .05$.
[b]Frequency (%).
[c]Fisher's exact test.

TABLE 4 Bivariate risk factor analysis of cohorts depicting number and percentage of laterality and sex of patients with and without postoperative IAI undergoing TPLO[a]

	Infection		
Variable	No[b]	Yes[b]	*P*-value[c]
Group			
Prechange	261 (93)	21 (7)	<.001
Postchange	525 (99)	5 (1)	
Laterality			
Left	415 (97)	15 (3)	.69
Right	371 (97)	11 (3)	
Sex			
Female	424 (96)	16 (4)	.55
Male	362 (97)	10 (3)	
Intact			
No	719 (97)	23 (3)	.48
Yes	67 (96)	3 (64)	
Explant			
No	781 (100)	0 (0)	<.001
Yes	5 (16)	26 (84)	

IAI, implant-associated infection; TPLO, tibial plateau leveling osteotomy.
[a]Data have been calculated for both the prechange cohort (2006-2008) and postchange cohort (2011-2014); statistical significance was set at $P < .05$.
[b]Frequency (%).
[c]Fisher's exact test.

TABLE 5 Summary of characteristics of patients who developed an IAI

	Infection		
Variable	No[a]	Yes[a]	*P*-value[b]
Age, y	5.4 (3.25-7.8)	6 (4-8)	.23
Weight, kg	32.6 (26-39)	34.7 (30-40.3)	.15
Time to explant, d	86 (22-92)	118 (78-264)	.27

IAI, implant-associated infection; IQR, interquartile range.
[a]Median (IQR).
[b]Wilcoxon test.

TABLE 6 Multivariable logistic regression model for dogs that underwent TPLO

Variable	Odds ratio	95% Wald confidence limits	
Group (postchange vs prechange)	0.122	0.05	0.33
Sex, female vs male	1.58	0.66	3.75
Laterality, left vs right	1.12	0.50	2.52
Intact, no vs yes	0.56	0.15	2.06
Age, y	1.13	0.98	1.31
Weight, kg	1.02	0.99	1.06

TPLO, tibial plateau leveling osteotomy.

Nine bacterial species were isolated from the 26 TPLO implants removed in this study (Table 7). Several culture results produced multiple isolates, and each isolate was counted individually. Five bacterial isolates were found in the prechange cohort, including coagulase-positive *Staphylococcus* spp. (13), coagulase-negative, nonhemolytic *S.* spp. (3), *Enterococcus* (2), *Serratia marcesens* (2), and *Actinomyces* (1). Five bacterial isolates were observed in the postchange cohort, including coagulase-negative methicillin-resistant *S.* spp. (1), methicillin-resistant *Staphylococcus aureus* (MRSA; 1), methicillin-resistant *Staphylococcus pseudintermedius* (2), *Escherichia hermanii* (1), and coagulase-positive *S.* spp. (1). Coagulase-positive *S.* spp. represented 63% (17/27) of all bacterial species isolated. All cultures from dogs with IAI in the postchange cohort produced an *S.* spp. isolate. Methicillin resistance was reported in 80% (4/5) of *S.* spp. isolates from the postchange cohort. No methicillin-resistant isolates were grown from the prechange cohort implants.

TABLE 7 Total number of bacterial isolates derived from aerobic and anaerobic culture and sensitivity testing of implant material from dogs following TPLO explantation[a]

Bacterial isolate	Prechange, n (%)	Postchange, n (%)
Coagulase-positive *Staphylococcus* spp.	13 (61)	1 (16.6)
Coagulase-negative, non-hemolytic *S.* spp.	3 (14)	0
Enterococcus	2 (10)	0
Serratia marcesens	2 (10)	0
Actinomyces	1 (5)	0
Coagulase-positive *S.* spp. methicillin-resistant	0	3 (50)
Coagulase-negative *S.* spp. methicillin-resistant	0	1 (16.6)
Escherichia hermanii	0	1 (16.6)

TPLO, tibial plateau leveling osteotomy.
[a]If multiple isolates were derived from 1 sample, each isolate was counted individually.

4 | DISCUSSION

In this study, the post-TPLO infection rate dropped from 7.4% to 0.94%, and implant removal rate decreased from 8.5% to 1.3% after implementing preventive measures against IAI. The rates of IAI and implant removal initially measured in our clinic (prechange group) were comparable to the previously reported 3%-12% IAI rate and 2.6%-8.5% explantation rate in veterinary medicine.[3,4,7,8] However, these findings prompted us to investigate methods to improve these measures of outcome.

Age, sex, weight, and affected limb were not associated with an increased risk of IAI in this study, but a nearly eight-fold greater risk for infection was calculated for dogs in the prechange cohort. Therefore, increased risk associated with SSI and subsequent IAI could be attributed to the TPLO protocol. Methods to reduce SSI were reviewed, and changes in technique were selected and implemented in a revised TPLO protocol for dogs in the postchange cohort.

S. spp. represented 63% of total bacterial isolates cultured from TPLO implants removed in this study and 83% of the bacterial species cultured from TPLO implants removed from dogs in the postchange cohort. As a normal inhabitant of canine skin, the growth of *S.* spp. from such a large number of implant devices was not unexpected.[4] The growth of methicillin-resistant *S.* spp. in 80% of dogs with IAI in the postchange cohort of this study is of concern both for animals and for their human counterparts because *S. aureus* and, more recently, *S. pseudintermedius* have been classified as zoonotic agents capable of bidirectional transmission.[4,9,10] However, the most important concern for increased prevalence of antibiotic resistance is difficulty in resolving infection. Dogs in contact with individuals engaged in the health industry have been suggested to be at greater risk for exposure to methicillin-resistant bacteria or to be possible carriers of the bacteria. Only 3 of 5 owners of postchange dogs infected with a methicillin-resistant *S.* spp. could be reached by phone. One owner worked in the health industry, whereas 2 owners had no relation to the health industry. Obtaining a nasal swab from canine patients prior to surgery could be considered in an effort to identify dogs at higher risk for methicillin-resistant infection following TPLO because identification of methicillin-resistant *S.* spp. carriers has been successfully performed with nasal swabs and bacterial culture in canines in the past.[11,12]

Prophylactic postoperative oral antibiotics were not included in the postchange protocol. Use of prophylactic postoperative oral antibiotics remains controversial. Retrospective studies that have found a significant correlation between postoperative antibiotic use and decreased rate of infection after TPLO did not control all other risk factors or eliminate the possibility that infection may have been related to another factor.[8,13,14] Future prospective studies comparing the use of prophylactic postoperative antibiotics vs the absence of postoperative antibiotic use in TPLO with control of other risk factors and variables would be helpful to determine a true correlation. The very small IAI rate achieved by the postchange protocol cohort in this study suggests that other protocol changes are capable of significantly reducing IAI, and we recommend avoiding prophylactic antibiotic use at this time to decrease further risk of development of antibiotic resistance.

Increased drug resistance as a result of increasing prevalence of SSI in recent years can result in a potentially devastating financial burden for clients.[9] Nicoll et al[15] determined that ~\$1559 in charges for postoperative care were accrued because patients developed an SSI following TPLO compared with ~\$212 when patients did not develop an SSI. Use of additional products, such as TCS or iodophore-impregnated adhesive surgical incise drapes, may increase preliminary cost but should reduce the overall cost of care by preventing SSI or IAI.

TCS materials were used explicitly for tissue closure in the postchange cohort, a decision that was based on recent CDC and World Health Organization (WHO) meta-analyses and systematic reviews that reported a statistically significant decrease in SSI in both humans and animal models regardless of the type of procedure.[1,2,16-18] TCS products have been found to inhibit bacterial adherence and the growth of several bacterial species that cause SSI, particularly methicillin-resistant and non–methicillin-resistant *S.* spp. that make up the normal flora of the skin in dogs.[2,16,17]

Use of stainless steel surgical staples for skin apposition was discontinued in the revised protocol because of evidence that use of subcuticular skin sutures reduces patient morbidity and postoperative incisional complication rates.[19-22] This may be a result of elimination of incisional defects between staples that could allow for bacterial migration into deeper tissues or elimination of a nidus for infection in the skin postoperatively.[21,22] Some authors suspect that intradermal closure of the skin may cause less irritation than skin sutures or staples, which may reduce the impulse for the patient to lick the incision. Furthermore, intradermal suture patterns may achieve more accurate reapproximation of tissue margins and retain tensile strength for a longer period of time in comparison to staples.[21]

In the current study, the same American College of Veterinary Surgeons Diplomate performed intradermal skin closure in all TPLO dogs, increasing the speed of closure and potentially negating claims of prolonged anesthesia time causing increased exposure to contamination. Although it was not used in this study, cyanoacrylate tissue sealant has been found to have bacteriostatic properties, but its use is discouraged by the CDC because of findings that there is no significant harm or benefit in SSI reduction and to avoid of additional cost to the client.[2,22]

Use of an alcohol-based chlorhexidine gluconate surgical scrub such as that used in this study is actively recommended to combat surface pathogens that can lead to SSI.[2] However, permeation of this product at effective antimicrobial levels below 300 μm is poor.[23] Hair follicles and other dermal structures reside far below this level (~1000 μm) and typically harbor bacteria that may migrate and recolonize the skin surface and incision.[23,24] Therefore, an iodophore-impregnated adhesive surgical incise drape was used to limit contact with residual microorganisms on the dog's skin while also preventing bacterial regeneration at the skin surface and wound edge.[24,25]

Ex vivo and in vivo studies have demonstrated iodine permeation at concentrations effective against MRSA at a depth of 1000 μm into the skin and a significant reduction or complete elimination of *S. aureus, Staphylococcus epidermidis, Pseudomonas aeruginosa, Enterococcus faecalis,* and *Escherichia coli* with the use of the iodophore-impregnated incise drape.[24,26] Appropriate placement of the drape is essential to its efficacy because separation of the drape from the skin during surgery interferes with the use of the drape at the wound edge and can result in a sixfold increase in SSI.[25,27] Medical adhesive can be applied to the limb to enhance adhesion to the skin if required.

The frequency of administration of cefazolin was increased to every 90 minutes intraoperatively and every 4 hours postoperatively in the revised protocol. Cefazolin has no postantibiotic effect and works best when its time over the minimum inhibitory concentration (MIC) is maximized.[28] On the basis of the canine and feline pharmacokinetics of cefazolin administered intravenously, the plasma concentration would remain over 2 μg/mL for up to a 4-hour time period.[29,30] This 2-μg/mL concentration is greater than the recently reported MIC90 value for canine *E. coli* and *Staphylococcus*.[30,31] Additional consideration for appropriate antibiotic use led to the application of mupirocin ointment to the incision because of the high levels of sensitivity of various methicillin-resistant *Staphylococcus* species in canine patients to this antibiotic, particularly those responsible for canine pyoderma.[10,32,33] This sensitivity may be due, in part, to its limited use in veterinary medicine and variability of exposure to various strains of *S.* spp. in human vs canine patients.[10,34,35] The bandage and the mupirocin were applied to the patient after radiographs were taken to confirm appropriate implant placement in this study. In the future, it may be beneficial to apply the bandage prior to taking radiographs to decrease the risk of nosocomial infection of the incision site during transportation of the patient from the operating room to the radiology table.

Orthopedic surgical gloves were worn by the primary surgeon during each TPLO to provide additional perforation resistance when manipulating bone, implant materials, and rotary orthopedic instruments.[36] However, this glove is recommended as an over glove in a double glove technique, which was not performed in this study.[37] In human medicine, a significant decrease in perforation rate has been seen when a double latex glove is used vs a single latex glove, but recent large-scale, randomized trials have determined that there is no statistically significant difference in perforation rate between orthopedic gloves and double latex gloves during TPLO and other clean orthopedic procedures.[36,38-40] This evidence, in conjunction with the lack of recommendation of use by the CDC and WHO to decrease SSI, led the authors to omit the use of a double glove or single glove technique from the revised protocol.

The main limitation of our study stems from the simultaneous implementation of several changes in our TPLO protocol. This design precludes the assessment of individual measures as the specific causative factors for decreased IAI. As a retrospective study, the data collected relies on appropriate documentation of all pertinent data regarding patient care during the study period. Data such as length of anesthesia time, surgical procedure time, blood pressure, and body temperature were not consistently reported and could not be evaluated to determine any relation between these variables and IAI. Improvement in postoperative IAI rates yielded a small population of culture-positive IAI patients, preventing statistical analysis of culture and sensitivity results. As such, recommendations for antibiotic therapy were not made. Postoperative complications were assessed after presentation of dogs to the clinic, and we cannot eliminate the possibility that some owners elected to pursue medical therapy elsewhere or elected not to pursue any medical therapy.

In conclusion, the implementation of stricter aseptic protocols during and after TPLO decreased postoperative IAI rates in our clinical setting. The use of TCS material for tissue closure, an intradermal suture pattern for skin apposition, an iodophore-impregnated adhesive surgical incise drape, cefazolin administration (22 mg/kg IV) every 90 minutes intraoperatively and every 4 hours postoperatively while in the hospital, orthopedic surgical gloves as well as the application of a soft-padded bandage with underlying mupirocin ointment and the use of single-use gloves by all personnel when handling TPLO patients are recommended. This revised protocol may be used as a guide by veterinary practices seeking to decrease their rates of IAI associated with TPLO. Additional monitoring of postoperative infections after implementation of this protocol is warranted to evaluate its potential impact on the emergence of antibiotic resistance.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

ORCID

Susan M. Odum PhD http://orcid.org/0000-0001-7769-4782

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