Topical Vancomycin Powder Decreases the Incidence of *Staphylococcus aureus* Infections in Operatively Treated Fractures

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Purpose: Topical vancomycin powder has demonstrated efficacy in decreasing infections in multiple retrospective spine surgery studies, but has not yet been examined in orthopaedic trauma surgery. Our primary hypothesis was that topical vancomycin powder will decrease the rate of *Staphylococcus aureus* infections in operatively treated fractures. Our secondary hypothesis was that topical vancomycin powder would decrease the surgical site infection rate in "high-risk" operatively treated bicondylar tibial plateaus, pilons, and calcanei.

Methods: We retrospectively reviewed all fracture fixation cases at one academic medical center that were treated with topical intrawound vancomycin powder. The study group was 91 patients with 99 distinctive injuries treated between October 2012 and November 2014. Deep infections were defined by CDC (Centers for Disease Control and Prevention) criteria and all had positive intraoperative cultures. Our baseline rates of S. aureus were determined from a recently published control group (n = 214) at the same institution prior to use of vancomycin powder. Our baseline rate of deep infection in high-energy pilon, plateaus, and calcanei was also determined from a recently published control group (n = 116) at the same institution. Fisher exact test was used to compare categorical values.

Results: The rate of S. aureus was significantly lower in patients receiving vancomycin powder cohort than the cohort of infections before vancomycin powder was used (12.5% [1 of 8] vs 58% [124 of 214], P = 0.03). A trend was observed for a lower rate of methicillin-resistant S. aureus (0% vs 32%, P = 0.06). We observed a lower infection rate in the 34 calcaneus, pilon, and/or plateau fractures treated with vancomycin powder than in the control group of patients prior to use of vancomycin powder (0% vs 13%, P = 0.02).

Conclusion: Our data demonstrate that vancomycin powder may alter the bacteriology of surgical site infections and perhaps lower the rate of surgical site infection. Although our results are statistically significant (P <0.05) these findings must be confirmed in larger randomized controlled trials. These initial data do present provocative evidence that vancomycin powder may have an important role in our attempts to prevent the devastating complication of surgical site infection after fracture fixation surgery.

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Topical Antibiotics for Infection Prophylaxis in Pelvic and Acetabular Surgery

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Background/Purpose: Application of topical antibiotics (TA) has been shown to reduce surgical site infection (SSI) in spine surgery. The purpose of this study was to determine if TA (vancomycin and tobramycin) reduces the incidence of SSI in open pelvic and acetabulum surgery. The authors hypothesize that TA will reduce incidence of infection without increasing incidence of renal failure.

Methods: A retrospective case control study of patients at a Level I trauma center undergoing operative fixation of the pelvis ring and acetabulum from March 2012 to November 2013 was conducted. Group 1 (10 months) had no topical antibiotics, and Group 2 (10 months) had TA applied to surgical site at time of closure. Statistical significance was determined using Fisher exact test and Student t test with $P < 0.05$. Univariate logistic regression determined effect of each covariate on the risk of infection with odds ratio $P < 0.05$.

Results: 153 patients were included. Group 1 ($n = 75$) and Group 2 ($n = 78$) were statistically similar for sex, age, ethnicity, and body mass index (BMI). The odds of infection for the non-vancomycin group were 3.52 times that for Group 2 ($P = 0.037$). Blood transfusions and intraoperative blood loss were also significant predictors of infection ($P = 0.029$ and <0.001, respectively). There were no adverse clinical outcomes from administration of topical antibiotics.

Conclusion: Topical antibiotics reduced the incidence of SSI following open pelvic and acetabulum fixation without increasing risk of renal failure. Increasing blood transfusions and intraoperative blood loss were associated with increased risk of infection.

Δ Vancomycin Powder Reduces Infection in an Open Fracture Model

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Background/Purpose: Use of locally applied vancomycin powder as a surgical adjunct to decrease surgical site infections has garnered increased attention in the spine literature where its use led to a 4-fold decrease in deep infections. The impact of this on the orthopaedic trauma community is largely unknown because spine infections are generally considered surgical site infections where bacteria are introduced at the time of surgery. However, open fractures are often contaminated at the time of injury, followed by early surgical intervention. Traditionally, a delivery device, such as polymethylmethacrylate (PMMA), has been used for local antibiotic application as it elutes antibiotic over time, but this requires an additional procedure for removal. The use of vancomycin powder allows for local antibiotic application that can be distributed throughout the wound and cleared by the body without the need for surgical removal. However, there is concern that its potential rapid disappearance from the wound would make it less effective in the setting of an open fracture. The purpose of this study was to determine if locally applied vancomycin powder in an established contaminated rat femoral defect model would decrease the incidence of infection.

Methods: Critical size (6 mm) defects were created in 40 Lewis rat femurs and supported by a polyacetyl plates and threaded Kirschner wires. Each animal was inoculated with 105 colony-forming units (CFU) of UAMS-1, a Staphylococcus aureus osteomyelitis isolate, at the time of surgery via a collagen matrix. The animals were then assigned to one of three groups: debridement and irrigation (D&I) without local antibiotics (Standard Treatment), D&I with vancomycin-loaded (10% wt/wt) PMMA beads (Vanc Beads), or D&I with 50 mg local vancomycin powder (Vanc Powder), which is a sufficient application to coat the entirety of the wound bed prior to closure. They were randomized for treatment at either 6 or 24 hours postinoculation, when the wound was then reopened, debrided, and irrigated with saline and the treatment applied. Every animal received 72 hours of twice daily cefazolin (5 mg/kg) beginning at the time of debridement. Serum antibiotic levels were measured at 24 hours, 7 days, and 14 days. All animals survived for 14 days post treatment. Following euthanasia, bacteria were quantified and local inflammatory markers (interleukin [IL]-6, TNFα [tumor necrosis factor alpha], and RANTES) were measured.

Results: Locally applied vancomycin powder effectively reduced bacteria both within the bone (Figure 1A) and on the hardware (Figure 1B) when treatment was not delayed ($P<0.001$). Furthermore, there were similar results for the Vanc Powder and Vanc Beads groups at both time points. Interestingly, neither of the local antibiotic strategies reduced infection rates when treatment was delayed until 24 hours. The inflammatory markers corresponded with the bacteria levels in all groups at each treatment time point (data not shown). Vancomycin was detectable in the blood of all Vanc Powder animals at 24 hours post administration with an average of 10.30 μg/mL. At 7 days, the serum antibiotic levels averaged 0.13 μg/mL and were present in only 30% of Vanc Powder animals. By day 14, only 20% of Vanc Powder

Δ OTA Grant
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animals had detectable serum levels of antibiotic, averaging less that 0.05 $\mu g/mL$. At each time point there was no vancomycin detectable in the serum of the Vanc Beads animals.

Conclusion: This study suggests that vancomycin powder is a promising adjunctive therapy for preventing infection in traumatic wounds if treatment is not delayed. This time-dependent effectiveness of vancomycin powder is similar to what has been observed with both systemic and other local delivery adjuncts due to rapid biofilm formation occurring within a few hours of contamination, making the bacteria recalcitrant to antimicrobials. Similar to what has been reported by the spine community, vancomycin powder may be particularly useful for infection prevention when used in early primary closure of traumatic wounds.

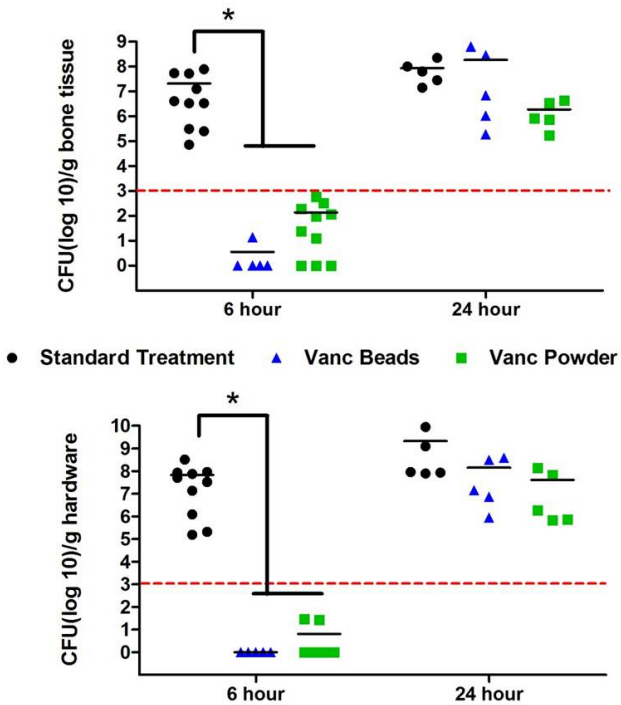

Figure 1. Effect of vancomycin treatment type and time on limb infection. (A) Bacterial count within the bone; (B) Bacterial count on the hardware. Significant difference between those infected (CFU > 10^3) and not infected (CFU < 10^3)(red line) at 6 hours ($P<0.001$) but not at 24 hours ($p=1$) (Fisher's Exact Test)

Open Ankle Fractures: What Predicts Infection?

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Purpose: Data on the complication rates of open ankle fractures are from small data sets or aggregate data that lack precision and detail. The purpose of this study was to identify the patient, injury, and treatment factors associated with infection of open ankle fractures in a large data set generated from individual chart reviews.

Methods: We reviewed the records of a consecutive series of patients presenting to 13 trauma centers with open indirect ankle fractures. Patients with plafond injuries were excluded. We gathered demographic information including: age, gender, BMI (body mass index), smoking history, diabetes, immunosuppressive medications, neuropathy, and OTA fracture type; and treatment variables including: timing and duration of antibiotics, timing of debridement, and method of closure. Infection was defined two ways: first as the combination of superficial or deep purulence, and second with the addition of wound dehiscence. Statistical comparisons were made using Fisher exact and Student t tests for categorical and continuous data.

Results: We reviewed 613 patients, (312 male, 301 female) aged 18-96 years (average 52) with an average BMI of 32 who sustained OTA types 44A (11%), 44B (60%), and 44C (29%) open ankle fractures; 433 (72%) were dislocated upon presentation. Average follow-up was 392 days. There were 95 patients with diabetes, of whom 31 were insulin dependent and 37 had documented neuropathy. 22 patients were on immunosuppressive medications. 226 patients (41%) were smokers. Increased BMI, OTA type, immunosuppressive medications, or presence of dislocation were not significantly associated with infection ($P > 0.05$). The overall infection rate in the series was 12% and rose to 17% when including wound dehiscence. Diabetes was associated with an increased risk of infection (24%; $P = 0.0006$) and was 32% when including wound dehiscence ($P = 0.0002$). Smoking ($P = 0.04$) and increasing Gustilo

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type (P = 0.005) also correlated with infection. The table details the rates of infection by open fracture type. Initial antibiotics were given within 6 hours in 86% and 12 hours in 94% and neither cutoff was associated with infection. There was no difference in the average time to antibiotic administration for those who developed infection versus those who did not (3.8 hours vs 3.7 hours; P = 0.95). The time to initial debridement tended to be longer for those who developed purulence (P = 0.15). Debridement at >6 hours (17% vs 9%; P = 0.03) and >12 hours (21% vs 11%; P = 0.003) after injury was associated with infection. Cases that developed infection were closed at an average of 14.2 days versus 3.3 days for those that did not become infected (P = 0.004). Primary and delayed primary closure was achieved in 93% of cases. Primary closure resulted in a lower rate of infection (P = 0.006). Overall there were 51 cases of malunion, nonunion, and loss of reduction. Infection resulted in a higher rate of these complications (P = 0.02).

Conclusion: In this large series of open ankle fractures, several patient and injury factors were found to be associated with infection and wound breakdown including diabetes, smoking, and increasing severity of open fracture. We found no association between the timing of initial antibiotics, but all centers were efficient and 86% were given antibiotics within 6 hours of injury, limiting our ability to evaluate this as a factor. However, debridement after 6 hours and 12 hours demonstrated incremental increases in infection rates. Finally, a shorter time to wound coverage and the ability to close the wound primarily were associated with a lower risk of infection.

Open Ankle Fractures: What Predicts Infection?

Table: Infection including wound dehiscence by Gustilo type

Gustilo Type	1	2	3A	3B,C
% Infection	6%	15%	18%	36%

Risk Factors vs. Infection			
NOT Associated with Infection		Associated with Infection	
Factor	P Value	Factor	P Value
BMI	0.22	Diabetes	0.0002
OTA Classification	0.81	Smoking	0.04
Dislocation	0.07	Gustilo Type	0.005
Immunosuppressive Meds	0.18	Time to Debridement	0.02
Time to Antibiotics	0.88	Time to Closure	0.004

Fracture Union Following Infected Hardware Fixation: A Prospective Population-Based Cohort Study

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Purpose: Orthopaedic devices are increasingly used for internal fixation of fractures. Approximately 5% of initially inserted internal fixation devices become infected, frequently leading to delayed fracture union, high morbidity, and significant mortality. Standard orthopaedic treatment involves antimicrobial therapy combined with surgical debridement and/or primary removal of infected hardware. Management remains a clinical dilemma, particularly regarding the need for primary device removal, as scant literature is available to aid decision making. The primary aim of this study was to determine the overall rate of fracture union following infected fracture fixation with combined orthopaedic and infectious diseases (ID) management.

Methods: 93 consecutive patients with infected hardware following fracture fixation referred by the orthopaedic service to the ID service for combined management were enrolled. Demographic information, fracture characteristics and fixation dates, time to fracture union, and details regarding infecting organism and antimicrobial therapy for every patient enrolled were entered into a computerized database in real time. Clinical assessment, medical records, and radiographs were reviewed to determine time to radiographic and clinical union. Non-normal numerical data was summarized by median and semi-interquartile range (SIQR). Survival analysis techniques were used to describe the time to union and assess its relationship to the initial surgical management and other factors. P values were calculated using Peto-Peto-Prentice test.

Results: 70 males and 23 females with a median age of 44 years (SIQR 13.5) met the inclusion criteria. Of these, 65 lower limb and 26 upper limb fractures were identified. 26 (28%) were open fractures. Methicillin-sensitive Staphylococcus aureus (MSSA) (58%) was the most frequent infecting organism, followed by methicillin-resistant S. aureus (MRSA) (12%), gram negative (9%), and other gram positive (4%) bacteria. A mixed growth of organisms not including MRSA or MSSA represented 2%, while no organism was identified in 15% cases. The median duration of IV antibiotics was 42 days (SIQR 5.5 days). Overall 82% of patients achieved union at 2 years following initial fracture fixation (Figure). Fracture union was achieved in 68 of 82 (83%) patients treated with initial hardware retention and 9 of 11 (82%) who underwent immediate removal of hardware at time of infection. The difference was not significant (P = 0.91). Median time from first fracture fixation to union was 267 days (SIQR 202). Fracture union did not vary between upper (median 227 days; SIQR 154) and lower (median 286; SIQR 369) limb fractures (P = 0.19).

Conclusion: Fractures with infected hardware requiring long-term antibiotic therapy, combined with management from a dedicated ID service, can expect a union rate of 82% at 2 years following initial fracture fixation. Differences in union rate were not observed between immediate hardware retention/removal or upper/lower limb fractures.

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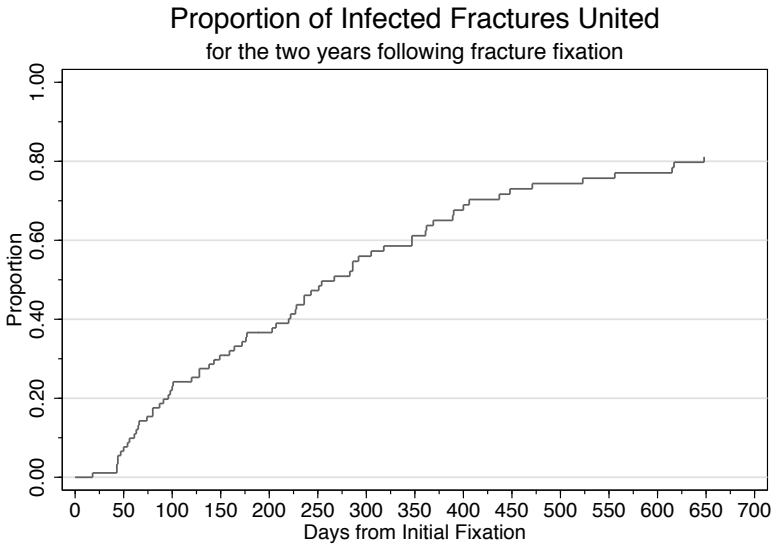

Correlation Between Routine Microbiology Results at Definitive Closure and Wound Infection in Type III Tibia Fractures: Results from a Multicenter, Prospective Cohort Study

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Purpose: Infection remains the most common and significant complication following high-energy fractures. However, we are currently unable to assess the relationship of a subsequent deep infection to the patient's bioburden profile at the time of wound closure and are unable to determine the efficacy / impact of the patient's antibiotic treatment during the hospitalization to the late infection pathogen. The goal of this analysis is to examine the correlation between routine microbiology results at the time of soft-tissue closure with subsequent wound infection.

Methods: Participants (N = 509) with open Gustilo Type III tibia fractures or traumatic amputation were recruited across 33 Level I trauma centers and followed for 6 months following definitive soft-tissue closure. Debrided tissues and swabs collected at the time of the soft-tissue closure were sent for routine microbiology at a central laboratory. Subsequent infections were diagnosed following CDC (Centers for Disease Control and Prevention) criteria, and microbiology results provided by the local hospital laboratories following standard of care procedures. Participants were 71% male, 63% white, 81% polytraumatized, and had a mean age of 39.2 years. Bivariate analyses and multivariate regression techniques were used to examine the relationship between routine microbiology results at baseline and subsequent infection. Bivariate analyses were conducted for 452 participants with baseline microbiology data and regression analyses were performed for 426 records with complete data for outcomes and all covariates.

Results: The overall infection rate was 13.2% (56 of 426). Among 347 participants with negative microbiology results at baseline, the 6-month infection rate was 11.2% (39 of 347). Among 105 participants with positive routine microbiology results at baseline, the infection rate was 19.1% (20 of 105). After adjusting for confounders (polytraumatized, traumatic amputation, smoking status, and wound contamination), participants with positive baseline microbiology results were twice as likely to come back with an infection (odds ratio [OR]: 1.92; 95% confidence interval [CI]: 1.06, 3.50; P = 0.032). Both the presence of surface and imbedded wound contamination noted at the initial debridement (as defined by the Orthopaedic Fracture Classification) were also predictive of infection (ORs of 2.13 and 2.41, respectively; P <0.05 for both). Overall, the percent of positive baseline routine microbiology species matching the species identified at the subsequent infection was 26.9%. The three most common species identified at soft-tissue closure were Enterobacter cloacae, Enterococcus species, and Serratia marcescens, with 3/7, 2/6, and 2/6 returning with subsequent infection with that particular species, respectively. However, by far the most common follow-up infectious species was Staphylococcus aureus, which comprised 30% of infectious species identified (roughly equally split between MRSA [methicillin-resistant S. aureus] and MSSA [methicillin-sensitive S. aureus]), but was only observed in 3 baseline microbiology results, none of which matched to subsequent infections. Interestingly, among participants with

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positive microbiology results at baseline, S. aureus was not a top five species in infected follow-up microbiology results. Instead, Enterobacter species was the most commonly observed, comprising 22% of infectious species identified among participants with positive routine microbiology results at baseline.

Conclusion: Overall, we document a moderate correlation between bioburden (as measured by routine microbiology) at the time of soft-tissue closure and subsequent infection. However, the relationship between pathogens at these time points was weak, with the most common infectious pathogen, S. aureus, being nearly absent in baseline routine microbiology results. This could be related to the perioperative antibiotic selection and short-term suppression, or high biofilm production. The results highlight the limitation of routine microbiology results, and suggest further advancement in this area will require the use of more advanced tools for baseline microbial bioburden identification. Identification of bacteria responsible for late infections is a critical next step to assess the potential of novel local and/or systemic antibiotic strategies.

Culture-Negative Infection After Traumatic Injury

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Background/Purpose: The diagnosis and treatment of infection associated with orthopaedic implants is a challenge. Clinicians make these diagnoses based on a combination of clinical presentation, laboratory studies and bacterial culture. Identification of the primary pathogen directs antibiotic regimen. Definitive culture growth is the primary method by which we determine the pathogen. However, this traditional approach often results in false positives (contaminants, but not pathogens) or false negatives (either previous treatment with antimicrobials or fastidious pathogens), both of which result in a clinical dilemma. False negatives are particularly problematic in patients with clear clinical signs of infection. This relatively common clinical scenario is the impetus to our study question: do culture-negative infections behave differently than infections with an identifiable pathogen? The purpose of this study was to compare outcomes of patients with culture-negative infections to those with culture-positive infections. Furthermore, we sought to identify the incidence and describe the common characteristics of culture-negative infections in patients who sustained traumatic injuries that required surgical stabilization/fixation.

Methods: Patients treated for surgical site infection at two Level I trauma centers were retrospectively identified. 392 patients between January 2007 and December 2013 met inclusion criteria. Inclusion criteria consisted of patients who underwent operative irrigation and debridement (I&D) for a surgical site infection after having undergone fixation of an open or closed fracture. Patients who underwent arthroplasty for primary fracture treatment were excluded. Infection was defined as erythema and/or purulent drainage presenting after definitive wound closure necessitating return to the operating room for I&D, as indicated by the responsible surgeon. The primary outcome measures were successful eradification of infection and time to fracture union. Secondary outcome measures included need for subsequent operative procedures. Cultures were taken at the time of index I&D. Antibiotic therapy was initiated with consultation by an infectious disease specialist.

Results: The overall rate of culture negative infection was 9% (34 of 392). An additional 8% (31 of 392) grew positive bacterial culture from broth only, which may represent contaminants rather than infecting pathogens. There were no significant differences between the two groups with regard to treatment failure, time to union, and need for subsequent procedure. 34% of culture-positive infections were treatment failures and 38% of culture-negative infections were treatment failures (P = 0.13). Time to union among culture-positive infection was 22 weeks and among culture-negative infection was 24 weeks (P = 0.185). 30% of patients with culture-positive infection required subsequent procedure (including amputation, arthrodesis, arthroplasty, girdlestone, soft-tissue reconstruction) and 35% of patients with culture-negative infection required similar secondary procedures (P = 0.6608).

Conclusion: To our knowledge, this is the first study evaluating culture-negative infection in the orthopaedic trauma literature. This remains a treatment dilemma that is encountered frequently, in nearly 10% of infections in this study, but has been poorly addressed in the

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literature. This study found no difference between patients with positive intraoperative cultures and those with negative intraoperative cultures with regard to success of treatment, need for subsequent procedure, or time to union. This suggests that current empiric therapy for negative intraoperative cultures is as effective as microbe-specific therapy.

Can MRSA Screening Swabs Help Predict Risk of Postoperative Infection Following Open Fracture Treatment?

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Background/Purpose: Postoperative infection following open fracture of an extremity can result in significant morbidity including further surgical intervention, increased length of stay, extended use of antibiotic therapy, and even limb loss. Standard antiSbiotic prophylaxis for open fractures (cefazolin) covers Staphylococcus species, but does not offer prophylaxis against methicillin-resistant Staphylococcus aureus (MRSA). Our hypotheses were: (1) open fractures in patients with MRSA positive nasal swabs will have higher overall infection rates; (2) in patients colonized with MRSA, there would be higher rates of MRSA infections.

Methods: We conducted a retrospective review of all patients undergoing surgical treatment of open fractures between 2008 and 2012 at single urban academic medical center. Data collected included: age, demographics, mechanism of injury, type of fracture, time to operation, perioperative antibiotics, outcomes, and intraoperative cultures (in cases of infection). Results of preoperative screening exams, including nasal swabs for MRSA, were also collected. At this center cefazolin was routinely used as prophylaxis at the time of surgery as well as on initial presentation to the center. Clindamycin was utilized in penicillin-allergic patients. No patients received perioperative MRSA coverage (vancomycin) regardless of nasal swab result. Patients without an available admission swab were excluded. Surgical site infection was defined as an infection that was treated with operative debridement. Data were analyzed using Fisher exact test.

Results: 1327 open fractures were screened; 193 developed postoperative infections (21%). Of these, 907 open fractures had available MRSA screening swabs comprising our study group. Fractures that did not have MRSA swab data were excluded (420) accounting for 16 infections (3.8% infection rate). Of the study group (n = 907) a total of 864 were MRSA swab negative and 43 MRSA swab positive. Postoperative infections were identified in 193 (21% of fractures) of the 907 for whom screening swabs were available. MRSA positive nasal swabs had a higher rate of postoperative infection (35% [15 of 43] vs 21% [178 of 864]; P = 0.0344). Of those with MRSA-positive swabs, MRSA infection was identified 6/15 versus 29/178 in those who were MRSA swab negative (40% vs 16.2%, P = 0.03). Of the MRSA swab positive group, 60% (9/15) developed a postoperative infection with Staphyloccus species, 67% (6/9) of which were MRSA.

Conclusion: In our data set, a positive MRSA nasal swab on admission was associated with an increased risk of developing a postoperative infection (P <0.05). Previous work

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has identified positive MRSA swabs as a risk factor for surgical site infection, but to our knowledge this is the first analysis that has demonstrated a similar risk for infection after open fractures. The etiology of this increase is not currently known, in light of the fact that most patients with MRSA positive swabs become infected with an organism other than MRSA (60%). It raises the question whether MRSA positivity is a marker for increased risk of infection. Prospective studies are warranted to investigate if changes in antibiotic prophylaxis or decolonization methods can affect infection rates.

Vancomycin and Cefepime Antibiotic Prophylaxis for Open Fractures Reduces the Infection Rates in Grade III Open Fractures Compared to Cefazolin and Gentamicin, Avoids Potential Nephrotoxicity, and Does Not Result in Antibiotic Resistance with MRSA

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Background/Purpose: Historically, Cefazolin with or without Gentamycin has been used for prophylaxis against post-traumatic infection after open fractures. While S. Aureus (SA) has traditionally been the most prevalent causative organism, there has been a notable increase in the prevalence of methicillin-resistant S. Aureus (MRSA). The purpose of this analysis is to report on the results of a new antibiotic prophylaxis regimen at a single institution using Vancomycin and Cefepime for open fractures.

Methods: Retrospective review of all patients requiring operative management of open fractures at a single institution between 2008 and 2013. Group 1 (CG) patients (2008-2010) received cefazolin and gentamicin as antibiotic prophylaxis for open fractures. Group 2 (VC) patients (2011-2013) received vancomycin and cefepime as antibiotic prophylaxis for open fractures. Patients not receiving their initial treatment at this institution were excluded from the analysis. Hospital records were reviewed to collect data regarding the nature of injury, grade of open fracture, and type of prophylactic antibiotic administration. Microbiology records were analyzed for the causative organisms for each patient who subsequently developed an infection, as well as the minimum inhibitory concentration (MIC) for vancomycin in MRSA cases we identified from year to year, looking for increased antibiotic resistance.

Results: There were 37 infections (5.5%) after 670 open fractures in group CG and 35 infections (4.0%) after 869 open fractures in group 2 VC (p=0.18). For open grade III, CG yielded an infection rate of 6.8% whereas the infection rate for VC group was 3.1% (p=0.03). Similar infection rates were seen in open grades I and II. Polymicrobial infection was found to be present in 48.6% (n=18) of all infection in CG group, and 28.5% (n=10) in VC group (p=0.22). Staphylococcus aureus remained the most prevalent pathogen isolated in open fractures in both groups. Eight of 37 (21%) infections in CG, and 8 of 35 (23%) infections in VC were positive for MRSA (p=1). Ten of 37 (27%) infections in CG, and 8 of 35 (23%) infections in VC were Methicillin Susceptible Staphylococcus Aureus (MSSA) (P=0.78). There were statistically more infections in CG group with Enteroccocus (6 CG, 0 VC) (P=0.02) and Pseudomonas (9 CG, 2 VC) (P=0.04). Acute kidney injury was not seen in any patient with normal renal function at admission (P=1). Minimum inhibitory concentration for Vancomycin for all patients with MRSA infection remained less than 1 for each of the six years evaluated, even after transition to vancomycin and cefepime.

Conclusions: Vancomycin and Cefepime regimen is superior to Cefazolin and Gentamicin for infection prophylaxis in Grade III open fractures. Vancomycin and Cefepime did not significantly decrease the incidence of polymicrobial infections after open fracture, but there was certainly a trend towards reduction. Forty-eight hours of antibiotic prophylaxis does not seem to affect renal function in patients with normal creatinine levels at the time of admission, regardless of the class of antibiotic employed. Vancomycin can be safely used for coverage of gram positive organisms without an increase in antibiotic resistance.

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A Supply and Demand Analysis of the Orthopaedic Trauma Surgeon Workforce in the United States

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Background/Purpose: The number of orthopaedic trauma surgeons (OTS) is increasing in the United States. Recent works have highlighted a growing concern among new orthopaedic trauma graduates over the availability of trauma-only positions, as well as the ability for OTS to develop expertise to properly care for complex injuries due to dilution of case volume. Additional effects include the potential impact on education due to decreased volume at training programs, and financial effects on OTS in the current fee-for-service reimbursement system. Increases in the US population correspond with increased trauma; however, it is not known whether the rate of increase in orthopaedic trauma injuries matches the rate of increase in the number of OTS. The purpose of this study is to investigate recent trends in orthopaedic trauma and to assess whether the increased supply of OTS matches with increased demand for their skills. We hypothesized that the supply of OTS has increased at comparatively faster rate than demand from 2002-2012.

Methods: Supply of OTS was estimated using OTA membership data (active, clinical, associate) as a surrogate. The annual number of operative pelvis and acetabulum fractures reported by American College of Surgeons (ACS)-verified trauma centers in the National Trauma Data Bank (NTDB) was used as a surrogate of demand for OTS. International Classification of Diseases, Ninth Revision (ICD-9) diagnosis and procedure codes were extracted from the NTDB. Cases were included only when both ICD-9 diagnosis and procedure codes for pelvis and acetabular trauma were present, in order to capture only operative injuries. Because surrogates were used to estimate supply and demand, the annual rate of change in OTA membership versus rate of change in operative injuries per NTDB center was compared.

Results: From 2002-2012, overall reported operative pelvis and acetabular injuries increased by an average of 21.0% per year. The number of reporting trauma centers increased by an average of 27.2% per year. The number of OTA members increased each year except in 2009, with mean annual increase of 9.8%. The mean number of orthopaedic surgeons per NTDB center increased from 7.98 to 8.58, an average of 1.5% per year. The annual number of operative pelvis and acetabular fractures per NTDB center decreased from 27.1 in 2002 to 19.03 in 2012, following a declining trend of 2.0% per year.

Conclusion: In the US from 2002-2012 the number of OTS increased significantly, as did the mean number of orthopaedic surgeons per NTDB center. However, the number of annual operative pelvis and acetabular cases per reporting NTDB center declined. These trends suggest an overall net loss of annual orthopaedic trauma cases per OTS over this 10-year period. This supply and demand analysis suggests that the need for newly trained OTS may be diminishing, and that further monitoring and scrutiny of the orthopaedic trauma workforce is necessary.

Table 1: Supply and Demand data for practicing orthopaedic traumatologists

Supply	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total U.S. Orthopaedic Surgeons[1]	-	-	23796	23905	24015	24739	25464	25463	25462	26617	27773
Percent change	-	-	-	0.5%	0.5%	3.0%	2.9%	0.0%	0.0%	4.5%	4.3%
Orthopaedists treating ortho trauma[2]	-	-	1904	1864	1825	1995	2164	3374	4583	4833	5083
Percent change	-	-	-	-2.1%	-2.1%	9.3%	8.5%	55.9%	35.8%	5.5%	5.2%
Total Orthopaedic Surgeons in NTDB† centers	-	-	-	-	-	3625	4159	5908	6090	6735	6903
Orthopaedic Surgeons per NTDB center	-	-	-	-	-	7.98	8.30	8.66	8.74	8.91	8.58
Percent change	-	-	-	-	-	-	4.0%	4.4%	0.9%	2.0%	-3.7%
Mean Orthopaedic Surgeons per NTDB centers											
Level 1	-	-	-	-	-	9.5	9.7	9.7	9.8	9.8	10.8
Level 2	-	-	-	-	-	8.8	9.5	9.5	9.9	9.9	9.8
Level ≥ 3	-	-	-	-	-	6.2	5.8	5.9	5.8	5.8	5.1
Unspecified	-	-	-	-	-	7.9	8.6	8.7	8.6	8.9	8.3
Trauma Fellowships Offered	-	-	-	-	-	-	81	81	82	81	78
Graduating trauma fellows	-	-	-	-	-	-	-	69	74	64	70
OTA Members‡	343	372	398	430	466	575	641	631	694	748	861
Percent Change	-	8.5%	7.0%	8.0%	8.4%	23.4%	11.5%	-1.6%	10.0%	13.0%	9.8%

Demand											
Total number of NTDB centers reporting	91	110	124	145	300	454	501	682	697	756	805
Level 1	-	-	-	-	101	104	110	124	119	119	120
Level 2	-	-	-	-	-	107	137	142	147	157	156
Level ≥ 3	-	-	-	-	-	52	61	90	91	92	93
Unspecified	-	-	-	-	-	192	193	326	340	388	436
Operative acetabulum fractures	1243	1368	1652	2137	3234	4673	5578	5904	6370	6639	7260
Operative pelvic fractures	1279	1354	1587	2415	3972	5268	6496	6749	7228	7204	8062
Operative P + A fractures*	2522	2722	3239	4552	7206	9941	12074	12653	13598	13843	15322
Percent change		7.93%	18.99%	40.54%	58.30%	37.95%	21.46%	4.80%	7.47%	1.80%	10.68%
Operative P + A cases per NTDB center	27.71	24.75	26.12	31.39	24.02	21.90	24.10	18.55	19.51	18.31	19.03
Percent change		-10.71%	5.56%	20.18%	-23.49%	-8.84%	10.1%	-23.0%	5.2%	-6.1%	3.9%

[1] From American Academy of Orthopaedic Surgeon (AAOS) Census Report

[2] AAOS Census data

† National Trauma Data Bank

‡ Orthopaedic Trauma Association: Includes active, associate, and clinical members

* Pelvic and acetabulum fractures

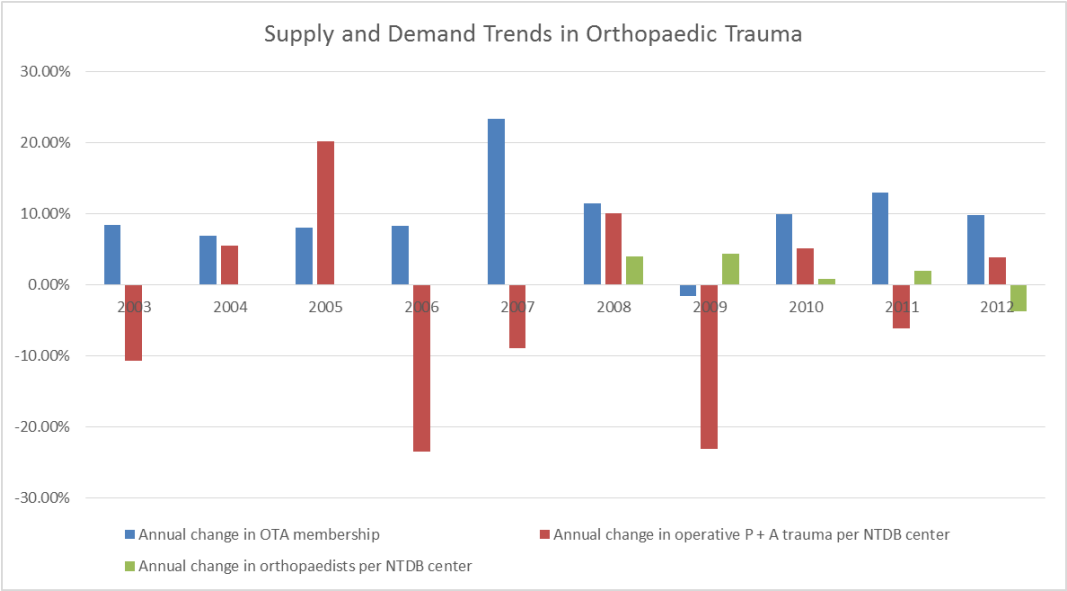

Figure 1: Annual rate of change is shown. Demand trends are estimated by change in operative case volume per NTDB center, supply trends are estimated by change in OTA membership as well as number of total orthopaedic surgeons per center

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Effect of a Dedicated Orthopaedic Advanced Practice Provider in a Level I Trauma Center: Analysis of Length of Stay and Cost

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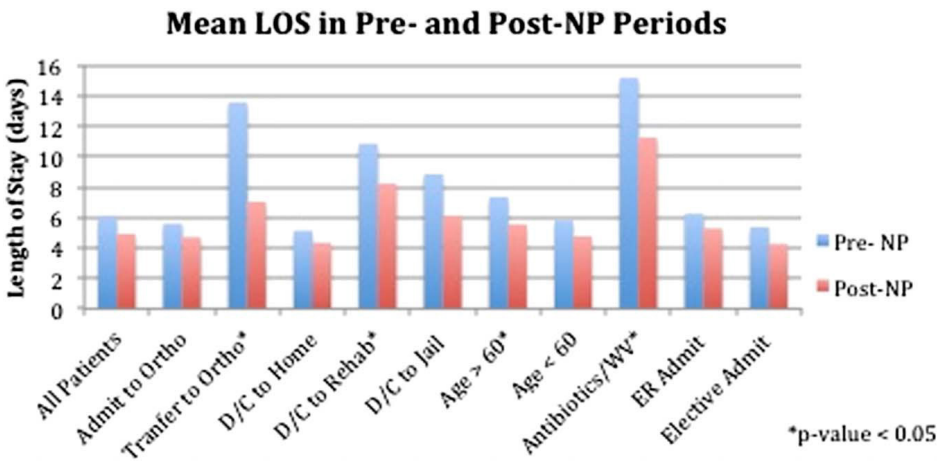
Purpose: The objective of this study is to analyze the effect of an orthopaedic trauma advanced practice provider on length of stay and cost in a Level I trauma center. The hypothesis of this study is that the addition of a single full-time nurse practitioner (NP) to the orthopaedic trauma team at a Level I trauma center would decrease overall length of stay (LOS) and hospital cost.

Methods: A retrospective chart review of all patients discharged from the orthopaedic surgery service 1 year prior to the addition of an NP (Pre-NP) and 1 year after the hiring of a NP (Post-NP) were reviewed. Chart review included age, gender, LOS, discharge destination, intravenous antibiotic use, wound-vac vacuum-assisted closure] therapy, admission location, and length of time to surgery. Statistical analysis was performed utilizing the Wilcoxon/Kruskal-Wallis test.

Results: The hiring of an NP yielded a statistically significant decrease in the LOS across the following patient subgroups: patients transferred from the trauma service (13.56 compared to 7.02 days; P <0.001), patients aged 60 years and older (7.34 compared to 5.04 days; P = 0.037), patients discharged to a rehab facility (10.84 compared to 8.31 days; P = 0.002), and patients discharged on antibiotics/wound-vac therapy (15.16 compared to 11.24 days; P = 0.017). Length of time to surgery was also decreased (1.26 compared to 1.01 days, P = 0.02). A cost analysis of the subgroup of patients transferred to orthopaedics from another service yielded a savings of $1,059,480 per year.



Conclusion: The addition of a dedicated orthopaedic trauma advanced practice provider at a county Level I trauma center resulted in a statistically significant decrease in LOS and

thus reduced indirect costs to the hospital. Given the substantial indirect cost savings from a reduction in LOS provided from hiring a dedicated orthopaedic NP, it can be concluded that they provide the hospital with a positive net present value. This supports the hiring and maintenance of an NP to an orthopaedic team at an academic Level I trauma county hospital and should serve as a model on which to base future orthopaedic practices.

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Does Nutritional Intervention Improve Nutritional Outcomes in Orthopaedic Trauma Patients: A Randomized Prospective Study

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Purpose: Malnutrition is associated with poor clinical outcomes, including higher infection rates, impaired wound healing, depression of the immune response, longer length of stay (LOS), increased muscle loss, increased recovery time and increased mortality. A previous study conducted by our group displayed high prevalence rates of malnutrition in orthopaedic trauma patients that progressively worsened during the acute hospital stay, as diagnosed by laboratory markers. The primary aim of this study was to determine if aggressive nutritional consultation and protein supplementation could prevent malnutrition in the orthopaedic trauma patient population.

Methods: Orthopaedic trauma patients at a Level I regional trauma center were electronically randomized on admission to a control group versus a treatment group. The treatment group received nutritional counseling from a nutritionist on admission with protein supplementation at every meal. Furthermore, patients were seen by a study member on a daily basis and reminded of the importance of nutrition and counseled accordingly. Serum laboratory markers were obtained for both the control and treatment group on admission, hospital day 3, hospital day 7, and at 2 and 6 weeks post surgery. Nutritional markers included albumin, prealbumin, transferrin, CRP (C-reactive protein), and vitamin D. Nutritional status was determined using the validated Rainey MacDonald Nutritional Index (RMNI), with negative numbers representing malnutrition. The control group was treated based on the preference of the admitting team. Patient demographics, ISS, and surgical treatment were also recorded prospectively.

Results: 94 patients were enrolled, but 14 patients were excluded because either they were discharged before and / or appropriate labs were not drawn on hospital day 3 or they refused to continue to be in the study. Final analysis included 40 patients randomized to the control group and 40 patients in the treatment arm. As a result, 80 orthopaedic trauma patients with an average age of 47 years were included in the final analysis. No statistically significant difference was noted between the two groups in regards to: age, sex, ISS, and BMI (body mass index). Average nutritional marker values and statistics for the control arm and treatment arm are reported in the table. Based on the RMNI 38% of control patients were diagnosed as malnourished on admission, which increased to 60% by day 3 and remained elevated at 57% of patients being malnourished at hospital day 7. In the treatment arm on admission 20% of patients were malnourished based on RMNI; this increased to 93% on hospital day 3, and decreased to 57% by hospital day 7. CRP values significantly increased from admission to hospital day 3, but we did not see a significant increase from day 3 to day 7. Furthermore, no statistically significant difference was noted between the treatment arm and the control arm at the 2 and 6-week follow-up appointments in regards to the nutritional markers.

Conclusion: The prevalence of malnourishment, based on serum values of albumin and prealbumin and the RMNI, in the presence of acute orthopaedic injury, is substantial, and it continues to rise during the acute hospital stay. We were not able to prevent malnutrition based on laboratory markers with nutritional supplementation and counseling. This suggests that the nutritional markers we routinely utilize are not sensitive enough to measure a difference, or that the supplementation is ineffective. The next stage is to determine if counseling and protein supplementation leads to lower complication rates and better outcomes.

	Control	Treatment	p-value
Age	44	50	0.17
BMI	28	27	0.52
LOS	8	7	0.41
Admit CRP	60	47	0.23
Admit Prealbumin	18	20	0.17
Admit Albumin	3.6	3.7	0.07
Admit RMNI	0.51	0.75	0.21
Admit Vit. D	23	22	0.97
Day 3 CRP	122	108	0.39
Day 3 Prealbumin	11.1	11.9	0.72
Day 3 Albumin	3.2	3.3	0.64
Day 3 RMNI	-0.2	-0.12	0.09
Day 7 CRP	125	128	0.9
Day 7 Prealbumin	10.9	10.3	0.66
Day 7 Albumin	3.3	3.1	0.17
Day 7 RMNI	-0.15	-0.62	0.16

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Do Patients Know Their Postoperative Plan?
A Prospective Cohort Study of Orthopaedic Trauma Patients

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Background/Purpose: Postoperative physical therapy in the orthopaedic trauma population is thought to be important to help patients maximize functional recovery following an injury and surgery. Little previous work exists regarding patient comprehension of the postoperative plan in orthopaedic trauma patients. It was hypothesized that patient knowledge of postoperative physical therapy instructions following an orthopaedic injury would be low.

Methods: 194 patients were given a questionnaire testing their knowledge of their physical therapy plan following an acute orthopaedic injury and intervention. 212 patients were prospectively enrolled and identified over four separate convenience sample time periods between August 2013 and November 2014. Inclusion criteria consisted of patients age 16 or older who were admitted with an acute orthopaedic injury and returned for their first follow-up appointment during these time periods. Patients did not need to have surgery to be eligible for this study. Exclusion criteria consisted of patients with moderate to severe traumatic brain injury, spinal cord injury with neurologic deficit, and pathologic fractures. Four patients declined the study, five were excluded due to seeing a health care provider prior to filling out the questionnaire, and nine questionnaires were incompletely filled out, for a total of 194 completed questionnaires. The study patients had an average age of 46 years and included 65% Caucasians, 31% African-Americans, and 4% other races. 60% of participants were male and 56% had private insurance. The primary outcome measure was the percentage of patients who knew their postoperative physical therapy plan, based on correctly answering questions pertaining to weight-bearing status, range of motion, and bracing instructions. A secondary outcome was a composite knowledge score (0-1) that was created for 21 patients with intra-articular fractures of the knee or elbow who also had specific range of motion and bracing instructions.

Results: Despite the fact that 73% of patients were performing therapy exercises following hospital discharge, only 66% (95% confidence interval [CI]: 60-73) of patients correctly identified their postoperative weight-bearing status. Bivariate analysis revealed that non-white patients have 51% decreased odds of correctly identifying their weight-bearing status (P = 0.02) and patients with private insurance are 1.96 times as likely to correctly identify their weight-bearing status (P = 0.03). However, a multivariate model demonstrated that these associations are confounded as neither factor was significant when controlling for the other (P range 0.08 to 0.10). There were no significant differences in correctly identifying weight-bearing status with respect to age, gender, or discharge location. Only 12 out of 21 patients with intra-articular elbow and knee injuries were performing any range of motion exercises, and their mean knowledge score was only 0.7 (standard deviation [SD] 0.44-0.99). There were no significant differences in therapy comprehension with respect to age, gender, race, socioeconomic status, or discharge location.

Conclusion: It was observed that orthopaedic trauma patient understanding of even the most basic postoperative physical therapy instructions is generally low. Intervention strategies to improve this deficit are likely justified. Surgeons should be aware that their postoperative plan may not be carried out correctly, even if the patient is undergoing physical therapy.

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