Does Timing to Operative Debridement Affect Infectious Complications in Open Long-Bone Fractures? A Systematic Review

Mara L. Schenker, MD, Sarah Yannascoli, MD, Keith D. Baldwin, MD, MSPT, MPH, Jaimo Ahn, MD, PhD, and Samir Mehta, MD

Investigation performed at the Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, Pennsylvania

Background: Existing guidelines recommend emergency surgical debridement of open fractures within six hours after injury. The aim of this study was to systematically review the association between time to operative debridement of open fractures and infection.

Methods: Searches of the MEDLINE, EMBASE, and Cochrane computerized literature databases and manual searches of bibliographies were performed. Randomized controlled trials and cohort studies (retrospective and prospective) evaluating the association between time to operative debridement and infection after open fractures were included. Descriptive and quantitative data were extracted. A meta-analysis of patient cohorts who underwent early or delayed debridement was performed with use of a random effects model.

Results: The initial search identified 885 references. Of the 173 articles inspected further on the basis of the title, sixteen (six prospective and ten retrospective cohort studies with a total of 3539 open fractures) were included. No significant difference in the infection rate was detected between open fractures debrided early or late according to any of the time thresholds used in the included studies. Sensitivity analyses demonstrated no difference in infection rate between early and late debridement in subgroups defined according to the Gustilo-Anderson classification, level of evidence, depth of infection, or anatomic location.

Conclusions: The data did not indicate an association between delayed debridement and higher infection rates when all infections were considered, when only deep infections were considered, or when only more severe open fracture injuries were considered. On the basis of this analysis, the historical “six-hour rule” has little support in the available literature. It is important to realize that additional carefully conducted studies are needed and that elective delay of treatment of patients with open fractures is not recommended.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Until 150 years ago, open fractures were synonymous with sepsis and death, necessitating immediate amputation as the definitive treatment. Advances in antimicrobial therapy, fracture stabilization, and wound management dramatically decreased mortality from open fractures although the number of open fractures and similar high-energy injuries

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. One or more of the authors, or his or her institution, has had a financial relationship, in the thirty-six months prior to submission of this work, with an entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete Disclosures of Potential Conflicts of Interest submitted by authors are always provided with the online version of the article.

This article was chosen to appear electronically on May 9, 2012, in advance of publication in a regularly scheduled issue.

A commentary by Jason H. Calhoun, MD, is linked to the online version of this article at jbjs.org.
has increased\(^2\). Epidemiologic studies have shown that open long-bone fractures occur at a rate of 11.5 per 100,000 persons per year\(^1\). The prevalence of infection following internal fixation of fractures is approximately 5% overall but may exceed 30% in open fractures\(^3\). Musculoskeletal infections place a cost burden on total health care expenditures, with the reported lifetime cost of the most severe open fracture injuries being as high as $680,000\(^4\). Traditional clinical guidelines suggest treatment of open fractures with an initial operative debridement within six hours after injury to reduce the risk of infection. It is believed that the “six-hour rule” originated from a study conducted on guinea pigs by Friedrich in 1898\(^5\). He found that when debridement of open wounds was performed within six hours, all animals remained healthy\(^6\). In 1973, Robson et al. quantified wound bacterial counts to define an “open fracture infection threshold,” characterized as a density of 210\(^7\) organisms per gram of tissue, and found that this threshold was reached within a mean of 5.17 hours after injury\(^8\).

Although expedient and appropriate treatment of these severe injuries should be the goal, there are circumstances in which delaying the initial debridement may benefit or at the very least not harm the patient. In a large observational study, it was noted that initial debridement of 42% of open tibial fractures was delayed for more than six hours\(^9\). The consequences of this delay in treatment are unknown. The purpose of the present systematic review and meta-analysis was to evaluate the association between the time to initial operative debridement of open fractures and the development of infectious complications.

### Materials and Methods

#### Data Sources

Two of the authors (M.L.S. and S.Y.) independently carried out a comprehensive search of the MEDLINE, EMBASE, and Cochrane computerized literature databases (through December 3, 2010) for randomized controlled trials, quasi-randomized controlled trials, and cohort studies (both prospective and retrospective) that evaluated the effect of early compared with late debridement of open fractures on infection outcomes.

The medical subject headings (MeSH terms) used were “open fracture” or “open fractures” and “debridement.” Reviewers traced the bibliographies of the retrieved articles, including review articles, for citations missed by the electronic search. The senior investigators (S.M. and J.A.) also reviewed their personal files and associated bibliographies for additional citations.

#### Study Selection

Two of the authors (M.L.S. and S.Y.) reviewed the abstract titles for relevance and determined which articles potentially contained relevant information. If an article was deemed eligible by either reviewer, the abstract was retrieved and reviewed in full. Only studies published in English were reviewed. Studies were included if they described (1) a minimum of twenty-six subjects; (2) data for patients over the age of eighteen years; (3) clinical and radiographic evidence of fracture union; (4) the age of eighteen years; (3) clinical and radiographic evidence of fracture union; (4) classified gunshot wounds as open fractures\(^1\); or (5) did not involve long bones (e.g., were fingers or toes). The review of pertinent abstracts was performed by three of the authors (M.L.S., S.Y., and K.D.B.). If any abstract was deemed relevant by any reviewer, the full text of the article was reviewed by the same three reviewers. If two of the three reviewers felt that the article should be kept, it was included in the review. Overall agreement among the reviewers was 64%, and the free marginal kappa was 0.53\(^1\) (indicating moderate agreement)\(^1\).

#### Data Extraction

Two of the authors (M.L.S. and S.Y.) independently extracted data, including general information (author and year of publication), type of study, period of patient enrollment, mean age, sex distribution, mean duration of follow-up, definition of infection (e.g., osteomyelitis or cellulitis), infection rate, time to initial debridement, Gustilo-Anderson classification, fracture location, type and timing of antibiotic administration, wound management strategy, and fracture management strategy.

Three of the authors (M.L.S., S.Y., and K.D.B.) assessed the methodological quality of the studies according to the criteria of Zaza et al.\(^1\), who described a systematic method of assessing the quality of observational studies of preventive medicine interventions. This quality assessment method spans five major areas of study design: descriptions of the population and intervention, sampling, measurement, data analysis, and interpretation of results. No summary score is generated by this tool\(^1\). The reviewers resolved disagreement by discussion and consensus.

#### Data Synthesis

A meta-analysis using a DerSimonian and Laird random effects model\(^14-16\) was then performed to compare dichotomous outcomes between early and delayed debridement groups aggregated from the parent studies. In cases in which no events occurred in the parent study, a continuity correction of 0.5 was added to each cell to permit analysis, as described in the Cochrane handbook\(^17,18\).

In addition to examining the relationship between the primary outcome of any infectious complication and the exposure factor of delayed compared with early debridement, five sensitivity analyses were performed. The first sensitivity analysis also evaluated the outcome of any infection, but it compared the outcomes of early and late debridement on the basis of each of the time thresholds provided by the authors of the parent studies (five\(^19\), six\(^20-29\), eight\(^30\), and twelve\(^31\) hours). The second sensitivity analysis evaluated only studies that described “deep infections” (defined in the parent studies as infections extending below the fascia\(^26,35\), as purulent discharge or osteomyelitis\(^20,25,31\), or as clinical diagnosis of pain and/or erythema and/or discharge with positive wound cultures\(^27\) (see Appendix). The third sensitivity analysis evaluated the outcome of any infection according to the level of evidence of the study, to determine whether focusing on studies with a higher level of evidence could uncover any significant differences in infection rate between the early and late debridement cohorts that were not identified in the primary meta-analysis. In this secondary analysis, the Level-II\(^19,24,27,32-34\) studies were analyzed separately from the Level-III\(^20,23,26,38-31\) studies. The fourth sensitivity analysis separately evaluated the results of the studies on the basis of the severity of the injury\(^31\), with Gustilo-Anderson type-I and II open fractures analyzed separately from type-III open fractures\(^20,22,28,32\). The final sensitivity analysis separately evaluated the results of the studies that included only lower-extremity fractures\(^21,25,26,28,30,31\) and those that included only tibial fractures\(^21-23,25,28,29,31\).

Forest plots were generated to qualitatively assess study heterogeneity and to provide summary estimates. A funnel plot and the Eggers intercept method were used to assess the existence of publication bias due to small-study effects. Because of the heterogeneity among the studies, which included different mixtures of patient types and injury severities, we utilized a random effects model (DerSimonian and Laird) to provide a conservative method of combining the effects of multiple studies\(^15,16\).

#### Source of Funding

No external funding sources were utilized in this investigation.

#### Results

The initial search yielded 885 citations: 294 from MEDLINE, 576 from EMBASE, and fifteen from the Cochrane Review.
Fig. 1. Flowchart showing the identification of articles included in the systematic review. MeSH = medical subject headings.

(Fig. 1). Of these, 712 articles were excluded on the basis of the title because they clearly represented a review paper, represented an editorial or contained commentary without primary data, or were unrelated to our topic. Of the remaining 173 articles, 144 were excluded on the basis of the abstract because they failed to satisfy the predetermined inclusion criteria or because they were editorial in nature or represented a review article, case report, or erratum. Nineteen of the remaining twenty-nine articles were excluded when the full article was reviewed because it failed to meet the inclusion criteria. This left ten unique studies from our initial review, and a manual reference search revealed six additional studies. Our systematic review included these sixteen articles with a total of 3539 open fractures.

The funnel plot to assess study heterogeneity was relatively symmetric, with no perceivable publication bias. The Eggers intercept was 0.85 (95% confidence interval [CI], −0.66 to 2.36; p = 0.24).

Study Characteristics

The Appendix summarizes the key characteristics of the included studies. Six prospective studies provided Level-II evidence, and ten retrospective studies provided Level-III evidence. No study was randomized on the basis of the time to debridement.

The time threshold used for the comparison between the early and late debridement groups was six hours in nine studies, five hours in two, eight hours in two, twelve hours in one, and not specifically reported in two. When raw data were provided and permitted separation between early and late debridement on the basis of a six-hour time threshold, the data were extracted and incorporated into the meta-analysis according to this time threshold.

Five studies used a cohort with upper and lower-extremity fractures, and eleven studies were limited to lower-extremity fractures. Seven of the latter studies evaluated only open tibial fractures, one examined only femoral fractures, and one classified the fracture types as tibial or non-tibial. The authors of this last study reported a significantly higher infection rate for tibial compared with non-tibial fractures. Of the studies that included both upper and lower-extremity fractures, both Harley et al. and Dellinger et al. reported that lower-extremity fractures were associated with a higher rate of deep infection.

We performed a quality analysis of each study according to the method described by Zaza et al. for assessing preventive medicine studies. The population was well described in thirteen of the sixteen studies, one study did not describe consistently which bone was involved in the open injury, and two studies had very little demographic information regarding the cohort. Thirteen of the sixteen studies described the intervention adequately; the antibiotic administration was not clear in the remaining three studies. One study did not fully describe why patients were excluded; it was mentioned that some patients were transferred, but the reason was not specified.

Seven of the sixteen studies did not use the full population over the entire study period. One study was performed in Nigeria, with initial and definitive care differing from that in the more developed world. An open fracture with exposed bone was described in all studies. The performance of a reliability analysis for either the classification of bone exposure (according to the Gustilo-Anderson type) or the diagnosis of infection was not described in any study. The criteria for deep infection varied among the studies and ranged from
osteomyelitis\textsuperscript{30,31} to cellulitis\textsuperscript{20}, with only a few studies using culture data to confirm the presence of infection\textsuperscript{22,24,27,30,32}. There was no consistent definition of superficial infection among the studies. Five studies adjusted for potential confounding factors with use of multivariate logistic regression\textsuperscript{19,25,26,31,33}, and one study showed no difference in multiple confounding factors between groups\textsuperscript{30}. No study corrected for the use of multiple tests. Three studies had <80% follow-up\textsuperscript{22,24,33}. Six studies either did not report the time to follow-up or had inaccuracies in their reporting\textsuperscript{25-29,32}.

Effect of Delayed Debridement on Overall Infection Rates
Fourteen studies provided early and late debridement times and infection rates; these studies included 3217 open fractures and a total of 396 infections suitable for meta-analysis. On further review, one study\textsuperscript{32} provided data for a large number of patients but did not adequately define the fracture population. No study corrected for the use of multiple tests. Three studies had <80% follow-up\textsuperscript{22,24,33}. Six studies either did not report the time to follow-up or had inaccuracies in their reporting\textsuperscript{25-29,32}.

Effect of Delayed Debridement on Overall Infection Rates
Fourteen studies provided early and late debridement times and infection rates; these studies included 3217 open fractures and a total of 396 infections suitable for meta-analysis. On further review, one study\textsuperscript{32} provided data for a large number of patients but did not adequately define the fracture population. Therefore, separate analyses were performed with and without inclusion of that study. Infection was defined differently in each study (see Appendix), ranging from positive intraoperative and wound cultures to culture-positive chronic osteomyelitis (more than four weeks) and nonunion. Seven studies presented the deep infection rate only\textsuperscript{21,23,24,26,29-31}, seven presented a combined rate for deep and superficial infections\textsuperscript{20,22,27,28,34-36}, and two presented separate data for combined deep and superficial infections and for deep infections alone\textsuperscript{12,29}.

The overall infection rates ranged from 4% to 63%. No significant difference in the overall infection rate between early and late debridement was detected (Fig. 2). The weighted cumulative odds ratio (OR) of developing an infection after late compared with early debridement was 0.91 (95% CI, 0.70 to 1.18). The risk difference between the early and late groups was −1% (95% CI, −4% to 2%) in favor of late debridement, although this difference was not significant (p = 0.46). The odds ratio was unchanged with inclusion of the single article with the heterogeneous fracture population\textsuperscript{32} (OR, 0.93; 95% CI, 0.74 to 1.17). Two studies indicated that the time to debridement was a significant factor in increasing infection outcomes\textsuperscript{21,34}; however, one of these articles provided insufficient data for inclusion in the meta-analysis\textsuperscript{34}, and further analysis of the other article\textsuperscript{21} with use of six rather than five hours as the threshold between early and late debridement yielded an odds ratio for infection of 3.68 (95% CI, 0.96 to 14.06), which did not reach significance.

When the studies were analyzed according to the time thresholds for early and late debridement used by the primary authors, no significant difference in infection rates was detected with use of any of the following cutoffs: five hours (OR, 0.96; 95% CI, 0.54 to 1.71; p = 0.88), six hours (OR, 0.81; 95% CI, 0.53 to 1.24; p = 0.34), eight hours (OR, 1.15; 95% CI, 0.51 to 2.59; p = 0.73), or twelve hours (OR, 1.04; 95% CI, 0.62 to 1.73; p = 0.789).

Effect of Depth of Infection
When only deep infections were considered, no significant difference in the infection rate between early and late debridement was detected (Fig. 3). The weighted cumulative odds ratio of infection was 1.07 (95% CI, 0.74 to 1.54). The risk difference between the early and delayed groups was 1% (95% CI, −2% to 4%); this difference was not significant (p = 0.69).
Effect of Injury Severity and Delayed Debridement

Five studies reported injury severity according to the Gustilo-Anderson classification and evaluated the effects of delayed debridement on infection rates. For Gustilo-Anderson type-I and II fractures, 310 patients with an overall infection rate of 8% in four of these studies were available for analysis. The infection rate was 12% in the early debridement group and 5% in the late debridement group. The risk difference between the early and delayed groups was −4% (95% CI, −10% to 2%) in favor of late debridement, although this difference was not significant (p = 0.25) (Fig. 4). The weighted cumulative odds ratio of developing an infection after late debridement was 0.58 (95% CI, 0.25 to 1.33).

For Gustilo-Anderson type-III fractures, 276 patients with an overall infection rate of 12.7% were available for analysis. The infection rate was 15% in the early debridement group and 11% in the late debridement group. The risk difference between the early and delayed groups was −4% (95% CI, −12% to 5%) in favor of late debridement, although this difference was not significant (p = 0.44) (Fig. 5). The weighted cumulative odds ratio of developing an infection after late debridement was 0.84 (95% CI, 0.31 to 2.31).

The Effect of Study Level of Evidence

When only deep infections were evaluated according to the level of evidence, the weighted cumulative odds ratio of infection after late compared with early debridement did not differ significantly between the studies that provided Level-II evidence and Level-III evidence. For studies with Level-II evidence, the weighted cumulative odds ratio of infection was 1.13 (95% CI, 0.63 to 2.03) for late debridement. For studies with Level-III evidence, the weighted cumulative odds ratio of infection was 1.04 (95% CI, 0.65 to 1.65) for late debridement.
The Effect of Anatomic Location of the Fracture (Lower Extremity Only and Tibia Only)

When infection rates were evaluated according to anatomic location, the weighted cumulative odds ratio of infection after late compared with early debridement was not significantly different for lower-extremity fractures or for only tibial fractures compared with all fractures. The weighted cumulative odds ratio of infection after late debridement of lower-extremity fractures was 0.88 (95% CI, 0.62 to 1.26). The weighted cumulative odds ratio of infection after late debridement of tibial fractures was 0.88 (95% CI, 0.62 to 1.26). The weighted cumulative odds ratio of infection after late debridement of lower-extremity fractures compared with all fractures. The weighted cumulative odds ratio was not different for lower-extremity fractures or for only tibial fractures compared with all fractures. The weighted cumulative odds ratio of infection after late debridement of lower-extremity fractures was 0.88 (95% CI, 0.62 to 1.26). The weighted cumulative odds ratio of infection after late debridement of tibial fractures was 0.88 (95% CI, 0.62 to 1.26).

Discussion

In this review, we present the aggregation and analysis of sixteen systematically identified studies on the effect of late debridement of open fractures on the infection rate. The meta-analysis revealed no association between later debridement times and higher infection rates when all infections were considered, when only deep infections were considered, or when only more severe open fracture injuries were considered.

Strengths and Weaknesses of This Review

In this review, we attempted to extract as much data as possible from the individual studies and we performed a systematic analysis of study quality with use of a previously described methodological tool. Fourteen studies (3217 fractures) that included the time to operative debridement as a recorded metric were available for the meta-analysis. Furthermore, the study data were amenable to subgroup analysis according to fracture severity (Gustilo-Anderson type), infection depth, study level of evidence, and anatomic location.

Inclusion of retrospective cohort studies has inherent risks of bias, confounding, and associations that are not improved by aggregating studies. However, despite their limitations in methodology, such studies included a substantial number of patients, and ignoring them might have affected the external validity of the findings of the meta-analysis. Furthermore, differing infection definitions, wound handling, irrigation practices, antibiotic administration, patient comorbidities, virulence of potential contaminants, injury characteristics, and skeletal instability could not be controlled for in this analysis, and these will require further study.

In addition, the details of antibiotic administration were not well described in most of the studies (see Appendix). As antibiotic use is likely a major factor in reducing infection rates, it is an important factor to consider when designing future studies. Two studies reported neither the type nor the timing of antibiotic administration. Nine additional studies reported the type of antibiotic administered but did not describe the timing after injury. Dellinger et al. reported a mean time to antibiotic administration of 2.1 hours (range, 0.2 to nine hours) but did not make any associations between delayed antibiotic administration and the infection rate. Spencer et al. reported that all patients received antibiotics within four hours of injury. Patzakis and Wilkins noted a higher infection rate in patients who received antibiotics more than three hours after injury (7.4% compared with 4.7%). Similarly, Pollak et al. noted that a prolonged time between injury and hospitalization (more than two hours)—which served as a proxy for the timing of antibiotic administration—was associated with a higher rate of infection. Finally, Al-Arabi et al. did not find an association between the timing of antibiotic administration and the infection rate, but they did note that two patients who had delays in both operative debridement and antibiotic administration developed infections.

Other Studies—Clinical Data

Two studies included in the systematic review did not provide extractable data for the meta-analysis. Dellinger et al. performed a prospective study that evaluated the development of deep and superficial infections in a cohort of 263 upper and lower-extremity fractures. The authors determined that the mean time to debridement was 5.7 hours for patients who did not develop infections compared with 5.0 hours for patients without infection; this difference was not significant. Ikem et al. prospectively evaluated a series of sixty-three consecutive open fractures and noted that patients who developed infections had a significantly longer...
delay to initial debridement. Of note, the clinical practice of orthopaedics in Nigeria differs to a substantial extent compared with that in more developed nations. In that series, fracture stabilization was achieved with skeletal traction, Steinmann pins, external fixation, and plaster casting with a cast window cut out for wound care.

Two additional retrospective case series were excluded from the systematic review and meta-analysis on the basis of the inclusion criterion involving the minimum level of evidence47-58. Furthermore, two Level-III studies of pediatric patients were excluded from the systematic review and meta-analysis on the basis of the inclusion criterion involving patient adulthood49,50. Nonetheless, the results of these additional clinical studies were consistent with the findings of our meta-analysis, suggesting that early initial debridement may not be a critical factor in reducing infection rates following open fractures.

Other Studies—Experimental Data

In a 1961 study involving subcutaneous inoculation of guinea pigs, Burke concluded that prevention of infection was best achieved when antibiotics were administered prior to bacterial inoculation and that the effect of systemic antibiotics decreased as the time interval after inoculation increased, reaching a threshold of no effect after three hours41. In another study involving administration of cephradine to prevent tibial osteomyelitis in a rabbit model, administration of the antibiotic prior to inoculation was shown to be significantly more effective than administration after inoculation; however, administration up to four hours after injury still had a dramatic effect on the prevention of infection42. There is also substantial clinical evidence to support early anti-biotic administration as a critical factor in preventing infection after open fractures43,44.

Implications of Our Review

Although initial expedient and appropriate irrigation and debridement of open fracture injuries should be the goal, there are circumstances in which early debridement may not be possible. For example, hospital facilities in a rural setting or in a remote military theater may not have the resources to accommodate treatment of these complex injuries46,49. Under these circumstances, immediate transfer to a specialty hospital may offer the patient an improved injury outcome even if it results in delayed initial debridement48. Moreover, many of these open fractures present outside normal hospital working hours. Given the limited resources (including surgical assistants, experienced operating room staff, and appropriate equipment and imaging services) available outside normal working hours in some hospital settings, some investigators have suggested an increased risk of complications associated with after-hours surgery49,51. Therefore, although urgent management of open fractures is encouraged, it has been suggested that abiding by the historical “six-hour rule” may offer a disservice to patients when antibiotic administration and appropriate initial fracture care are provided under suboptimal operating conditions.

In this review, late surgical debridement was not associated with a higher infection rate in patients with open fractures. Even patients with severe injuries, classified as Gustilo-Anderson type-III fractures, did not have a higher infection rate with late initial debridement. Given the available data, it is difficult to determine the length of time between injury, administration of antibiotics, and operative debridement that provides the best outcome for the patient with an open fracture. Ideally, any delay should be minimized if possible. It is important to realize that additional carefully conducted studies are needed and that purposeful delay of treatment of patients with open fractures is not recommended.

Unanswered Questions and Future Directions

Our study cannot be considered to conclusively invalidate the “six-hour rule.” However, it provides sufficient equipoise to justify prospective investigations into the timing of initial debridement of open fractures. Clearly, open fractures can lead to substantial infectious morbidity. The identification and analysis of modifiable risk factors (including the previously suggested factors of time between injury and admission to a trauma center49, quality of debridement48, timing of antibiotic administration39, substantial bone loss >2 cm50, fracture location19,20-34, patient comorbidities, and smoking status35-37) in well-designed prospective trials will allow us to decrease the morbidity associated with open fractures.

Appendix

Tables showing the characteristics and outcomes of the included studies are available with the online version of this article as a data supplement at jbjs.org.
Background: Open proximal femoral fractures are rare injuries that often result from wartime high-energy causes. Limited data exist regarding the treatment and complications of these injuries.

Methods: We retrospectively reviewed the records of combat casualties treated at two institutions between March 2003 and March 2008. The casualty patient databases, medical records, radiographs, and laboratory data were reviewed to determine time to union, complication rates, and patient outcomes.

Results: Forty-one patients (thirty-nine men and two women) with a mean age of 25.7 years were identified as receiving treatment for open proximal femoral fractures. The mechanisms of injury for these forty-one patients were blast (twenty-nine patients [71%]), gunshot wound (eight patients [20%]), motor vehicle crash (three patients [7%]), and helicopter crash (one patient [2%]). There were thirty Type-IIIA, six Type-IIIB, and five Type-IIIC open fractures. The predominant method of definitive fixation was a cephalomedullary or reconstruction nail in thirty-four patients (83%). Thirty-nine patients had at least two years of follow-up data available for assessment of complications and radiographic union. The mean time to union was 5.1 months (range, 2.8 to 16.0 months). Complications requiring reoperation occurred in twenty-two (56%) of thirty-nine patients. Wound infection (twelve patients [31%]) and symptomatic heterotopic ossification (ten patients [26%]) were the most common complications.

Conclusions: Cephalomedullary nail fixation of open Type-III wartime subtrochanteric and pertrochanteric femoral fractures can be reliably used to effect fracture union in a timely manner. The most frequent complications of treatment are wound infection and symptomatic heterotopic ossification.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.
outcomes of open proximal femoral fractures. The most recent and largest case series to date discussing open proximal femoral fractures comes from the Bosnian conflict of the 1990s. In 2002, Miric et al. reported on the management of seventeen patients with open Type-III pertrochanteric femoral fractures by means of definitive pelvifemoral external fixation to union, which occurred at a mean of 11.5 months. They noted that the patients in their study had problems with permanent hip and knee stiffness as well as a 12% rate of chronic osteomyelitis.

With the advent of third-generation intramedullary nailing techniques, cephalomedullary nails have become a standard fixation device for the treatment of pertrochanteric and subtrochanteric femoral fractures. Several authors have reported excellent results with the use of intramedullary nails in treating closed and open femoral shaft fractures. The advantage of cephalomedullary fixation over external fixation in patients with open proximal femoral fractures is that the nail provides stable, internal fracture reduction, allowing early rehabilitation with range of motion of the hip and knee joints. In contrast, the most worrisome disadvantage of treating these open fractures with intramedullary nail fixation is the risk of seeding the intramedullary space with deep infection and/or osteomyelitis. The current literature is deficient regarding the incidence and impact of this complication following intramedullary nail fixation of open proximal femoral fractures. The purpose of this study was to evaluate the outcomes and complications following treatment of open pertrochanteric and subtrochanteric femoral fractures sustained in combat operations in Iraq and Afghanistan.

Materials and Methods

We retrospectively reviewed the records of the combat casualties managed at two institutions during the study period of March 2003 to March 2008. We identified forty-one patients with open Gustilo-Anderson Type-III fractures of the proximal femur, which included femoral head, femoral neck, pertrochanteric, or subtrochanteric fractures (defined as being within 5 cm of the base of the lesser trochanter) fractures. We reviewed the casualty patient databases, electronic medical records, radiographs, and laboratory culture data.

We recorded data to include sex, age, mechanism of injury, fracture classification, modes of provisional and definitive fixation, number of debride,ments before and after definitive fixation, time to definitive fixation, need for skin-grafting and/or flap coverage, and time to union. We defined fracture union as bridging callus being present on both the anteroposterior and lateral radiographs, the patient being nonambulatory at the fracture site, and the patient being able to bear full weight on the affected extremity. We recorded complications requiring reoperation.

Although the definition of wound infection following operative treatment of fractures has considerable variation, we utilized the following Centers for Disease Control and Prevention (CDC) criteria for surgical site infection as applied to orthopaedic wounds. A superficial wound infection was one that was located entirely above the fascia and did not require exposure of the bone or hardware. In those cases in which the fascia was absent secondary to the initial injury or subsequent debridements prior to definitive fracture fixation, the wound infection was considered superficial if there was no exposed bone or hardware and the infection did not track down to these structures. A deep wound infection was one that tracked down to the level of the bone and/or implants. In this study, all deep infections, in addition to meeting the CDC criteria, were required to have positive deep-tissue cultures and/or were treated with six weeks of parenteral antibiotic treatment in addition to irrigation and debridement of the wound.

Statistical Methods

Descriptive statistics were calculated for the results obtained. Categorical data were analyzed with use of the Student t test or Fisher exact test for binomial data.

Source of Funding

No external funding was provided in the completion of this study.

Results

Injury Characteristics

Forty-one patients (thirty-nine men and two women) with a mean age of 25.7 years (range, twenty to forty-nine years) were identified as receiving treatment for open proximal femoral fractures. Blast was the predominant mechanism of injury (twenty-nine patients [71%]), followed by high-energy motor vehicle crash (eight patients [20%]), high-energy motor vehicle crash (three patients [7%]), and helicopter crash (one [2%]). The fractures were classified as Type IIIA (thirty patients [73%]), Type IIIB (six patients [15%]), and Type IIIC (five patients [12%]) according to the Gustilo-Anderson classification. The fractures were further classified according to the AO/OTA classification: five fractures were 31-A; two, 31-B; one, 31-C; three, 32-A-1; seven, 32-B-1; and twenty-three, 32-C-1. Subtrochanteric fractures (32-X-1) and intertrochanteric fractures with subtrochanteric extension (31-A) accounted for thirty-eight patients with injuries (93%). The three other fractures were 31-B1 (basivertical femoral neck fracture with an ipsilateral transfemoral amputation), 31-B2 (transcervical femoral neck fracture), and 31-C3 (femoral head, femoral neck, and ipsilateral acetabulum fracture).

Vascular, Peripheral Nerve, and Skin Injuries

Open proximal femoral fractures often did not occur in isolation, but frequently were associated with additional trauma to the chest, abdomen, and/or head in thirty patients (73%), in addition to multiple other orthopaedic injuries. Ipsilateral fractures to the hemipelvis or distal extremity occurred in fifteen patients (37%). Concomitant peripheral nerve and vascular injuries were often encountered. Ipsilateral peripheral nerve injuries occurred in fourteen patients (34%). Of these fourteen patients, ten had nerve injuries that were in communication with the open fracture wound (eight sciatic nerve injuries, one femoral nerve injury, and one combined sciatic and femoral nerve injury), and the other four had nerve injuries that were distal to the fracture wound (three traumatic amputations and one common peroneal nerve injury associated with an open tibial plateau fracture). At the time of the latest follow-up examination, nerve function recovered in only one patient (sciatic neuropraxia injury), with proximal nerve injury associated with the open fracture. This patient recovered M4 motor strength and protective foot sensation by five years after the time of injury. Five patients sustained open Type-IIIC...
fractures requiring vascular repair and/or reconstruction at the time of injury to restore distal limb perfusion.

Additional wound coverage with split-thickness skin-grafting was necessary in eighteen patients (44%), and seven patients (17%) had extensive thigh musculature loss with substantial exposed femur that required muscle or fasciocutaneous flap coverage. Five rotational flaps (two biceps femoris, one vastus lateralis, one sartorius, and one cross-leg fasciocutaneous) and four free flaps (three rectus abdominis and one latissimus dorsi) were used.

Fracture Treatment
The patients arrived at our institutions with a mean evacuation time of 5.9 days (range, two to twenty-five days) from the time of injury. A mean of 2.7 irrigation and debridement procedures (range, one to six procedures) were performed prior to arrival at our institutions, and an additional mean of 3.2 irrigation and debridement procedures (range, one to twelve procedures) were performed at our facilities prior to definitive fracture fixation. Perioperative antibiotic prophylaxis (Ancef [cefazolin] and gentamycin in the first seventy-two hours, followed by Ancef alone) was started in the operating room and typically was maintained until wound coverage. Intraoperative deep wound culture specimens were initially obtained in thirty-five patients (85%). Of these thirty-five patients, twenty-one (60%) had initial positive cultures, and sixteen of these twenty-one patients with initial positive wound cultures were managed with different and/or additional antibiotics (most commonly imipenem or amikacin) tailored to initial culture results and antibiotic sensitivities. Antibiotic-impregnated cement beads (1 g of vancomycin and 1.2 g of tobramycin per 40 g of cement) were utilized during debridement procedures in thirty-seven patients. Definitive fracture fixation occurred at a mean of 12.3 days (range, zero of thirty-one days) after injury. Postoperative rehabilitation was according to the preference of the surgeon on the basis of fracture pattern, fixation quality, and comorbid injuries. The mean number of total operating room encounters for treatment of the open proximal femoral fracture was 10.3 procedures (range, two of thirty-four procedures), which include a mean of six procedures prior to definitive stabilization and four procedures after definitive stabilization for ongoing soft-tissue management and/or to treat complications. We had a minimum two-year follow-up evaluation in thirty-nine (95%) of forty-one patients with a mean follow-up time of 56.5 months (range, twenty-four to eighty-four months).

Of the forty-one patients, forty underwent provisional fixation of the fractures on the day of injury (thirty-nine patients had external fixation and one had a skeletal traction pin), and one directly underwent definitive fixation (a displaced femoral neck fracture initially treated with open reduction and internal fixation utilizing four cannulated screws). Of these thirty-nine patients, seventeen (44%) underwent external fixation that spanned the hip joint (Fig. 1) and twenty-two (56%) underwent monolateral external

Fig. 1
Anteroposterior pelvis radiograph of a thirty-year-old man after provisional spanning pelvifemoral external fixation for the initial treatment of a left, open Type-IIIa, comminuted subtrochanteric femoral fracture.
fixation with half-pins in the femoral neck of the proximal fracture fragment and half-pins in the femoral shaft distally.

Definitive treatment of the fractures was performed predominantly in our patient group of forty-one patients with a cephalomedullary nail or reconstruction nail in thirty-four patients (83%) (Fig. 2). Other fixation methods utilized included using a proximal femoral locking plate (two patients [5%]), spanning pelvifemoral external fixation (two patients [5%]), open reduction internal fixation with cannulated screws (one patient [2%]), hip fusion (one patient [2%]), and hip disarticulation (one patient [2%]). No patients underwent primary bone-grafting at the time of definitive fixation. For patients who underwent provisional external fixation, conversion from external to internal fixation was performed in a single stage. At the time of internal fixation, the extremity underwent a sterile surgical preparation, the external fixation pins were removed, and the pin tracts were curetted. The used instruments were then removed from the surgical field. The extremity had an additional sterile preparation and drape, and conversion to internal fixation was performed. None of the external fixation pins exhibited obvious signs of infection before conversion to internal fixation.

Complete data to assess fracture union were available in thirty-eight patients (93%), as one patient underwent hip disarticulation and two patients were lost to follow-up one month after definitive fixation. The mean time to union in this group was 5.0 months (range, 2.8 to 16.0 months). The mean time to union for subtrochanteric and pertrochanteric fractures (thirty-five patients) was 5.1 months (range, 2.8 to 16.0 months) (Fig. 3).

Associated Amputations
At the time of the latest follow-up, lower-extremity amputations (proximal to the ankle joint) had been performed in twelve (29%) of forty-one patients for a total of sixteen lower-extremity amputations. Traumatic amputations occurred in twelve limbs in nine patients. The traumatic amputations were subdivided into three bilateral lower-extremity traumatic amputations and six contralateral lower-extremity traumatic amputations. Six patients had amputations that occurred ipsilateral to the open femoral fracture. These amputations were related to the open
fracture injury in two patients (one patient undergoing hip disarticulation as definitive treatment in a Type-IIIIC injury with acute complicated wound infection and sepsis, and one patient undergoing a delayed transtibial amputation for a dysesthetic foot secondary to a concomitant sciatic nerve injury). The remaining four patients had ipsilateral amputations for lower-extremity injuries sustained distal to the open femoral fracture wound (three traumatic transtibial amputations and one delayed amputation for failed limb salvage of open hindfoot fractures).

Complications
Twenty-nine complications requiring reoperation were observed in twenty-two (56%) of thirty-nine patients (Table I). The complications included infection in twelve patients (31%), symptomatic heterotopic ossification requiring excision in ten patients (26%), malunion requiring osteotomy and revision open reduction and internal fixation in one patient (3%), malreduction requiring revision open reduction and internal fixation in one patient (3%), nonunion requiring delayed bone-grafting in one patient (3%), flap failure requiring a repeat flap procedure in one patient (3%), hematoma in one patient (3%), wound dehiscence in one patient (3%), and a heel decubitus ulcer from an insensate foot requiring debridement in one patient (3%).

Infection occurred after definitive fixation in five (18%) of twenty-eight Type-IIIA fractures, four (67%) of six Type-IIIB fractures, and three (60%) of five Type-IIIC fractures. When comparing the Type-IIIA fractures (five of twenty-eight [18%]) with the Type-IIIB and IIIC fractures combined (seven of eleven [64%]), patients who had Type-IIIA fractures demonstrated a significantly lower rate of infection (p = 0.009). The mean time to diagnosis of postoperative infection was twenty-nine days after fixation, with a median of sixteen days (range, zero to 174 days). As may be expected, the total mean number of operative encounters for proximal femoral fracture treatment per patient was significantly higher in those patients with postoperative infection (17.2 operative encounters) compared with those patients without infection (7.4 operative encounters) (p = 0.0002).

Comparing available intraoperative culture data by the Gustilo-Anderson classification of the fractures, positive cultures were present in fourteen (56%) of twenty-five patients with Type-IIIA fractures and seven (70%) of ten patients with Type-IIIB and IIIC fractures (p = 0.36). When evaluating initial culture results compared with the development of infection, positive cultures were present in eleven of twelve patients who developed infection and in ten of twenty-three patients who did not develop infection (p = 0.006). Presented another way, a negative wound culture on presentation had a 93% negative predictive value for development of infection in our patient population, but a positive wound culture only carried a positive predictive value of 52%. The organisms isolated from the twelve intraoperative wound culture specimens in patients with postoperative infection were gram-negative in eight cultures (two *Klebsiella pneumoniae*, two *Escherichia coli*, two *Pseudomonas aeruginosa*, and two *Acinetobacter baumannii*), gram-positive in one culture (*Enterococcus faecium*), and polymicrobial.

---

**TABLE I Complications of Treatment Requiring Reoperation in Thirty-nine Patients with ≥2-Year Duration of Follow-up***

<table>
<thead>
<tr>
<th>Types of Complication</th>
<th>No. of Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection</td>
<td>12</td>
</tr>
<tr>
<td>Symptomatic heterotopic ossification</td>
<td>10</td>
</tr>
<tr>
<td>Malunion</td>
<td>1</td>
</tr>
<tr>
<td>Malreduction</td>
<td>1</td>
</tr>
<tr>
<td>Nonunion</td>
<td>1</td>
</tr>
<tr>
<td>Flap failure</td>
<td>1</td>
</tr>
<tr>
<td>Hematoma</td>
<td>1</td>
</tr>
<tr>
<td>Wound dehiscence</td>
<td>1</td>
</tr>
<tr>
<td>Heel decubitus ulcer</td>
<td>1</td>
</tr>
</tbody>
</table>

*Twenty-nine total complications occurred in twenty-two of thirty-nine patients, resulting in a complication rate of 56%.
gram-negative in three cultures (two *Klebsiella* and *Escherichia coli*, and one Pseudomonas and Candida yeast species).

**Intramedullary Nail Fixation**

Thirty-two patients were managed with an intramedullary nail fixation for definitive fixation, with >2-year follow-up evaluation available (twenty-four Type-IIIA, six Type-IIIB, and two Type-IIIC fractures). The time to union in the intramedullary nail fixation subgroup was 5.1 months (range, 2.8 to 16.0 months). Postoperative hip-motion data were available in fifteen of the thirty-two patients who had undergone intramedullary nail fixation with a mean arc of extension-flexion of 95°.

Complications were encountered in nineteen (59%) of thirty-two patients throughout the course of treatment. Infection was the most common complication, occurring in ten (31%) of thirty-two of all patients who had undergone intramedullary nail fixation (Table II). The total mean number of irrigation and debridement procedures performed prior to definitive intramedullary nail fixation was 6.0 procedures for patients who developed infection compared with 5.6 procedures for those who did not develop infection (p = 0.75). The mean time from injury to the time to definitive intramedullary nail fixation was 14.8 days (range, two to thirty-one days) for patients who developed infection, compared with 13.0 days (range, zero to thirty-three days) for those who did not develop infection (p = 0.57). After intramedullary nail fixation, the mean time to union was 6.5 months for patients who had postoperative infection, compared with 4.6 months for those who did not have infection (p = 0.040). Of the ten patients who had undergone intramedullary nail fixation and had developed infections, two had superficial infections, requiring irrigation and debridement and a short course of ten to fourteen days of antibiotics to clear the infection, and eight had deep infections and/or osteomyelitis, requiring serial irrigation and debridements and organism-specific parenteral antibiotics for at least six weeks. Patients with Type-IIIB and IIIC fractures combined had an infection rate of 63%, and patients with Type-IIIA fractures alone had an infection rate of 19% (p = 0.042). Five patients with deep infection required intramedullary nail removal to clear the infection.

**Discussion**

Open proximal femoral fractures are severe injuries often associated with other major trauma. Our patient group, like the one described by Miric et al., had a high rate of concomitant injuries, including ipsilateral fractures, lower-extremity amputations, and associated neurovascular injuries, demonstrating the severity of the global injury sustained with these open fractures. Likewise, the peripheral nerve injury rate of 34% in our study was similar to the sciatic nerve injury rate of 30% seen in their 2002 study, with recovery of nerve function occurring in only one patient in each study. We also demonstrated that obtaining fracture union can be accomplished without the need for initial bone-grafting in these extremely comminuted fractures, regardless of the fixation method utilized. However, in their study, Miric et al. evaluated the use of pelvifemoral external fixation to definitively treat open wartime proximal femoral fractures. Their reasoning for choosing...

---

**TABLE II Postoperative Wound Infections in Patients Managed with Definitive Intramedullary Nail Fixation**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Infection Type</th>
<th>Mechanism of Injury</th>
<th>Gustilo-Anderson Classification Type</th>
<th>AO/OTA Classification</th>
<th>No. of Irrigation and Debridement Procedures Prior to Definitive Fixation</th>
<th>No. of Days to Definitive Fixation</th>
<th>Organism Grown on Wound Culture</th>
<th>Implants Removed by the Time of the Latest Follow-up Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Superficial</td>
<td>Blast</td>
<td>IIIA</td>
<td>32-C1-1</td>
<td>4</td>
<td>10</td>
<td><em>Enterococcus faecium</em></td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>Deep</td>
<td>Blast</td>
<td>IIIB</td>
<td>32-C1-1</td>
<td>4</td>
<td>12</td>
<td><em>Escherichia coli</em></td>
<td>Removed</td>
</tr>
<tr>
<td>3</td>
<td>Deep</td>
<td>Blast</td>
<td>IIIB</td>
<td>31-A3</td>
<td>12</td>
<td>31</td>
<td><em>Escherichia coli</em></td>
<td>Removed</td>
</tr>
<tr>
<td>4</td>
<td>Superficial</td>
<td>Blast</td>
<td>III C</td>
<td>32-C3-1</td>
<td>3</td>
<td>4</td>
<td><em>Acinetobacter baumannii</em></td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>Deep</td>
<td>Gunshot wound</td>
<td>III A</td>
<td>32-C3-1</td>
<td>5</td>
<td>17</td>
<td><em>Klebsiella pneumoniae</em></td>
<td>—</td>
</tr>
<tr>
<td>6</td>
<td>Deep</td>
<td>Blast</td>
<td>III A</td>
<td>32-C3-1</td>
<td>5</td>
<td>10</td>
<td><em>Pseudomonas aeruginosa</em></td>
<td>Removed</td>
</tr>
<tr>
<td>7</td>
<td>Deep</td>
<td>Blast</td>
<td>III A</td>
<td>32-B3-1</td>
<td>6</td>
<td>12</td>
<td><em>Klebsiella pneumoniae</em></td>
<td>Removed</td>
</tr>
<tr>
<td>8</td>
<td>Deep</td>
<td>Blast</td>
<td>IIIB</td>
<td>32-B2-1</td>
<td>2</td>
<td>2</td>
<td><em>Pseudomonas aeruginosa</em></td>
<td>—</td>
</tr>
<tr>
<td>9</td>
<td>Deep</td>
<td>Blast</td>
<td>IIIB</td>
<td>32-C3-1</td>
<td>8</td>
<td>19</td>
<td><em>Klebsiella pneumoniae and Escherichia coli</em></td>
<td>Removed</td>
</tr>
<tr>
<td>10</td>
<td>Deep</td>
<td>Blast</td>
<td>III A</td>
<td>32-C3-1</td>
<td>11</td>
<td>31</td>
<td><em>Acinetobacter baumannii</em></td>
<td>—</td>
</tr>
</tbody>
</table>
definitive external fixation was that they noted that intramedullary nail fixation carried too high a risk for nonunion, collapse, and infection, although no supporting data for that opinion were presented. Miric et al. reported obtaining union via hip-spanning external fixation in all of their patients, but they also noted universal postoperative stiffness, most likely due to the long period of immobilization and time to union, at a mean of 11.5 months. Those results contrast with the results of our intramedullary nail fixation patient group, which demonstrated a time to union at a mean of 5.1 months and began hip and knee motion immediately after wound closure or as soon as other comorbid injuries allowed. Our reported time to union was very similar to previously reported civilian data describing the treatment of open femoral shaft fractures by means of intramedullary nail fixation.

Another difference between the two studies, besides the method of fixation of the fractures, was that all seventeen fractures in the Miric et al. study were Gustilo-Anderson Type-IIIA injuries; in contrast, we reported on the treatment of six Type-IIIB fractures and five Type-IIIC fractures, in addition to thirty Type-IIIA fractures. Gustilo-Anderson Type-IIIB and IIIC fractures often pose an even greater treatment challenge because of the extensive soft-tissue injuries, need for flap coverage and/or vascular repair, reconstruction, and increased risk of infection. These devastating wounds require extreme diligence and serial meticulous, aggressive debridements to remove all devitalized tissue as the wound continues to evolve after injury. In our study, patients with Type-IIIB and IIIC fractures treated with intramedullary nail fixation had a substantial infection rate of 63%, but it is unknown what the infection rate would have been in these same patients had the injuries been treated with a different mode of fixation.

In our study, the infection rate was 19% for patients with Type-IIIA fractures treated with intramedullary nail fixation. Additionally, the majority of our patients sustained blast injuries rather than gunshot wounds, which were primarily treated in the pelvifemoral external fixation study. Although high-energy gunshot wounds may obviously cause severe injuries, a wartime blast trauma has the potential of causing even more soft-tissue injury and contamination than an isolated gunshot wound. As all of these details may help to explain the higher infection rate seen in our study compared with that in the pelvifemoral external fixation study, two possible risk factors that did not demonstrate any correlation with the development of infection in our intramedullary nail fixation patients were the total number of debridements received prior to definitive fixation and the time from injury to definitive fixation.

The majority (60%) of the patients in this study presented with initial positive deep wound cultures. Although a positive culture result in our study demonstrated a sensitivity of 92%, it only showed a positive predictive value of 52% for the development of infection. However, our data may suggest that a negative initial culture result may be more clinically useful as it represented a negative predictive value of 93% for the development of infection in our patient population. Also of note, most reports have demonstrated that gram-positive organisms are the most common cause of postoperative wound infection. However, gram-negative organisms grew on culture of specimens obtained from eleven of twelve patients at the time of debridement. We believe that this discrepancy may be due to several factors, including the high-energy mechanisms with gross wound contamination at the time of injury, the proximity of the fracture wounds to the groin and anus, and associated polytrauma.

Not surprisingly, the mean number of operative encounters required was much higher in patients who developed infection (17.2 encounters) compared with those who did not (7.4 encounters). However, despite requiring more operative procedures (including intramedullary nail removal in five patients) and a mean of 1.9 additional months to produce fracture union, all patients who had development of infection had successful treatment of the infection, with no new recurrences of infection at the time of the latest follow-up evaluation. Similar to previously reported data on open femoral shaft fractures treated with intramedullary nail fixation from civilian trauma, our data suggest that proper surgical debridement and eventual intramedullary nail removal in selected cases are an effective method to eradicate deep infection when it occurs. Although intramedullary reaming and intramedullary nail fixation can be a potential mechanism to spread infection along the intramedullary space, the deep infection and/or osteomyelitis encountered in our patients was seen uniformly at the open fracture site and was not localized distally in the intramedullary canal.

There were several limitations to our study. As a retrospective study of a rare wartime trauma injury in U.S. service members, no standardized treatment regimen was instituted and no control group was generated for comparison. Only two patients were managed with pelvifemoral external fixation to union, and, because of this small sample size, statistical analysis was not appropriate. Throughout the course of this study, there were seven attending surgeons who definitively managed patients with these injuries. The surgical and rehabilitative protocol was at the discretion of the attending surgeon, not allowing for the evaluation of a single treatment method, but possibly making the results of this study more generalizable for various surgeons. Finally, limited functional outcome data were obtained in this patient group regarding lower-extremity or global functional status.

Cephalomedullary nail fixation of open Type-III A wartime subtrochanteric and pertrochanteric femoral fractures can be reliably used to effect fracture union in a timely manner, with a mean time of 5.1 months. Open Type-III wartime proximal femoral fractures occur from high-energy mechanisms and are often associated with trauma to multiple organ systems as well as considerable morbidity and complications. Because of the increased risk of deep infection in treating open Type-IIIB and IIIC injuries, especially for those patients with positive initial wound cultures, thorough patient counseling should be undertaken and caution should be exercised in managing these patients with intramedullary nail fixation. Further research initiatives are required to evaluate the functional outcomes obtained after treating wartime open proximal...
femoral fractures, as well as the means of potentially reducing postoperative infection in these devastating injuries.

Andrew W. Mack, MD
John J. Keeling, MD
Romney C. Andersen, MD
Walter Reed National Military Medical Center,
8901 Wisconsin Avenue, Bethesda, MD 20889.
E-mail address for A.W. Mack: amack2@caregroup.harvard.edu

Brett A. Freedman, MD
Landstuhl Regional Medical Center,
AE, 09180-0402

Adam T. Groth, MD
Tripler Army Medical Center,
1 Jarrett White Road,
Honolulu, HI 96859-5000

Kevin L. Kirk, DO
Brooke Army Medical Center,
3551 Roger Brooke Drive,
San Antonio, TX 78234

References