The Urgency of Surgical Débridement in the Management of Open Fractures

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Abstract

Emergent débridement of open fractures within 6 hours of injury has long been considered to be critical to prevention of infection. The basis for this mandate is unclear, however. In clinical practice, physiologic and logistical challenges frequently limit the degree to which such emergent surgical care can effectively be rendered. Furthermore, concerns exist that quality of care might be improved when services are performed during normal working hours. The current literature suggests no obvious advantage to performing surgical débridement within 6 hours after injury versus doing so between 6 and 24 hours after injury. The effect of delays >24 hours is unclear. Further research in this area would be helpful, but development of definitive level I evidence seems unlikely. Surgical débridement of open fractures should be accomplished urgently, as soon as the patient's physiologic condition permits and as soon as appropriate resources are available to safely perform the procedure.

Perspectives on Modern Orthopaedics articles provide an objective appraisal of new or controversial techniques or areas of investigation in orthopaedic surgery.

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Treatment of open fractures includes immediate splinting and administration of antibiotics, tetanus prophylaxis, early surgical débridement, fracture reduction and stabilization, and definitive soft-tissue coverage.[1] Outcome is likely related to all or many of the treatment variables.[2,3]

Current protocols for the timing of initial surgical débridement are based on the long-standing theory that open wounds should be débrided within 6 hours of injury to decrease the risk of deep infection. This theory is likely based on the 1898 report presented by Paul Leopold Friedrich,[4] who used garden mold and dust from stairs as infective agents in a guinea pig model to illustrate the importance of surgical débridement. Friedrich showed that the early phases of bacterial growth within contaminated wounds terminated within 6 to 8 hours after inoculation. After that time, simple débridement was less likely to be effective in wound sterilization. Friedrich recommended circumferential wound border excision to viable tissue margins within approximately 6 hours of injury or inoculation to reduce the risk of wound infection.

The 6-hour recommended time frame for débridement of open fractures was established before the era of modern resuscitation, antibiotics, pulsatile lavage, and systematic débridement protocols. Few modern clinical data support this recommendation as being critical in reducing the likelihood of later infection.[5-7]

In clinical practice, the actual de-

lay between time of injury and surgical débridement often is longer than 6 hours. This delay may be the result of a variety of factors, including the need for treatment of concomitant injuries before surgical fracture treatment, delay in transferring the patient from an outside hospital, and logistical challenges, such as operating room availability. Delays to surgical treatment create an opportunity to evaluate the outcomes of open fractures managed with relatively late débridement; several studies recently have done so.[2,5-15]

Further mandating an examination of the role of timing of débridement in outcome after treatment of open fractures is the growing body of evidence suggesting that physician fatigue produces measurable impairment and therefore may play a role in the genesis of medical errors and poor outcomes.[16-19] When urgent surgical débridement is mandated, surgical management of open fractures must occur immediately, even during late-night hours. Such timing may lead to treatment by a less experienced surgeon or to appropriate decision-making being influenced by fatigue. In either scenario, the potential exists for compromised technical or cognitive performance, potentially leading to poor outcomes.

Timing of Débridement and Risk of Infection

In 1976, Gustilo and Anderson[20] reported, "There is universal agreement that open fractures require emergency treatment including adequate débridement and irrigation of the wound." Their statement was not referenced, however; rather, it was presented as opinion. Since the publication of that series, several other trauma series have independently examined the effect of timing of débridement on risk of infection.[2,5-15] Most have been unable to define a specific independent risk of infection associated with delay in surgical débridement to between 6 and 24 hours after injury[2,8-15] (Table 1).

In 1988, Dellinger et al[21] retrospectively analyzed 263 open extremity fractures managed at three different trauma centers. Of the 114 patients for whom such information was available, the incidence of infection was determined to be 16%. Three independent risk factors for fracture infection were identified: higher Gustilo type (particularly type IIIB and IIIC fractures), the use of external or internal fixation, and the location of the fracture within the lower leg. The authors addressed the association between timing of first débridement and risk of infection; they reported no statistical difference in injury-to-operation interval between infected patients (5.0 ± 2.0 hours) and uninfected patients (5.7 ± 3.2 hours). Furthermore, patients were not grouped according to time delay. The authors also conducted a multivariate regression analysis in which time delay was not identified as an independent risk factor for the development of deep infection.

In 1988, Merritt[8] prospectively collected tissue samples at the beginning and at the end of the first surgical débridement of open fracture in 70 patients. Tissue that had undergone débridement was cultured, and the results were recorded along with a large number of other data elements. Each data element was correlated with infection incidence. Thirteen of the 70 patients became infected (19%). A significant correlation was shown between the bacterial count after wound débridement and the occurrence of infection. Bacterial count at the beginning of the débridement did not significantly correlate with infection risk. Time from injury to initial treatment at the emergency department and that from emergency department arrival to actual time of débridement in the operating room did not significantly correlate with infection risk.

Patzakis and Wilkins[9] retrospectively evaluated 77 infections in 1,104 open fractures caused by direct trauma other than gunshot wounds. They found that the single most important factor influencing the rate of infection was early administration of antibiotics. When antibiotics were administered within 12 hours of injury, the time elapsed from injury to surgical débridement had no effect on the occurrence of wound infection. In another study, Patzakis et al[23] compared ciprofloxacin alone with gentamicin plus cefamandole for treatment of open fractures in a prospective randomized trial of 163 patients with 171 open fractures. The authors found a trend toward increased infection in type III open fractures treated with ciprofloxacin. In the 152 type III open fractures, average time from injury to débridement was slightly higher in the noninfected group than in the infected group (20.4 versus 18.8 hours).

Bednar and Parikh[10] retrospectively studied 75 patients with 82 open fractures secondary to high-energy blunt trauma. The fractures consisted of 30 femur and 52 tibia fractures, 63 (77%) of which were Gustilo type III injuries. Time from injury to arrival at the operating room averaged 8.8 hours (range, 3 to 20 hours), with a delay >6 hours from injury in 62 of the 82 open fractures. The cause of delay was multifactorial. The effect of time from injury to definitive surgical management was analyzed in 6-hour blocks for the first 24 hours. No significant difference in deep infection rate was found among any of the four time blocks. No apparent advantage was observed for the patients whose fractures were treated surgically within 6 hours of injury (9% infection rate) compared with the remainder of the study population who received treatment >6 hours after injury (3.4% infection rate, $P = 0.62$). Gustilo type IIIA was the only open fracture type with a sufficient number of cases to enable calculation of the effect of time to surgical management. In the sub-

Table 1

Summary of Studies That Failed to Define a Specific Independent Risk of Infection in Association With Delay in Surgical Débridement to Between 6 and 24 Hours After Injury

Study	Study Design	No. of Patients	No. of Open Fractures	No. Infected (%)	Study Conclusions
Dellinger et al[21]	Retrospective	114	263	42 (16)	No statistical difference in injury-to-operation interval between infected and uninfected patients
Merritt[8]	Prospective	70	N/A	13 (19)	Time from injury to initial débridement does not significantly correlate with infection risk
Patzakis and Wilkins[9]	Retrospective	N/A	1,104	77 (7)	Time from injury to surgical débridement has no effect on occurrence of wound infection. Rate of infection strongly influenced by early administration of antibiotics.
Bednar and Parikh[10]	Retrospective	75	82	N/A (9 <6 hr delay) (3.4 >6 hr delay)	No advantage in early surgical débridement (within 6 hours of injury) of open fractures compared with treatment within 24 hours of injury
Harley et al[11]	Retrospective	227	241	20 (8.8)	Time from injury to surgical débridement not statistically related to development of deep infection or nonunion
Khatod et al[2]	Retrospective	103	106	N/A (22.6)	No significant difference between fractures that became infected and those that did not with respect to time from injury to initial surgical débridement
Ashford et al[22]	Retrospective	45	48 (12 <6 hr delay, 36 >6 hr delay)	2 (17 <6 hr delay) 4 (11 >6 hr delay)	Delay in surgical treatment can still yield satisfactory results. Emphasis on treatment protocol utilizing minimal preoperative handling of the wound, meticulous débridement, fracture stabilization, soft-tissue coverage, and appropriate antibiotic administration
Spencer et al[12]	Prospective	103	115 (69 <6 hr delay, 46 >6 hr delay)	7 (10.1 <6 hr delay) 5 (10.8 >6 hr delay)	No significant increase in infection rate seen in patients who underwent surgical débridement >6 hours after injury
Noumi et al[13]	Retrospective	88	89	5 (5.6)	Time from surgery to surgical débridement not identified as an independent predictor of infection risk
Skaggs et al[14]	Retrospective	536	554 (344 <6 hr delay, 210 >6 hr delay)	12 (3 <6 hr delay) 4 (2 >6 hr delay)	Time between injury and surgical débridement has little effect on incidence of acute infection in children who receive timely antibiotic treatment after injury
Mathes et al[15]	Retrospective	N/A	891	99 (11)*	Increased risk of nonunion and infection not shown to be associated with delay in surgical débridement

* Includes both deep infection and nonunion cases

N/A = not available

group of Gustilo type IIIA injuries, no significant difference in incidence of deep sepsis was shown among the four time-related groups. The authors concluded that no advantage was shown with early surgical débridement of open fractures (within 6 hours of injury) compared with débridement within 24 hours of injury.

Harley et al[11] retrospectively analyzed 241 open long-bone fractures in 227 adults. Multiple regression statistical analysis showed that time from injury to surgical débridement was not statistically related to the development of either nonunion or deep infection (which occurred in 20 patients). The strongest predictors for the occurrence of deep infection were open fracture type and location of the fracture in the lower extremity.

In 2003, Khatod et al[2] retrospectively reviewed 106 severe open tibia fractures in 103 patients. The overall reported infection rate was 22.6%, with a 5.7% reported incidence of osteomyelitis. The authors found a highly significant correlation between Gustilo open fracture type and rate of infection ($P < 0.0001$). No infection occurred in any fracture type when surgical débridement was done within 2 hours of injury. No significant difference was shown between fractures that became infected and those that did not with regard to time from injury to initial surgical débridement for any Gustilo fracture type (unpaired *t* test). However, the authors did not directly compare the incidence of infection in early versus late débridement groups. These investigators concluded that the data were inadequate to support the mandated 6-hour maximum time between injury and surgical débridement. However, in the absence of conclusive data, they maintained support for treating all open fractures emergently.

Ashford et al[22] retrospectively reviewed the outcomes of 48 open tibia fractures sustained in 45 patients in the Northern Territory of Australia. Some patients experienced significant delay in treatment because of geographic isolation. Primary surgical treatment was administered within 6 hours in 12 patients and >6 hours after injury (range, 7 to 37 hours) in 33 patients. Superficial wound infection or colonization with bacteria occurred in 11 fractures (23%), pin-site infections in 5 (10%), and in all fractures treated with external fixators. Deep infection of the injury site occurred in 6 (13%) of the 48 fractures. Two deep infections occurred in the group treated within 6 hours (17%), whereas four deep infections were noted in the delayed treatment group (11%). The authors concluded that if delay in treatment is inevitable, satisfactory results can still be achieved. They emphasized the importance of a treatment protocol that includes minimal preoperative handling of the wound, meticulous débridement, fracture stabilization, provision of soft-tissue coverage, and appropriate antibiotic administration.

Spencer et al[12] conducted a prospective study to determine whether a delay >6 hours from injury to surgical débridement affected the infection rate in open long-bone fractures. The study included 142 fractures in 130 patients; 115 fractures in 103 patients were available for follow-up. Primary débridement was performed within 6 hours after injury in 60% of the fractures and >6 hours after injury in 40%. Infection rates in these two groups were 10.1% and 10.8%, respectively. No significant increase in infection rate was shown in patients in whom surgical débridement was performed >6 hours after injury. The investigators concluded that these injuries might be better treated with delayed surgery during normal operating hours by experienced teams in combination with early administration of intravenous antibiotics, basic wound care, and appropriate splinting.

Noumi et al[13] retrospectively analyzed 89 open femur fractures in 88 patients, using multivariate analysis. Time to débridement was evaluated in two groups: <6 hours after injury and >6 hours after injury. Five fractures (5.6%) developed deep infection. Only the Gustilo open fracture type significantly correlated with occurrence of deep infection ($P < 0.05$). Time from injury to surgical débridement was not identified as an independent predictor of infection risk.

Skaggs et al[14] retrospectively analyzed 554 open fractures in 536 children. They reported an infection rate of 3% (12 of 344 fractures) for fractures treated within 6 hours of injury and 2% (4 of 210 fractures) for those treated ≥7 hours after injury. This difference was not statistically significant. When the fractures were subcategorized according to Gustilo open fracture type, the authors found no significant difference in infection rate between those treated within 6 hours of injury and those treated >7 hours after injury. The authors concluded that regardless of Gustilo open fracture type, the time between injury and surgical débridement has little effect on the incidence of acute infection in children who receive timely antibiotic treatment for an open fracture.

In 2006, Mathes et al[15] reported the results of a retrospective review of 891 open long-bone fractures treated during a 12-year period at a tertiary trauma center with a large catchment area. Geographic challenges frequently prolonged the time from injury to surgical débridement. The investigators were unable to show an increased risk of complications, including nonunion and infection, associated with delay in surgical débridement.

Although most studies published to date have shown no apparent relationship between infection risk and time from injury to débridement, three studies have presented evidence that led the authors to conclude that a real relationship exists between time from injury to dé-

Table 2

Retrospective Studies Showing a Positive Relationship Between Infection and Time From Injury to Débridement

Authors	No. of Patients	No. of Open Fractures	No. Infected (%)	Conclusions	Limitations
Jacob et al[5]	N/A	37 (25 early débridement, 12 delayed)	2* (22 early débridement) 4† (67 delayed débridement)	Results support need for early surgical débridement to prevent infection in open fractures	Insufficient power to achieve statistical significance and inadequate control for injury severity and type. Specific time delays to treatment not recorded.
Kreder and Armstrong[6]	55	56 (42 <6 hr delay, 8 >6 hr delay, 6 unknown)	5 (12 <6 hr delay) 2 (25 >6 hr delay)	Significant correlation between time to surgical débridement and the occurrence of infection (P = 0.0447)	Small sample of patients and limited data presented
Kindsfater and Jonassen[7]	46	47 (15 <5 hr delay, 32 >5 hr delay)	1 (7 <5 hr delay) 12 (38 >5 hr delay)	Statistically significant results conclude that débridement should be performed on all Gustilo type II and III open fractures within 5 hours of injury (P < 0.03)	Retrospective study design precludes comparisons of anatomic/physiologic descriptions of injury between groups, creating selection bias

* Of nine graded as Gustilo type III open fractures
† Of six graded as Gustilo type II open fractures
N/A = not available

bridement and infection (Table 2).[5-7]

Jacob et al[5] reported on a series of 37 open fractures sustained by United States military personnel during the 1989 Panamanian conflict. The fractures varied widely in location, severity, and treatment method. Twenty-five of 37 open fractures first underwent débridement in the United States after air evacuation, and the rest were managed with initial surgical débridement in Panama. Specific time delays from injury to débridement were not recorded. Infection developed in two of nine Gustilo type III open fractures that had undergone surgical débridement in Panama before transport to the United States (22%) versus infection in four of six cases in which initial surgical débridement was delayed until after air evacuation (67%). The investigators concluded that their study supports the need for early surgical débridement to prevent infection after open fracture. However, the validity of the conclusion was limited by inadequate control for injury severity and type as well as insufficient power to achieve statistical significance.

Kreder and Armstrong[6] retrospectively reviewed 56 open tibia fractures in 55 children. Infection occurred in eight limbs (four deep and four superficial), for an overall incidence of 14%. For six patients, the time from injury to surgery could not be established. Forty-two extremities underwent surgical débridement within 6 hours, and 8 fractures were treated >6 hours after injury. Five fractures in the group treated within 6 hours after injury became infected (12%), compared with two fractures in the group treated >6 hours after injury (25%). The authors showed a significant correlation between time to surgical débridement and occurrence of infection (P = 0.0447). The presence of neurovascular injury also was significantly associated with infection. The authors concluded that delay between injury and surgical treatment and the presence of neurovascular injury were more important than other factors in predicting the development of infection. The study was substantially limited by the small number of patients and the limited data presented.

Kindsfater and Jonassen[7] retrospectively analyzed data from 47 Gustilo type II and III open tibia fractures in 46 patients. Time delay from injury to débridement was statistically analyzed in 1-hour increments. One of the 15 fractures that underwent débridement <5 hours after injury became infected (7%). In contrast, in the group that underwent débridement >5 hours after injury, 12 of 32 fractures became infected (38%). The difference was statisti-

cally significant ($P < 0.03$) and remained significant when type II and III fractures were considered separately. Osteomyelitis occurred at a mean of 4.8 months after injury. The authors concluded that every possible effort should be made to perform débridement on all type II and III tibia fractures within 5 hours of injury. Although the surgeons attempted to control for injury severity, the retrospective study design precluded an in-depth comparison of anatomic and physiologic descriptions of injuries in the early and late débridement groups, thereby predisposing the results to selection bias.

Discussion

Surgical débridement of open fractures often is clinically delayed because of patient or administrative factors. Patient factors include inadequate resuscitation and ongoing physiologic instability. Administrative factors include lack of surgeon or operating room resources and a delay in patient arrival at the definitive treatment center. To more consistently achieve surgical débridement within 6 hours of injury, several changes in protocols related to treatment of the injured patient seem to be necessary. One change would be to adopt a practice of open fracture débridement before physiologic stabilization. Such an aggressive surgical approach to achieving timely débridement of an open fracture would and should require compelling data that show the urgency of the débridement procedure. In the absence of such compelling data, urgent débridement in the context of physiologic instability seems difficult to support. Similarly, diverting hospital resources to allow earlier débridement of open fractures and mandating emergent transfer of patients with open fractures to definitive treatment facilities are difficult to justify in the absence of data supporting the critical independent role of timing of débridement in outcome following treatment of open fracture.

Currently, the body of available data fails to provide full support for emergent débridement, but it also fails to provide support for elective delay in surgical débridement of open fractures. Most of the studies examined the difference in emergent (<6 hours after injury) versus urgent (<24 hours after injury) débridement of open fractures. However, the studies examined do not provide sufficient information regarding the potential increased risk of infection associated with delay in surgical débridement >24 hours after injury.

It also is important to note that statistical failure to show a difference between two groups is not the equivalent of showing no difference between them. A small difference in infection rates between emergent and urgent débridement groups could potentially require much larger numbers of patients than any study thus far has been able to include. Further complicating such an analysis is the number of confounding variables contributing to the same outcome variable: infection. Any valid analysis of the role of time to débridement must control for local injury severity, total body injury (including degree of shock and resuscitation), and patient comorbidities. One way to control for a great number of confounding variables is to use a prospective, randomized study design. Such a study, however, would be potentially extremely difficult to design and administer, considering the multitude of factors that naturally influence time to surgical débridement in the typical clinical setting.

Summary

Considering that a definitive prospective, randomized study may be difficult to achieve, clinical practice should be based on the best available information and applied in the context of the entirety of the patient's medical condition. Therefore, we recommend that débridement of open fractures be accomplished urgently, once the patient's medical condition has been stabilized, once life-threatening emergencies have been surgically or medically addressed, and once appropriate surgical resources are available, including an adequately trained and qualified operating room staff, appropriate assistance, and an adequately prepared surgeon. Neither emergent surgical intervention in the absence of physiologic stability nor prolonged elective delay is supported by the available literature or otherwise warranted in the management of open fractures.

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Evidence-based Medicine: There are two level I prospective, randomized studies cited (references 12 and 23). The remaining references are case-control and cohort studies, retrospective analyses of case series, or level V expert opinion (reference 1).

Citation numbers printed in **bold type** indicate references published within the past 5 years.

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