The Rate of Non Union in High Velocity Missile Open Limb Fractures and the Factors Influencing It: a 5 Year Retrospective and Prospective Study from Medical City in Baghdad(part 1)

Ali Bakir Al-Hilli

ABSTRACT :

BACKGROUND:

High velocity missile injuries (HVMIs) are increasing among civilians, the mechanism causing such injuries are totally different from blunt trauma. These injuries associated with complications such as soft tissue injury, vascular injury, infection and nonunion. in addition to systemic, economic and psychological complications.

OBJECTIVE :

A retrospective and prospective review of case series aimed to conclude the rate of non union in HVM fractures, and to explore the important factors that increase this risk (timing, severity, Infection, and non-steroidal anti-inflammatory drugs).

In this part of the study we will discuss the effect of severity, timing of wound debridment and infection.

PATIENTS AND METHOD:

A 109 limb injuries in 97 patients (victims of high velocity missiles) treated at Orthopedic department in Medical City in Baghdad/Iraq in the period 2004-2008 were studied. Data for timing of surgical management, severity, deep infection rate, nonunion, drug administration and smoking were collected from medical city records, patient questionnaire and follow up in outpatient department both clinically and radiologically for a minimum of one year.

RESULTS:

The rate of non union was 29.36%, and the rate of deep infection was 28.44%, the most important factor affecting non union is infection, nonunion associated with infection in 50% of nonunion (infection increases the risk of nonunion three times), Severity(minor, moderate and severe) is another important factor the rate of nonunion was 26.51% in moderate and 38.46% in severe injuries, infection was 25.30% in moderate and 38.46% in severe injuries.

Timing of debridment in our study showed no effect on the rate of non union or infection (nonunion rate was 28.57% and infection was 30.35% if debridment done less than 6 hours after injury and 30.19% nonunion and 26.41% infections for more than 6 hours after injury treated group).

CONCLUSION:

HVMIs causing severe types of open fractures, with high rate of non union and infection. Severity of the injury increases the risk of nonunion and infection. Infection increases nonunion risk three times, and there is no effect of timing of surgical management on the rate of nonunion or infection.

KEY WORDS: high velocity missiles,compound limb fractures,non union,severity,deep infection, timing.

INTRODUCTION:

High velocity missile injuries are very common now it is not peculiar things to battle fields because in certain parts of the world explosives and other weapons are used by terrorists; these injuries are one of the important causes of open fractures.

Orthopaedic and Trauma Senior Lecturer, College of Medicine/Baghdad University.

The pathophysiology of such injuries is different from compound fractures in blunt trauma such as that caused by road traffic accidents or fall from height the difference mainly in the severity and the extensive tissue damage associated with high velocity missiles and the associated cavitational effect that lead to a major disproportion between the size of the original wounds and the underlying soft tissue damage.

As encountered in civilian practice, wounds are of three distinct types:

1-Low-velocity pistol or rifle wounds (Low velocity=Less than 2000 feet/sec).

2- High-velocity rifle wounds (High velocity=More than 2000 feet/sec).

3-Close range shotgun wounds[1,2].

More important is the efficiency of energy transfer, which is dependent on the projectile's physical characteristics including deformation and fragmentation, kinetic energy, stability, entrance profile, path traveled through the body, and the biologic characteristics of the tissues[3].

High-velocity missiles such as shell fragments, land mines and rifle bullets produce damage by laceration, crushing, shock wave and cavitational effect while low velocity missiles produce damage by laceration and crushing only[3,4].

The economic impact of gunshot trauma also is high: it is the third most costly etiology of injury (first among causes of fatal injury) and the fourth most expensive form of hospitalization [5].

There are many factors play together to produce the early , intermediate and late effects of HVMIs, many articles talked about the effect of severity of the wound on the final outcome and complication rate in addition to effectiveness of triage and evacuation of the victims, early and good resuscitation, administration of antibiotics , timing of wound debridment, mechanical stabilization of these fractures, early wound coverage and rehabilitation of the injured limb and the patient as whole to minimize the psychological and economical effects, all these factors play early and late to cause the complications which could be devastating and retarding factors to the patient and his community.

Nonunion was defined as a fracture with radiographic features, including persistent fracture line, lack of bridging trabeculae, or cortical continuity on more than one cortex, and with these radiographic findings remained unchanged on sequential follow up X-ray studies[6], and nonunion may result in bone lying adjacent to bone without continuity, despite large amount of callus, another form of nonunion is referred to as psudoarthrosis, in which cartilage appears in between or around the fracture fragments. The cartilage is usually not hyaline cartilage and often has a markedly increased concentration of type I collagen rather than type II [7].

There are many explanations for fractures healing slowly or at times not at all. These include an inadequate or badly damaged blood supply; anemia; elderly or chronically ill patient with osteoporosis or osteonecrosis; patients with diabetes or any array of genetic disturbance affecting bone strength and healing; malnutrition, steroid, and anticoagulant use; cigarette smoking and alcoholism; excessive damage to soft tissue and/or bone; wound infection; prior radiation treatment; and immune failures, such as with medications, autoimmune deficiency syndrome, etc. [7,8,9,10,11]

Infection is another important complication associated with high velocity missile injuries whether early or late infections this could be a life threatening to the patient and may increase the late local complications such as nonunion of fractures and chronic osteomyelitis, or general complications.

It was concluded that injuries caused by high-velocity missiles (greater than 2000 feet per second), have notoriously high rates of infection [8, 9].

The standard recommendations for treatment of such injuries include wide and thorough wound debridment with the removal of foreign material, fracture stabilization, and administration of 48 to 72 hours of intravenous antibiotics [10, 11].

Severity of the injuries is another important factor in the management of compound fractures in general, and it was shown that the rate of infection and nonunions increases as the grade of tissue damage increases.

Most texts recommend surgical debridment within 6 to 8 hours of injury for any open fracture, The American College of surgeons committee on trauma, in its resources for optimal care of the injured patients, indicates 6 hours as the benchmark for time from injury to debridment of open fractures in trauma centers [12, 13], but there were no many supporting data for early management and in the recent years many publications discuss the idea of no time effect on the rate of infection and nonunion [14, 15, 16, 17].

PATIENTS AND METHODS:

In the period between 2004-2008 in Medical city (tertiary center)/Baghdad/Iraq we treated more than 900 patients who are victims of the conflict in Iraq most of them had injuries due to gun shots, rifles and missile injuries (high or low velocities), in this retrospective and prospective study we include only the high velocity injuries and those who are free from any medical comorbidities and available for follow up in the outpatient department in medical city and we selected 97 patients(85 male and 12 female) with 109 open limb fractures their age between 12-66 years, most of the injuries are leg (tibia with or without fibulae) 57, thigh (femur) 33, arm (Humerus) 13 and forearm (radius and ulna) 6 cases (table 1and 2).

Table 1: Total number of injuries

Upper limb injuries		Lower limb injuries	
Humerus	Radius and ulna	Femur	Tibia
13	٦	٣٣	٥٧

Table 2: Age distribution.

Age (years)	10-20	21-30	31-60	61-more
No. of injuries	6	58	43	2

The classification of missiles injuries (grading system) [4]:

1- *Minor*: only soft tissue involvement no bony, vascular, or neural injury, with or without retained metal (shrapnel or gunshot fragments).

2- *Moderate*: soft tissue involvement, nondisplaced or drill fracture, no vascular or neural injury, with or with out retention of metal.

3- *Severe*: soft tissue injury, severely displaced, comminuted fracture, usually with retained single or multiple metallic fragments, with vascular or neural injury or both.

4-*Avulsive*: extensive soft tissue damage, bone loss associated vascular or neural injury.

Thus the elements that define severity of injury are [4]:

1- The degree of soft tissue damage.

2- Bone defect or severe comminution.

3- Vascular or neural injury.

Our injuries were 83 injury moderate and 26 injury were severe.

All the patients treated first in the emergency department at Medical City, resuscitation, splinting the injured limb, pain killer, triple antibiotics and ATS (not all our patients received ATS because of drug shortage) and then we did radiological assessment to decide the need for mechanical stabilization of these injuries. The patients (97 patients) then transferred to the orthopedic department where surgical wound debridment and skeletal stabilization were done for 56 injuries with in 6 hours and less from the time of accident and 53 injuries were treated 7 hours and more, the cause of that delay was mostly due to delay in transfer of the patient from other cities in Iraq or other centers where medical facilities are deficient, and few of them delayed because of unavailability of certain supplies such as anesthetic drugs or skeletal stabilization products due to the bad security situation in Baghdad.

After surgical treatment the patients either stayed in the orthopedic ward (for maximum two weeks) or transferred to the plastic surgery department for soft tissue coverage and then our patients followed up at our outpatient department clinically and radiologically for a one year minimum.

We don’t have dependable records for the treatment with anticoagulants but some of our patients had been received prophylactic and postoperative antibiotics, anticoagulants in the form of subcutaneous heparin because they had risk factors for venous thrombosis.

Superficial infection was defined as the presence of cellulitis or pus involving the soft tissue area of the traumatic wound in the absence of clinical or radiological features of osteomyelitis that required antibiotic treatment or surgical intervention, and deep infection was defined as the development of osteomyelitis diagnosed clinically (development of chronic discharging sinus) or radiologically, that required surgical bone debridment. The microbiological culture was not considered essential for the diagnosis of superficial or deep infection but it is used essentially in the treatment of infection [15].

Nonunion was defined as a clinically and radiographically failure of fracture healing for more than 6 months that required additional rocedures to achieve union as determined by the attending surgeon [6].

Forty five (out of 97) of our patients were smokers, patients smoking ten cigarettes or more per day were considered regular smokers (we will discuss the effect of smoking and drugs in the second part of this study).

Source of Funding: no external funding source.

RESULTS:

The rate of nonunion in our patients was 29.36% (32 fractures out of 109) (table 3).

Table 3: The rate of nonunion.

And the rate of deep infection was 28.44% (31 wounds out of 109) (table 4).

Nonunion				
	Frequency	Percent	Cumulative frequency	Cumulative percent %
Union	77	70.64	77	70.64
Nonunion	32	29.36	109	100.00

Table 4: The rate of deep infection.

The anatomical location of each injury and the

Infection				
	Frequency	Percent %	Cumulative frequency	Cumulative percent
No infection	78	71.56	78	71.56
Infection	31	28.44	109	100.00

frequency of nonunions and infections per site are well shown in table (5) below:

Table 5: No. of infections and nonunion according to anatomical location.

Site	Frequency	Nonunion	Infection	Nonunion +Infection
Humerus	13	٣	٣	2
Radius and ulna	٦	٠	١	٠
Femur	٣٣	٩	٩	٤
Tibia	٥٧	٢٠	١٨	١٠
Total no.	109	32	31	١٦

As shown in table 5 most of the injuries were leg (tibia with or without fibula) 57 case out of 109, then femur, Humerus and forearm (radius and ulna), with more nonunions in the tibia(35.08%) then femur (27.27%), Humerus (23.07%) then radius and ulna (0%). Deep infection rate was more in the tibia (31.57%), femur (27.27%), Humerus (23.07%) then radius and ulna(16.66%), there were 50% of the nonunion tibiae with associated infection.

Nonunion rate for patients treated 6 hours and less from the time of injury was 28.57%(16 injury out of 56), and in patients treated more than 6 hours was 30.19% (16 injury out of 53), so the effect of early surgical treatment on nonunion rate was not an important factor , as well as the effect of timing on deep infection rate, the 56 injury treated 6 hours and less from the injury had 30.35% infection and the 53 injury treated more than 6 hours had 26.41% infection (table 6 and 7).

Table 6: The relation between union and timing of surgical treatment.

0-6 hours		7 hours and more	
Union	Nonunion	Union	Nonunion
40	16	37	16
56		٥٣	
71.43%	28.57%	69.81%	30.19%

Table 7: Infection rate relation with timing of surgical debridment.

Time from injury to operating room	Less than 6 hours	More than 6 hours
Total injuries	56	53
Total infections	17	14
Percent infection	30.35%	26.41%

The more severe injury the more rate of nonunion and infection as shown in table (8),

Table 8: Severity increases the rate of nonunion and infection.

Severity		Nonunion		Infection	
Grade	Frequency	Frequency	Percentage	Frequency	Percentage
Moderate	83	22	26.51%	21	25.30%
Severe	26	10	38.46%	10	38.46%
Total	109	32		31	

we had 22 nonunions out of 83 moderate injuries (26.51%), and 10 nonunions out of 26 severe injuries (38.46%), so we can conclude that the rate of nonunion increases with more severe injuries. We had 21 deep infections out of 83 moderate injuries (25.30%) and 10 deep infections out of 26 severe injuries (38.46%), this result is expected for both nonunion and infection (Odd ratio 1.472).

Infection was the most important factor increasing the rate of nonunion in our patients; the association between nonunion and deep infection was observed in 16 out of 32 nonunions (50%) ,(the odd ratio is 4.432) so infected fractures have three times risk of developing nonunion (table 9, 10).

Table 9: The percentage of infections in nonunions

Nonunion		Infection		Nonunion + Infection	
Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
32	29.36%	31	28.44%	16	50%

Table 10: Odds ratio when nonunion is a response variable.

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
infection	4.432	1.6684	11.666
severity	1.472	0.548	3.950

DISCUSSION:

Compound limb fractures due to high velocity missiles represent a major challenge to orthopedic surgeons due to increase in local and systemic complications, In our opinion nonunion and infection are the most important two local complications.

In Iraq we don't have statistical studies about the cost of treating compound fractures and their complications but it is obvious that the cost of these injuries comes from; the cost of operating room, instruments used to fix the fractures, the cost of hospital stay usually those patients stay between one week and four weeks (in our facilities), and the cost of treating the complications of these injuries.

A study from US shows that the average cost for patients suffering from fractures following motor vehicle accidents has been estimated at US$10,000 per case. Nonunions cost about US$25,000; the estimate varies according to the location of the fracture site (Humerus<Tibia< Femur) [18, 19, 20].

So we can imagine that nonunion carries more than double costs and it is a critical economic problem to the community and also the patient.

In our study we found that the rate of nonunion for compound limb fractures due to high velocity missiles was 29.36 %(32 nonunions from 109 injuries), and the rate of deep infections was 28.44% these high rates are expected for injuries due to high velocity missiles.

Because femoral nonunions occur infrequently, several studies have attempted to pool data from multiple bones in an attempt to identify risk factors for nonunion (as we did in our study). Malik,et al in a review of 221 tibial, femoral, and humeral fractures and occurrence of nonunions identified nonunions in 14.2% but the patients he included in this review had fractures due to many causes including closed and opened and all treated by intramedullary fixation [21].

Severity of the injuries in compound fractures is a very important in deciding the rate of nonunion and infections, in a retrospective study Brian J. Harley, et al, (University of Alberta Hospital, Edmonton, Alberta, Canada) collected 241 open long bone fractures and found that the rate of deep infection was in Grade I = 2%, Grade II = 6% and Grade III = 22%, and they found that the rate of nonunion Grade I= 5%, Grade II = 14% and Grade III= 37%, in Brian's study most of the injuries are due to causes rather than missiles and bullet and such injuries were the least, also their study shows that patients who had a longer duration of antibiotic treatment were more likely to develop nonunion [14], we couldn't find the cause of that possibly the patients treated with antibiotics for a long time are more prone for drug resistance, they develop infections by virulent micro-organisms and their infections are more resistance to treatment and produce severe tissue damage and stay longer, possibly this will increase the risk of nonunion in those patients, but in the previous study the causes of compound fractures were mostly blunt trauma and we can not classify the HVMIs as blunt trauma injuries because of the pathophysiology is different as mentioned before, all high velocity missile injuries are considered as type III in severity according to Gustilo classification, i.e. all missile injuries should be treated as severe open injuries, and also close range shotgun injuries, although the missiles may be technically low velocity are treated as high-velocity wounds because the mass of shot transfers large quantities of injury to the tissues[22], but there is a misleading point, the entry of the bullet or blast fragments could be small but the internal damage is huge so we tried to study each case in isolation and we documented the injuries before and after surgical treatment.

In our opinion the cavitational effect of high velocity missiles usually made any classification system beyond the true estimation of the damage and there are many inter and intra observer variation in deciding the severity, even with the widespread use of the Gustilo classification for open fractures in blunt trauma, interobserver agreement has been reported to be only 60% [23] .

The Gustilo classification system also has prognostic significance; increasing infection rates and worse outcomes are associated with increasing severity of injury, Infection rates range from zero to 2% for type I fractures, 2% to 10% for type II fractures, and 10% to 50% for type III fractures [24], this is also applied for HVMIs whatever the suitable classification system used we noticed an increase in the rate of infection and nonunion with more severe grades of injury.

The source of infection in high velocity missile injuries comes from different factors, as contrary to popular belief, bullets are not sterilized on discharge [9, 10, 25, 26, 27, 28, 29, 30].

Additional sources of infection include clothing fragments, skin flora, and other contaminants, therefore, primary wound closure is contraindicated [2, 3, 22].

For example Infection of an open tibia fracture is a serious complication that can lead to significant morbidity, delayed union or nonunion, and even amputation. In the absence of antibiotic prophylaxis, infection occurs in approximately 24% of open fractures [31].

Cultures from the wounds were not done primarily; we did cultures only for infected wounds. Studies suggest that there is no benefit in obtaining preoperative or intraoperative cultures of open tibia fracture wounds. In early studies, routine wound culture indicated that 8%of predébridement wound cultures resulted in infection [9,32] ,However, many subsequent studies have demonstrated that initial wound cultures in the early post fracture setting are ineffective in predicting either infection or the identity of causative organism [9, 32]. Additionally, postdébridement wound cultures fail to isolate the infecting organism in 58% of cases. Thus, early post fracture wound cultures are not routinely recommended. In general, wound culture should be obtained only through sterile technique when clinical signs of infection are present [33].

Although definitions vary, infected nonunion has been defined as a state of failure of union and persistence of infection at the fracture site for 6 to 8 months [34, 35].

Early resuscitation of the patients and antibiotic administration which seems to be so crucial in the management of HVMIs (all our patients received triple single dose of antibiotics in the emergency department (ampicilline, with gentamycine and metronidazole) because we considered high velocity missile injuries as potentially infected wounds, but all of them continue to receive antibiotics for two weeks minimum.

Antibiotics were long believed to prevent infection in open fractures, However, there was no evidence to support this assumption [36].

However, contamination is not always apparent. In animal studies, Dahlgren and coauthors [37] reported that as many as 60% of wounds can be infected within 12 hours of missile trauma and that the early administration of antibiotics seems to inhibit the bacterial growth associated with delays in debridment, while reducing the amount of subsequent tissue necrosis, also, Patzakis and Wilkins [31] evaluated 1104 open fracture wounds and found that the most important factor in reducing the infection rate was the early administration of antibiotics. Therefore, many authors continue to recommend routine prophylaxis [10, 37, 38, 39, 40, 41, 42, 43].

At least 24 to 48 hours of intravenous antibiotics is recommended after joint penetration, although some authors have advocated a 3-day course of cefazolinand gentamycine[44,45].

Other studies established strong evidence for the efficacy of first-generation cephalosporins in the management of open fractures. However, investigators also concluded that antibiotic prophylaxis should include gram-negative coverage as well, which is suggested but not directly supported by data. Currently, there are insufficient data to conclude that gram-negative prophylaxis is beneficial in the management of open fractures [32, 46, and 47].

The timing of initial surgical debridment of open tibia fractures is controversial. Most current guidelines recommend that debridment be performed within 6 hours of injury [12, 13, and 48].

However, few recent data exist to support this recommendation, which is believed to stem from Friedrich 1898 study of guinea pigs [49].

Most of the current literature is unable to demonstrate a decreased infection rate for open fractures that are initially débrided within 6 hours of injury compared with those débrided later [14,15,16,17,50].

Some suggests that High-energy and contaminated wounds require immediate and aggressive irrigation and debridment, including a thorough search for the presence of foreign material such as clothing and shotgun wadding [51, 52, 53].

Spencer et al [54] in a prospective audit over 5 years study for (142) open long bone fractures between 1996-2001 (The Princess Margaret Hospital, Swindon, UK) they could not demonstrate significant increase in infection rate (10.1% for early wound debridment and 10.8% for late) and all their patients received intravenous antibiotics with in four hours of injury.

Brian_et al [14] in their retrospective review of (241) open fractures; they concluded that the risk of developing an adverse out come was not increased by aggressive debridment/lavage and definitive fixation up to 13 hours from the time of injury when early prophylactic antibiotics administration and open fracture first aid were instituted.

Charalambous et al(UK) [15] in a retrospective study reviewed (383) open tibia fractures and concluded no difference between early and delayed treatment groups with respect to overall infections.
Sungaran et al (Australia)[17] in a retrospective review of (161) open tibia fractures and they indicated no increase in infection rate as 5 infections occurred in 0-6 hours treatment group and no infection in occurred when treatment was delayed by more than 12 hours and they found that the infection correlate with the grade of open injury.
Most surgeons agree that highly contaminated type III open tibia fractures are best treated with urgent surgical debridment and irrigation [33].

CONCLUSION:

HVMIs have a high rate of nonunion and infection, we believe that non union due to high velocity missile injuries is a multifactorial problem.
The rate of nonunion of high velocity missile compound fractures in our study was 29.36%. The rate of deep infection was 28.44%. Severity of the injury increases the rate of nonunion and infection, moderate injuries had 26.51% and severe injuries had 38.46% of nonunions, and regarding infections moderate injuries had 25.30% and severe injuries had 38.46% infections. The rate of deep infection with nonunion was 50%, so infection increases the risk of nonunion by three times. No effect of timing of surgery on nonunion or infection rate. Early resuscitation and antibiotics reduce the complications.

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