# THE OUTCOMES OF DELAYED TREATMENT FOR OPEN FRACTURE DIAPHYSEAL FOREARM

**BY**

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| | |
|---|---|
| HUSM | Hospital Universiti Sains Malaysia |
| sd | Standard deviation |

**Abstrak**

Pengenalan

Kepatahan tulang terbuka dianggap sebagai kecemasan ortopedik dan perlu pembedahan membersihkan luka segera untuk mencegah jangkitan. Walau bagaimanapun disebabkan oleh keadaan tertentu beberapa hospital tidak dapat melaksanakan pembedahan membersihkan luka awal dalam tempoh 12 jam. Tambahan pula, di beberapa hospital pembedahan membersihkan luka ditangguhkan sehingga lebih daripada 48 jam. Tujuan kajian ini untuk mengkaji semula mengenai hasil kepatahan tulang lengan terbuka apabila pembedahan membersihkan luka dilakukan mengikut pada klasifikasi masa yang berbeza

Kaedah

Lima tahun kajian data sekunder mengenai hasil kepatahan tulang lengan terbuka apabila pembedahan membersihkan luka pesakit yang dimasukkan ke pusat kami di antara 2008 dan 2013 pesakit tidak termasuk gred IIIC kepatahan tulang terbuka. Data demografi, masa pembedahan, sebarang jangkitan dan jenis kesembuhan tulang telah direkodkan.

Keputusan

Kami mempunyai 26 kes kepatahan tulang lengan terbuka dengan 10 kes Gred I, tujuh kes Gred II, 8 kes Gred IIIa dan 1 kes Gred IIIb. Dua jangkitan tisu lembut dan satu osteomielitis berlaku apabila pembedahan memebersihkan luka dilakukan selepas 12 jam. Dua kes tulang tidak sembuh berlaku di Gred II dan satu kes tulang tidak sembuh dalam Gred IIIa.

Kesimpulan

Terdapat risiko berkadar jangkitan jika pembedahan membersihkan luka ditangguhkan lebih daripada 12 jam. Risiko tulang tidak sembuh  juga meningkat secara berkadar mengikut gred kepatahan tulang terbuka

**Abstract**

Introduction

Open fractures considered as orthopaedic emergency and need prompt wound debridement to prevent infection. However due to unavoidable circumstances debridement cannot be performed perform within 12 hours. Furthermore, some times wound debridement was delayed up to more than 48 hours. The purpose of this study to review on the outcome of diaphyseal forearm open fracture when wound debridement was performed according different time classification

Methods

A five-year secondary data review on the outcome of diaphyseal forearm open fractures patients admitted to our centre between 2008 and 2013. Patients with grade IIIc open fractures were excluded. Demographic data, time of debridement, present of infection and type of union were recorded.

Results

We had 26 cases of open fracture diaphyseal forearm with 10 cases Grade I, seven cases Grade II, 8 cases Grade IIIa and 1 case Grade IIIb. There was one non union with no soft tissue infection or osteomyelitis among patients with wound debridement done before 12 hours of injury. One soft tissue infection without osteomyelitis cases and one non union case among patients with wound debridement done with 13-24 hours of injury. There was one soft tissue infection with osteomyelitis case and one non union case among patients who had debridement after 24 hours of injury.

Conclusion

There was a proportionate higher risk of infection if wound debridement was delayed more than 12 hours. Osteomyelitis was proportionately higher if wound debridement was done after 24 hours of injury. Non union was proportionately similar if wound debridement was done before 12 hours, within 13-24 or after 24 hours of injury.

# 1.INTRODUCTION

An open fracture breaks the protective barrier provided by the skin and allows communication between the underlying tissue with external environment, resulting in microorganism invasion locally and eventually to the body (Egol KA, 2015).

As a result of a fracture, vascular compromise and soft tissue injury to the injured area may also lead to increased risk of infection and consequently disturb bone healing. The primary aim of open fractures management, is to prevent infection.

Since the era of Hippocratus, debridement has been used as a method to prevent wound infection. According to Gustillo and Anderson, open fractures is considered as an orthopedic emergency and requires prompt wound debridement (Gustilo and Anderson, 1976).

Early teaching recommends wound of open fractures to be debrided within 6-hours to prevent spread of infection due to wound contamination. This was based on laboratory studies by Robinson (Robinson *et al.*, 1989)and Friedrich (Friedrich, 1898); and supported by clinical study Kreder and Armstrong (Kreder and Armstrong, 1995) and Kindsfater (Kindsfater and Jonassen, 1995).

However, challenges such as transportation of patients to referral centers and resuscitation of multiply-injured patient may cause debridement of wounds within six hours not feasible (Pollak *et al.*, 2010a). Certain authors have also started to argue regarding emergency debridement of open fractures within six hours rule as some complex injuries such as Grade IIIb Gustillo Anderson open fractures being managed by inexperienced surgeon and operation theatre staff in the middle of the night when it is to be done with in 6 hours(Spencer *et al.*, 2004).

Recent studies have shown that currently there is little evidence to support the 6 hours-rule Skaggs et al  in their study showed no difference of infection rate between wound debridement done before and after six hours (Skaggs *et al.*, 2005). Bednar in their study also showed delayed  wound debridement within 24 hours of injury did not significantly influence risk of infection (9% for <6 hours versus 3.4% for 7-24 hours) (Bednar and Parikh, 1993).

Instead, many studies however have now shown that risk of infection correlates well with Gustillo and Anderson grading of open fracture instead off time of debridement (Ashford *et al.*, 2004; Bednar and Parikh, 1993; Harley *et al.*, 2002; Spencer *et al.*, 2004). Gustillo and Anderson  in their study showed that infection rate increased with severity of the grade of open fracture with grade III carried risk up to 41%(Gustilo and Anderson, 1976).

In their study Patzakis and Wilkins showed that delaying wound debridement for up to 12 hours was not a factor for infection and administration of early broadspectrum antibiotics was an important factor in reducing infection rate (Patzakis and Wilkins, 1989). This was supported by Gosselin who showed in a meta-analysis that early prophylactic antibiotics can reduce the rate of early infection (Gosselin *et al.*, 2004).

However, the question arises whether by delaying debridement of open fracture will affect bone union. Charalambous in 2004 showed that there we no significant difference if debridement was carried out in less than 6 hours or after 6-hour in treatment for open tibia fractures (Charalambous *et al.*, 2005). The severity of the grading of Gustillo and Anderson open fracture however corrleates well with the risk of non union. As shown by Harley, the strongest predictor for non-union of open fracture were infection and the grade of open fracture (Harley *et al.*, 2002).

In our setting, wound debridement for open fracture is frequently delayed. Therefore the purpose of this study was to evaluate the outcome of open fracture when the wound debridement is delayed. In this study, we focused our study on diaphyseal forearm fracture only as there were little literature regarding the outcome of open fracture diaphyseal forearm and there was no local data regarding this.

## 2.LITERATURE REVIEW

### 2.1Definition

An open fracture is defined as an osseous disruption in which a break in the skin and underlying soft tissue communicates directly with the fracture and its haematoma. The term compound fracture has been previously referred to the same injury but it is archaic(Egol KA, 2015).

Any fracture that are exposed to the environment through breaks in the skin are referred to as open fractures (Court-Brown C, 2015).

Open fracture with soft tissue injuries may have three important consequences (Egol KA, 2015)

1. Bacterial contamination from external from the external environment due to the wound and fracture
2. High energy trauma that crushed, stripped and devitalized soft tissue and bone results in increase susceptibility to infection and problem with healing
3. Loss of the soft tissue cover or envelope affecting fracture immobilization and healing and loss of function from muscle, tendon, vascular, ligament and nerves

## 2.2Etiology

Open fracture occurs as a result of the application of a violent force. The applied kinetic energy ($KE=0.5\ m\ V^2$) is dissipated by the soft tissues and osseous structure (Egol KA, 2015). The kinetic energy (KE) is directly proportional to the mass (m) and the square of velocity (V) of an object at the time of impact.

The magnitude of force can be either high energy or low energy. The high energy can be from road traffic accident, gunshot injuries or fall from height. A simple fall from standing height or rotational injury from sport activity can lead to low energy open fracture.

## 2.3Epidemiology

Open fractures in Edinburgh population in the year 2000 was 3.1% of 5953 fractures (Court-Brown C, 2015). Open fractures most commonly occur in the leg and foot with tibia diaphysis and distal tibia most commonly affected. This is 19.1% and 13.1% respectively.

A 15-year study on adult open fracture incidence showed, the incidence of open fractures was 30.7/100 000 population per year (Court-Brown *et al.*, 2012). The gender proportion for open fracture was 69.1% among male while 30.9% occurred among female with highest incidence of open fracture occurred in male age 15-19. Crush injuries was the commonest cause of upper limb open fractures at 30.5% while road traffic accident was the commonest cause for lower limb open fractures at 15.9%. The majority of open fractures are from low energy trauma while 22.3% of open fractures was cause by road traffic accident and fall form height.

Matos et al also reported open fractures patients caused by motorcycle accident in Brazil mostly were young adult (mean age 32.9 years old) with male gender making up 83.9% of the total cases and mostly involved open fracture of the tibia (Matos *et al.*, 2014).

## 2.4Classification

A number of classification have been developed to classify open fractures including the Gustillo, Tscherne, Orthopedic Trauma Association and Hannover Open Fracture Score. However, Gustillo and Anderson classification of open fractures is the most widely described Veliskakis was the first to grade open fracture according to soft tissue injury in 1959 into 3 grades (Veliskakis, 1959). Gustillo and Anderson refine the classification in 1976 (Gustilo and Anderson, 1976). In 1984 Gustillo et al further revised and updated the classification to its present day classification (Gustilo *et al.*, 1984).

Gustillo and Anderson  retrospectively studied 673 open fractures of long bone in 602 patients to determine the impact of primary versus secondary closure, use of primary internal fixation and routine use of antibiotic in the treatment of open long bone fractures (Gustilo and Anderson, 1976). Then in a prospective study between 1969 and 1975 they studied 352 patients and categorized open fractures into three grade. The grading is based on wound size, degree of contamination and fracture pattern. Grade 1 is wound less than 1cm long and clean. Grade II is laceration wound more than 1cm without extensive soft tissue damage, flap or avulsion. Grade III is either open segmental fracture, open fracture with extensive soft tissue damage or a traumatic amputation. Special consideration in type III is gunshot injury, farmyard injury and any open fracture with vascular injury requiring repair.

In 1984 Gustillo et al (Gustilo *et al.*, 1984)  further classified high energy type III fracture into A, B and C according to the degree of soft tissue injury, vascular injury need repair and worsening prognosis after realizing that Type III open fractures had different outcome in term of infection and union (Gustilo *et al.*, 1984). Type IIIA is open fracture with adequate soft tissue coverage of fracture bone despite extensive soft tissue laceration or flap or high energy trauma regardless of the size of the wound. Type IIIB is open fracture with extensive soft tissue loss with periosteal stripping and bone exposed. This is usually associated with massive contamination. Type IIIC is open fracture associated with vascular injury requiring repair.

Gustillo's contribution was a milestone in management of open fractures as it stressed on the importance on soft tissue injury and wound contamination instead of fractures per se (Court-Brown C, 2015). Gustillo reported infection rate increase with the grade of fracture, this was 1.9% in Grade I open fracture, 8% in Grade II and significantly high in up to 41% in Grade III. Gustillo and Anderson classification gave a good prediction with regards to infection risk and the open fracture type.

However, Gustillo's classification has limited interobserver reliability of up to 60%. Brumback and Jones in a study involving 245 orthopedic surgeons were ask to classify, using videotape and pictures, 12 open fracture according to the Gustillo and Anderson classification. The interobserver agreement was only 60% (Brumback and Jones, 1994). This was because the classification relies on subjective description such as 'extensive tissue loss' and 'significant periosteal stripping' leading to significant variation in the interpretation and evaluation by the surgeons (Court-Brown C, 2015). Another limitation of Gustillo classification was that it does not account for tissue viability and necrosis as surface injury does not reflect deeper soft tissue injuries (Kim and Leopold, 2012). As such open fractures are best classified in the operating room after wound debridement as initial pre-theatre assessment may result underclassification.

Despite these limitations the Gustillo Anderson classification (Table 2.1) is still the most widely used in open fracture classification since the fractures type correlates well with risk of infections and complications (Okike and Bhattacharyya, 2006)

**Table 2.1: Classification of Gustilo Anderson Open Fracture**

| Type | Wound | Level of contamination | Soft tissue injury | Bone injury |
|---|---|---|---|---|
| I | <1cm | Clean | Minimal | Simple, minimal communition |
| II | >1cm | Moderate | Moderate, some muscle damage | Moderate communition |
| IIIa | >10cm | High | Severe with crushing | Usually comminuted;soft tissue coverage of bone possible |
| IIIb | >10cm | High | Very severe loss of cover | Bone cover poor; usually requires soft tissue reconstructive surgery |
| IIIc | Usually >10cm | High | Very severe loss of cover and vascular injury requiring repair | Bone cover poor; usually requires soft tissue reconstructive surgery |

(Court-Brown C, 2015)

### 2.5Antibiotics

Gustillo and Anderson also showed that open fractures wound are contaminated by positive bacterial culture (70%) (Gustilo and Anderson, 1976).

Robinson et al conducted a prospective study of contaminating organism of 89 open fractures. Of those surveyed, 39% were from gram negative and mostly was *Pseudomonas aeruginosa* and the rest was the gram positive Staphylococcus group (Robinson *et al.*, 1989). They concluded that most open fractures wound were already contaminated by community acquired gram negative and staphylococci.

Gustillo and Anderson also recommended that antibiotics in open fractures has a therapeutic function rather prophylactic(Gustilo and Anderson, 1976). In their study, use of antibiotics reduced the infection rate from 11.8% to 2.4%.

#### 2.5.1Choice of antibiotics

Patzakis et al showed that cephalosporin (cephalotin) significantly reduced infection rate compare to penicillin and streptomycin of the infections(PATZAKIS *et al.*, 1974).

In another prospective study, Patzakis reported that if antibiotic started within 3 hours after injury infection rate is 4.7% compare to antibiotics started 3 hours after injury infection rate is 7.4% (Patzakis and Wilkins, 1989). A combination of cephalosporin and aminoglycoside (cefamandole and tobramycin) reduce the infection rate up to 4.5%. The combination of these antibiotics shown to be effective in preventing infections because of their anti-staphylococcal and expanded gram negative coverage. However, monotheraphy with cephalotin showed infection rates of 5.6% which is not significantly different combination therapy.

A meta-analysis of Cochrane database in 2004 support the use first generations of cephalosporin as early as possible in open fractures as most of the contamination is by gram positive organisms (Gosselin *et al.*, 2004).

Glass et al in a retrospective study 2008 noted that most of the deep infections from open fractures grade III tibia is from gram negative and methicillin resistant *Staphylococcu aureus* (MRSA) nosocomial infections (Glass *et al.*, 2011). They proposed a single dose prophylactic antibiotic, gentamicin and teicoplanin, at the time of definitive closure.

East Practice Guidelines Work Group 2011suggest for antibiotic effective for *Staphylococcus aureus* is adequate for grade I and II open fractures (Luchette FA, 2000). While broader gram negative coverage through the addition of aminoglycoside is beneficial in grade III open fractures. High dose penicillin should be added if suspicious fecal/Clostridial contamination such as in farm related injuries.

Recommendation of antibiotics from (Court-Brown C, 2015).

1. Type I and II open fractures first or second generation cephalosporins.
2. Type III to add aminoglycoside.
3. In gross organic or sewage contamination to add high dose of penicillin with or with metronidazole.

The Standard for the Management of Open Fractures of the Lower limbs by British Orthopedic Association and Association of Plastic, Reconstruction and Aesthetic Surgeons Standard for Trauma 2009 antibiotics guideline for open fractures (BOA/BAPRAS Jagdeep Nanchahl, 2009)

1. Give antibiotics as soon as possible

2. Agent of choice co-amixoclav (1.2g 8 hourly) or a cephalosporin (eg cefuroxime 1.5g 8 hourly) continued until first debridement.

3. At the time of first debridement, co-amixoclav (1.2g) or cephalosporin (such as cefuroxime 1.5g) and gentamicin (1.5mg/kg) should be administered and co-amixoclav/cephalosporin continued until soft tissue closer or for a maximum 72 hours whichever is sooner.

4. Gentamicin (1.5mg/kg) and either vancomycin 1g or teicoplanin 800mg should be administered on induction of anesthesia at the time of skeletal stabilization and definitive soft tissue closure. These should not be continued post operatively. Ideally start the vancomycin infusion 90 minutes at least before surgery.

5. True penicillin allergy (anaphylaxis) clindamycin (600mg iv preop/qds) in place of co-amoxiclav or cephalosporin. Lesser allergic reaction penicillin (rash etc) cephalosporin considered to be safe and is agent of choice.

### 2.5.2Duration of antibiotics

Patzakis and Wilkins 1989 (Patzakis and Wilkins, 1989) recommend duration of antibiotics maximum of three days in view there is no difference antibiotic given for either three, five or ten days in their study.

In a double blinded prospective study by (Dellinger *et al.*, 1988) Delllinger et al showed short course of one day was not inferior to prolonged course of five days antibiotics.

Zalavras et al (Zalavras and Patzakis, 2003) suggested for three days of antibiotics and additional three days for subsequent procedures such as bone graft or wound closure.

East Practice Guidelines Work Group 2011 (Luchette FA, 2000) recommend for grade I and II open fractures antibiotics be discontinued after 24 hours of wound closure. For grade III open fractures antibiotics should continue for 72 hours or not more than 24 hours after soft tissue cover of the wound.

BOA/BAPRAS(BOA/BAPRAS Jagdeep Nanchahl, 2009) suggest of not more than 24 hours of antibiotics for open fractures grade I. For grade II and grade III antibiotics should continue until definitive soft tissue cover or for a maximum of 72 hours whichever is shorter.

## 2.6Tetanus prophylaxis

*Clostridium tetanus* is an anaerobic gram positive bacillus and a spore forming bacteria. The spores can be found in soil and animal faeces. *Clostridium tetanus* itself is heat sensitive and cannot survive in oxygen environment however it's spore is resistant to heat and antiseptic. The tetanus toxoid and tetanus immunoglobulin are used to enhance immunity towards *Clostridium tetani*. Table below show indication for tetanus vaccine and tetanus immunoglobulin.

Table 2.2 **Type of tetanus prophylaxis**

| | Clean minor wound | | All other wounds* | |
|---|---|---|---|---|
| Vaccination history | Vaccine | TIG | Vaccine | TIG |
| Unknown or incomplete | Yes | No | Yes | Yes |
| Complete 3 doses | Yes[1] | No | Yes[2] | No |

Taken from http://www.cdc.gov/vaccines/pubs/pinkbook/tetanus.html

TIG – tetanus immunoglobulin

Yes[1] – if more than 10 years since the last tetanus toxoid vaccine

Yes[2]- if more than 5 years since the last tetanus toxoid vaccine

## 2.7Wound Irrigation

Wound irrigation is a key component of the effort to prevent infection in open fractures, as it serves to decreases bacterial load and removed foreign body (Okike and Bhattacharyya, 2006). Copious or adequate volume of fluid must be use for irrigation as the solution to pollution is dilution.

Using study by Gainor et al  increasing the volume of irrigation with saline will reduce bacterial contamination but only up to 10L saline, Anglen et al 2001 suggesting irrigation of grade I open fractures 3L, grade II is 6L and 9L for grade III given the availability of 3L irrigation fluid bag (Anglen, 2001).

Crowley et al noted that although studies had shown high pressure pulsatile lavage is more effective in bacterial clearance than low pressure lavage but it has been noted to cause damage to the structure of bone, interfere with healing and to damage soft tissue (Crowley *et al.*, 2007b). He suggests irrigation with low pressure methods and limit the high pressure pulsatile lavage pressure to 50 psi.

Other than sterile saline for irrigation other solutions have been added to saline medium such as antiseptic, antibiotic and surfactant to increase wound healing and prevention of infection.

The most commonly use antiseptic are povidone iodine, chlorohexidine gluconate and hydrogen peroxide (Anglen, 2001). Since antiseptic are effective against broad spectrum of bacteri, fungi and viruses they will help eliminate wound pathogen. However, they also toxic to host cells such as leukocytes, fibroblast and osteocytes which may cause delayed wound healing.

Crowley et al summarise that although animal studies show that irrigation with antibiotics reduce infections rate compare use with saline however there are no well design and control studies to show it effect on human (Crowley *et al.*, 2007b). Beside there are two case report of bacitracin causing anaphylaxis reaction after irrigation in surgical procedure. Using antibiotics also costly and promotion of antibiotics resistance.

Koch use soap solutions to clean open wounds before the widespread use of antibiotics. Soap belong category to surfactant. Surfactant function by disrupting the hydrophobic or electrostatic forces that drives initial stages of bacterial adhesion (Anglen, 2001). Soap lower the bacterial load in the wound rather than killing them. Angle et al found that there are no differences between nonsterile castile soap and bacitracin on irrigation of lower extremity open fractures in term of infection or bone healing (Anglen, 2005).

**2.8Wound cultures**

Previously wound cultures pre and post debridement were routinely done to identify the microorganism in open fractures (Gustilo and Anderson, 1976). However now most authors began to question the rationale of taking pre debridement wound cultures since most of infecting organism are nosocomial infections not organism that contaminating open fractures wound.

Lee in his retrospective study found only 8% of 226 organism positive in pre debridement wound cultures causing infections and 7% of 106 negative predebridement cultures were infected (Lee, 1997). In infected cases only post debridement cultures only 42% of the infecting organism were positively cultured on post debridement wound culture.

Faisham et al 2001 study the role pre debridement and post wound debridement culture in 33 open fractures tibia noted 40% positive pre wound debridement culture but none developed into infection (Faisham *et al.*, 2001). Twenty-four percent of post debridement culture were positive but only 50% (4 out of 8) of positive post wound debridement develop infection.

A prospective study by Valenziano et al in 2002 only 24% of 114 open fracture wounds had positive pre wound debridement culture(Valenziano *et al.*, 2002). None of the organism cultures from the infected wound were from positive pre debridement culture.

Glass and Carsenti-Ettese et al found that infecting organism of open fracture are mostly nosocomial infection; methicillin resistant *Staphylococcus aureus*, resistant *Pseudomonas, Enterococci and Acinobacter* (Carsenti-Etesse *et al.*, 1999; Glass *et al.*, 2011)

Okike did not recommend obtaining pre and post debridement wound culture as it did not have any values in management of open fractures (Okike and Bhattacharyya, 2006).

## 2.9Debridement

Gustillo and Anderson in their recommendation to treat open fractures as emergency with early debridement and copius irrigation as to prevent deep infection.(Gustilo and Anderson, 1976) The traditional teaching is that debridement must be done within 6 hours of injury to prevent bacteria contamination of the wound becomes colonization and infections. The basis of this is by study of Robinsonson et al who showed that the threshold for open fracture infections is $10^5$ organisms per gram of tissue. The time to reached the count is 5.7hours (Robinson *et al.*, 1989).

This was also influenced by Friedrich in 1898 inoculating guinea pigs wound with mould and dust particle (Friedrich, 1898). He theorized that wound debridement was ineffective after 6 hours since the numbers of microorganism already reach infective after 6 hours.

Kreder and Armstrong in their studies support the 6 hours rule. In a review of fifty-five open fractures tibia in children they had 12% infection rate if debridement done before 6 hours and 25% if debridement done after 6 hours (Kreder and Armstrong, 1995). However, the comment is the number of cases in the debridement group is too small for comparison (2 out of 8).

Debridement within 6 hours also is difficult to achieve for few reasons. Some patients had delayed referral to tertiary centre, optimization of multiple injury patients and not enough operating room time (Pollak *et al.*, 2010b). In their study average time for debridement for patients who was transferred to tertiary centre is 7.3 ±8.7 hours. Similarly, Matos et al had 82% of their open fractures done after 12 hours with average 27.9 hours and most of the patient are referred from rural hospitals (Matos *et al.*, 2015). Ashford et all study in Australian Outback minimum for patients to arrive from a rural hospital is 12 hours (Ashford *et al.*, 2004).

To date there is not much evidence to support the 6 hours' rule. Patzakis and reported infection rates is the same if debridement done less than twelve hours (7% or twenty seven of 396) and after twelve hours (7% or fifty of 708) (Patzakis and Wilkins, 1989).

Harley et al 2002 performed a retrospective reviewed of 215 fractures did not showed significant risk for infections or non-union between fracture debrided before or after 8 hours of injury (Harley *et al.*, 2002). The significant risk for infection are grade III open fractures and lower extremity open fractures. While risk for non-union are infections and grade of open fractures.

Ashford et all showed no difference between infection and non-union if debridement done before or after 6 hours (Ashford *et al.*, 2004). 33 out of 48 fractures in the study were treated after 6 hours with average time for debridement is 9 hours (range from 6-37hours) (Ashford *et al.*, 2004). He also suggested for early antibiotics and meticulous debridement in delayed debridement to achieved good outcomes.

In 2004 Spencer in a prospective study of 142 open fractures with 40% of cases done after 6 hours found no statistically evidence to support the 6 hours' rule (Spencer *et al.*, 2004). They also concluded that open fractures best be treated during normal daytime hours by regular and experienced team with no increases of infection rate if delayed debridement of open fractures is done. Pollak AN in the LEAP study group showed that time to debridement was not a risk factor for infections however delayed time to transfer to tertiary centre is a factor for infections (Pollak *et al.*, 2010a)

**Table 2.3: Summary of studies regarding impact of timing of debridement on infection in open fracture**

| Author | Year | No. of fractures | Time of threshold for wound debridement | Infection rates early vs late debridement |
|---|---|---|---|---|
| Patzakis and Wilkins | 1989 | 1104 | 12H | 6.8% vs 7.1% |
| Kreder and Armstrong | 1995 | 56 | 6H | 12% vs 25% |
| Skaggs et al | 2000 | 118 | 6H | 2.5% vs 6% |
| Harley et al | 2002 | 215 | 8H | 8% vs 7% |
| Ashford et al | 2003 | 46 | 6H | 17% vs 11% |
| Spencer et al | 2004 | 142 | 6H | 10.1% vs 10.8% |

Taken from Crowley(Crowley *et al.*, 2007a)

A meta-analysis of MEDLINE, EMBASE and Cochrane databases by Schenker et al 2012 also showed no increased risk of infection in delayed debridement although debridement is done after 12 hours of injury (Schenker *et al.*, 2012).

Crowley et al following a review of literature conclude that the 6 hours rule should be re-evaluated and they recommend wound debridement should be done at the earliest opportunity that experience orthopedic and plastic surgeon available (Crowley *et al.*, 2007a).

BOA/BAPRAS 2009 states that the wound, soft tissue and bone exsicion (debridement) is performed by senior orthopedic and plastic surgeon working together on a scheduled trauma operating list with normal working hours and within 24hours of the injury unless there is a marine, agricultural or sewage contamination. The rule for 6 hours does not apply to solitary open fracture. Urgent surgery also needed in some multiply injured patients with open (BOA/BAPRAS Jagdeep Nanchahl, 2009).

## 2.10Wound closure

One of controversial issues of open fractures is regarding wound closure. Standard teaching is to leave the wound open and to delayed the closure to a later date. The reason for it is to reduce the risk infection and to prevent gas gangrene (clostridial myonecrosis) which is catastrophic event to the patient that can lead to amputation and death. This practice mostly influences from war surgeons experience when there is no antibiotics available and meticulous wound debridement was not practice (Rajasekaran, 2007).

The major concerns for delay closure of the wound is risk of infection from the organism that penetrate the open fracture wounds during trauma.

Edlich et al 1969 study in animal models found that delayed wound closure reduce the risk of infection and the optimal time for wound closure is day 4 post wound debridement (Edlich *et al.*, 1968).

Gustillo and Anderson in 1976 suggested for primary closure of grade I and II but delayed closure for grade III open fractures. Together with the practice of antibiotics their infection reduces from 11.8% to 2.4% (Gustilo and Anderson, 1976).

Russel et al 1990 (Russell *et al.*, 1990) compare between primary and delayed closure of 90 patients sustaining open tibia factures. They noted there are higher rate of infection and non-union in group treated with primary closure (Russell *et al.*, 1990).

However, with current practice of meticulous debridement and early antibiotics coverage the organism that contaminating open fractures wound are not anymore the one causing infections and wound is assume to be sterile after debridement. As evidence by Faisham et al 2001 none of organism that causing infection were the same organism as in positive pre debridement culture (Faisham *et al.*, 2001). Glass et al 2011 in their retrospective study found that the organism responsible in their deep surgical infections grade IIIB open tibia fracture were nosocomial infections such as methicillin resistant *Staphylococcus aureus*, *Pseudomanas* species and *Acinobacter* species (Glass *et al.,* 2011).

Gustillo and Anderson also noted in their study five of eight infected wounds were nosocomial infections (Gustilo and Anderson, 1976). They concluded "the during long interval such wounds are open, secondary infections, usually from gram negative organism maybe a problem since these organisms are usually difficult to control by antibiotics alone". The findings were similar with Patzakis et al 1989 where nosocomial infections occurred in 18 out of 26 (69%) delayed closure of open grade tibia fractures (Patzakis and Wilkins, 1989).

Since most of the infection of open fractures wound due to nosocomial infection there are trend of primary closure or early cover of the wound to prevent infection. Benson et al 1983 in a double blind prospective study showed infection rate is independent of wound closure (Benson *et al.*, 1983). However, Osterman et al 1994 (Ostermann *et al.*, 1994) showed that delayed closure of wound more than 7 days can lead to increase infections (Ostermann *et al.*, 1994).

DeLong in a review of 119 open fractures divide 6 methods of wound closure depending on the surgeon assessment of the wound after debridement that is immediate primary closure, second look primary closure, delayed primary closure, delayed skin grafts, delayed flap and amputation (DeLong *et al.*, 1999). They found no significance difference in terms of infection rate and union rate between all methods of closure. They concluded that immediate primary closure by experienced surgeons after a thorough debridement does not cause significant increase in delay/nonunion and infections.

Hohman et al 2006 compare between primary and delayed closure within mean of 9 days in low energy open tibia fractures (grade I, II and IIIa) (Hohmann *et al.*, 2007). They conclude that primary closure is a safe option in a properly selected cases.

Rajasekaran et al 2008 had done a primary closure of 173 grade IIIa and IIIb open fractures with strict criteria of debridement performed within 12 hours, no skin loss primarily or secondarily during debridement, skin approximation without tension, no farmyard or sewage contamination, debridement performed to the satisfaction of surgeon and no vascular insufficiency (Rajasekaran *et al.*, 2009). They had good outcome where 91% had no infection and bone union.

Some author advocate for early, if not immediate flap coverage. Godina paper in 1986 revolutinized the free tissue transfer for open fractures (Godina, 1986). He divided five hundred and thirty-two patients into three group. First group underwent free-flap transfer within 72 hours of injury,2$^{nd}$ group underwent free-flap transfer within 72 hours and 3 months after injury while third group underwent free-flap transfer within 3 months and 12.6 years after injury. Flap failure rate was 0.75% in group 1, 12% in group 2 and 9.5% in group 3. Infection rate was 1.5% in group 1, 17.5% in group 2 and 9.5% in group 3. Bone union time was 6.8 months in group 1, 12.3 months in group 2 and 29 months in group 3. This has revolutionized free muscle flap converting an open fracture to a closed fracture in a single stage.

Gopal in a retrospective reviews of 84 open tibia fractures of grade IIIb and IIIc in which 66 fractures underwent radical debridement, early skeletal stabilization and early cover within 72 hours while another 21 fractures underwent delay cover (more than 72 hours) (Gopal *et al.*, 2000). They achieved 6% superficial infection and 9.5% deep infection. Delay in cover (>72hours) was associated with most complications and they recommend