

# HIGH ENERGY TRANSFER MISSILE WOUNDS IN THE SIEGE OF SARAJEVO AND THEIR RELATION TO MINE INJURIES

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## Historical Background

In order to survive as a carnivorous species it was imperative that Homo sapiens hunted efficiently. It is speculative, but distinctly possible, that not only the implements of hunting but also the psychological traits of the chase led to, or at least accentuated, the proclivity of our ancestors to kill and maim their fellows. Our modern fragile and turbulent societies must surely mirror the violence that erupted from conflicts over food, territory and sex.

Because early man possessed both the tendency and the tools for destruction it is not surprising that there is archaeological evidence of injuries and their treatment.

After the invention of representational art around 35,000 BC1 scenes from the early societies are portrayed in the caves of France and Spain but with very few actually showing conflict or wounds<sup>2,3</sup>. Nevertheless even at this early stage in man's history violence is demonstrated as in the wall painting of an individual who has obviously been struck by several arrows (**Fig 1**).

### FIGURE 1

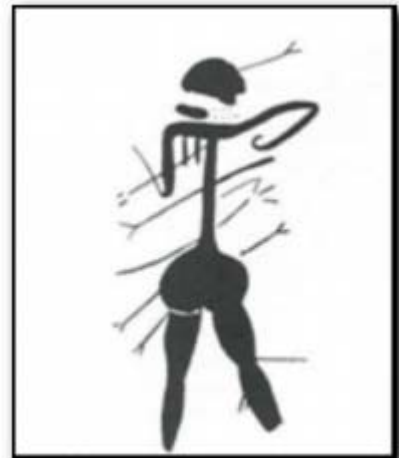
A detail of a cave wall painting from eastern Spain. The victim has been struck by eight arrows and may be trying to extract one. Perhaps the first record of Trauma Surgery! (From the work of H Breuil<sup>4</sup>)

There are also many archaeological examples of primitive and quite complex surgery of which some may even have been effective! As **figure 2** shows some patients survived despite complex interventions because the edges of the trephine hole in the skull are smooth thus demonstrating that bone remodelling occurred over several months after the procedure.

Figure 2 - Ethnological Museum Berlin

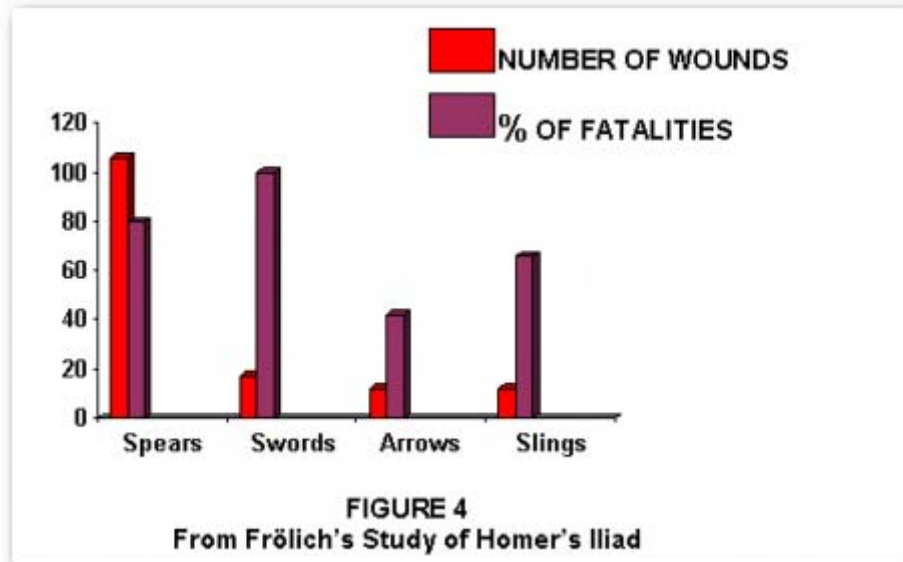


Figure 3 - 5th Century BC sostia bowl in the Berlin Museum.



With a short leap of over 20,000 years we learn that by the time of the siege of Troy it was considered essential for all educated Greeks to understand simple medical care<sup>5</sup>. For instance figure 3 shows Achilles binding the wounds of his comrade Patroclus.

The other information that we have of the Trojan siege is derived mainly from Homer's Iliad in which the author gives detailed accounts of the wounds. Frölich has analysed Homer's work and demonstrated that there was a variation in the number of wounds (in red) caused by each weapon and the percentage of fatalities (in purple)



It is interesting to note that the chance of actually hitting the enemy was greatest with the spear and with a fatality of 80% it was the best of the weapons. The swordsman was more accurate with 100% fatality but was much less likely to hit his opponent who in turn would be close enough to offer a, possibly fatal, response. Slingshots and arrows had a very low hit rate and medium fatality with arrows the worst. This is a startling contrast with the success of the mediaeval English bowmen at Crécy and Agincourt. It surely indicates that technological progress and tactics as well as the English attention to obligatory training played a large part in the development of the bow before explosive weapons replaced it.

This primitive, though bloody form of warfare was changed completely by the invention of explosive devices. Although these were initially an inaccurate and relatively weak form of weaponry they soon developed to combine high hitting potential with lethal precision.

The science of all weapons, and in fact of all injuries, is to direct sufficient energy into biological tissues to disrupt them. All moving particles are possessed of a certain amount of energy and when they are stopped or slowed by an object that energy is transferred to the object and distorts or destroys it. Soft animal tissue is particularly vulnerable and severe wounds occur (figure 5).

Physics tells us that the amount of energy (**E**) within a moving object depends on the combined effect of its mass (**M**) and the velocity (**V**). This applies to a wounding object whether it is a car a bullet or a fragments of a mine. The actual equation is: -

$$\text{Energy (E)} = \text{Mass (M)} \times \text{Velocity (V)}^2 \text{ or } E = M \times V^2$$

By and large the smaller the injuring object in war the more accurate is its path and so the size of antipersonnel weapons were designed to be smaller but to travel at a greatly increased speed hence the effective of a sniper's bullet. The simple mathematics show that with an object of 10 grams travelling at 10 kilometres per minute to double the mass will double the energy by 20 times ( $10 \times 2 = 20$ ) but to double the velocity will increase the energy by 400 times ( $20^2 = 20 \times 20 = 400$ ). Velocity is, therefore, the major factor in determining energy content of a moving particle.

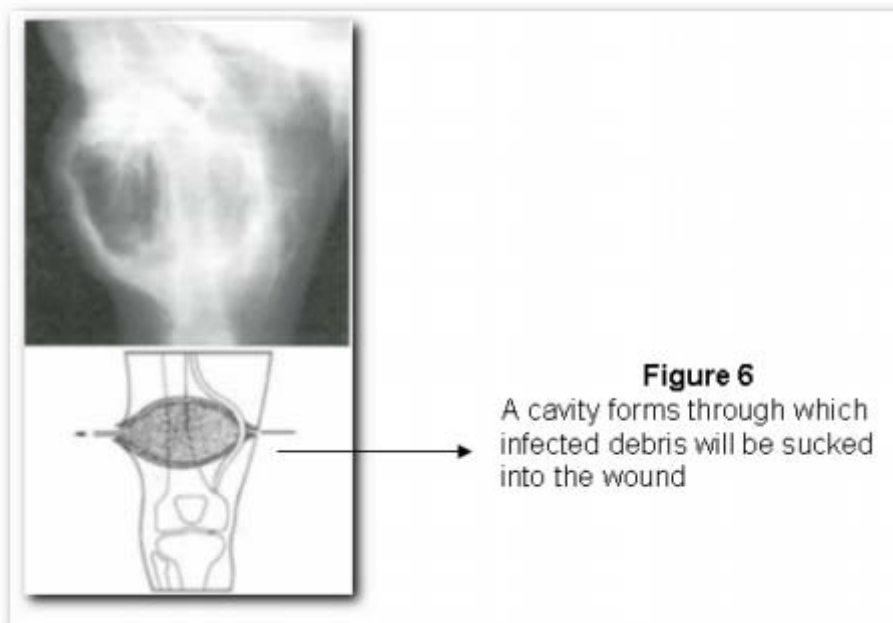
**FIGURE 5**

Mine injury, Sarajevo 1993, in which massive energy from many small moving particles were transferred to the tissues causing wide spread destruction.



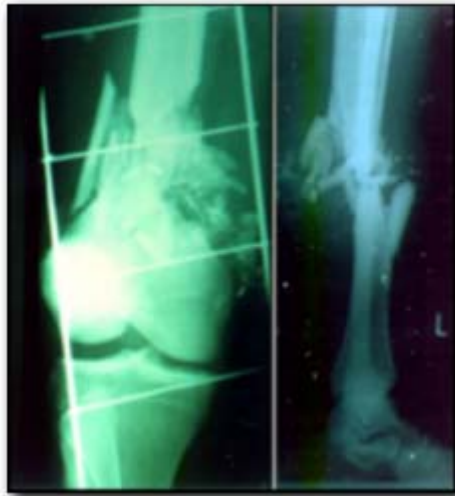
These forms of injuries are designated "High Energy Transfer Wounds"<sup>6</sup> and can occur from any object that moves with sufficient energy. There are particular properties of such injuries apart from the initial, severe wound and these should be considered in detail because they demonstrate why there is a high complication rate even after good initial treatment.

1. Massive tissue destruction is characteristic of such wounds and often the limb cannot be preserved. The missile, whether it is a bullet, a piece of a mine or shell will fragment further and spread violently through the tissues.
2. The high speed of the missile causes cavities to form destroying local tissue beyond the site of the track and creating a vacuum that sucks in infected air and contaminated material from clothes etc (**figure 6**)



3. The wounds are always infected both from the debris of shell or mine fragments and from the material sucked in behind the fast moving particles or bullet.
4. The tissues are literally torn apart from the energy that is released by the particles slowing down and this is independent of the direct effect of the missile debris
5. Injuries to nerves and large blood vessels are ten times more frequent than in peacetime wounds.
6. The patients are usually shocked from blood loss and delay in treatment is often fatal.
7. Complex "shattered bone" fractures usually occur (figure 7).
8. Multiple sites of injury will occur (figure 8)

**FIGURE 7 -**  
These fractures are frequently the sites of chronic bone infection.

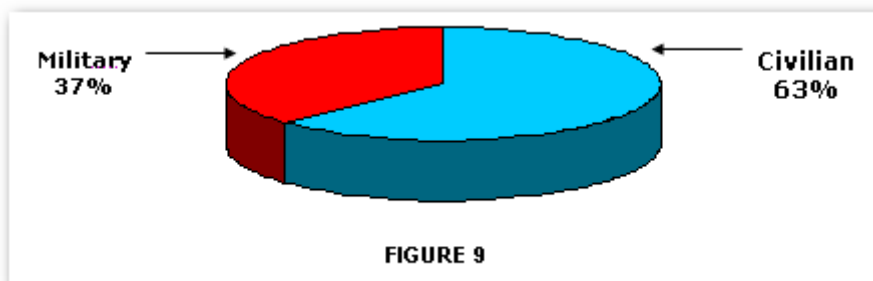


**FIGURE 8**  
Multiple fragment wounds from mine injury Sarajevo 1994.



### The Situation In Besieged Sarajevo 1992-1996

The siege of Sarajevo was the longest in modern times. It was an example of a method of warfare, as old as recorded history, in which attrition is focused on the civilian population with the ultimate aim of attacking the citizens psychologically and physically. As well as wounding and killing, the weapons used are those of fear, uncertainty and deprivation. All will suffer but the sick and elderly, the unborn child and infants and the wounded are particularly vulnerable to starvation and loss of basic amenities. That every one in Sarajevo was effectively in the front line is reflected in the distribution of wounded between military and civilians (figure 9).



In the summer of 1993 the new NGO HMD Response International asked for volunteers from British Orthopaedic and Trauma Surgeons to assist their Sarajevo colleagues. As with all wars nothing went entirely to plan but it began a presence of this NGO in Bosnia that still continues.

By August 1993 the devastation of over a year of war was obvious in the destroyed buildings (figure 9) and the hospital wards filled with patients suffering from complex wounds. Surprisingly, considering the terrible circumstances in which the surgeons had worked, the level of infection was much lower than expected. This was soon to change.

**FIGURE 10** - Battered but defiant Sarajevo State Hospital 1993.



The succeeding months demonstrated the problems from the blockade of food convoys and the effects of a freezing winter. In Sarajevo the temperature ranges from as high as 40 C in summer to -150 in winter. The city is set on a high plateau surrounded by mountains that inhibit air transport and the poor roads, already militarily blockaded, were obstructed by heavy snowfalls.

Medical supplies soon failed and in particular the devices for fixing fractures were exhausted within weeks of the beginning of hostilities. Undeterred a local external fixator was designed by an engineer and two surgeons and produced in Sarajevo throughout the war. This device – the Sarafix (figure 11) – was used in all Bosnia on over 3,000 patients. HMD Response International provided a critical component of the fixture, its surgical steel pins, as part of its support programme for the surgical development.

**FIGURE 11** - Management Of The Soft Tissue Component Of High Energy Wounds



The majority of the wounds treated in the Sarajevo siege were from shell and bullet wounds because the population was confined so severely that to reach mined areas was in itself hazardous. Nevertheless, because of the similarity of high energy transfer wounds the principles of treatment and the complications that occur are entirely relevant to a study of mine injuries



**FIGURE 12**

Typical dirty wounds from mine fragments treated with thorough cleansing and subsequent grafting when infection controlled

War wounds are complex and inevitably infected (composite figure 12). In the early months of the First World War British Army Medical Officers were inexperienced in treating such terrible wounds and a massive number of lethal infections occurred. In 1917 orders were given to remove all dead and foreign material and to never primarily close wounds. The technique is known as debridement from the French to unsaddle or release. This tested method was employed in Sarajevo with great success with the addition of anti tetanus toxin and antibiotics. Injuries near the buttocks were particularly at risk of such infection.

#### Management Of Fractures In High Energy Wounds

Stabilising fractures resulting from such injuries is both imperative and difficult. The fractures are often multiple and very unstable (fig 13) with considerable implanted debris. They must be managed without closure of the wound and must be stabilised to allow treatment of other injuries of the arteries and viscera. External fixation is the first choice but Coupland states<sup>8</sup> that devices can be too complex for adverse war situations. The reliability and simplicity of Sarafix proved ideal for this work.

**FIGURE 13 - Debrided Wound**



The device was used at many sites including complex pelvic injuries with bowel and vascular damage (figures 14 a & b).

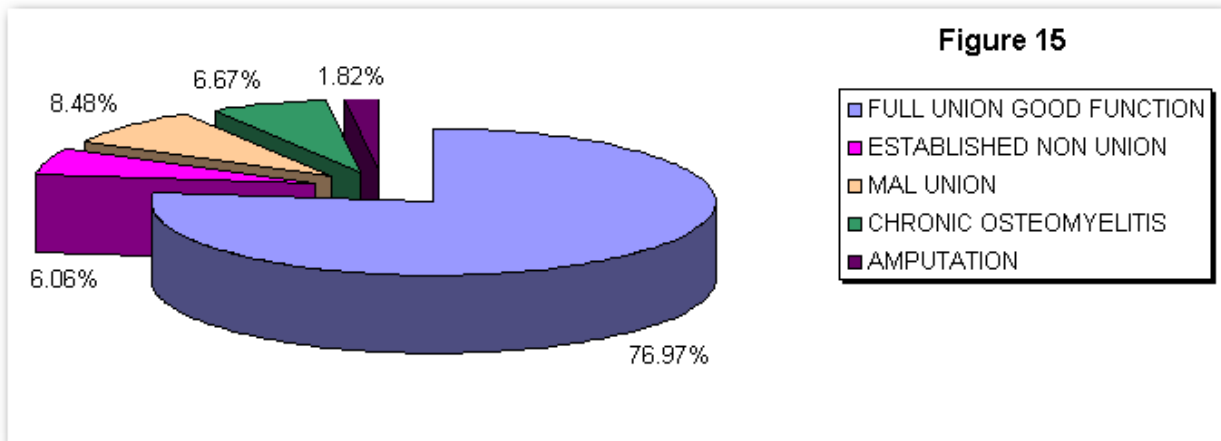
**Figure 14 a** - Notice the wounds are left open



**FIGURE 14 b -** Sarafix stabilises the pelvic and femur fracture while recovery from bowel and arterial injuries progress



Despite the overall success of the Sarafix device (76.97% of a studied cohort) there were inevitable complications as shown in figure 15

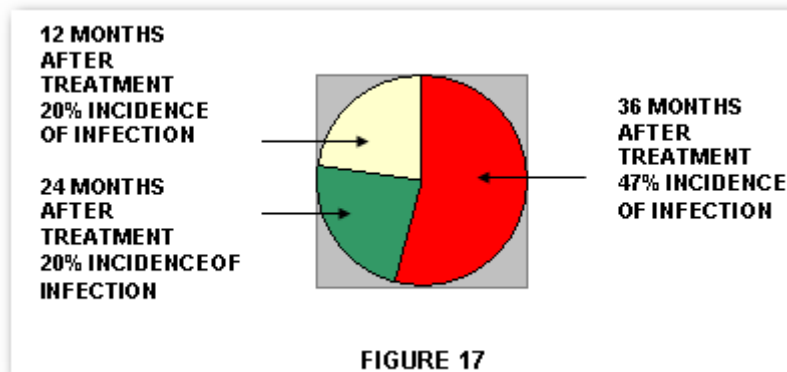


RESULT	%	NUMBER
FULL UNION GOOD FUNCTION	76.97	254
ESTABLISHED NON UNION	6.06	20
MAL UNION	8.48	28
CHRONIC OSTEOMYELITIS	6.67	22
AMPUTATION	1.82	6
<b>TOTAL</b>	<b>100</b>	<b>330</b>

There are no simple complications of these wounds and all cause considerable persistent symptoms that are often permanent. Osteomyelitis (6.67%) has a particularly sinister recurrent and debilitating effect over many years and an estimate suggests that 15,000 Bosnians suffer from this crippling disease.



Gavrankapetanovic and Beavis reported the results of radical treatment of chronic osteomyelitis following Bosnian war injuries and found that after an initial improvement the incidence began to increase considerably after two years figure 17.



### Nutritional Problems in a Siege Situation

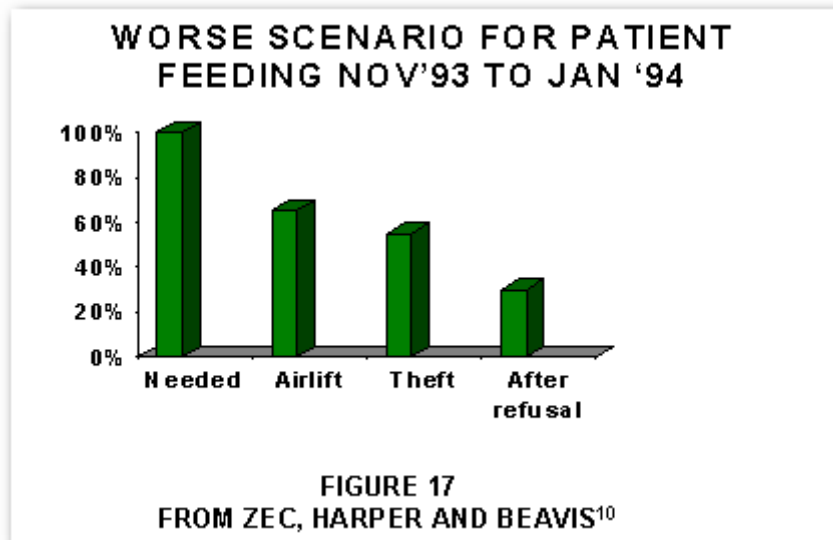
For patients with massive injuries from bullets, shells and mines the effects of starvation and winter cold increased the incidence of infection. A study between September 1993 and January 1994 showed a massive rise in wound infection

It was considered that the injured patient in Sarajevo was at risk from malnutrition for several reasons

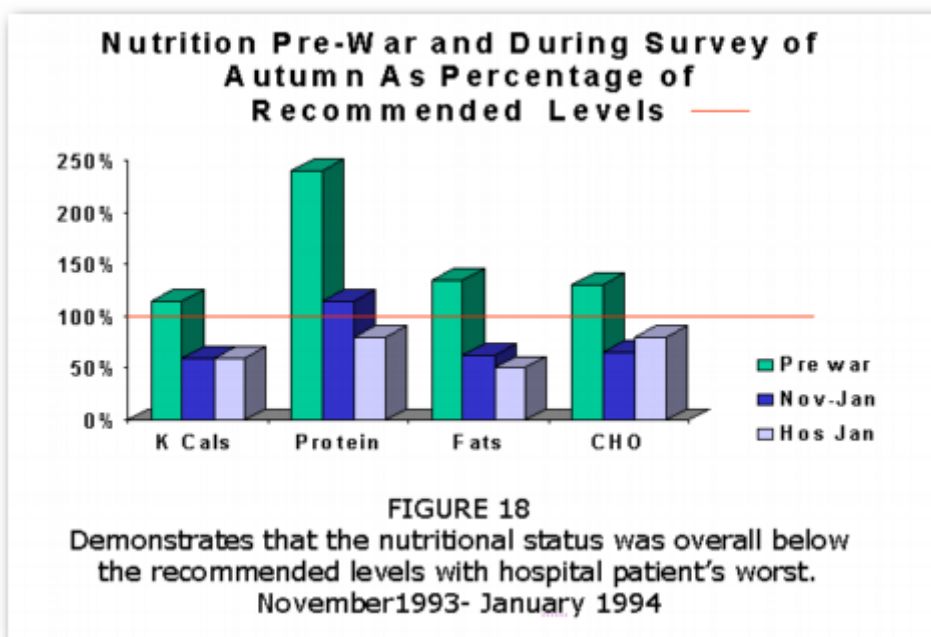
- Poor supply of essential nutrients.
- Increased requirement for protein, carbohydrates and micronutrients because of increased metabolic response to injury.
- Increased requirement for endogenous heat production during winter because of inadequate heating of the wards—5% increase for every 10o drop in temperature.
- Increased demand for nutrition with infection –10% rise in calorie requirement for each 1o rise in body temperature
- The poor circumstances of the patients caused anorexia and depression leading to refusal of food.
- Poor quality food that was unpalatable and rejected.

It is easy to envisage a situation where a severely injured patient -- with a 10% increase in nutritional requirement from the effects of trauma, lying in a ward at 10o with a pyrexia of, say, 39o and suffering from anorexia for the many physical and emotional reasons -- will soon become a victim of malnutrition.

HMD instituted a survey of the relationship between malnutrition and wound infection in Sarajevo between August 1993 and January 1994. Assessment by Zec, Harper and Beavis in 1994 of food delivery in the winter months of the survey (November-January) demonstrated that no more than 60% of the required food would reach the city due to roadblocks and weather preventing air support. As well as blockade there was inevitable loss of food by theft reducing the food to a little over 40% of the required amount. Finally the rejection of food by patients in all hospitals in peaceful circumstances is well recognised as a major problem9 reducing the final amount to 25%. In the Sarajevo hospitals in winter the circumstances of the injured were, despite the best efforts of the staff, truly terrible. It is not surprising therefore that depression anorexia and rejection of unpalatable food contributed to the malnutrition. A graphical scheme of such a scenario is represented in figure 17.

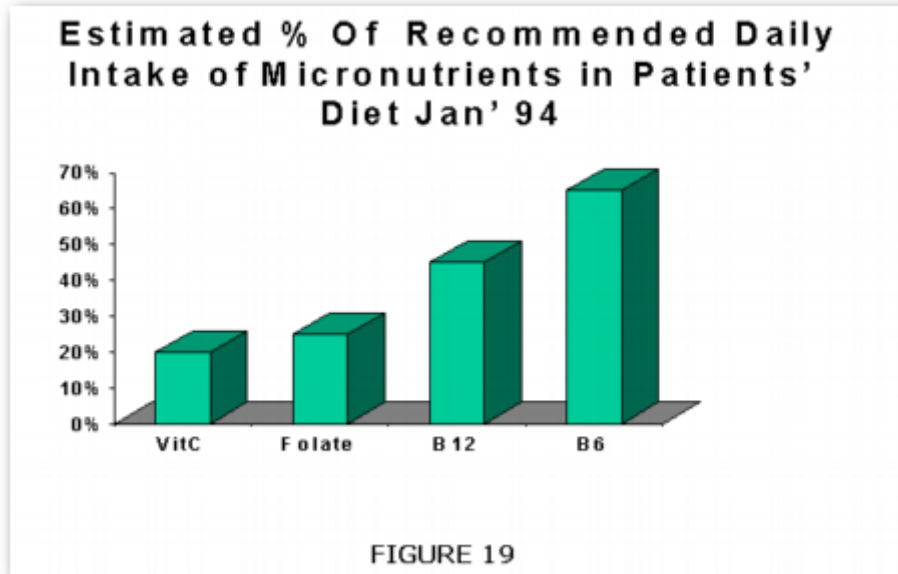


A further HMD study demonstrated that the nutritional requirements of the patients were not satisfied and that this became more obvious as the autumn progressed (figure 18). It can be seen that the pre war nutritional status was in excess of the recommended levels and body weight was also higher than optimum<sup>10</sup>. It is tempting to speculate that the excess of body fat in the Sarajevans protected them from malnutrition during the first severe winter.

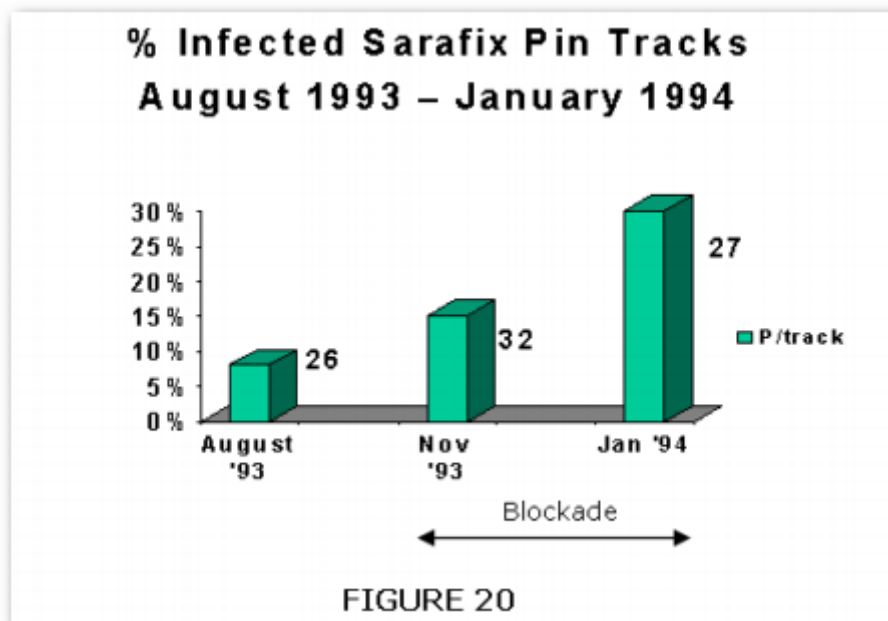


Very significantly dietary micronutrients such as vitamins greatly decreased during the early winter months of 1993/94<sup>11</sup> (figure 19)

As can be seen in figure 19 there are serious deficiencies in the intake of Vitamins C, Folate, B12 and B6 that are essential in tissue repair. Although no cases of scurvy were recorded the potential for it to occur is obvious.



It was important to try to quantify the relationship between the care of patients and the change in nutritional status during the early winter months of 1993/94 and the obvious parameter to review was infection. A direct relationship was observed between the incidence of reduction in food supplies and an increase in wound infection when the pin track sites of the Sarafix device were inspected<sup>11</sup> (figure 20).



Unfortunately extra food could not be brought in by aircraft despite the obvious case that was made for considering the wounded patients as vulnerable.

#### Conclusion

Sarajevo was besieged for nearly four years and during this time the population was subjected to all the terrors of modern warfare and massive deprivation. Demoralising the civilian population by depriving them of their basic needs has always been the aim of besieging armies throughout history and Sarajevo was no exception.

Modern weapons have a primary anti personnel role in civil wars of this nature and the incidence in Sarajevo of high-energy transfer wounds in the civilian population reflects this fact. The well-tried immediate treatment of wound toilet and adequate debridement along with stable fracture fixation proved once again to be effective in producing a satisfactory cohort of results.

The nutritional deprivation was objectively shown to be important in the wounded patients by a significant rise in the infection rate during winter months when the food supply fell well below the required levels. In a war situation where evacuation is not possible and food supplies are precarious then the injured patients must be considered as a vulnerable group. Aid agencies should concentrate on relieving this problem as part of their overall medical aid

strategy.



Mine injuries were not common in the citizens of Sarajevo because enemy snipers and artillery confined them to a very localised life. Military personnel were most likely to be injured by mines during frontline service. Those civilians who were injured by mines had usually left the city for various reasons such as wood collecting for fuel (figure21).

The risks that these unfortunate individuals were prepared to take just to warm their families or obtain meagre amounts of food is an indication of the terrible effects of siege warfare on ordinary people.

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