HISTOLOGIC ANALYSIS OF PIG MUSCLE TISSUE AFTER WOUNDING WITH A HIGH-VELOCITY PROJECTILE – PRELIMINARY REPORT

Želimir Korać, Suad Crnica and Nenad Božić Božo

Department of Surgery, Karlovac General Hospital, Karlovac, Croatia

SUMMARY – Terminal ballistics of high-velocity projectiles is focused primarily on evaluation of the effects of penetrating projectiles on tissue simulants, but there is always a question of their similarity with live tissue. Ethical problems related to using live animals in terminal ballistic researches have resulted in a reduced number of these experiments. The aim of this study was to analyze histologic effects of high-velocity missiles in swine muscle tissue. The hypothesis was that a penetrating projectile caused tissue lesions that could be observed at various distance and at various levels of damage around the wound channel. Hind legs of pigs killed for commercial purposes were used in the study. The time span between killing of pigs and shooting was not longer than half an hour. The shots were made with a Russian AK-74 assault rifle (5.45 mm). A total of 30 fresh swine cadaver legs of an average weight of 15 kg were shot from a distance of 8.5 m. Samples of muscle tissue along the wound channel were collected and analyzed under a light microscope at Department of Histology, School of Veterinary Medicine, University of Zagreb. Muscle tissue analysis revealed four types of findings: normal findings of skeletal muscle, edema between muscle fibers without rupture or bleeding, rupture of individual fibers with bleeding in the interstitium, and massive destruction of muscle fibers with bleeding. Accordingly, the effects of high-velocity projectiles on muscular tissue can be histologically identified in various forms, from edemas to muscle fiber destruction accompanied by bleeding in the interstitium. The extent of particular lesions depends on the distance from the wound channel and projectile behavior.

Key words: *Wounds, gunshot – physiopathology; Wounds, gunshot – therapy; Wounds, penetrating – diagnosis; Muscles – pathology; Military medicine – methods; Comparative study; War; Animals*

Introduction

Terminal ballistics of high-velocity projectiles is focused primarily on evaluation of the effects of penetrating projectiles on tissue simulants (gelatin blocks, clay, soft soap, etc.)[1-5]. Work with tissue simulants is much simpler and cheaper, but there is always a question of their similarity with live tissue. For some decades, a few authors were researching the projectile-tissue interaction using live experimental animals (dogs, pigs)[6-8]. Recently, ethical problems related to using live animals in terminal ballistic researches have resulted in a reduced number of these experiments. All these investigations were performed with the goal to better understand the factors involved in producing missile wounds. The final repercussion would be improvement in the treatment of such wounds, because in the field of wound ballistics there are many different interpretations, misconceptions and various recommendations[9-13].

The aim of the present study was to analyze histologic effects of high-velocity missiles in swine muscle tissue. The hypothesis was that a penetrating projectile caused tissue lesions that could be observed at various distance and at various levels of damage around the wound channel.

Correspondence to: *Želimir Korać, MD, PhD*, Department of Surgery, Karlovac General Hospital, Andrije Štampara 3, HR-47000 Karlovac, Croatia
E-mail: zelimir.korac@ka.t-com.hr

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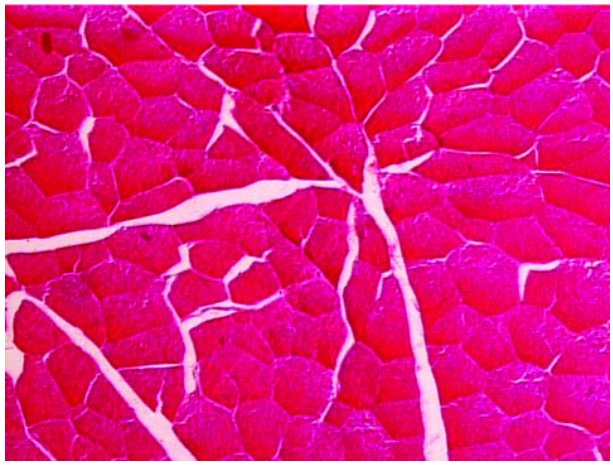

Fig. 1. Normal finding of skeletal muscle.

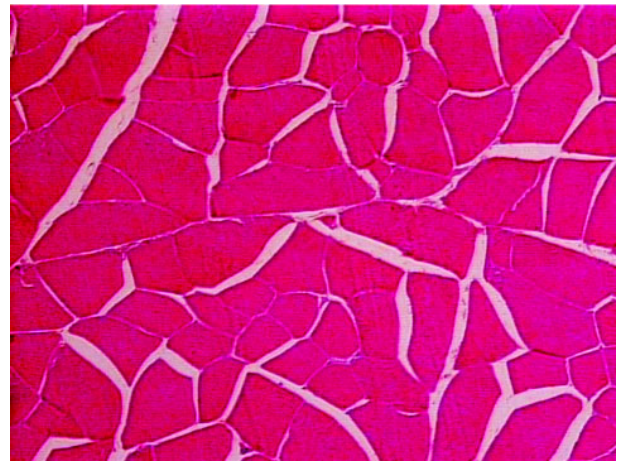

Fig. 2. Edema between muscle fibers without rupture or bleeding.

Materials and Methods

Hind legs of pigs killed for commercial purposes were used in the study. The time span between killing of pigs and shooting was not longer than half an hour. The shots were made with a Russian AK-74 assault rifle (5.45 mm). The projectile velocity at the barrel muzzle as declared by the manufacturer is 900 m/s. The rifle and ammunition are intended for military use, the bullet is declared as resistant to deformation and fragmentation.

A total of 30 fresh swine cadaver legs of an average weight of 15 kg were shot from a distance of 8.5 m. After that the wound channel was first marked and then opened with a knife. Using a scalpel, samples of the muscle tissue along the wound channel (6 samples along the channel) and additional samples at 3 cm from the wound channel were obtained. The samples were put into test tubes with 10% formaldehyde and referred to Department of Histology, School of Veterinary Medicine, University of Zagreb, for further preparation and analysis under a light microscope.

Results

Muscle tissue analysis revealed the following four types of findings: normal findings of skeletal muscle (Fig. 1); edema between muscle fibers without rupture or bleeding (Fig. 2); rupture of individual fibers with bleeding in the interstitium (Fig. 3); and massive destruction of muscle fibers with bleeding (Fig. 4).

Among the samples taken from the wound channel wall there were no findings of normal muscle tissue,

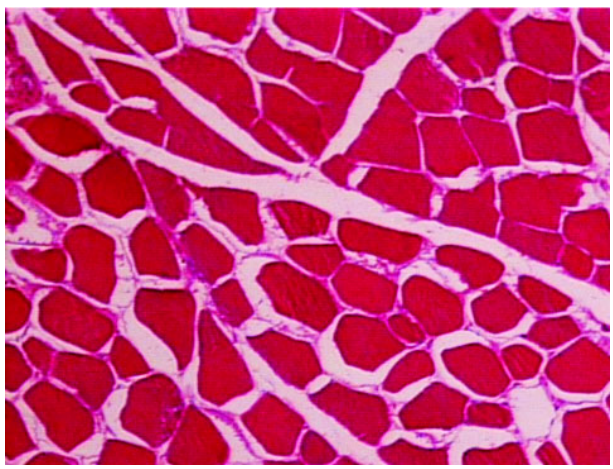

Fig. 3. Rupture of individual fibers, bleeding in the interstitium.

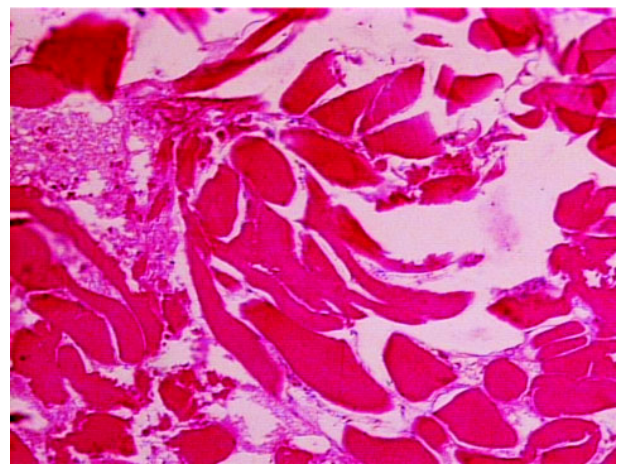

Fig. 4. Massive destruction of muscle fibers with bleeding.

whereas among the samples taken at 3 cm from the wound channel there were no samples with massive destruction of muscle fibers.

Discussion

It was John Hunter (1728-1793), a famous English surgeon and anatomist, who concluded, working as a military surgeon, that a gunshot wound differed from other wounds[14]. Today we consider mainly the problem of energy transfer from the missile into the tissue, i.e. the more energy missile transfers onto the tissue, the greater damage should be expected[15-17].

Therefore, missiles can be divided according to the energy they possess into: (a) missiles of low energy, e.g., knife, needle, etc.; (b) missiles of medium energy, e.g., most guns; and (c) missiles of high energy, e.g., most rifles.

Within every gunshot wound three different zones can be distinguished: (a) the zone of direct trauma necrosis – it is immediately seen and can range from a few millimeters to a few centimeters; (b) the zone of massive quakes – a temporary cavity that depends on numerous ballistic characteristics. In several hours, irreversible changes manifesting as circulation problems, thrombosis and necrosis can develop in the tissue; and (c) the zone of molecular quake – it is caused by molecular movement in the tissue and involves the largest area. Clinically it is seen as an edema. The damaged tissue can fully recover. This fact is of particular importance for the surgeon who needs to determine the volume of tissue excision on primary treatment of the patient.

Until today discussions have been going on concerning the best method of treatment for missile wounds. Some authors claim that too radical debridement of a missile wound (overtreatment) poses a more serious problem due to unnecessary mutilation than minor debridement (undertreatment) that leaves nonviable tissue and focus of infection. In the peacetime comfort of large hospitals, the missile wounds caused by low-velocity and low-energy missiles can often be successfully treated by minimum or no excision and primary stitch, however, in the battlefield such practice would be disastrous for many of the casualties[9,18-20]. Most authors agree that the management of a ballistic missile wound should include excision of devitalized tissue, removal of accessible foreign material, hemostasis, subsequent wound closure, and routine antibiotic prophylaxis[21]. Debridement is still based on the famous four-C criteria: color, consistency, contractility, and circulation.

There is still much controversy in the literature regarding histologic changes in the muscle tissue after missile wounding. Ziervogel performed experiments with dogs that were wounded by a projectile from a 7.62 NATO rifle[22]. After the wounding the dogs underwent surgery under general anesthesia 1.5 hour after wounding. The aim was to achieve the same average time between wounding and surgical intervention as it was in Vietnam. Tissue samples from the wound channel wall and at 2.5 cm and 5 cm from the wound cavity were taken for biopsy. Sample collection and analysis were repeated at 24, 48 and 72 h. The samples were analyzed using an electronic microscope. The results showed that the most extensive muscle damage occurred at the very edge of the wound channel in the samples taken at 1.5 h of the wounding. The degree of muscle damage recorded by electronic microscope was less extensive in the samples taken at 72 h of the wounding compared to the equivalent samples taken at 1.5 h of the wounding. It was concluded that there was no delayed tissue damage; in fact, the recovery mechanisms improved the condition. The results of this experiment suggested that the wounds caused by a projectile from the 7.62 NATO rifle should be managed by excision of overtly devitalized tissue only, while more extensive debridement would not be necessary.

Some other authors find that delay in the wound treatment increases the amount of necrotic tissue. Dalgren *et al.* showed the tissue necrosis to be progressive[23]. As the amount of transferred energy varied slightly, the amounts of debrided tissue had to be commensurated to filter out the effect of this difference.

Our investigation indicated a different degree and amount of muscular tissue damage in the experimental model used. For surgical treatment of such wounds it is necessary to know that only the muscle damage described as massive destruction of muscle fibers with bleeding (Fig. 4) requires debridement of damaged tissues, whereas other histologic changes of the muscular tissue are subject to reparation.

Today there are a huge number of different guns, revolvers, rifles, gun machines and the like on the market, along with differently designed ammunition. Therefore, the number of weapon-missile combinations that are of crucial importance for terminal ballistics is enormous. That is, it is almost impossible to test all the existing weapons and ammunition which can be found on

the market today. Also, it is very common that the wounded are admitted to the hospital without having any information on the kind of weapons they were wounded with. The basis of treatment of each wound is the knowledge of the mechanism of wound infliction and of the pathophysiologic events in the part of the body around the wound as well as in the whole body.

It would be necessary to verify the theory described by collecting accurate information on actual shootings[24]. In addition to describing the injury and the treatment, any firearm injury documentation should therefore include information on the wounding weapon, caliber, bullet type, shooting distance, retained weight of the bullet if possible, and weight of fragments captured and removed from the tissue.

When treating the wounded hit by an unknown missile, the knowledge of terminal ballistics allows for the staff treating the patient get an insight into the character of the wound, which makes the treatment plan much easier.

The research in the field of terminal ballistics involves analysis of the tissue or tissue simulant interaction with the missile[25-27]. Experimental animals were used before; nowadays, due to many complaints of numerous animal protection societies as well as to the cost and demanding application, they have been used less often. Before tests on animals are initiated, two basic questions should be answered: how close the similarity between organ systems of the chosen animal and humans is, and whether it is possible to get a bullet trajectory of an appropriate size. Many common experimental animals such as mice, rats, guinea-pigs, rabbits and so on, are not suitable for ballistic tests because of their small size. On the other hand, horses and cattle are not suitable because of their size, price and built, which cannot adequately simulate human body, thus also being rarely used for experimental purposes. In the past 30 years, pigs have been the most frequently used experimental animals for this purpose, so they are considered the animals of choice.

Terminal ballistics is a very demanding research area. Many phenomena which determine the missile effects on the tissue or tissue simulant have not yet been completely studied. There is no ideal and comprehensive method to follow and exactly document all the events associated with the missile impact on the tissue.

Conclusion

The effects of high-velocity projectiles on muscular tissue can be histologically identified in various forms, from edemas to muscle fiber destruction accompanied by bleeding in the interstitium. The extent of particular lesions depends on the distance from the wound channel and projectile behavior. The treatment of these penetrating wounds includes wound revision and excision of only massively destructed tissue, while other histologic changes are reversible.

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Sažetak

HISTOLOŠKA ANALIZA SVINJSKOG MIŠIĆNOG TKIVA NAKON RANJAVANJA PROJEKTILOM VELIKE BRZINE – PRIVREMENO IZVJEŠĆE

Ž. Korać, S. Crnica i *N. Božić Božo*

Terminalna balistika projektila velike brzine usmjerena je prvenstveno na analizu učinaka projektila u tkivnim simulantima, ali tu se uvijek postavlja pitanje sličnosti sa živim tkivom. Etički problemi uporabe živih životinja u terminalno balističkim istraživanjima rezultirali su smanjenjem broja takovih pokusa. Cilj ove studije bila je analiza histoloških učinaka projektila velike brzine na mišićnom tkivu svinje. Hipoteza je bila da penetrirajući projektil uzrokuje promjene u tkivu koje se mogu promatrati s različitih udaljenosti i u različitim stupnjevima oštećenja oko strijelnog kanala. Za potrebe našega istraživanja upotrijebili smo zadnje noge svinja koje su usmrćene iz komercijalnih razloga. Vremenski razmak između usmrćivanja svinje i prostrjeljivanja nije bio duži od pola sata. Pucalo se je iz ruske automatske puške AK-74 (5,45 mm). Ukupno 30 svinjskih nogu prosječne težine 15 kg je prostrijeljeno s udaljenosti od 8,5 m. Uzimani su uzorci mišićnog tkiva duž strijelnog kanala, a njihova je analiza izvedena na Zavodu za histologiju Veterinarskog fakulteta Sveučilišta u Zagrebu. Analiza mišićnog tkiva pokazala je 4 tipa nalaza: normalni nalaz skeletnog mišića, edem između mišićnih vlakana bez rupture ili krvarenja, rupture pojedinih vlakana s krvarenjem i masivnu destrukciju mišićnih vlakana s krvarenjem. Učinci projektila velike brzine u mišićnom tkivu mogu se histološki raspoznati u različitim oblicima, od edema do destrukcije mišićnih vlakana praćenih krvarenjem u intersticiju. Opseg pojedinih promjena ovisi o udaljenosti od strijelnog kanala i o značajkama projektila.

Ključne riječi: *Rane, prostrijelne – fiziopatologija; Rane, prostrijelne – liječenje; Rane, penetrirajuće – dijagnostika; Mišići – patologija; Vojna medicina – metode; Usporedbena studija; Rat; Životinje*