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Terminal Ballistics of the Russian AK 74 Assault Rifle: Two Wounded Patients and Experimental Findings

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Objective: To study the effects of the Russian AK 74 assault rifle missile (5.45 × 39 mm) on an experimental model and on two wounded patients. Design: Experimental and clinical study. Setting: Brodarski Institute, Marine Research and Special Technologies, Zagreb, Croatia, and General Hospital, Karlovac, Karlovac, Croatia. Materials and Patients: Twenty gelatin blocks used as tissue simulants and two patients with gunshot wounds caused by AK 74 assault rifle missiles. Interventions: After being fired at, gelatin blocks were filmed with a high-speed television camera and radiographs were made of the blocks. Wounds of our patients were treated with minimal excision and drainage. Main Outcome Measures: The correlation between the wound profile method and our experimental model, and the correlation between the wound profile method and the wounds of the patients we treated. Results: Bullets were not found to deform or fragment in tissue simulant. The bullet path through the gelatin block was found to differ from the path predicted according to the wound profile method. Conclusion: Gelatin disruption in the initial 8 to 11 cm of the bullet path is minimal. Even the highest-velocity military missiles, like the AK 74 5.45 × 39 mm bullet, may cause only minimal tissue disruption in this initial part of tissue penetration.

Introduction

During the Croatian homeland war (1991–1995), hundreds of patients with gunshot wounds were treated in the Department of Surgery at Karlovac General Hospital. Understanding of the wounding mechanisms and characteristics of these injuries is vital for the choice of optimal surgical treatment. Even though the principles of war surgery are clear and explicit,[1–4] recognition of wounding mechanisms is very helpful for management because the effects of individual types of bullets can be predicted. Unfortunately, information about the type of weapon and bullet that had caused the wound is usually limited or inaccurate. However, in some cases, bullet type can be established before surgical treatment. In two patients treated for gunshot wounds in the Department of Surgery at Karlovac General Hospital, the information about the weapon and bullet type could be obtained (AK 74, 5.45 × 39 mm). Both injuries were uncomplicated soft tissue lower extremity wounds. The wound profile method[5,6] emerged as an appropriate method to predict wound extent because it provides a clear and simple outline of a particular missile's effects. According to this method, significant wounds occur even in uncomplicated extremity hits (Fig. 1),[7] and significant yaw is present at approximately 8 cm of the wound track and extensive temporary cavitation is visible after only 3 to 4 cm of the missile path. Considering the length of the wound channels in our patients, we expected to find larger exit wounds. Because surgical exploration of the wounds of our patients did not quite confirm the expected wound extent, a terminal ballistic trial was performed to study the effects of this missile on an experimental model.

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Materials and Methods

The effects of missiles fired from the Russian AK 74 assault rifle (5.45 × 39 mm) were studied. The ammunition was manufactured in Russia in 1992. Missiles were fired into 20 gelatin blocks that were used as tissue simulants, with one shot fired into each block. Shots were fired from a range of 8.5 m (distance from the muzzle to the front face of the gelatin block). Missile velocities were measured using a chronometer composed of two optoelectric modules with infrared transceivers at a distance of 2 m. Gelatin blocks measured 0.47 (length) × 0.22 (width) × 0.16 (height) m. The blocks were stored at 4°C and fired at within 1 to 2 minutes after their removal from the refrigerator. The blocks were made as 20% (v/v) aqueous solution of gelatin powder made by Kemika (Zagreb, Croatia; physical properties, 70–100 Bloom). By weight, it was a 15.3% solution (1 L of gelatin powder = 720 g). The missile track was filmed using a television camera with a high-speed shutter (DiCam2, PCO Computers). Images of the gelatin block and of the position of the missile were digitalized and stored in the computer memory. After the exit of the missiles, radiographs were made of the blocks to detect possible fragmentation of the bullets.

Results

The mean impact velocity of the missiles, measured on a sample of 20 blocks, was 887.5 ± 15.2 m/s. All bullets exited the blocks. Analysis of images acquired by high-speed photography and radiography showed that none of the missiles deformed or fragmented. The missiles were found to be unstable during their path through the gelatin blocks in two ways: the path of the missile was not linear, and it was erratic and unpredictable. The bullets were found to curve to the top, bottom, and the sides of the blocks; the longitudinal axis of the trajectory was found to deviate from the long axis of the bullet.

Images obtained with the high-speed camera revealed significant yaw at 8 to 11 cm of bullet penetration, whereas maximum disruption occurred between 15 and 22 cm of the trajectory. Then it gradually decreased toward the bullet's exit point. A large temporary cavitation was visible after considerable instability of the bullet appeared (at 8–11 cm of the trajectory).

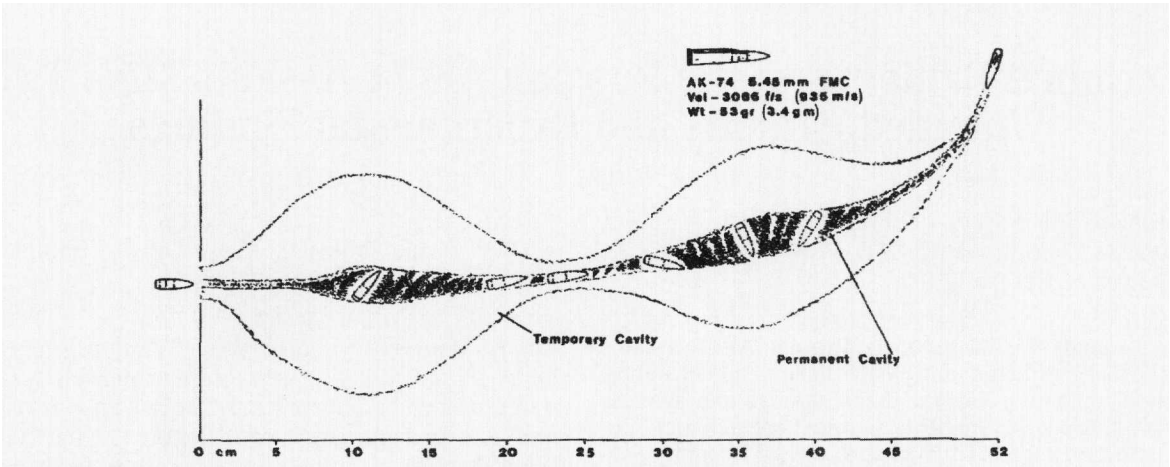

Fig. 1. Wound profile of the AK 74 missile (5.45 × 39 mm) according to Fackler and colleagues.[5,7]

Figure 2 shows the bullet deviating downward before exiting the block through its bottom face. In Figure 3, the bullet appears stable, somewhere between 25 and 30 cm of the path through the block (markings on the top border of the block are 5 cm apart). This image partly resembles the wound profile shown in Figure 1. In Figure 4, the bullet is shown to have lost its stability, with a yaw angle of about 70°. However, there is no "second" temporary cavity (as proposed by the wound profile method). Figure 5 shows the collapse of the temporary cavity after the bullet's exit from the block; the exit channel has almost collapsed. A cross-section of the AK 74 5.45 × 39 mm missile is presented in Figure 6. An empty space is visible in the tip of the missile.

Discussion

Two patients with gunshot wounds caused by the Russian AK 74 assault rifle were treated in the Department of Surgery at Karlovac General Hospital in 1994 and 1995. Both wounds resulted from accidental short-range shootings. One wound was through the thigh, and the other was through the lower leg. Both wounds were uncomplicated, without bone or vascular injuries. Penetration depths were 12 cm and 9 cm, respectively. Entry and exit wounds in the lower leg (wound track, 9 cm) resembled each other in size, whereas the exit wound in the thigh (wound track, 12 cm) was approximately two times the size of the entry wound. The tissue along the bullet track had a macroscopically viable appearance. Both wounds were treated with minimal excision and drainage, and they healed uneventfully.

According to the wound profile method,[5,6], an extensive zone of temporary cavitation is to be found in wounds caused by AK 74 missiles immediately after the entry of the missile, whereas the size of the permanent cavity increases significantly after the initial 8 cm of the bullet path. Minimal tissue damage in the wound channels of our patients can most probably be explained by the fact that forces of temporary cavitation do not necessarily cause irreversible damage to elastic tissues such as skin and muscle. However, both of our patients had small exit wounds, although according to the wound profile method (Fig. 1) a large permanent cavity and a bullet's yaw angle of about 50° (expected to result in a large exit wound) are found between 10 and 12 cm of the penetration depth.

We assumed that the observed differences were caused by differences in the design of the bullet and by different production technologies used by various manufacturers. However, these findings prompted us to perform an experiment to study the effects of AK 74 missiles.

Films obtained with a high-speed camera revealed only minimal gelatin disruption in the initial 8 of 11 cm of the missile path. Maximum destruction was found at 20 cm of the trajectory, where, according to wound profile method, minimal destruction is expected. Furthermore, even though we found the

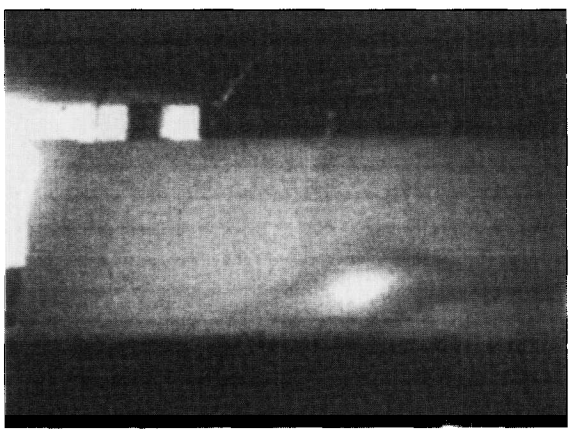

Fig. 2. Image of the gelatin block obtained by high-speed photography. The bullet is deviating downward before exiting through the bottom face of the block.

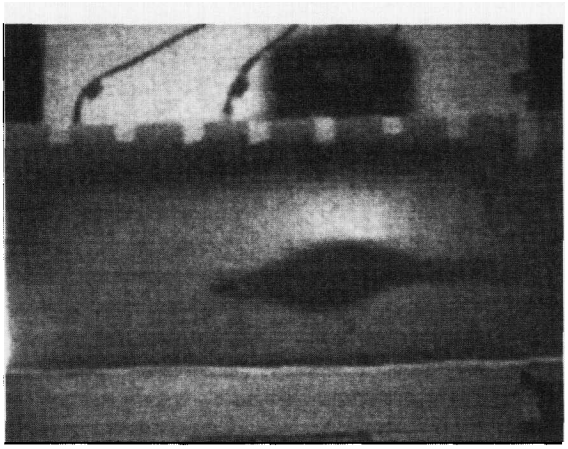

Fig. 3. The missile is stable between 25 and 30 cm of its track. A large residual permanent cavity is visible.

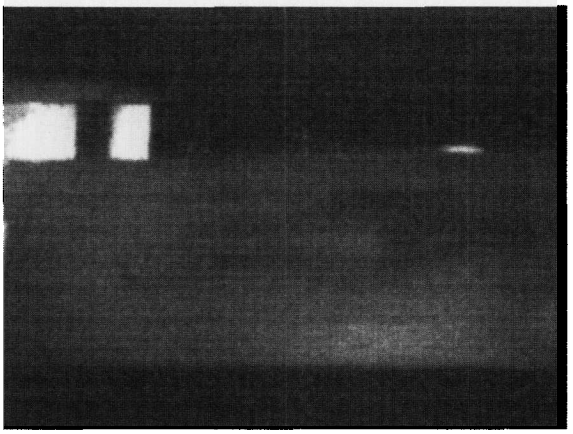

Fig. 4. The missile has lost stability. The yaw angle is about 70°.

missile to be unstable, we did not visualize two temporary cavities. With regard to the changes of directions of our missiles, it can be said that every shot resulted in an unpredictable wound. The wound track shown in Figure 1 most probably represents only one possibility of the behavior of the missile in the gelatin block.

The Russian AK 74 assault rifle was introduced in the mid 1970s as the successor of the older AK 47 rifle. A cross-section of the AK 74 5.45 × 39 mm missile is shown in Figure 6. The bullet has a gilding metal envelope, and inside it there is a 15-mm-long mild steel core coated with lead. The bottom of the steel core lies at the bottom of the metal envelope. On the tip of the steel core, there is a 3-mm lead plug, and in front of that a 5-mm-long hollow space displacing the missile's center of gravity backward and making the missile more prone to tumbling after collision with the target. Small variations in the size of the empty space in the tip of the bullet may be causing the unpredictable path of each missile.

The gelatin blocks we used were 47 cm long, and all bullets exited the blocks, but only six of them exited through their back face. This finding is in correlation with a report by Fackler et al.,[8] who found two of three bullets to exit through the upper or lateral faces of the block.

We believe that the differences between our results and those of Fackler et al. cannot be explained solely by possible differences in the physical properties of the gelatin blocks or different shooting ranges (3 m vs. 8.5 m). Potential differences in bullet design have to be considered as well.

Our gelatin blocks were not calibrated. According to some

Fig. 5. The image of the block after exit of the missile. The temporary cavity has collapsed. The permanent cavity is largest between 15 and 25 cm of the missile track.

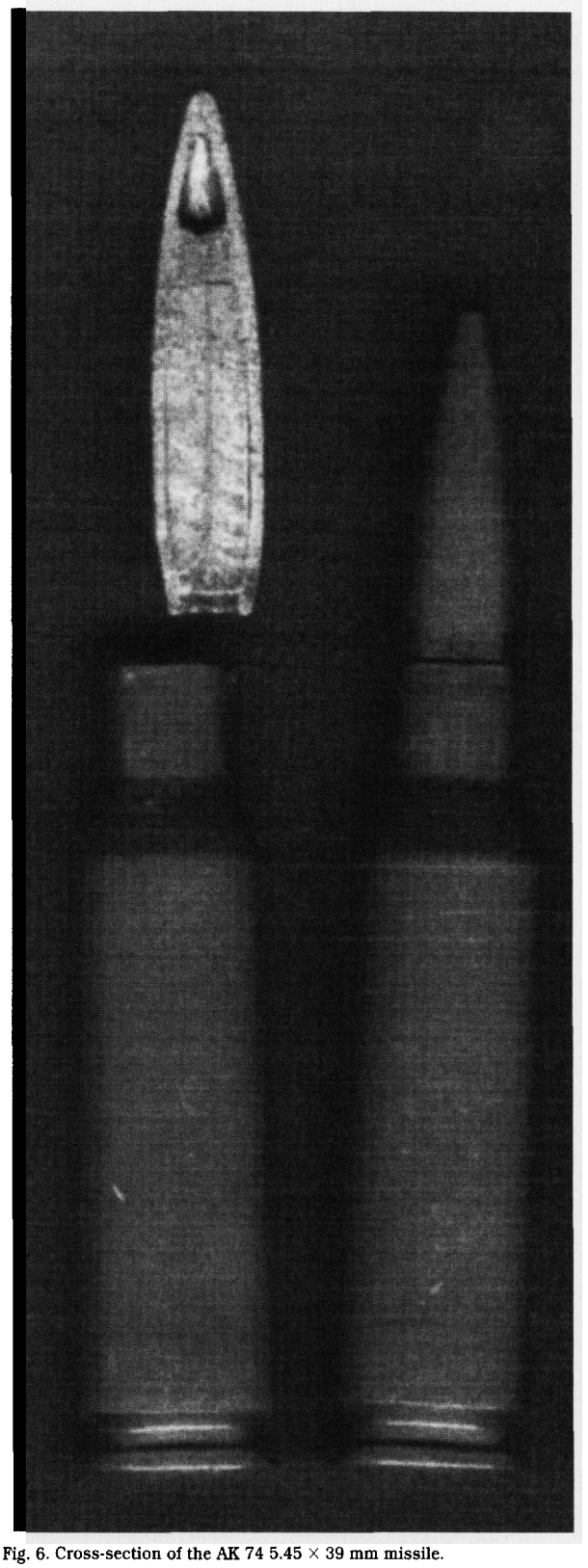

Fig. 6. Cross-section of the AK 74 5.45 × 39 mm missile.

authors, the calibration of the blocks is essential for reproducibility of terminal ballistic studies. However, significant variations exist in the composition and preparation of gelatin blocks reported by different authors. In studies by U.S. authors, gelatin blocks are usually made of ordnance gelatin (type 250 A, Kind and Knox Co., Sioux City, Iowa) in 10%[5,6,10,11] or 20%[12-15] (w/w) aqueous solutions. European researchers use blocks made of different types of gelatin in various ratios and at various temperatures. Gelatins are usually graded by jelly strength, which is expressed as "Bloom strength," "Bloom rating," or "Bloom number," and this characteristic is, according to some reports, even more important than temperature and concentration.[16] We used an aqueous gelatin solution that was 20% by volume and 15.3% by weight.[17] According to the subjective evaluation of the blocks performed by the surgeons involved in the team, the consistency of the gelatin after the cooling approximated the consistency of human striated muscle.

The clinical significance of the absence of double temporary cavities is limited to very long wound channels. The loss of stability of our missiles occurred at somewhat longer penetration distances than in experiments by Fackler et al.[7] (Fig. 1). Possible reasons are differences in bullet design and in physical characteristics of the gelatin blocks. Also, it must be remembered that wound profiles are averages and not exact prescriptions of wound patterns to the nearest centimeter.

Minimal soft tissue damage in our patients confirms the fact that highly elastic tissues such as skin and muscle are resistant to forces that appear in terminal ballistic phenomena.[18] These tissues are soft and flexible, and they possess the physical properties of good shock absorbers. We also confirmed the finding of Fackler and Burkhalter that even the highest-velocity military bullets may cause only minimal disruption in the initial 12 cm of tissue penetration.[19] We believe that one should be conservative in the debridement of this zone of such wounds. Unpredictable missile behavior regarding the direction of its path before the appearance of significant yaw was well documented for M16 A1 military rifle bullets.[9] Contamination of the wound and the presence of surface material in the wound should be treated according to the established principles of war surgery.[1-4]

Our results agree with the opinion often expressed in the literature that many terminal ballistic phenomena remain largely unexplained despite the recent technological advances that frequently makes the findings reported by different authors contradictory.[7,20-23] It is hoped that future research will clarify which phenomena found in terminal ballistics can be reproduced and which variations can be ignored in the analysis of the results. Results of such research will be helpful for understanding and for the treatment of gunshot wounds.

Conclusion

Russian AK 74 assault rifle bullets (5.45 × 39 mm) were not found to deform or fragment in tissue simulant (gelatin blocks). These missiles are unstable and unpredictable with regard to the direction of the bullet path through the tissue simulant and the beginning of significant yaw. Gelatin disruption in the initial 8 to 11 cm of the bullet path is minimal. The same phenomenon was observed in two patients treated for gunshot wounds caused by this missile. We believe that one should be conservative in debridement of this zone of such wounds. Contamination of the wound and the presence of surface material in the wound should be treated according to the established principles of war surgery.

The bullet path through the gelatin block was found to differ from the path predicted according to the wound profile method, and we observed a lack of double temporary cavities caused by the missile's bi-lobed yaw cycle. Possible reasons for this phenomenon may be differences in bullet design and in the physical characteristics of the tissue simulants. Our findings indicate that every bullet's path is a unique event.

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