Reprint from
SURGERY, *Gynecology & Obstetrics*
February, 1991, Vol. 172, 153-160

THEODOR KOCHER AND THE SCIENTIFIC FOUNDATION OF WOUND BALLISTICS

Martin L. Fackler, M.D., F.A.C.S., *and* Paul J. Dougherty, M.D.,
Presidio of San Francisco, California

EMILE THEODOR KOCHER was born in Bern, Switzerland in 1841 and became Professor of Surgery at the University of Bern in 1872. He remained there until his death in 1917. The Kocher incisions, the Kocher clamp and the Kocher maneuver for reducing dislocations of the shoulder have made the name Kocher recognizable to any student of surgery. However, his work on the physiologic and surgical aspects of the thyroid gland, which made him the first surgeon to win the Nobel prize in Medicine in 1909, is not well known, and his research on wound ballistics is virtually unknown.

Throughout history, war has been the teacher of the surgeon. The Swiss, despite their proximity to warlike neighbors, have maintained their neutrality by sustaining a constant state of military preparedness and remaining on the cutting edge in technology of armaments. Kocher, a Swiss citizen and member of the Swiss Army Militia, recognized that the interaction of penetrating projectiles and body tissues must be understood before wounds could be treated rationally and effectively.

Kocher's studies on wound ballistics combined his knowledge of the human body and scientific method with the technical expertise obtained from weapon engineers at Thun, Switzerland. This blending of the two disciplines generated a comprehensive body of knowledge that has provided us with a scientific foundation for the study of wound ballistics in modern times. It also provided Rubin, then Director of the Swiss Government ammunition factory in Thun, with the foundation to develop the full-metal-jacketed bullet, which became the standard type of military bullet used by all the armies of the world.

From the Letterman Army Institute of Research, Wound Ballistics Laboratory, Presidio of San Francisco.

The opinions and assertions contained herein are the private views of the author and are not to be construed as official nor do they reflect the views of the Department of the Army of the Department of Defense. (AR 360-5).

Reprint Requests: Commander, Letterman Army Institute of Research, SGRD-ULY-MT Attention: Dr. Fackler, Presidio of San Francisco, California, 94129-6800.

EXPERIMENTS DONE BY KOCHER

Ueber die Sprengwirkung der modernen Kleingewehr-Geschosse [Concerning the explosive effect of the modern small caliber rifle bullet], 1875, (1).—In the last one-half of the 19th century, much discussion and research was concentrated on the latest generation of military rifles. These rifles (the Vetterli, used by the Swiss and Italian armies, 45-70 Springfield used in the United States, the Chassepot used in France, and the Dreyse Needle-gun used in Germany) shot a round-nosed cylindro-conoidal lead bullet weighing 20 to 25 grams at an initial velocity of 400 to 450 meters per second.

At that time, there were three theories to explain the mechanisms by which bullets caused the disruption of tissue: a partial melting of the bullet on impact; a centrifugal force from the rotation of the bullet, and hydraulic pressure. Kocher began to examine these postulates in 1874 and published the first of his studies on wound ballistics as a three part article in 1875 (1).

In this study, Kocher shot through inanimate objects: stacks of fir boards, metal and glass bottles, empty and filled with water; a book, and iron plates. For most of these shots he used the standard Swiss Army Vetterli rifle; he also used a French Chassepot rifle for several shots, as well as a special smooth-bore Vetterli from which he fired a round ball. These shots were fired from distances of 50 to 100 feet. He also fired a series

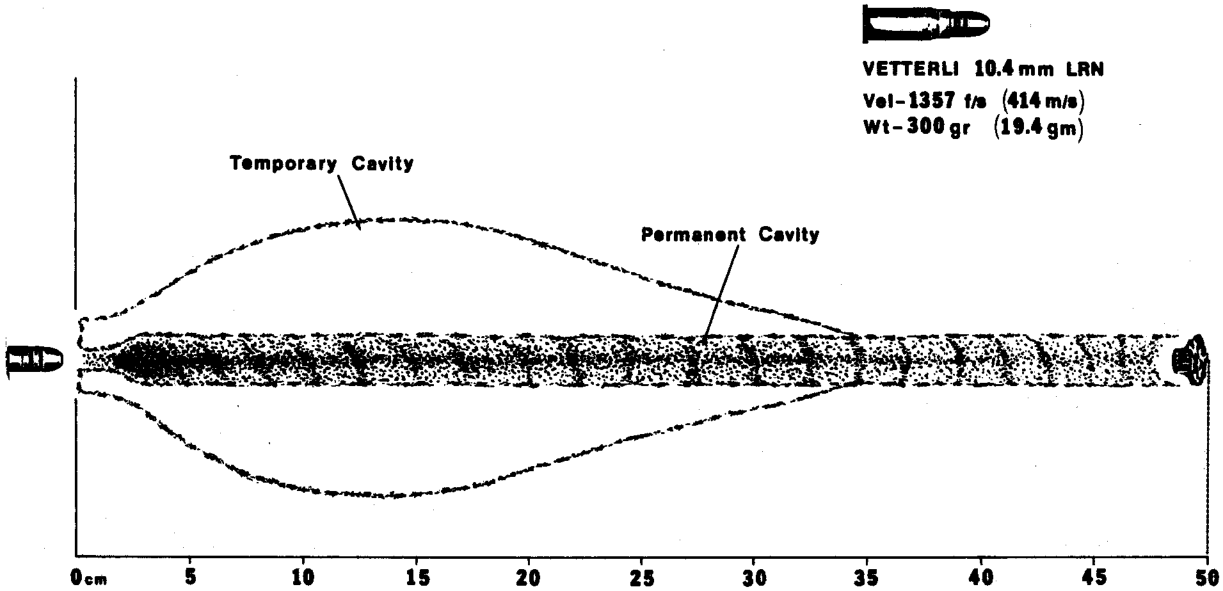

FIG. 1. Wound profile of the Vetterli rifle bullet. The heavy soft lead bullet expands in tissue to double its original diameter. This causes increased "crush" damage as well as a large temporary cavity because of the nonaerodynamic shape of the "mushroomed" bullet.

of shots through pig bladders filled with air, sand and water; pig intestines filled with water; oxen leg bones, and human skulls, both empty and filled with water.

Kocher fired a series of long range shots into two human cadavers—six hits were recorded with the Vetterli rifle from 700 feet, seven from 400 feet and five from 100 feet. Three shots were fired with the Chassepot rifle from 100 feet.

To study the effects of hydraulic pressure, Kocher constructed a box (150 centimeters long, 36 centimeters deep and 50 centimeters wide at the top and 30 to 35 centimeters wide at the bottom), filled it with water and shot into it through a piece of pig bladder stretched over a hole in one end. The first shot into this box, from a Vetterli rifle loaded with a hard lead alloy bullet, penetrated through the entire length and stuck in the back wall of the wooden box. The pressure from this shot also caused the box to break at the seams.

Kocher concluded that partial melting of the projectile and centrifugal force were of little or no consequence in disrupting tissue, and that the results of his experiments supported the hydraulic pressure postulate. He found that the increased velocity of the new rifle bullets contributed to the increased hydraulic pressure.

In Kocher's perception, the sudden arrest of motion of the projectile when the bullet hit a bone converted the kinetic energy into heat and partially melted the bullet. He used this logic to explain that fragmentation of the bullet only occurred when the bullet hit the bone.

Kocher ended this article discussing the principle of "civilized war." He suggested that rendering the enemy soldier unable to fight, rather than killing him, should be of primary concern. To this end, he advised limiting the size of the bullet (caliber) and making bullets from a material of a higher melting point than lead to limit disruption of tissue.

Neue Beitrage zur Kenntnis der Wirkungsweise der Modernen Kleingewehr Geschosse [New contributions to understanding the effects of the modern small caliber rifle bullet], 1879, (2).—In assessing the projectile-tissue interaction, Kocher recognized the critical importance of projectile construction, projectile mass, projectile shape and target characteristics as well as the projectile velocity. Sound scientific method demanded that each of these factors be varied independently to determine the relative contribution of each to the disruption of tissue. To accomplish this, he had projectiles made from a variety of materials and varied the velocities by reducing the amount of powder in the cartridge. He studied the effects of the hardness and melting point of the bullet by evaluating projectiles of pure copper and of "Rose-Metal" (an alloy of tin, lead and bismuth; substantially harder than lead, but with a melting point of only 65 degrees Centigrade—lead melts at 325 degrees C.).

In addition to the standard Vetterli rifle, he

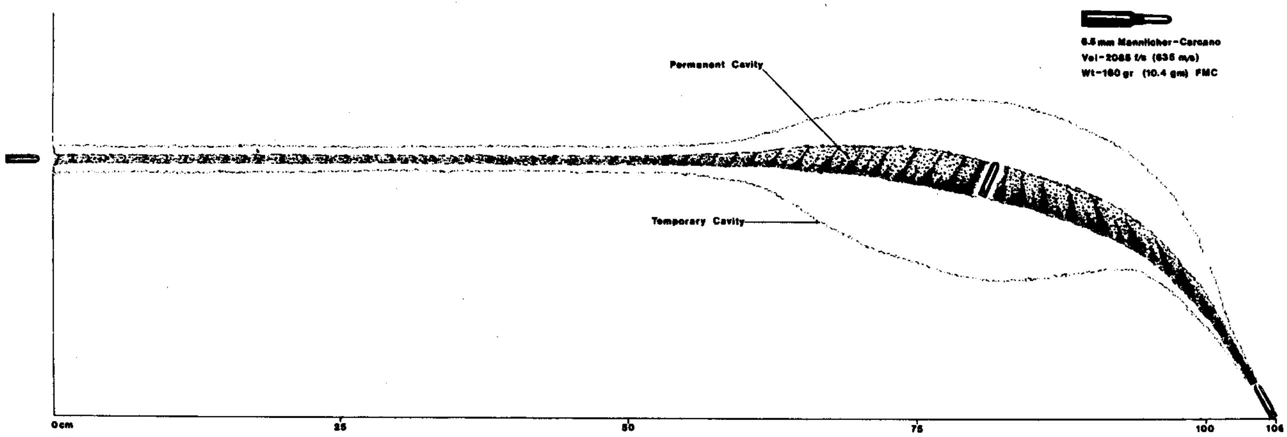

FIG. 2. Wound profile of the bullet from a 6.5 millimeters Mannlicher-Carcano rifle, typical of the first generation of "compound" or full-metal-jacketed bullets, with a lead core and harder metal covering. The bullet in the position of point-forward, maintained for more than 50 centimeters of penetration of the tissue, in combination with the hard resistance of the bullet to deformation, explains the unanimous reports of minimal severity of the wound compared with the earlier deforming bullets.

used the smooth bore Vetterli from which he had fired round balls in a study done in 1875, but in these experiments he shot the standard cylindro-conoidal lead bullet weighing 20.2 grams. In this study, four of 27 shots were made using a Swiss military pistol and one shot was made with a British Martini-Henry rifle.

Results of the studies done in 1874 showed that the box filled with water needed a longer water column. This article reported that three shots were fired into a box large enough (345 centimeters long, 56 centimeters wide and 61 centimeters deep) to capture the entire trajectory of the projectile. Shots into the box filled with water showed that the pure copper bullet and the "Rose-Metal" bullet did not deform at all. However, the softer lead bullet expanded into a typical "mushroom" shape. Other targets used in this study were empty metal cans, metal cans filled with water and gravel, an iron plate 3 centimeters thick, a lead plate 5 centimeters thick, a book 4 centimeters thick, two bones (both human femurs) and a target consisting of two gelatin slabs 3 centimeters thick, one on each side of a cement slab 3 centimeters thick.

From the results of these studies, Kocher concluded that the hardness of the bullet, not the melting point of the bullet, determined deformation of the bullet. Deformation released the potential of the bullet for increased disruption of tissue.

Kocher ended this article with an appeal to reduce the caliber of the military rifle bullet in the interest of humanity. He knew that technology would inevitably bring increases in velocity of projectiles, but predicted that, no matter what the velocity, the disruption of tissue caused by the projectile could be kept within acceptable limits by controlling the size bullet.

BOOKS BY KOCHER

Ueber Schusswunden. Experimentelle Untersuchungen ueber die Wirkungsweise der Modernen Klein-Gewehr-Geschosse [Concerning gunshot wounds. Experimental investigations concerning the effects of the modern small caliber bullet], 1880, (3).—Kocher continued to expand the methods of study described in his articles. In addition to the projectiles he had used previously, he added Vetterli bullets made of iron, aluminum, hard lead (containing 5 per cent antimony), hollow tin bullets and tin bullets with a wood filling. Fresh ox liver, soap blocks, metal cylinders 12 centimeters in diameter (both empty and filled with water), metal cans filled with toy marbles, sandstone plates 6 centimeters thick, lead plates 3.5 centimeters thick and glass plates 3 millimeters thick were added to previously used targets. Cadavers were shot from a distance of 30 meters to control the location of the hits. To recover the bullets that were fired, Kocher had placed sacks filled with cotton and wool yarn behind the targets.

In a series of 31 shots fired into boxes filled with water, Kocher recorded the depth of penetration into the water, degree of deformation and position in which the bullet came to rest (pointing forward, backward and crossways). From the results of this experiment, he concluded that deformation of the projectile (only the lead bullets deformed—the soft lead more than the harder lead-antimony alloy) was a purely mechanical event and did not depend on the bullet heating to near its melting point as he had previously thought. He also found depth of penetration of the projectile was in direct proportion to velocity and specific gravity, and inversely proportional to the cross sectional diameter (which increased with deformation of the bullet). He used "reciproke Wirkung" (reciprocal effect) to describe the relationship between deformation and depth of penetration of the bullet. The results of these studies reaffirmed the previous conclusion that the disruptive effects of bullets used in modern rifles were largely a result of hydraulic pressure.

Kocher realized that the kinetic energy possessed by a bullet as it strikes tissue needed to be put into proper perspective so he divided kinetic energy into four elements. First, some kinetic energy is converted into heat and is, thus, lost as far as disruption of tissue is concerned; Kocher pointed out the extreme difficulty in measuring this fraction. Second, some kinetic energy is used in propelling tissue surrounding the path of the projectile radially outward, producing temporary cavitation. Kocher accurately described this process as "hydraulic pressure." Third, the kinetic energy that is used by the projectile in forming its primary penetration or permanent cavity; direct crush of tissue that is struck by the penetrating projectile. Fourth, that used in deforming the projectile; this fraction was approximated by dropping weights on unfired bullets to duplicate the deformation observed in the fired shots.

Kocher ended this book with suggestions for practical application of the studies. He recommended that the military bullet be made of the smallest possible diameter (specifying less than 10 millimeters). He also recommended the projectile be constructed from a metal much harder than lead, about the same as the hardness of copper, but cautioned that solid copper would be unsuitable because its specific gravity was too low to allow it to retain enough velocity for an adequate wounding capacity at long ranges.

Zur Lehre von den Schusswunden durch Kleinkalibergeschosse [Instruction on gunshot wounds from small caliber bullets], 1895, (4).—In the introduction to this book, Kocher confirms the leading role of his work in the development of the full-metal-jacketed military rifle bullet that had been produced by Colonel Eduard Rubin. About 1880, Rubin introduced a full-metal-jacketed bullet, which he combined with his newly patented bottleneck cartridge case. By the turn of the century, the armed forces of all major countries had adopted this type of bullet—it remains the standard to this day.

In addition to the bullets used in previous studies, Kocher shot the following: full-metal-jacketed (steel jacket) bullets 5.8 millimeters in diameter; steel-jacketed and solid hard lead bullets 6 millimeters in diameter; bullets of solid steel, steel jacketed, of hard lead with a steel tip, of hard and soft lead and of aluminum 7.5 millimeters in diameter; an Hebler hard lead bullet 8.5 millimeters in diameter; round balls of copper and of lead 10 millimeters in diameter, and round balls of iron, copper, lead, and wax 15 millimeters in diameter. In addition to targets previously used, moist clay blocks, soap blocks of two different hardnesses and metal cans filled with iron balls were used. Pressure sensors (lead cylinder "crush" type) were added to the box filled with water in an attempt to measure the hydraulic pressure generated by the various projectiles. After applying various bacteria to pieces of soldier uniforms, he shot through the fabric into gelatin cylinders (5 by 9 centimeters), which served as a culture medium.

Kocher included an excellent review of wound treatment from the literature of experimental wound ballistics and reports of actual war surgery experiences. In the summary of experimental results, Kocher emphasized the difference in the effect produced by the same degree of temporary cavitation depending upon the elasticity of the tissue involved—the more elastic the tissues, the less the disruption. He also pointed out the reciprocal effect between the "Durchschlagskraft" or penetration potential, and the "Seitenwirkung," or temporary cavitation potential of a given projectile—the larger the amount of a projectile's potential that is directed toward pushing tissue sideways from the path of the projectile, the less potential there is left to be directed straight ahead for deeper penetration.

ADDRESS TO MEDICAL CONGRESS IN ROME

In 1894, Kocher spoke to an international medical congress in Rome on the subject of improving the bullets used in military rifles from a humanitarian standpoint (5). He described his experimental work and made three recommendations: 1, keeping the surface of the bullet that contacts the tissue as small as possible by reducing the caliber to 5 or 6 millimeters; 2, preventing deformation of the bullet by increasing its hardness, especially on the forward end, making the tip of the bullet pointed so that it would enter the tissues with less chance of deformation, and 3, increasing the rotational velocity (he thought this would increase stabilization of the bullet to avoid bullet yaw).

WAR SURGERY OBSERVATIONS

In 1915, 20 years after the last of his studies on wound ballistics, Kocher published an extensive report of his visits to German military hospitals in the early part of World War I (6). Since the Armies involved in World War I used a full-metal-jacketed bullet no larger than 30 caliber, he was able to observe, first hand, the results of his research on wound ballistics in the ultimate laboratory—the battlefield. He remarked that the wounds he saw were entirely consistent with the work he had done. He pointed out that the minimal damage produced by small caliber rifle bullets "...wie Verletzungen ohne hautwunde ausheilten" (healed like injuries that had no skin wounds) under aseptic dressings. Especially striking were perforating chest wounds, whose track included the lung, which healed so rapidly the wounded soldiers rejoined their units after only a few weeks.

WOUND BALLISTICS INNOVATIONS—TECHNICAL

Bullet recovery in cotton and wool. Kocher recognized that deformation of the projectile was the most critical determinant of its effect on the body. Thus, accurate assessment of deformation was essential. He devised a method to recover the bullet after it had passed through various targets that did not add to the deformation of the projectile. Kocher used sacks filled with cotton and wool yarn as a nondeforming bullet trap. This basic method is still used in most forensic laboratories to capture test bullets (the firearms examiner must avoid deformation of the bullet, which could distort rifling impressions on the bullet and consequently interfere with valid matching).

Bullet recovery in water—water as a tissue simulant. To examine water as a tissue simulant, Kocher designed and used a horizontal water tank, shooting through a a peice of pig bladder stretched across a hole in the entrance. During World War II, others used shots into water to clearly separate the effects of the sonic pressure wave and temporary cavitation (7). Vertical water tanks are used currently to recover test bullets for microscopic matching in many forensic laboratories. In fact, most forensic laboratories have available both the cotton waste box and a water recovery tank. Water continues to be used as an easy to perform screening test for performance of bullets. Comparisons between gelatin and water as a tissue simulant done at the Letterman Army Institute of Research showed that deformation of the bullet is nearly identical with both. This finding led to the recommendation of using water as a test medium for those who do not wish to go to the expense of preparing gelatin (8).

FIG. 3. Two Vetterli rifle bullets recovered from 10 per cent ordnance gelatin. Lengths of these bullets were 13.6 and 15.0 millimeters; the Vetterli rifle bullets recovered by Kocher from a box filled with water were 14 millimeters long.

Gelatin and soap tissue simulants. The work done by Kocher is the earliest in which we have seen gelatin and soap used as a tissue simulant. Gelatin and soap are the major tissue simulants currently in use by investigators of wound ballistics.

Full-metal-jacketed bullet. The development of the full-metal-jacketed bullet has been attributed to "to the almost inspired deductions of Major Rubin" (9). The source of "inspired deductions" attributed to Rubin are the solid scientific studies and conclusions of wound ballistics done by Theodor Kocher (1–3). Rubin reduced the caliber to 7.5 millimeters and introduced his newly patented bottle-neck cartridge. The full-metal-jacketed projectile with a bottle-necked cartridge was adopted by most countries by the turn of the century.

Kocher predicted that disruption of tissue could be minimized regardless of the velocity of a projectile if two conditions were met—the caliber of the projectile had to be limited and the material had to be hard enough to prevent deformation or fragmentation of the projectile in its path through tissues of the body. This prediction has been verified repeatedly on the battlefield.

In 1895 in India, the British Army issued a full-metal-jacketed 30 caliber bullet. Its minimal disruption of tissue became painfully evident. The new bullets were far less effective in stopping charging enemy warriors than the large, slower, soft lead bullets that had been used previously. To improve the performance of these bullets, the hard jacket at the tip of the bullet was ground off so that the bullet would expand or "mushroom" upon penetrating the body. This measure increased the disruption of tissue and "stopping power" of the bullet. These bullets were altered at the British arsenal in Dum-Dum, India. Later, at the Peace Conference in 1899 at The Hague, this type of altered bullet was declared "inhumane" and the so-called "Dum-Dum bullet" was prohibited by international law (10).

In the United States, Army surgeon Captain Louis LaGarde compared a similar full-metal-jacketed 30 caliber bullet to the then standard United States military rifle (a model 1873 Springfield), which fired a larger, slower, lead bullet. In 1893, he reported to the Surgeon General that the new, smaller but higher velocity rifle bullet caused less damage to tissue—findings in agreement with the British experience and predictions made by Kocher (11).

In the Spanish-American War, United States military surgeons saw first hand the effects of these new full-metal-jacketed projectiles; they noted a marked decrease in both morbidity and mortality from wounds caused by bullets (12). Similar findings were reported in every war from the introduction of the full-metal-jacketed bullet to the present; including the Boer war (13), the Russo-Japanese war (14), World War I (15), the Spanish Civil war (16), World War II (17), Vietnam (18) and Afghanistan (19).

The development of the full-metal-jacketed bullet combined with two other small-arms technologic advances—the bottleneck cartridge and smokeless powder—enabled the velocity of the bullet to increase by 60 to 100 per cent. In the history of firearms, this was by far the largest increase in velocity, yet the disruption of tissue caused by these "high velocity" bullets proved to be far less than that caused by their "low velocity" predecessors. For comparison, the highly touted velocity of the bullet of the M-16 rifle was only about 10 per cent higher than that of its predecessor, the bullet of the NATO rifle, which is 7.62 millimeters in diameter. Also, for the enlightenment of those who think "high velocity" was a recent advance, in 1891, Holland, Romania and Italy provided their armed forces with a rifle (6.5 millimeter Mannlicher-Carcano muzzle, velocity, 730 meters per second [2395 feet per second]) whose muzzle velocity was higher than the most widespread "assault rifle" of the modern world, the Communist bloc AK-47 (muzzle velocity 713 meters per second [2340 feet per second]).

Comparing the wound profiles of the Vetterli (Fig. 1), the projectile that Kocher used for the majority of his experiments, with the wound profile of the 6.5 millimeter Mannlicher-Cacano (Fig. 2), which was typical of the first generation of full-metal jacketed bullets, reveals the very deep penetration and minimal disruption caused by the nondeforming jacketed bullet and the much greater disruption caused by the large lead bullet, which doubles its diameter by expanding. Two Vetterli bullets recovered from ordnance gelatin are shown in Figure 3. Their dimensions match those reported by Kocher for shots recovered from a box filled with water.

The "humane" bullet, designed by Rubin, who followed the guidelines suggested by Kocher, also possessed attributes making it especially useful in warfare because it was, 1, more likely to wound than kill—wounded soldiers cause more of a drain on enemy resources since they must be removed from the battlefield and cared for; 2, flatter trajectory and lessened recoil allowed an accurate shot at longer ranges, and 3, the soldier could carry more of these lighter-weight bullets. The goals of the surgeon and the weapon designer are remarkably similar and both goals were well served by the full-metal-jacketed bullet.

WOUND BALLISTIC INNOVATIONS—PRINCIPLES

Kocher accurately described the bullet's tissue disruption mechanisms, the direct pulverizing of the tissue struck and indirect displacement of tissue around the path of the projectile. He correctly described the radial displacement of tissue away from the path of the projectile (temporary cavitation), as a result of hydraulic pressure, and correlated its magnitude with mass, shape, velocity and deformation of the projectile.

It remained for another famous surgeon, Sir William MacCormack, to determine that the temporary cavity occurs after passage of the bullet. In an exceptional example of objective observation and deductive reasoning, MacCormack noted that, after shooting a metal can full of water, when he folded the leaves of the typical stellate exit hole back to their original position, a punched out round hole of bullet diameter remained. This proved that the bullet passed through the back wall of the can before the wall was split and displaced by the hydraulic pressure of temporary cavitation.

Kocher pointed out the reciprocal relationship between the depth of penetration and the diameter of damage from the projectile; for example, if a bullet travels straight within the tissue and does not deform, it penetrates deeply. If the bullet flattens and makes a hole larger in diameter, then it will penetrate less deeply. Common sense would predict a simple, logical, reciprocal relationship between projectile penetration depth and the diameter of tissue disruption. Yet the depth of penetration, which is the most meaningful of effects caused by the projectile, has been overlooked by nearly every researcher of wound ballistics during the past 20 years (20).

The fundamental relation of the size (mass), shape, construction and velocity compared with the effects of a projectile on a given tissue is, in the final analysis, also logical. Yet contemporary authors, lacking sufficient depth of understanding, have attempted to clarify wound ballistics by oversimplification—they have predicted the damage a projectile will cause by considering its velocity alone. This unfortunate mistake has become widespread and has found its way into many recent surgical textbooks (21–24), and has confused, as well as misled, the modern generation of surgeons. Those misled by the recent misconceptions will, no doubt, be surprised to learn that the bullet from the Vetterli rifle (Fig. 1), developed over 120 years ago, produces a temporary cavity as large as the most modern bullet from the "assault rifle," despite a velocity less than one-half that of the current weapon (M-16). The wound profile of the Vetterli rifle bullet illustrates the most basic of principles that Kocher elucidated in his studies—the critical relationship of deformation of the projectile to disruption of tissue.

A corollary for using velocity alone to explain the effects of a projectile is the use of kinetic energy. Kocher pointed out the extreme difficulty in measuring the portion of kinetic energy of a projectile that is converted into heat during the collision with tissue and is, thus, lost as far as disruption of tissue is concerned. We are unaware of any investigator successfully measuring this heat loss; yet "kinetic energy deposit" continues to be used as a measure of disruption of tissue, despite this lack of validation (20, 25, 26).

The studies done by Kocher had clarified the significance and relative importance of all the factors involved in the projectile-tissue interaction. Mass and velocity combine to set the theoretic limit of the potential for disruption of tissue, but construction and shape limit the amount of potential that can be realized (Figs. 1 and 2).

It is ironic that Kocher, using sound scientific methods, observation and common sense, described the interaction of a projectile-tissue interaction clearly and accurately, while modern researchers, who have high speed cine and roentgenography at their disposal, have distorted it badly (20–26). Presently, a solid understanding of the fundamental principles is essential to avoid seduction by the dramatics of spectacular technology that can easily become an end in themselves rather than a tool to aid in an over-all understanding of wound ballistics.

SUMMARY

The systematic and rational approach used by Kocher, coupled with his interest in research of wound ballistics for more than 40 years, resulted in a clear elucidation of the principles that form the basic scientific foundation of modern wound ballistics. The validity of his work has been proved repeatedly on the battlefields of the world for more than a century. Presently, more than ever before, the sound scientific precepts revealed by Kocher are essential to keep technologic investigation within the framework of good judgment.

REFERENCES

1. Kocher, T. Ueber die Sprengwirkung der modernen Kleingewehr-Geschosse. Cor.-Bl. Schweiz Aerzte, 1875, 5: 3-7; 29-33; 69-74.
2. Idem. Neue Beitrage zur Kenntnis der Wirkungsweise der Modernen Kleingewehr Geschosse. Cor.-Bl. Schweiz Aerzte, 1879, 9: 65-71, 104-109, 133-137.
3. Idem. Ueber Schusswunden. Experimentelle Untersuchungen ueber die Wirkungsweise der Modernen Klein-Gewehr-Geschosse. Leipzig, Germany: F. C. W. Vogel, 1880.
4. Idem. Zur Lehre von den Schusswunden durch Kleinkalibergeschosse. Cassel, Germany: G. Fischer & Co., 1895.
5. Idem. Die Verbesserung der Geschosse v. Standpunkte d. Humanitaet. Atti Dell'XI Congresso Medico Internazionale, Roma, 29 Marzo-5 Aprile, 1894. Volume I, Parte Generale, pp. 320-325. Rome: Ripamonte & Colombo, 1895.

6. Idem. Eindruecke aus deutschen Kriegslazaretten. Cor.-Bl. Schweiz Aerzte, 1915, 45: 449-479.
7. Harvey, E. N., Korr, I. M., Oster, G., and McMillen, J. H. Secondary damage in wounding due to pressure changes accompanying the passage of high velocity missiles. Surgery, 1947, 21: 218-239.
8. Fackler, M. L. Handgun bullet effectiveness. Assoc. Firearm Toolmark Examiners J., 1988, 20: 446-448.
9. Ommundsen, H., and Robinson, E. H. Rifles and Ammunition. P. 102. New York: Cassell & Co. Ltd., 1915.
10. Greenwood, C. The political factors. In: Gun Digest, 34th ed. Edited by K. Warner. Pp. 161-168. Chicago: Follett Pub. Co., 1980.
11. LaGarde, L. A. Report of a series of experiments conducted at Frankfort Arsenal, in connection with the Ordnance Department of the U.S. Army. Report to the Surgeon General for the Secretary of War, Fiscal Year 1893. Pp. 73-95. Washington: Government Printing Office, 1893.
12. Idem. Gunshot Injuries; 2nd Ed., p. 45. New York: William Wood, 1916.
13. Makins, G. H. Surgical Experiences in South Africa 1899-1900. P. 69. Philadelphia: Blakiston, 1902.
14. Havard, V., and Hoff, J. V. R. Reports of military observers attached to the armies in Manchuria during the Russo-Japanese war. No. 8, Part 2. War Department Office of the Chief of Staff second division (military information). P. 70. Washington: Government Printing Office, 1906.
15. LeMaitre, R. A propos de 2537 cas de sutures primitives pour plaies de guerre. Lyon Chir., 1918, 15: 65-108.
16. Jolly, D. W. Field Surgery in Total War. P. 68. New York: Hoeber, 1941.
17. Crile, G., Jr. Experiences of the surgical service of the USNH, Aukland, NZ with casualties from the initial Solomon Island engagement. U. S. Nav. M. Bull., 1943, 41: 306-324.
18. King, K. F. Orthopaedic aspects of war wounds in South Vietnam. J. Bone Joint Surg., Br., 1969, 51: 112-117.
19. Coupland, R. M., and Howell, P. R. An experience of war surgery and wounds presenting after 3 days on the border of Afghanistan. Injury, 1988, 19: 259-262.
20. Fackler, M. L. Wound ballistics research of the past twenty years: a giant step backwards. Proceedings of the NATO Wound Ballistics Research Group 11, Royal Army Medical College, London, 17 to 21 October 1988.
21. Davis, J. H., Drucker, W. R., Foster, R. S., and others. Clinical Surgery. Pp. 2117 and 2337. St. Louis: C. V. Mosby Co., 1987.
22. Owen-Smith, M. S. Wounds caused by the weapons of war. In: Wound Care. Edited by S. Westaby. Pp. 110, 112, 114. London: Heinemann Medical Books, 1985.
23. Dufour, D., Kroman-Jensen, S., Owen-Smith, M., and others. Surgery for Victims of War. Pp. 7, 11, 13, 14, 43. Geneva: International Committee of the Red Cross, 1988.
24. Sedwitz, M. M., and Shackford, S. R. Vascular trauma. In: Essential Surgical Practice. Edited by A. Cuschieri, G. R. Giles and A. R. Moossa. 2nd ed., p. 305. London: Wright, 1988.
25. Fackler, M. L. Wound ballistics—a review of common misconceptions. J. A. M. A., 1988, 259: 2730-2736.
26. Fackler, M. L., and Bellamy, R. F. Considering the wounding effects of a hit. Army Times, 1989, 49: 24.