OPEN WOUND DRAINAGE VERSUS WOUND EXCISION IN TREATING THE MODERN ASSAULT RIFLE WOUND

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Open wound drainage versus wound excision in treating the modern assault rifle wound

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Military dogma of the past 20 years preaches that excision of all injured tissue around the path of a penetrating projectile is essential in wound treatment. To find out whether excising injured muscle surrounding a bullet path benefits healing over and above the benefit provided by a simple release of tension by incision, two groups of 90 kg swine were shot in the hind leg with a replica of the AK-74 assault rifle projectile. One group was treated by excision of injured tissue around the projectile path; in the other group no tissue was excised. Both groups were given parenteral penicillin for 5 days, and simple gauze dressings were used to cover the wounds. No difference in healing time occurred; the wounds in both groups had closed, and no epithelial defect remained by 20 to 22 days. These results indicate that the simple extremity wound caused by the modern-generation assault rifle, provided with adequate open drainage and systemic penicillin, heals as rapidly when the body defense mechanisms handle the disrupted tissue as when an attempt is made to excise it surgically. (SURGERY *1989;105:576-84.*)

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THE BODY'S REACTION to local injury results in swelling. If this engorgement caused by increased circulation and transcapillary protein and water loss is confined, as in fascial compartments of the extremities, it may cause strangulation of circulation with destruction of far more tissue than that disrupted by the initial injury. French surgeons as early as Paré[1] understood this concept and its practical consequences. They incised or dilated the projectile path to relieve tissue tension around wounds. In 1737 LeDran[2] used "débrider" to describe incision to relieve tension on the underlying parts and establish drainage, as did Percy[3] in 1792 and Larrey[4] in 1812. In this context, the French verb "débrider" (from which the noun *débridement* is derived) means "to remove constriction by incision."[5] Severely disrupted tissue might also have been removed during the procedure, but the emphasis was distinctly on the release of tension and drainage by *incision*. Although débridement continues to be used in this meaning by present-day French surgeons, it means *wound excision* to most English-speaking surgeons. This confusion of terms appears to have originated from the 1917 Inter-Allied Surgical Conference in Paris.*[6]

Although modern military dogma, especially since the Vietnam conflict, has stressed wound excision as the sole savior of life and limb on the field of battle,[7-9] we have been unable to find any valid clinical or experimental data to show that excising the injured tissue around a wound added any benefit over that obtained from incision to release pressure and establish adequate drainage.

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In conducting the research described in this report the investigators adhered to the "Guide for Laboratory Animal Facilities and Care" as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences, National Research Council.

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*The confusion generated in the wound ballistics literature by the mistranslation/misinterpretation of the Inter-Allied Surgical Conference's French text persists to this day. Rather than *débridement* we will use the terms *wound incision* and *wound excision* to avoid misunderstanding.

Excision of the entire projectile path, including all surrounding tissue that appears injured, may require a much larger operation than the incision needed to release tension and establish drainage. Larger operations take longer and have increased risks (anesthetic complications, blood replacement risks, etc.). The potential for deformity and disability increases with the amount of tissue removed. Good sense demands that this extra use of surgical resources and increased risk to the patient be unequivocally justified. This is especially pertinent in the battlefield scenario, where the number of wounded may overwhelm available surgical facilities.

This study was designed to determine whether excision of apparently nonviable tissue from the projectile path has a beneficial effect on wound healing in the uncomplicated extremity wound caused by the modern assault rifle. The study was modeled to conform as closely as possible to the real-life battlefield situation. Pigs with thighs approximately the size of the average human thigh were shot with a bullet that caused the same disruption as the Russian AK-74 assault rifle, and all the animals were given parenteral penicillin (beginning 30 minutes after the shot and maintained for 5 days).

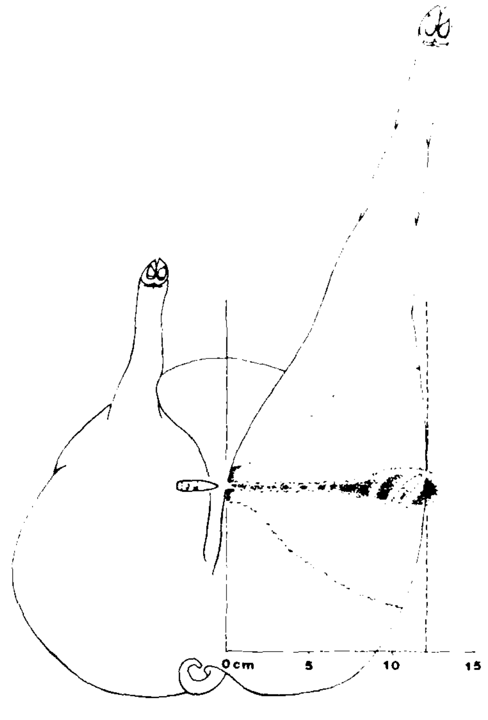

Fig. 1. Bullet path superimposed on leg of swine shows maximum temporary cavity occurring at site of bullet exit. The approximate limits to which the bullet path is stretched by temporary cavitation are indicated by the outer lines encompassing the bullet path on the drawing.

METHODS

Two groups, each composed of five large, white domestic (90 ± 5 kg) pigs, were studied. Each pig was anesthetized with an initial dose of intramuscular ketamine (10 mg/kg) followed by intravenous ketamine given via ear vein as needed. Each pig was shot once through the proximal part of one hind leg while under general anesthesia. All shots were made with the pig in the supine position with a hind limb held in the extended position (Fig. 1). All shots were made transversely: the bullet path at 90 degrees to the long axis of the swine body and the shot placed so that the entrance wound was on the inside of the leg and the exit on the outer surface. The shots traversed the thickest muscle group (semimembranosus, semitendinosus, adductors) of the leg.

To ensure that each shot was placed in exactly the same anatomic location in the leg, measurements taken from bony landmarks were used to determine the shot location. A No. 26 injection needle was placed in the skin to mark the point of aim, and an x-ray film was taken with a portable machine. The needle position was adjusted as needed, and additional x-ray films were taken to verify the location. This was repeated as many times as necessary to assure anatomic reproducibility of the shots from pig to pig. After the shot, another x-ray film was taken along the bullet track to compare muscle disruption identifiable on the x-ray film. The bullet path through tissue was placed 7 cm from the nearest cortex of the femur. A 25 × 25 × 50 cm block of ordnance gelatin (10% by weight) was placed behind the leg in order to catch the bullet after it had passed through the leg and verify that there was no fragmentation or deformation of the projectile. All shots were made using a heavy test bolt action mounted on a solid adjustable base. A 50 cm long barrel with a 5.56 mm bore diameter, chambered for the standard French and American (M-16) military cartridge and having a rifling twist of one turn per 23 cm, was used for all shots. This barrel was chosen after previous experimentation showed that it provided sufficient bullet rotation to stabilize the bullet in air and to guarantee that it strike the leg while traveling point forward (with little or no perceptible yaw angle). All shots were made with the rifle muzzle 3 meters from the surface of the leg. Bullet velocities were measured with a chronograph (Model 33, Oehler Research, Inc.,

Fig. 2. Exit wound, control group, immediately after shot.

Austin, Texas); impulses to start and stop the timer were generated by the bullet breaking a circuit of fine metal foil printed on thin paper. Screens were spaced 1 meter apart and placed midway between the rifle muzzle and the target.

The bullets used were made on a lathe from solid brass rod. They had the same length and same basic ogival form as the bullet from the Russian AK-74 assault rifle. Experimentation was done with shots into ballistic gelatin at the wound ballistics laboratory of the Letterman Army Institute of Research to determine the exact projectile shape that would yaw at the same penetration depth as the bullet from the Russian AK-74 assault rifle. The bullet developed in these studies reproduces the tissue-disruption pattern shown in Fig. 1. This brass bullet does not deform or fragment on striking soft tissue and replicates the wound produced by the AK-74 assault rifle bullet. All of the modern small-caliber assault rifle bullets (M-16A1 and M-16A2, French FAMAS, AK-74) share the characteristic of producing a temporary cavity of about 14 cm diameter. The AK-74 was chosen as the model in this experiment because it produces its maximum cavity diameter at a penetration depth of 12 cm. This places it at the point of exit in the leg of the 90 kg swine (Fig. 1).

Thirty minutes after wounding, each animal in both groups was given 2.5 million units of penicillin G intramuscularly. This dose was given two times daily for 5 days. The animals in the experimental group were operated on 45 minutes after wounding, while still under anesthesia. Each operation was done by the same team—one French military surgeon and one American military surgeon (both were experienced combat surgeons). Each wound was explored through the large exit wound. No additional incisions were needed to adequately expose the depths of the wound. Near the exit where marked disruption had occurred, was found some muscle that appeared severely disrupted and nonviable. It was excised, photographed, and weighed. The projectile path was a tiny punctate hole in its initial half (see Fig. 1) or until bullet yaw and cavitation had dilated it. This initial portion of the bullet path through muscle was not opened; the second half of the path did not have to be opened since the dilation of temporary cavitation had already opened it. The punctate entrance wounds were excised with an elliptical skin incision (1 cm wide and 3 cm long); the wounds were irrigated with normal saline solution to remove blood clots and any foreign material; hemostasis was attained using electrocautery; and the wounds were dressed with bulky, sterile dry gauze laid lightly in the gaping wound cavity and held in place with elastic adhesive bandage.

In each of the five animals of the control group, visual inspection showed large stellate exit wounds. The decompression and drainage were judged to be adequate, and thus no incisions needed to be done. No surgery was done on the control group animals. Dressings were applied to the wounds as described above for the experimental group.

All dressings were changed every 48 hours until the

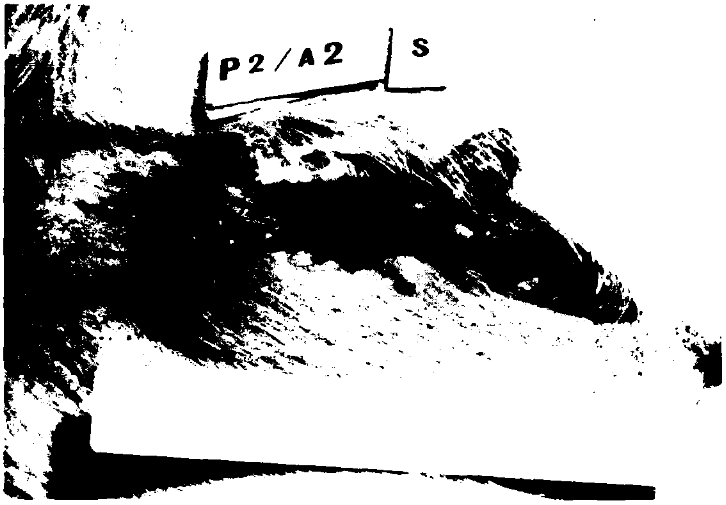

Fig. 3. Exit wound, experimental group, immediately after shot.

skin wound had closed and was completely covered with epithelium. The same anesthesia technique was used for the dressing changes as had been used for the shot. Photographs were taken of the entrance and exit wounds immediately after wounding, after the operation (for experimental group), and at each dressing change.

After healing was complete, the animals were killed and the area of the thigh with the gunshot wound was sectioned for histologic study.

An additional animal was shot under the same conditions but was not included in either group. It was shot to follow the evolution of the marked skin blanching around the exit wound that was noted to some degree in all of the animals of both groups. The evolution of this intense cutaneous vasoconstriction could not be followed in the control or experimental animals since the protocol called for covering these wounds with a dressing, but it was noted that in all cases the blanching had disappeared by the time of the first dressing change. The additional animal was kept anesthetized in the position it was shot, and the wound was photographed at 30-minute intervals until the blanching disappeared (3 hours). The animal was then killed.

RESULTS

All the exit wounds in the experimental and control groups were stellate and measured between 11.5 and 13.5 cm from the tips of opposing skin splits (Figs. 2 and 3). After the anesthetic effects disappeared, all of the swine moved about. After 24 hours they began to bear weight on the injured leg and after 48 hours had little limp in their gait. During the dressing changes, obviously necrotic muscle was apparent in all of the control animals, as shown in Fig. 4. Some necrotic muscle was also seen in two of the five animals in the experimental group. Fig. 4 shows a control exit wound after 4 days, and Fig. 5 shows an experimental group exit wound after 4 days. Necrotic tissue in both groups separated and was expelled between the tenth and twelfth day. Healthy granulation tissue appeared in all the wounds and had lined the wounds under the separating necrotic muscle. Rapid wound contraction took place beginning about the tenth day and by the twentieth to the twenty-second day all the wounds were healed. There was no difference in time of healing between the two groups. All animals in both groups remained afebrile throughout the healing process. All recovered bullets were undeformed except for rifling marks.

The control wounds all appeared "dirty" before the nonviable tissue had been rejected. Two of the wounds in the experimental group, in which all "nonviable appearing" tissue had been excised, showed some remaining nonviable tissue at the first dressing change.

Comparison photographs taken of the exit wound in the extra pig that was shot to show the evolution of vasoconstriction around the exit wounds are shown in Figs. 6 and 7. Marked blanching that extended from the wound around almost half the circumference of the

Fig. 4. Exit wound, control group, 4 days after shot.

Fig. 5. Exit wound, experimental group, 4 days after surgery.

leg was seen immediately after the shot (Fig. 6). This blanching disappeared gradually over a 3-hour period as the hyperemic border moved toward the wound (Fig. 7).

In none of the wounds was there loss of more than a few cubic centimeters of blood from the wound, and no measures were needed to control blood loss except when additional excision of tissue was done (in the experimental group).

All of the wound exits shown are located in the same anatomic area. Figs. 6 and 7 show more of the leg and may be used to provide orientation for all the exit wounds.

DISCUSSION

The experimental work presented here shows that the large stellate exit wounds caused by the modern assault rifle (Figs. 2 and 3) may appear devastating, but they heal in 20 to 22 days even with no surgical treatment whatsoever, as shown by the control group in

Fig. 6. Exit wound shows localized intense cutaneous vasoconstriction immediately after shot.

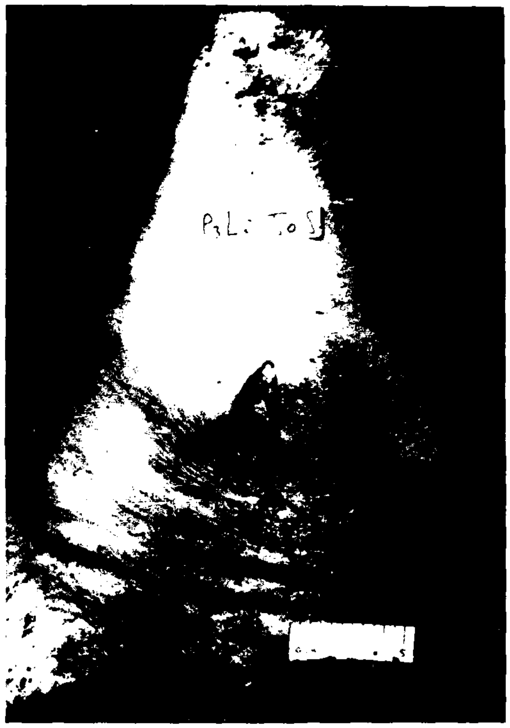

Fig. 7. Exit wound 3 hours after shot shows disappearance of cutaneous vasoconstriction.

this study. This is consistent with what would be expected from our knowledge of wound pathophysiology. The splits in skin, muscle, and fascia were caused by stretching of these tissues from temporary cavitation (Fig. 1). This mechanical decompression, along with penicillin coverage to eliminate the threat of invasive bacteremia by hemolytic streptococcus, presumably produced conditions that ensured unimpeded access to the damaged area by the body's defense mechanisms. Rather than causing the widespread tissue destruction suggested by many,[7-9] the temporary tissue displacement in these uncomplicated extremity wounds produced well-drained stellate exit wounds that actually appeared to augment the healing process. The temporary tissue displacement also caused localized intense, but transient, vasoconstriction in the skin. The attenuation of blood loss from the disrupted muscle indicates that probably a transient vasoconstriction also occurred there.

The rapidity with which nonviable soft tissue was separated and expelled was particularly impressive, although the time is consistent with historic reports based on direct observation of human soft tissue extremity wounds.[4] If, as in common practice, excision of an extremity wound is done the day the wound occurred and the wound is closed by suture 5 days later, sutures must generally remain in place for 14 days. This totals 19 days. There appears to be little, if any, time saved by the method of excision and delayed primary closure over the 20 to 22 days the body's healing mechanisms took to do the job in our study.

Origins of wound excision date from the late 1890s. By that time, general anesthesia allowed prolonged surgical procedures, and Semmelweis and Lister had already shown the dangers of bacterial invasion. Nevertheless, despite antiseptic measures, pyemia, septicemia, and erysipelas remained major causes of death in the war wounded.[10] Friedrich originated the idea of excising the bacteria-containing area around the contaminated wound. He lamented, in regard to invasive infection, "dann noch direct treffende Angriffsmittel besitzen wir nicht [we have no direct means of fighting the problem]."[11] His guinea pig experiments had shown that it took clostridia at least 6 hours to invade past 2 mm in muscle in a wound in which he had placed dirt and then *closed*. He reasoned that if the wound could be excised in this 6-hour period, the bacteria would be removed and the wound would heal without infection.

In World War I cultures taken from fresh war wounds grew hemolytic streptococcus in 10% to 15% of cases, but after a week in the hospital more than 90% of wounds were infected with this bacteria,[12,13] and "streptococcus bacteremia was by far the most important cause of death in cases of war wound."[14] At that time in history, no effective means of combatting invasive streptococcal infection was available. Early wound excision with immediate wound closure was the only way to avoid the common and deadly consequences of secondary streptococcal infection of open wounds.[13]

Meticulous excision of the war wound, done under strict aseptic conditions before bacterial invasion has taken place, by able, conscientious, and well-trained surgeons working under ideal conditions, *may* be followed by immediate wound closure by suture and yield superb results. The remarkably low breakdown rate of only 2.36% for 1760 medium to large uncomplicated soft tissue wounds was reported by LeMaitre.[15] DePage[16] also reported impressive results, and Gray[17] was a strong proponent of the method. It must be emphasized that the surgery detailed by LeMaitre and DePage was done in specialized treatment units. LeMaitre's group received only patients with soft tissue wounds of no more than moderate severity; DePage worked in an 80-bed experimental clinic. In both cases they were able to keep those operated on under their care until the wounds were healed. *Any possibility that the patient might have to be moved in the first 2 weeks after surgery was considered a contraindication to wound excision.*[15,16] The region operated on was immobilized, and the patient was not moved for 16 to 18 days; LeMaitre stated that if these conditions could not be fulfilled, wound excision and primary suture could not be expected to yield good results.[15] Other prerequisites to the use of the technique were as follows: (1) The patient must be in good condition, not in shock, and have a recently inflicted, uncomplicated (no bone or arterial injury) soft tissue wound. (2) There must exist ideal conditions for a long, meticulous operation, absolutely sterile conditions in the operating room, and an experienced and skilled surgeon provided with ample assistance. (3) There must be good general anesthesia (only Gray[17] attempted wound excision with the patient under local anesthesia). (4) Surgical resources must be more than adequate to handle the number of wounded. LeMaitre admits that this procedure in wartime is suited only to periods of relative calm.

Encouraged by the reported successes of wound excision with primary closure, others used the technique in cases for which it was never intended. High mortality resulted.[18-20] These poor results led the Inter-Allied Conference in 1917 to recommend wound excision *without immediate closure*.[9] This unfortunate choice kept the disadvantage of the method (massive use of surgical resources) and lost its main benefit (the closed wound). The conference delegates apparently forgot that the tedious, meticulous wound excision was done in the first place only to allow immediate closure. The originator of wound excision, Friedrich,[11] advised simple incision as needed to release tension and establish drainage ("offenhaltende Behandlung") in cases that did not meet his prerequisites for use of the technique. LeMaitre,[15] the most successful practitioner of wound excision in the war wounded, adopted the same "débridement judicieux"—or incision and open treatment—for those who did not meet his even more rigorous prerequisites for wound excision and immediate closure. Friedrich and LeMaitre, in giving us the scientific basis for wound excision, also give us the best argument *against* its use in a wartime scenario. The first author of this article cannot remember a time in 1968 in Da Nang, RVN, when any patient met the LaMaitre prerequisite for wound excision, that is, after surgery the patient must remain in bed with the wounded area immobilized for 2 weeks without being evacuated to another hospital. Fresh wounded were constantly arriving, and those who had been operated on had to be moved out to make room.

This historical review shows how the method of wound excision, designed to avoid deaths from invasive hemolytic streptococcus bacteremia, has persisted despite the elimination of this threat by the use of penicillin. Also, regarding the threat of gas gangrene, in 1947 Altemeier et al.[21] reproduced the guinea pig model (the scientific foundation of wound excision) used in 1898 by Friedrich but added crushed muscle and injected live clostridial organisms in addition to the dirt. All these control animals died in 3 days just as in Friedrich's experiment. Altemeier et al., however, were able to keep the experimental group of animals alive by treating them with parenteral penicillin. British studies using sheep showed comparable convincing results,[22] and massive, detailed controlled studies[23] on the effectiveness of penicillin treatment of battle casualties in World War II were unanimous in their recognition of the formidable importance of this, then new, treatment modality. Had the Inter-Allied Conference of 1917 adopted the rational method of handling all wounds by release of tension and open drainage, the wound excision method might not have persisted into an era in which its raison d'être no longer exists. On the modern battlefield, it cannot be claimed that the simple open and well-drained wound of the extremity poses a threat to life in the presence of an adequate blood level of penicillin or other comparable antibiotic.

The marked skin blanching, seen around and to the right of the wound shown in Fig. 6, gradually diminishes after wounding and is generally gone after 3 hours have passed (Fig. 7). Those familiar with the body's reactions to trauma will not be surprised by this transient vasoconstriction in response to the sudden and violent stretch of temporary cavitation (Fig. 1). The subsequent graphic demonstration of increasing blood supply in the area around the projectile wound is inconsistent with the concept that one must "cut till it bleeds" in removing tissue for treatment of gunshot wounds. This observation of gradually increasing blood flow after initial intense vasoconstriction in the skin of the area stretched by temporary cavitation, along with the lack of any significant bleeding from the underlying muscles, fits with what we would expect of the body's defenses in reaction to injury. These observations are consistent with all studies we could find in which animals were kept alive after wounding for objective evaluation; less lasting damage was reported than was estimated from observation of the wound in the first few hours after it was inflicted.[24-29] Objective observations from the field of battle in World War II also showed that it was "surprising to see how much apparently nonvital tissue recovered."[30] Review of experience from the Korean conflict also revealed that "excision of devitalized tissue failed to express the objectives of initial wound management . . . such experiences led naturally to the principle of incision, applicable to both skin and fascia, as one of the major steps in initial wound management,"[31] and that "the role of antibiotics in the prevention and treatment of infections cannot be overemphasized."[32] Thus the objective experience gained by treating great numbers of the wounded appears quite consistent with our experimental findings.

What, then, is the origin of the modern military dogma on treatment of gunshot wounds? It appears to have resulted from the wound ballistics misconceptions of the post-Vietnam era.[33,34] Although objective testing shows that a bullet's striking velocity does *not* correlate with the amount of tissue disruption it causes,[35] much fallacious dogma has been generated from the false premise that a projectile's striking velocity does foretell the amount of tissue disruption it causes. An example of the illogical and unsupported modern dogma is the idea that an uncomplicated extremity wound with small, punctate entrance and exit and no evidence of significant muscle damage must be widely excised *if it was made by a "high-velocity" projectile.*[7-9] Throughout history, it has been pointed out by those who have treated this type of wound that it heals well, *needing no surgery.*[13,30,36-40] Even the practitioners of wound excision in the pre-antibiotic era of World War I[15-17] specifically excluded this type of wound from surgical treatment.

In summary, our study showed excellent healing in uncomplicated extremity rifle-bullet wounds that were free from tension and well drained. Wounds in which apparently nonviable tissue was excised healed no faster than those in the control group in which no tissue was excised. We suggest that these findings, coupled with the objective historical evidence supplied, support a simpler treatment alternative (release of tension and provision of good drainage—if the bullet has not already accomplished this) to the excision of tissue in treatment of uncomplicated penetrating extremity wounds.

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