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MIGRATORY MISSILES

(Conditions for the Penetration of Vessels by Bullets)

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→ Missiles that penetrate the body can come in contact with a large vessel, perforate it, and be carried well away from the point of impact by the bloodstream. These missiles, under these conditions, are called migratory missiles. The coroner is concerned with them because he is the one who tries to locate them in the course of a criminal autopsy. Moreover, these foreign objects have been tolerated, in certain cases. The time that has elapsed before they had become the cause of arterial obstruction accompanied by gangrene, or of cardiac irritation having caused death, has varied. ←

Wartime observations are not uncommon, but forensic medicine observations are rarer. Migration can be arterial, or venous.

This question of foreign objects in the vessels has, moreover, been under study for quite some time now. It was discussed at some length in an article by Leon Binet and N. Peron on the intravascular migration of war missiles [1].

I. Arterial Migration

Observations are numerous. These, for example, are from Rouault [2]; a war victim hit by a missile in the right scapular region suffered flaccid paralysis of the lower left limb, with radiographic localization of the bullet below the femoral arch at a depth of 3 cm; and from Mazet [3], whose wounded man had taken a grenade burst that entered the thoracic-abdominal region and localized in the right femoral artery in the upper 1/3rd of the trigonum femorale.

*Teacher who has passed the competitive examination conducted by the State for admission to posts on a teaching staff.

And then there are the observations by Boeckel [4], Morizot [5], O'Neill [6], Fulleurton [7], and so on.

Several facts now have emerged and have been made public. The first of these is that there is real penetration into the arterial system. Second, that the body has a certain tolerance to this foreign object after immediate stoppage of bleeding from the arterial wound, so-called dry hemostasis. There then is migration. Migration generally takes place in the direction of the iliac arteries, or of the femoral artery, most often to the left.

There are forensic medicine observations, albeit rare, that confirm this view. Those of Leclercq and Muller [8], of Dervieux [9], among others, are similar. Leclercq and Muller provide an explanation of the more frequent presence of the missile to the left than to the right in terms of arterial arrangement. We cannot say if this is actually the result of chance, or the result of an anatomical quirk. The bifurcation of the abdominal aorta into the primitive iliac is indeed quite special, and the two arterial trunks, diverging from each other, take slightly different directions. Chalier and Murard [10], in an interesting article on the termino-aortic region, provide details on the natural course to each of the vessels. In any case, we too, in an uncommon observation, had the occasion to study the shunting of a missile towards the left iliac. Here is the observation.

A young man was hit by a pistol bullet fired at a distance of one or two meters. He died instantly. A coroner's autopsy was ordered. Examination of the corpse revealed a hole in the skin 6 to 7 mm in diameter where the bullet had entered the body in the anterior region of the chest, near the median line in the right part of the sternum at the level of the 3rd intercostal space. There were no signs of tattooing by powder grains.

Careful probing indicated that the sternum had been perforated, and that the direction of the shot was from anterior to posterior, very slightly upward and from right to left.

Examination of the opened thorax revealed that the bullet had nicked the most superior part of the pericardium, then had penetrated the antero-lateral wall of the arch of the aorta. There was quite a bit of blood in the pericardium. The blood had spread toward the left common carotid artery and along the descending part of the thoracic aorta on its left lateral part. There was no blood in the pleurae.

No trace of blood was found on the vertebral column after separation of the tongue, trachea, and esophagus, thus unblocking the entire mediastinum. Neither the trachea nor the esophagus were perforated. Both lungs were intact, as was the heart.

The missile was sought for with a great deal of care throughout this region. Having failed to find the bullet, those of us who had been directed to provide an expert opinion thought that perhaps the orifice of the arch of the aorta had not been the path followed by the bullet, that perhaps there had simply been a ricochet that had caused the bullet to exit. But

there had been no success in finding the missile anywhere within this entire hemorrhagic region of the thoracic cavity.

The autopsy was continued. No abdominal lesions were found.

The contents of the abdomen were removed. The abdominal aorta was opened, as were the iliac arteries, then the femoral arteries.

The missile was found in the left femoral, about two finger's breadths below the crural arch, in the vicinity where the femoral artery divides. It was caught, ogive forward, right at the bifurcation. The presence of the bullet could be guessed at before the vessel was opened up in this area because the artery had formed a protrusion, and because the walls were stretched by the foreign object.

The missile was of uncoated lead, caliber 8 mm, slightly deformed.

Ch. Achard and Léon Binet [11] have observed that the arterial pressure is high enough to rapidly sweep grains of lead introduced into a large artery toward its periphery, even when the member is elevated. Their experiment, involving the introduction of a grain of lead into the femoral artery of a dog, is demonstrative of this point of view.

II. Venous Migration

Observations here are more numerous. Characteristics resembling those already described have been found. The missile penetrates the venous system. Hemostasis often is immediate, and the foreign body is carried along toward the right heart. Here too tolerance is observed. We are unable to cite many observations of missiles whose presence is not incompatible with life. Belot and Duvoir [12] recently presented an interesting observation, with x-rays, to the Société de Médecine légale [Forensic Medicine Society].

Monti, in Italy in 1917 [13], and Ch. Achard and Léon Binet, in France in 1918 [11] studied migration conditions by introducing grains of lead (as well as grains of rice because their density is not too different from that of blood clots) into the vena femoralis of different dogs placed in various attitudes.

They claim that venous migration is subject to greater diversity than is migration in the arteries, but that gravity has much more to do with migration than does the blood flow. Low density foreign objects (grains of rice) will be displaced along with the flow of blood in the same manner as will blood clots, for example, but the displacement of metal objects will depend on the attitude of the subject.

What should be pointed out, therefore, is that displacement will vary with the foreign object. The best condition is that in which the foreign object is a polished sphere. There are, in all, three forces acting; entrainment, resistance, and friction. Gravity must be added, and this complicates movement.

These experiments are just as interesting as those previously described because the experimental data they yielded confirmed clinical, anatomic-pathologic, and forensic medicine facts.

* * *

This group of readings, of particulars, of observations of all sorts, will lead to an understanding of how a missile, once it has penetrated a vessel, artery or vein, can be carried along for some distance.

But having studied a great many different types of arms, and having fired a great many rounds, over a long period of time, the question which to us up to this point appears to be the most complex, and the most difficult one to resolve, is that of penetration itself. The evidence suggests that it remains unresolved. In fact it has not even been well studied. So far as arteries, or veins, are concerned, there is little understanding of how a bullet, reaching the end of its flight, can pierce the first wall it hits and then fail to perforate the second wall of the vessel (artery or vein) (what we are talking about here in particular are bullets, and from our point of view in the practice of forensic medicine). There should be an ideal penetration force of some sort. And if it is suggested that this perhaps is the resistance of an arterial membrane with respect to the force of a missile, the surprise is that the projectile would be able to produce that force (it would nevertheless appear to be produced in the second of the Leclercq and Muller observations [8]).

But it is indeed fact that modern missiles, regardless of type, have tremendous penetrating power, and it would appear to be virtually impossible that a missile would be at precisely the end of its flight at the moment it enters the vessel after having penetrated the anterior wall. Moreover, the case would be even more exceptional were it not for the fact of having the observations on record.

In the killing we reported above, the shot was fired at a distance of 1 or 2 meters (police investigation). The bullet had penetrated the thoracic region after having passed through the sternum. What was involved was an uncoated lead missile, 8 mm in diameter, that is, one fired by a stub-nosed revolver (ordinary bull-dog type). The penetrating force certainly was still quite high at the moment the aorta was hit. The muzzle velocity, V_0 ,* of a bullet such as this is not accurately known, but is certainly in excess of 100 m/s. At the instant the missile hit the membrane of the aorta its velocity would have been such, its kinetic energy so high, its capacity to perforate so intense, that it would not have been able to enter the lumen of the vessel without exiting the other side.

* V_0 is used to designate the muzzle velocity, that is, the velocity of the missile at the moment it leaves the barrel of the weapon. V_{16} thus would indicate the velocity of a missile that had traveled 16 m, V_{535} the velocity after having traveled 535 m, etc.

The following data are pertinent and are presented by way of example.

The bullet fired by the old French regulation revolver (1892) has muzzle velocity $V_0 = 220$ m.

The Browning 6.35 mm fires a bullet with muzzle velocity $V_0 = 220$ m, and the Browning 7.65 mm fires a bullet with muzzle velocity $V_0 = 270$ m.

The German infantry rifle fires the steel- or German silver-jacketed lead Spitzgeschoss [pointed bullet] weighing 10 grams with muzzle velocity $V_0 = 880$ m/s.

The Level rifle (Desaleux bullet) fires a 12.80 grams bronze missile with muzzle velocity $V_0 = 720$ m/s. The same holds for the magazine pocket pistols (Général Journée [14]).

No. 6 bird shot, one pellet weighing 0.137 gram, and having striking velocity $V_{48} = 73$ m/s at 48 m, will penetrate soft tissues of a cadaver to a mean depth of 30.2 mm.

No. 8 shot, one pellet weighing 0.075 gram, fired at a distance of 36 m, and having a striking velocity of 131 m/s, has a mean penetration of 2 mm.

12-gauge buckshot, in three layers, diameter from 7 to 8.54 mm, one pellet weighing 3.75 grams, fired at 250 m has velocity $V_{250} = 106$ m/s and mean penetration of 7 mm into tissue (Général Journée and Piédelièvre [15]).

These figures are indicative of local violence as severe as that to be expected from a press punch. It would be something of a paradox to think that even in an observation such as the one we made, that a bullet, after perforating the sternum (which offers little resistance to a missile) would have had exactly the force needed to traverse one of the arterial walls and enter the cavity without at the same time having the force to traverse the other wall, thus being sufficiently resistant to prevent passage of the missile.

Admitting, as we said above, that the missile would be able to meet this ideal condition in certain very rare cases, there must be some other penetration mechanism at work because observations of migration of missiles in vessels, albeit rare, are not uncommon.

The following experiments were conducted for the purpose of seeking this mechanism.

First Experiment. We put together the following experimental device on the assumption that a bullet that penetrates the aorta by passing through the anterior wall of the vessel could be seized and entrained by the violence of the current of blood.

One end of a rubber tube with a diameter and a thickness reasonably comparable to those of the first part of the aorta was fitted to a water pipe. The other end was suspended above a crystallizer. The rubber tube was vertical and was suspended without an extension.

A strong stream of water was sent through the tube. The water was, as a result, violently discharged into the subjacent receptacle by the lower, free, end of the tube. The tube was replaced by a new, unperforated, tube after each round had been fired.

The rounds were fired by a 6 mm rifled carbine using lead bullets (Bosquette type), fulminate of mercury cartridges, single and double heads. $V_0 = 100$ (?). (Single head: round bullet weighing 1 gram. Double head: pointed bullet weighing 1.80 grams).

A. First Series of Rounds

Distance 2 meters. The missile passed through the anterior and posterior walls of the tube. Noteworthy is the fact that the hole through which the missile exited (posterior wall) was found to be in the same horizontal plane as the hole through which the missile entered (anterior wall) and showed the punctiform feature normal for rubber. The bullet thus had not been drawn downward by the violent stream of water, and had in no way been influenced by the water (it had not been turned, something that would have produced a slit, or a tear in the exit hole, and not a punctiform hole). The result was the same in all the experiments that follow, so will not be repeated.

B. Second Series of Rounds

Firings were executed in a like manner up to 10 m (moving the weapon back 1 m each time).

Results were always the same, even though the force of penetration was reduced ($V_{10} < V_0$).

C. Third Series of Rounds

Because the velocity of the missiles was too great to satisfy the ideal condition for perforation of the anterior wall without perforation of the posterior wall, we inserted progressively greater resistance in front of the tube, sheets of paper, sheets of rubber, small boards,** arranged so

** Indeed, it was impossible to operate in any other way. The cartridges used are among the least powerful. It would have been necessary to fire at greater distances in order to reduce their velocity. The precision of missiles such as these decreases quickly with distance, despite the rifling of the weapon, and it was essential that the point of impact of the missile and its axis correspond exactly to the diameter of the tube. Otherwise the tube, because of its elasticity, would move and the bullet would slide over one of its lateral faces and ricochet, occasionally without even

as to progressively stop the bullet before contact with the anterior wall of the tube and thus diminish the force of penetration.

Two phenomena resulted. The bullet had sufficient velocity to perforate the two walls of the tube, as before, or it did not have enough force to do so, and instead bounced back against the anterior wall, leaving its imprint, but not penetrating.

In no case, after numerous rounds, did we see the missile drop in the tube, only the anterior wall having been passed through.

Second Experiment

We next placed a deal board in contact with the posterior wall of the rubber tube, thus making a device somewhat similar to that of the aorta pressed against the vertebral column.

A. Rounds were fired at distances from 2 to 10 m such that the bullets hit the anterior wall of the tube, its posterior wall, then the board.

B. Other rounds were fired with paper, rubber, and a wooden board, inserted in the trajectory as before in order to artificially reduce the velocity.

In this, as in the other case, when the bullet struck right in the middle of the tube it penetrated into the lumen in the majority of cases and fell into the crystallizer, sucked down by the violent stream of water.

Examination of the rubber tube revealed the hole in the anterior part of the tube, and on the other side, the wooden board side, either a hole, more or less jagged and a depression in the wood, or simply an imprint and a contusion of the rubber, without perforation, but with a depression in the wood, the rubber having been pinched between the bullet and the board, without having been ruptured.

damaging the tube. It is probable that the same thing often is the case in the human body and that the arteries in some way or other recede before the missile when not hit dead center (research is now in progress on this special point in the forensic medicine laboratory in order to understand this mechanism).

We also used an air carbine, but the force was not sufficient to perforate the rubber, and the bullet bounced off. On the other hand, use of a signal pistol firing a 2 mm caliber blank cartridge loaded with fulminate was impossible for the opposite reason; we loaded these cartridges with bird shot of the corresponding caliber (weight of shot 0.474 gram). Penetration was substantial, almost of the order of Bosquette type bullets.

Finally, we tried to reduce the velocity of our missile by having them ricochet off a metal plate, the ricochet limitation being significant (Général Journée [14]; Général Journée and Piédelièvre [16]). Precision was lost and the bullets no longer reached the center of the vessel.

What took place here is somewhat similar to that which no doubt took place in the case we reported, that is, that the aorta showed but one hole and that the posterior part of this vessel was found to have been pinched between the vertebra and the bullet without having been perforated. Without a clue concerning this mechanism at the time of the autopsy, we had not thought to look to see if the vertebra showed a small hollow as did the boards.

* * *

We therefore are of the opinion that when a missile penetrates a vessel, this penetration occurs because of the mechanism we have indicated. Vessels, arteries or veins, have little resistance to the power of all missiles fired by modern firearms. There is no need for so many observations of migratory missiles to assume that the capacity of the bullet to perforate is just sufficient for the bullet to pass through the first wall encountered, and just insufficient for it simply to contuse the second wall. The number of such observations is an index of another mechanism which perhaps makes this condition one that is out of the ordinary.

In any event, we have never been able to duplicate the results experimentally. On the other hand, bullets can be readily introduced by firing real rounds at a rubber tube, or they can be passed through a stream of water, if there is an obstacle in contact with the second elastic wall.

When migratory missiles penetrate the aorta, or the vena cava, they no doubt rebound into the lumen of the vessel in accordance with the procedure we have pointed out.

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