Experimental Observations of Incapacitation via Ballistic Pressure Wave without a Wound Channel

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Abstract:
This article describes experimental observation that incapacitation and injury can be caused by a ballistic pressure wave independently from wounding caused by crushing effects of a bullet in the wound channel. Live animal test subjects partially immersed in water were observed to be incapacitated by a ballistic pressure wave created by a bullet passing through the water close to the test subject without hitting the test subject. The water coupled the pressure wave to the thoracic cavity of the test subject without perforation. Bullets producing larger pressure waves caused incapacitation, whereas a load producing smaller pressure waves did not.
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I. Introduction

The hypothesis that a ballistic pressure wave plays a role in incapacitation has been described and tested in humans [COC06b], goats [COC06c], and deer [COC06d]. In addition, traumatic brain injury has been linked to the ballistic pressure wave [COC07b]. These ideas build upon earlier work by Suneson *et al.* in which a ballistic pressure wave reaching the brain was measured directly with high speed pressure transducers implanted in the brain of swine shot in the thigh [SHS88, SHS90a, SHS90b].

The work of Suneson *et al.* was later confirmed by a similar experiment in dogs [WWZ04]:

> *These findings correspond well to the results of Suneson et al., and confirmed that the distant effect exists in the central nervous system after a high-energy missile impact to an extremity. A high-frequency oscillating pressure wave with large amplitude and short duration was found in the brain after the extremity impact of a high-energy missile . . .*

This experiment in dogs is not the only evidence in the literature tending to confirm the findings of Suneson *et al.* The lateral fluid percussion model of traumatic brain injury has demonstrated conclusively that transient pressure pulses of similar magnitude as observed by Suneson *et al.* can cause traumatic brain injury and incapacitation [THG97, TLM05, and references therein].

Analysis of a large epidemiological-type data set employed the hypothesis that pressure wave and wound channel effects are independent. This analysis yielded correlation coefficient of R = 0.939 [COC06b]. This data set has been criticized, but these criticisms have been shown to be exaggerated and to contain serious logical flaws and fallacies [COC06a]. Within the accuracy of the data set, this supports the pressure wave mechanism acting independently of the wound channel.

Independent incapacitation mechanisms are consistent with the pressure wave and wound channel mechanisms being associated with

fast (< 5 seconds) and slow (> 5 seconds) incapacitation, respectively [COC06c]. Since the ballistic pressure wave affects the central nervous system, it can create incapacitation quickly, in contrast to the wound channel that works through the physiological consequences of blood loss and acts slowly [NEW92].

The pressure wave hypothesis and the independence of pressure wave and crush mechanisms are well supported by the literature referenced above. However, the case is made even more compelling by observing incapacitation by a ballistic pressure wave without the presence of a wound channel.

This article describes experimental evidence of incapacitation caused by a ballistic pressure wave independently from wounding caused by crushing and cutting effects of a bullet in the wound channel. Test subjects (10-20 lb mammals) immersed in water were observed to be incapacitated by a ballistic pressure wave created by a bullet passing through the water very close to the test subject without any wound channel.

The most convincing and irrefutable way to demonstrate that the internal pressure wave created as a handgun bullet passes through tissue plays a role in incapacitation would be an experiment where the pressure wave alone was responsible for incapacitation. The experimenters reasoned that if a wound channel is present, the analysis might always be subject to the criticism that the wound channel rather than the pressure wave that caused the incapacitation.

In part, this experiment was inspired by anecdotal observations that many small animals such as fish, frogs, snakes, squirrels, etc. can often be incapacitated by near misses, especially if the animal is immersed in water. A pilot experiment was done that showed that incapacitating bluegill (small fish, *Lepomis macrochirus*) in a container of water depends on the force on a bullet being stopped in the water and on the distance from the bullet path to the bluegill. This observation agrees with the pressure wave being proportional to the retarding force and inversely proportional to the square of the distance to the bullet path [COC06c].

II. Method

The goal of the experimental design was to apply a ballistic pressure wave into the internal organs of a medium-sized mammal without creating a wound channel. The basic idea is to immerse the test subject in approximately 5 gallons of water and fire the bullet into the water so that the bullet path passes within a few inches of the test subject without the bullet or any fragments penetrating the test subject and creating a wound channel. The bullet path needed to be kept very close to the test subject because the pressure falls off as the square of the distance.

A simple estimate of the peak pressure experienced a distance R from the bullet path is [COC06c]:

$$P = \frac{5E/d}{4\pi R^2},$$

where *E* is the kinetic energy of the bullet, and *d* is the penetration distance in water.

The limiting factor in precise quantitative analysis of these experiments is the unknown coupling strength of the pressure wave from the water to the inside of the test subject. At the boundary between the water and the test subject, some fraction of the incoming pressure wave is reflected, some is absorbed, and some is transmitted to the internal organs of the subject. All we know for sure is that the pressure inside the test subject is less than the

pressure in the water. (In other words, the ballistic pressure wave effect in this experiment is smaller than if the wound channel is actually in the body. Eliminating the coupling loss by shooting directly into the body will produce a larger pressure wave.)

The experiment used *Procyon lotor*. Each test subject was immersed in a 5 gallon bucket of water, using ½" hardware cloth to exclude the test subject from a 3" diameter vertical cylinder along one side of the bucket and using a milk crate to keep the test subject confined to the bucket. Typically, the test subject moved close to the exclusion cylinder and kept its nose out of the water at the small air gap at the top of the bucket.

The bullet was fired from 15' above the bucket downward into the center of the 3" diameter exclusion cylinder. Within 3 seconds of the bullet being fired, the milk crate was removed from the top of the bucket. The test subject was determined to be incapacitated if it failed to run a distance of 20 feet in one minute.

In determining whether the test subject was incapacitated, there were no borderline cases. Either the test subject seemed unaffected, climbing quickly out of the bucket and moving quickly to a distance of 20 feet in less than 10 seconds, or (if it exited the bucket at all) only made it a few feet and was quickly recaptured after the minute had expired.

In each case of pressure wave induced incapacitation, the experimenters confirmed that there was no penetration into the test subject.

III. Results

Five different test subjects were observed for each of three different loads producing three different peak pressure wave magnitudes. The peak pressure wave magnitude depends on distance from the center of the bullet path, and for comparison with earlier work [COC06b, COC06c], a standard distance of R=0.5" is used. (This is the pressure on the surface of a 1" diameter cylinder centered on the bullet path.)

For example, a bullet impacting with a kinetic energy of 500 ft-lbs and penetrating to a depth of 1 foot creates a pressure wave with a peak magnitude of 796 PSI at the edge of a 1" diameter circle centered on the bullet path. $P_{1"}$ represents the peak pressure wave magnitude at the edge of a 1" diameter circle centered on the bullet path.

The three different bullets and the pressure wave magnitudes they produce when fired into water are:

- The Winchester 147 grain 9mm JHP at 990 FPS. This is the load currently sold under the Winchester USA label. This bullet penetrates 20" in water giving $P_{1"}$ = 306 PSI.
- The Triton Quik-Shok 115 grain JPH at 1450 FPS. This is the bullet loaded in the .357 Sig cartridge and sold by Triton before they were bought by American Ammunition. This bullet penetrates 10.4" in water giving $P_{1"}$ = 987 PSI .
- The Hornady 110 grain .308 VMAX loaded to 3400 FPS in a 30-06. This bullet penetrates 9.5" in water giving $P_{1"}$ = 5676 PSI .

Load 1: 147 grain Winchester JHP at 990 FPS
None of the five test subjects were incapacitated or showed any other sign of obvious injury or effect. It appears that the pressure wave produced by this bullet is too small to create incapacitation in this experimental configuration.

It is interesting to note that this load also has a relatively small pressure wave contribution to incapacitation (55%) in analysis of the Marshall and Sanow data [COC06b], and in the empirical pressure wave model of the Strasbourg tests (< 10%) [COC06c]. This bullet also yielded a much larger average incapacitation distance (98 yards) in testing in deer compared with the 115 grain Quik-Shok (50 yards) [COC06d].

Load 2: 115 grain Quik-Shok at 1450 FPS.
Three out of five test subjects were incapacitated. One out of three incapacitated test subjects was deceased with 24 hours. The pressure wave produced by this bullet is sufficient to produce incapacitation in a significant fraction of test subjects.

This bullet also has a significant pressure wave contribution to incapacitation in the empirical best-fit model based on the Marshall and Sanow data (83%) [COC06b], and in the empirical pressure wave model of the Strasbourg tests (60%) [COC06c]. Compared with the low pressure wave 147 grain Winchester JHP, this bullet also yielded a much shorter average incapacitation distance in testing in deer [COC06d].

Load 3: 110 grain .308 Vmax at 3400 FPS
Four out of five test subjects were incapacitated. One test subject was immediately deceased. Two out of four incapacitated test subjects were deceased within 24 hours. The pressure wave produced by this bullet is sufficient to produce incapacitation in a significant fraction of test subjects.

One might think that the increase in pressure wave magnitude between Load 2 and Load 3 should have been sufficient to incapacitate all of the test subjects. However, this was not the case. This result is consistent with the result from the goat model [COC06c, Figure 6] suggesting that even at larger pressure waves, some percentage of test subjects are resistant to incapacitation via ballistic pressure wave.

IV. Discussion and Conclusion

In conclusion, the direct observation of incapacitation by ballistic pressure wave apart from permanent crush cavity and temporary stretch cavity effects strongly supports the validity of the pressure wave hypothesis, as well as the independence of pressure wave and wound channel contributions inferred from analysis of the Marshall and Sanow data set [COC06b].

While the experiment described here provides compelling evidence for the incapacitation effects of a sufficiently large ballistic pressure wave, this work is primarily a qualitative demonstration. This experimental method should not be interpreted as a recipe for evaluating the incapacitation potential of individual handgun loads because the wound channel also plays an important role in incapacitation. A quantitative analysis of the relative importance of the pressure wave and wound channel as contributors to incapacitation is presented elsewhere [COC06b].

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