The Electromagnetic Pulse Cause of Shellshock

Frank H. Makinson ***IEEE Member***

Abstract—The pathology of shell shock has been identified by researchers, so stated a newspaper article. Why the brain injury occurs primarily in the frontal lobes and its "distinctive honeycomb pattern of broken and swollen nerve fibres" was not identified. Every munitions explosion emits a broadband pulse of electromagnetic energy. The electromagnetic energy pulse reaches the victim before the compression and particle components of the explosion. The characteristics of the head protection used by soldiers explains why the particular brain injury is as prevalent today as it was in World War I, but without the massive artillery barrages. The victims are receiving what can be termed an electromagnetic shock to their brain.

I. Introduction

A newspaper article titled, "The mystery of shellshock solved: Scientists identify the unique brain injury caused by war."[1] The description of the brain injury is provided in one paragraph: "*Described as a 'distinctive honeycomb pattern of broken and swollen nerve fibres', the injuries were not the same as those found in car crash and drug overdose victims, or sufferers of punch-drunk syndrome, which is caused by repeated blows to the head.*" The researcher specifically cited in the report is Professor Vassilis Koliatsos of John Hopkins University.[2] The researchers identified the pathological characteristics of the brain damage, but they did not identify the specific mechanism that caused the unique damage. The contemporary term for the damage is referred to as traumatic brain injury (TBI) and is associated with post-traumatic stress disorder (PTSD).

In World War I (WWI), the massive artillery barrages exposed soldiers to nearby munitions explosions and many of those that survived the blast damage, with no obvious cranial injuries, afterward displayed various levels and combinations of emotional and motor control behavior. The term *shell shock* was coined to describe the outward characteristics. The term *shellshock* was banned (censored) by the British after WWI. The terms *thousand yard* and *two thousand yard stare* are associated with those that experienced shellshock.

One might expect that World War II and the Korean War, where U.S. soldiers were exposed to nearby munitions explosions, would have produced the same scale of shell shock, but the percentage of shell shock victims appeared to be much lower as the condition was not mentioned prominently in the press. There is a common thread associated with the incidence of PTSD and the type of cranial protection issued to U.S. and British soldiers in the different wars.

In WWI, the steel Brodie helmet was standard for British troops and the similar design steel M-1917 was issued to U.S. troops. These helmets covered the top cranial area and the flared rim did not extend below the top of the ear lobe and much of the forehead was exposed. The steel U.S. M1 helmet was adopted in 1941, and it covered a larger percentage of the cranial area in the front, and the sides extended downward about halfway over the ear lobe. The non-steel Kevlar helmet was adopted by the U.S. in the mid-1980s. Kevlar helmets have superior ballistic performance over steel and its size protects a greater percentage of the cranial area from ballistic injuries.

It is not commonly recognized that a munition explosion produces a broadband high intensity electromagnetic (EM) pulse (EMP), even though the observed bright flash of an explosion is EM energy in the optical spectrum.[3-5] A high intensity broadband EMP will not readily penetrate steel, but the Kevlar will provide little protection from the microwave spectrum of such a pulse.

II. EMP Spectrum of Chemical Explosion

The EM spectrum covers frequencies from very low to very high frequencies that extend well above the optical spectral range. Our human sensory systems can directly detect the presence of EM radiation in the optical range and the invisible infrared and ultraviolet frequencies when they produce secondary effects, such surface heating and sunburn. The effects of long term cranial exposure to various levels of EM emissions are being studied, but none of the studies involve very high magnitude EM sources, as it is already known these can cause severe internal body damage.

The visible and heat frequencies of the spectrum of a nearby munitions explosion are readily detected, but the proliferation of other frequencies, with their additive and subtractive components can produce frequencies with wavelengths that can interact with the conducting structures of the brain as well as other conducting parts of the human body. The acronym EMF refers to *electric and magnetic fields*, and is used in the guidelines that limit human exposure to these fields, such as the *specific absorption rate* (SAR) regulations.[6] The EMF exposure guidelines are not keeping up with the rapid development of devices that produce higher and higher frequencies.

EM energy can come in non-ionizing and ionizing form. The ionizing form is that produced from radioactive sources and high intensity EM discharges. If the magnitude of an EM pulse is high enough, even though it is does not have the high frequency of an ionizing emission, it will produce major damage in a human body. It is now known that high altitude electrical discharges can produce both gamma and X-rays, and it is suggested they can pose a danger to passengers in high altitude aircraft.[7]

Frequency and wavelength are inversely proportional. A large wavelength has a lower (smaller) frequency, and inversely, a very small wavelength has a very high (larger) frequency. For EM waves the speed of light is the constant of proportionality between wavelength and frequency. Algebraically, the relationship is expressed as $\mathbf{c} = \boldsymbol{\lambda}\mathbf{f}$, where $\mathbf{c}$ represents the speed of light, $\boldsymbol{\lambda}$ the wavelength and $\mathbf{f}$ the frequency.

EM waves are produced by the motion of electric charges. In a wire, valence electrons near the surface, also called free electrons, are induced to break their molecular bonds by applying a voltage potential across the conductor; the higher the voltage the more electrons are influenced to move. A Los Alamos National Laboratory (LANL) report stated that millions of volts are created within a munitions explosion.[8] The explosion produces a large volume of accelerating electrons and ions that will produce EMFs. The EM dynamics of an explosion are not well documented and no assumptions can be made as to the characteristics of EM waves produced by the combination of electrons and ions produced by the process. The polarization of the resulting EMFs would be in all directions, which means there will always be propagating fields that are properly aligned to transfer their energy to conducting structures in the human body.

An explosion that creates broadband EM pulses presents a problem in the distance where measurement sensors are placed. The terms *near field* and *far field* refer whether a measurement is made within two wavelengths of the EM source, whereas *far field* is beyond two wavelengths. This means that most of the very high frequency pulses will be measured in the *far field*, but a considerable percentage of the low frequency pulses will be measured in the *near field*. This is an issue that will have to be resolved by those that make the measurements. The intensity of the pulses produced at different frequencies is another factor that will determine the placement of measurement sensors.

III. EMP Magnitude of a Munitions Explosion

"*The emission of electromagnetic radiation from a chemical explosion is well established.*" That quote is from the LANL report, but it is not known to the general public and to many in other scientific disciplines. The LANL report was limited by the frequency capability of the measurement instruments available at that time. All the references cited in ref. (8) were before 1993 and there have been significant improvements in antennas and measurement instruments, which now includes high-speed video recording equipment. Another interesting quote from the LANL report is, *"A statistical analysis of an excess of 100 experiments at various distances from several different charge masses shows that the magnitude of the electric field is directly proportional to the explosive mass.*" Some explosive materials with the same mass produce higher energy output than others, and improved measurement instruments and techniques should be able to distinguish characteristic differences.

The EMP characteristics of munitions explosions are still being explored to identify how electronic equipment can be protected from them; this effort is separate from protecting the equipment from the blast pressure effects of explosions. A recent report on EMP emissions from explosions is in a 2010 IEEE publication on electromagnetic compatibility.[9] The abstract does not identify the specific frequencies and magnitudes of the associated EMP, but it indicates that electronic equipment needs protection from the EMP produced by explosives.

Many contemporary studies of TBI caused by nearby munition explosions are centered around identifying the physical blast effects; the EMP aspects of the explosions are not mentioned.[10] The alteration of brain characteristics by EMF exposure is being studied, but most studies involve rather low levels of exposure, typically that produced by cell phones. However, relatively low levels of electric current, that are induced by EM wavelengths that are well matched to the physical size of the conducting neural structures, can alter the permeability of mammalian brains.[11]

A magnetic field of an EMP moving through a conducting structure, metal or fluid, will induce an electric current in the structure. If the current produced exceeds the current capacity of the conducting structure, the structure will be damaged. If the conducting circuit was a metallic wire, it overheats, melts or vaporizes a segment of the wire, which creates a gap which terminates the conduction; adjoining insulation and wires can be damaged. If the conducting circuit is a fluid, such as cerebrospinal fluid, an over-current would cause heating that converts the fluid into a gas bubble that expands and ruptures the neural fiber connection. One might suspect that a severe over-current condition in a bundle of neural fibers could be the cause of a "*honeycomb pattern of broken and swollen nerve fibres.*" The honeycomb pattern would be related to particular wavelengths of the EMP.

A November 2016 report is titled, "Neuronal and glial changes in the brain resulting from explosive blast in an experimental model."[12] The first two sentence of the abstract states, "Mild traumatic brain injury (mTBI) is the signature injury in warfighters exposed to explosive blasts. The pathology underlying mTBI is poorly understood, as this condition is rarely fatal and thus postmortem brains are difficult to obtain for neuropathological studies. Here we report on studies of an experimental model with a gyrencephalic brain that is exposed to single and multiple explosive blast pressure waves." The pressure from the explosion was stated as, "An average pressure of 100psi was generated near the head." The researchers made the assumption the damage is being caused by concussion effects of the explosive blast. The EMP was not measured.

References (1), (11) and (12) provide images of brain damage. Those with experience examining these structures may be able to determine whether the damage observed is similar.

IV. Recommendations

The EM signatures, such as frequencies, amplitudes and pulse duration times produced by various types of explosive material should be determined. Researchers should determine whether gamma and X-rays are produced by specific munitions explosives.

Researchers using animal subjects should conduct explosive tests using animals with and without a Kevlar type helmet. You do not need an animal to test whether a Kevlar helmet will protect them from the EMP of a chemical explosion, but it would provide evidence whether animal brains protected by Kevlar still have the same type of brain damage as those without a non-metallic head protection.

Military ballistic protection head gear should provide protection from the EMP produced by munition explosions. Once the duration and pulse intensities of munition explosions are determined the thickness of the EMP shield can be established.

The susceptibilities of the nerve fibers in the frontal lobes of the brain to damage by EMPs should be determined in comparison with nerve fibers in other parts of the brain and body. Many WWI shellshock victims had significant motor control problems.

V. References

[1] www.independent.co.uk/news/the-mystery-of-shellshock-solved-scientists-identify-the-unique-brain-injury-caused-by-war-9981443.htm

[2] http://www.hopkinsmedicine.org/psychiatry/expert_team/faculty/K/Koliatsos.html

[3] A.G. Ivanov, Seismic-electrical effect of second kind, *Transaction of USSR Academy of Sciences. Geography and Geophysics Series*. (Russian). 5:699 (1940)

[4] Kolsky, H. (1954) Electromagnetic Waves Emitted on Detonation of Explosives. Nature, 173, 77. http://dx.doi.org/10.1038/173077a0

[5] Takakura, T. (1955) Radio Noise Radiated on the Detonation of Explosives. Publications of the Astronomical Society of Japan, 7, 210-220.

[6] FCC, "Radio Frequency Safety"Available: http://www.fcc.gov/encyclopedia/radio-frequency-safety

[7] "Lightning-produced radiation a potential health concern for air travelers", Phys.org Dec. 7 , 2009 Available: http://phys.org/news179426300.html

[8]Kelly, B. "EMP From Chemical Explosions" Los Alamos National Laboratory, Group P-14, March 1993 Available: http://library.lanl.gov/cgi-bin/getfile?00205425.pdf

[9] Jingyang, Cao. et.al., "Measurement of electromagnetic pulses produced in a chemical explosion", Antennas Propagation and EM Theory (ISAPE), 2010 9th International Symposium, Nov. 29,2010-

Dec. 2 2010 pages 1005-1007, ISBN: 978-1-4244-6906-2 INSPEC Accession No. 11772978,
DOI: 10.1109/ISAPE.2010.5696644
Abstract Available: http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=5696644

[10] Courtney, M.W., Courtney, A.C., "Working toward exposure thresholds for blast-induced traumatic brain injury: thoracic and acceleration mechanisms."
Available:http://arxiv.org/ftp/arxiv/papers/1102/1102.1508.pdf

[11] H. Nittby, et al., "Increased blood–brain barrier permeability in mammalian brain 7 days after exposure to the to the radiation from a GSM-900 mobile phone", Pathophysiology (2009), doi.10.1016/j.pathophys. 2009.01.001
Available: http://www.pathophysiologyjournal.com/article/S0928-4680(09)00013-3/pdf19345073

[12] James A. Goodrich, et al., "Neuronal and glial changes in the brain resulting from explosive blast in an experimental model." Acta Neuropathologica Communications (2016) 4:124
DOI: 10.1186/s40478-016-0395-3 © The Author(s) 2016
Available: https://actaneurocomms.biomedcentral.com/articles/10.1186/s40478-016-0395-3