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TM-03-90
Evaluation of Personal Protection Device - Power Stun Gun

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TECHNICAL MEMORANDUM

Submitted by
National Research Council

1990

NOTE: Further information about this report can be obtained by calling the CPRC information number (613) 998-6343

EXECUTIVE SUMMARY

This technical memorandum describes the evaluation of the power Stun Gun as a personal protection device in the following two situations;

1. Measurement of generated current and comparison with simulated threshold levels.

2. The effects of current pulses on animals such as pigs.

It was found that in the first situation that the units tested delivered a net charge of 27.5 $\mu C\ cm^{-2}$ which could induce fatal fibrillation to the human heart.

The second situation evaluated the effect of current pulses on pigs in two stages. The first stage analyzed the effects of the Stun Guns on a normal open chested pig, while the second analyzed the effects of Stun Guns on pace-maker implanted pigs. The stage one results were:

1. The Stun Gun could create permanent burn marks on the skin.

2. With the pigs skin moistened with water the guns paralysing effects were increased.

3. The pigs heartbeat during excitation changed but returned to normal when the excitation was removed.

4. The use of the smallest Stun Gun (No. 3) caused short stoppages of the heartbeat, The heart resumed normal operation once excitation was removed.

5. The larger, stronger guns (Nos. 4 815) resulted in repeated heart stoppages, the heart had to be defibrillated.

During the second stage the effects of the Stun Guns on a pace-maker implanted pig were recorded. Stun Gun No. 3 (the smallest) had little effect on the heartbeat rate whereas gun No. 5 (the largest) stopped the heart during excitation. Once the excitation was removed the heart resumed normal operation. When the pig skin was moistened with water Stun Gun No. 5 could stop the heart completely. In order to revive the pig defibrillation was performed.

The placement of cloth between the pig skin and the Stun Gun resulted in decreased excitation, the placement of more cloth further decreased the level of excitation.

A more extensive explanation of findings and problems encountered during the experiment can be found in the conclusion at the end of the report.

PROBLEM FORMULATION

The following experiments could be performed to establish the safety factor of the transient current flow from the personal protective device (Stun Gun).

a. The generated current could be measured and compared with the simulated cardiac threshold levels.
b. The effects of current pulses could be verified on animals such as pigs.
c. Experiments on people.

Experiment A and B was performed. If a and b were found to be safe then c might be performed on volunteers.

EXPERIMENT A - Current **measurement of stun gun units**

Experiment A was conducted with the use of special current measuring equipment simulating the real life conditions. Five different units were tested.

Units
1 - Power Stun Gun (medium size)
2 - Power Stun Gun (medium size)
3 - Power Stun Gun (small size)
4 - Power Stun Gun (large size with flashlight)
5 - Power Stun Gun (large size)

The electrical design of the Stun Gun is such that it can operate through cloth. This effect is achieved by the implementation of an impulse generator that can "punch - through" a thick layer of clothing and/or skin. The "punch - through" effect opens the electrical channel (reduced resistance) making the injection of current possible.

If the injection of current occurs without a spark due to close contact the maximum value of the injected current is limited to 3.8 A for about 3 μs. The value of the current is independent of the skin or clothing resistances contained between 0 n (ohms) to 50 kn. If the injection of current takes place with a spark over a gap of 1/8" a spike of current occurs at the beginning of the long 3 μs impulse. The spike can reach a value of 140 A and persist for about 20 ns. For larger or smaller gaps the amplitude of the spike lowers.

The studies conducted previously show that the heart rhythm disrupting thresholds for pulses shorter than 100 μs or for higher frequency oscillatory transients are a function of net charge transferred. Table 2 gives the net charge transferred from the Stun Gun for a single impulse. It can be seen that for 5 impulses per second a charge transfer of 2.84 $\mu C\ cm^{-2}$ is possible. Such a charge transfer is almost identical to the 3.4 $\mu C\ cm^{-2}$ that can result in a cardiac stimulation.

It should be noted that a fatal fibrillation could be induced with a net charge transferred density of 27.5 μC cm” obtained in the unit 5.

TABLE 1

(current measurements for Unit 1)

Punch through resistance(r)	5	55	400	3000	14000	56000
Current (A)	3.2	3.2	3.75	2.9	3.2	1.0
Estimated internal voltage of the Stun Gun (kV) (before punch through)		15	32.5	162	-	168

TABLE 2

Unit 1	charge	
charge of the high current impulse	Q (μC)	for a 2” electrode spacing (area = 25 cm^2)
resulting form the gap presence	140*20 μS = 2.8* μS	.I12 $\mu C\ cm^{-2}$
charge of the low current impulse (no gap present)	3.8A*3 μS = 11.4 μC	.456 $\mu C\ cm^{-2}$
TOTAL		.568 $\mu C\ cm^{-2}$

ALL OTHER UNITS

Maximum charge transferred for 5 flashes per second;

Unit 3 - 1.56 $\mu C\ cm^{-2}$

Unit 4 - 7.2 $\mu C\ cm^{-2}$

Unit 5 - 27.5 $\mu C\ cm^{-2}$

Experiment **B: Effect of Current Pulses on Pigs**

Experiment B was conducted by the NRC Biomedical Section, Division of Electrical Engineering and the Ottawa General Hospital. The experiment was performed in two stages. During the first stage the effects of Stun Guns on a normal open chested pig were analyzed. The second part of the experiment focused on analyzing the effects of Stun Guns on pace-maker implanted pigs.

Experiments were conducted on two normal, healthy, Yorkshire pigs whose weights were 40 and 52 kg. The animals were fasted for a period of 24 hours prior to surgery. They were tranquillized with valium 10 mg/pig administered intra-muscularly. The animals were anaesthetized with Ketamine, 10 to 15 mg/kg of body weight administered intramuscularly. Anaesthesia was maintained by 1.5% flouthane and oxygen/nitrogen mixture of 1 L/min 0_2/1 L/min N. The respiration rate was set at 12 respirations/min with tidal volume 500 to 600 cc.

The femoral artery was cannulated and the urterial pressure was recorded using a Bell and Howell Type 4-327-l pressure transducer and the blood pressure channel of an Electronics for Medicine I.M. Bedside monitor. The ecg was measured using electrodes on the animal’s four limbs and amplified by the Electronics for Medicine edg amplifier. Both the arterial pressure and the edg were displayed on a Gould two-channel chart recorder. The electrical parameters of the Stun Gun were not measured at the time of the experiments.

Blood gases (pCO_2, pO2) and pH were obtained from blood samples taken hourly. The values of these parameters were:

PH	7.24 - 7.46
pCO_2	35 - 45 mmHg
PC2	150 - 250 mmHg

The experiment was such that the Stun Gun current was applied either on the chest over the heart or on the intact pericardium of the heart. Where the heart was exposed, entry was made by means of a sternal approach.

In the case of pacemaker interference studies, a screw type Medtronic 6917A-53T lead was attached to the heart on the left ventricle and coupled into a Spectrax Model 6423 programmable Medtronic pacemaker. The sternum was closed and the pacemaker was implanted subcutaneously. When the animal fibrillated, defibrillation was accomplished by means of a commercial D.C. defibrillation (Corbin Farnsworth). After a fibrillation - defibrillation episode the animal was allowed to recover for a five - minute period.

During an experimental run the Stun Gun was moved to various chest locations and the effect on the heart, while the Stun Gun current was flowing, was monitored on the blood pressure channel. The electrical interferences from the Stun Gun obliterated the ecg signal.

At first the Stun Guns were used to induce burn marks on the skin. All of the Stun Guns could create permanent burn marks. The next step was to surgically open the pig's chest. The testing began with the Stun Guns attached to the left and right side of the chest. In order to increase the paralysing effects of the Stun Guns the pig's skin was moistened with water. The paralysing effects of using the Stun Gun No. 5 was found to be the greatest. Changes in heart beat caused by the Stun Gun were observed during the excitation but they disappeared when excitation was removed.

It was evident during the current waveform measurements (experiment a) that an increased amount of charge was delivered by the Stun Gun when arcing was included into the excitation process. In order to induce arcing two 1/16" spacers were inserted on the Stun Guns electrodes. The test conducted with the spacers installed shows that the presence of very large and very fast current spikes resulting from arcing does not introduce any additional negative effects on the heart beat or blood pressure. The presence of arcing which introduces additional resistance in the pad of the current, actually diminishes the impact of the Stun Gun on the heart. The experiments were repeated many times. It was observed that although the heart beat was disrupted no loss of heart beat occurred. All further measurements were conducted by the excitation applied directly to the heart with Stun Guns No. 3, 4 and 5.

It was established that the use of the smallest Stun Gun (No. 3) resulted in short stoppages of the heart beat, once the excitation was removed the heart resumed its normal operation.

The larger and stronger Stun Guns No. 4 and 5 were used and resulted in repeated heart stoppages. The heart had to be defibrillated. It is evident that a direct heart stimulation with a strong Stun Gun can result in a heart stoppage.

The second part of the experiment was performed on a pig that had a heart-pacemaker installed and the chest cavity closed. Only the impact of the smallest (No. 3) and the largest (No. 5) Stun Guns was assessed. The excitation was applied to the chest area closest to the heart. Stun Gun No. 3 had little effect on the heart beat rate where as Stun Gun No. 5 actually stopped the heart during the excitation. However the heart resumed its operation when the excitation was removed.

When the pig skin was moistened with water Stun Gun No. 5 could actually stop the heart completely. To revive the pig the heart had to be defibrillated.

The effect of cloth was simulated by placing a folded towel between the pig skin and the Stun Gun. Placing more layers of towel resulted in decreasing heart excitation.

CONCLUSIONS

The design of Stun Guns was based on the assumption that the injection to the human body of extremely short current impulses (in order of a few μS) will not result in heart or muscle stimulation. The experiments conducted indicate that the heart beat can be affected by μS impulses generated by Stun Guns and that a pacemaker supported heart could be stopped completely by an external stimulus.

It was also observed that the charge transferred by the strongest Stun Gun is comparable with the charge transfer density required for heart fibrillation.

During our experiments the following problems related to the use of Stun Guns were observed:

-the device can cause burns to the skin and it could result in eye damage;

-the device is capable of igniting flammable substances;

-the use of the device can result in unexpected current injection into the hand of the operator, the effect is particularly evident in humid and damp conditions;

-a low reliability of the Stun Gun was observed, following four months of testing four out of five Stun Guns became inoperative.

Considering the results of our tests we feel very strongly that the use of the Stun Guns in their present form may create a serious safety hazard.