

DSAC Sub-committee on the Medical Implications of Less-lethal Weapons (DOMILL).

**Statement on the comparative medical implications of use of the X26 Taser
and the M26 Advanced Taser.**

Background

1. This statement has been produced by the Defence Scientific Advisory Council (DSAC) sub-committee on the Medical Implications of Less-Lethal Weapons (DOMILL). It provides an independent view for the UK Government on the medical implications of the use of the X26 Taser in the UK, within the policy and guidance of the Association of Chief Police Officers (ACPO). Specifically, this statement compares the predicted principal medical risks associated with the X26 Taser, and the M26 Advanced Taser (referred to subsequently as the M26).
2. On 30th January 2003, the Home Secretary gave authority to proceed with an operational trial of the M26 as a less-lethal option in incidents at which authority to use firearms had been granted. The M26 would be used by police officers already trained in the use of firearms. The operational trial commenced on 21st April 2003 for an initial duration of 12 months. Five police forces took part in the trial, employing a joint policy, operational guidance and training strategy developed by ACPO.
3. Prior to the start of the trial, DOMILL provided an independent statement on the medical implications of the use of the M26 within the ACPO Policy and ACPO Operational Guidance¹². The statement was based primarily on an assessment of the medical risks undertaken on behalf of DOMILL by the Defence Science and Technology Laboratory (Dstl). The DOMILL statement concluded that: *“From the available evidence on the use of the device, the risk of life-threatening or serious injuries from the M26 Advanced Taser appears to be very low.”*
4. DOMILL recommended that research be undertaken to clarify the cardiac hazards associated with use of the M26 on individuals who could be considered to be at greater risk of adverse effects. The main thrust of the investigations addressed the possible cardiac hypersusceptibility to M26 currents arising from drugs commonly used illegally in the UK and a review of the vulnerability of pacemakers and other implanted devices.
5. A report on the operational trial of the M26 was produced by PricewaterhouseCoopers. The report concluded that use¹³ of the M26 *“helped secure a positive outcome to an incident, minimising the potential need for officers to deploy other, possibly more lethal technologies”*. ACPO proposed that, subject to a review of the medical assessment and Ministerial approval, the trial should be extended: With Chief Officer agreement, the trial should be extended to all forces for use by existing firearms officers, in situations where an authority for firearms would be granted in accordance with criteria presently laid down within the ACPO Manual of Guidance on the Police Use of Firearms.
6. Consequently, DOMILL issued a second statement¹⁴ subsequent to a review of:
 - revised and reviewed ACPO policy, operational guidance and training;

¹² DSAC Sub-committee on the Medical Implications of Less-lethal Weapons (DOMILL). Statement on the medical implications of the use of the M26 Advanced Taser. DSTL/CBS/BTP/PAT-ACPO/MAN/REP/4/ dated 9 Dec 02.

¹³ “Use” by ACPO’s definition is the: (i) drawing of a device in circumstances where any person perceives the action as a use of force or a threat of use of force; (ii) discharging the darts at a subject; (iii) application and discharge in “touch stun” mode.

¹⁴ DSAC Sub-committee on the Medical Implications of Less-lethal Weapons (DOMILL). Second statement on the medical implications of the use of the M26 Advanced Taser (July 2004). DSTL/CBS/BTP/PAT-ACPO/MAN/REP/4/ dated 27 Jul 04.

- the outcome of the research addressing the recommendations in their first statement;
- the data presented to them by ACPO on the outcome (to date) of the initial trial then proceeding.

The second statement also concluded that: “*The risk of life-threatening or serious injuries from the M26 Taser is very low*”.

7. On the basis of the second DOMILL statement and other evidence, the Home Secretary agreed to ACPO’s proposal and the Parliamentary Under Secretary of State at the Home Office (Caroline Flint MP) announced the decision to Parliament in a Written Answer on 15th September 2004. The Home Secretary’s decision applies only to the M26 Advanced Taser.
8. In May 2003, the manufacturers of the M26 introduced another Taser weapon - the X26. ACPO expressed the view that the X26 may have operational benefits over the M26 and requested that the Police Scientific Development Branch (PSDB) conduct a handling trial with users on the X26, similar to the trial undertaken on the M26 before its introduction. Subsequent to the X26 handling trial, in which the X26 showed some potential operational benefits, the Home Office requested that DOMILL prepares this statement on the medical implications of the use of the X26.

Comparison of M26 and X26 Taser outputs

9. The manufacturers claim that the direct incapacitating effect of the X26 is 5% greater than that of the M26¹⁵. They claim that the X26 is 60% smaller, 60% lighter and consumes one fifth of the power. The electrical pulses from the two weapons have a different shape, magnitude and pulse repetition frequency. The X26 pulse has a lower peak voltage and a longer duration than the M26; it also has a lower pulse repetition frequency.
10. The evidence from the electro-physiological literature is that the threshold for stimulation of excitable tissues reduces as pulse duration is extended, and as the number of pulses is increased¹⁶. Although the implied reduction in peak current for the X26 would suggest a lower risk of adverse cardiac events from currents that may flow in the heart, the extended duration may offset some of that benefit. Because of the complex shape of the Taser waveforms, the overall effect of this trade-off cannot be assessed from the literature, which has been developed using simple waveforms such as rectangular or sinusoidal pulses.

Technical approach to compare risks from X26 and M26

11. DOMILL requested that Dstl undertake the following modelling and experimental work:
 - a. Characterisation and comparison of the electrical output of the X26 and M26 Tasers (in conjunction with PSDB).
 - b. A comparison of the currents predicted to flow in the human heart from the M26 and X26 Tasers. This would require the use of a computer model of electromagnetic interactions of applied Taser pulses with the superficial tissues of the body, and the flow of currents to the heart.

¹⁵ Taser International Inc. use a rating scale entitled “Muscular Disruption Units”. The M26 is used as the baseline of 100 units. The X26 has 105 units. The rationale and method for determining these values is not stated, but is believed to have been based upon the Taser-induced contractile force in the muscles of a pig limb.

¹⁶ Reilly JP. Applied Bioelectricity: From Electrical Stimulation to Electropathology. Springer - Verlag, 1998, ISBN 0-387-98407-0. Chapter 6 – Cardiac sensitivity to electrical stimulation. Pages 220-225.

- c. Application of the predicted currents to isolated, spontaneously beating hearts to establish the threshold for any potentially adverse effects on cardiac rhythm.

Additionally, DOMILL requested a review of : (i) experimental work undertaken by, or on behalf of the manufacturers to support the introduction of the X26; (ii) operational and training data compiled by the manufacturers and global police forces; (iii) medical assessments undertaken by organisations and individuals unconnected with the manufacturers.

Review of the modelling and experimental work undertaken by Dstl

12. **Prediction of Taser currents in the human heart.** Computational electromagnetic modelling of M26 and X26 Taser currents flowing in the human heart was achieved using a digital mannequin of the human body, in which the electrical properties of human tissues were represented.
13. Studies on the effect of dart separation on the predicted current density (mA/mm^2) flowing in the heart from the M26 showed that a vertical separation of 225 mm, with the upper dart overlying the heart, gave the maximum cardiac current of the scenarios modelled¹⁷. In this most severe scenario, about 20% of the applied current from the M26 was predicted to pass through the heart during the M26's 2½ cycle, 50 μs pulse. The peak predicted current density was about 0.66 mA/mm^2 . With regard to the X26, initially about 10% of the applied current from the X26 was predicted to pass through the heart, rising to about 20%. During the X26's 4 cycle, 160 μs pulse, the peak current predicted was about¹⁸ -0.11 mA/mm^2 .
14. Thus, the model predicted that the peak current density flowing in the human heart from the X26 pulse was about one sixth that of the M26. The current duration of the X26 in the heart was about 3-4 times that of the M26.

Effects of the predicted Taser currents on cardiac rhythm.

15. **Method:** Excised, spontaneously beating guinea-pig hearts (the Langendorff preparation) were used to determine if the predicted M26 and X26 waveforms in human heart could induce either or both of two phenomena:
 - Ventricular ectopic beats (VEBs) – cardiac contractions out with the normal inherent rhythmicity of the heart;
 - Ventricular fibrillation (VF) – chaotic, asynchronous contractions of the heart muscle fibres that result in no effective heart output. If uncorrected, this would lead rapidly to death in the human.
16. The modelled cardiac M26 and X26 Taser waveforms were applied to the ventricular outer surface of the isolated hearts. Both the absolute values of the peak currents predicted from the modelling, and higher magnitudes, were applied to determine the thresholds for the two phenomena. Rectangular pulses were also applied to hearts to determine the relationship between current density and pulse duration for a well-characterised, simple waveform, and to ensure that the heart preparations were capable of eliciting VEBs or VF.
17. **VEB induction:** When applied during the most vulnerable phase of the heart's electrical cycle (the T-wave of the electrocardiogram) at peak current densities predicted in the human heart during Taser discharge, neither the simulated M26 nor X26 waveforms evoked VEBs.

¹⁷ The dart separations modelled were those determined in M26 user trials undertaken by PSDB.

¹⁸ The minus term indicates that this was flowing out of the heart (measured at the peak of the second half cycle).

However, VEBs could be elicited by both Taser waveforms by increasing the peak current density of the applied waveforms above those predicted to arise in the human heart. The threshold current density for generation of VEBs for both the M26 and X26 Taser waveforms was greater than 60-fold the modelled current density predicted to occur at the heart, implying a wide safety margin for this particular type of potentially pro-arrhythmic response.

18. **Ventricular fibrillation:** In an attempt to evoke ventricular fibrillation, trains of simulated M26 or X26 Taser waveforms (designed to mimic the discharge patterns of the respective Taser devices) were applied to the ventricular muscle. When the simulated waveforms were applied in this way, neither the M26 nor X26 waveforms elicited ventricular fibrillation at peak current densities up to the maximum output available from the laboratory electrical stimulation system. The threshold peak current density for generation of ventricular fibrillation for the simulated M26 waveform was greater than 70-fold the modelled current density predicted to occur at the heart during Taser discharge. In the case of the simulated X26 waveform, the threshold peak current density was greater than 240-fold the modelled current density. That this failure of the simulated M26 and X26 Taser waveforms to induce ventricular fibrillation was not a function of the biological test system was demonstrated in each experiment by the generation of VF using the rectangular stimulation pulses.
19. **Conclusions:** The results show that the simulated M26 and X26 waveforms, *when amplified*, are capable of eliciting VEBs, but not VF, when applied to the ventricular muscle of spontaneously beating guinea-pig isolated hearts. The guinea-pig heart is more susceptible than hearts of larger animals (e.g. dog, calf and pig, and presumably human) to VF induced by extrinsic electrical stimulation¹⁹. The present findings provide indirect evidence for a wide margin of safety in relation to induction of this type of lethal arrhythmia in man. A broadly similar conclusion was reached in a study in the US, in which trains of simulated X26 waveforms of varying intensity, applied across the thorax of anaesthetised pigs, induced ventricular fibrillation only at intensities 15- to 42-fold that of the standard X26 waveform²⁰.
20. On the basis of the present study, it is considered unlikely that the electrical discharge from the M26 and X26 Taser devices will influence cardiac rhythmicity by a direct action on the heart of healthy individuals.
21. **Contributing factors to cardiac susceptibility:** The possibility that other factors, such as illicit drug intoxication, alcohol abuse, pre-existing heart disease and cardio active therapeutic drugs may modify the threshold for generation of cardiac arrhythmias cannot be excluded. Similarly, other indirect responses to Taser deployment (e.g. arrhythmias precipitated by stress- or exercise-induced catecholamine release) may, in themselves, predispose to an adverse cardiac outcome independently of the primary (electrical) action of the Taser devices.
22. DOMILL's first statement on the M26 Advanced Taser concluded that (paragraph 28):
"There is no experimental evidence that the aforementioned pro-arrhythmic factors increase the susceptibility of the heart to low- or high-power Tasers specifically, sufficient to cause an arrhythmic event. Nevertheless, there is sufficient indication from the forensic data and the known electro-physiological characteristics of the heart (and the effects of certain drugs on this) to express a view that excited, intoxicated individuals or those with pre-existing heart disease could be more prone to adverse effects from the M26 Taser, compared to unimpaired individuals. The ACPO Guidance to Users reflects this view."

¹⁹ Ferris et al. (1936). Effect of electric shock on the heart. *Electrical Engineering* 55: 498-515.

²⁰ McDaniel et al. (2005). Cardiac safety of neuromuscular incapacitating defensive devices. *Pacing Clin Electrophysiol* 28(S1): S284-S287.

Experimental work reported in DOMILL's second statement on the effects of drugs on cardiac function supported this view. The view expressed above is also applicable to the X26 Taser.

Falls to the ground

23. The claim that the X26 is more effective than the M26 in stimulating skeletal muscle implies that falls following X26 application may be less controlled. This will increase the risk of head injury. It is anticipated therefore that there may be a greater likelihood of head contact with surfaces following use of the X26. Overall, the risk of serious head injury is considered to be low.

Overall conclusion

24. The risk of a life-threatening event arising from the direct interaction of the currents of the X26 Taser with the heart, is less than the already low risk of such an event from the M26 Advanced Taser.

Recommendations

25. The Home Office should continue to provide DOMILL with reports outlining the circumstances of every use of the M26, the post-incident medical assessments undertaken by the Forensic Medical Examiner (FME), and the clinical consequences noted by the FME or clinical staff. This audit should include the X26 Taser if this system is made available for use. DOMILL should be advised as soon as practical of any primary or secondary injury that could be classed as life-threatening, unexpected, or potentially leading to disability.
26. DOMILL should be advised of any changes in:
 - a. the specification or performance of the M26 and X26 Taser devices;
 - b. the guidance to users and training practices;
 - c. the policy and practice of deployment, use and audit.

[signed]

Chairman, DSAC Sub-committee on the Medical Implications of Less-lethal Weapons.