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Systematic Review/Meta-analysis

Estimating the Risk of Cardiac Mortality After Exposure to Conducted Energy Weapons

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ABSTRACT

Background: Conducted energy weapons (CEWs), commonly known as Tasers, are a reputed nonlethal law enforcement weapon. Nevertheless high profile cases have suggested a causal association with cardiac death but the magnitude of any putative risk is unclear.

Methods: An electronic systematic review of all real world, cohort studies of consecutive CEW cases was performed. "Pessimistic" and "optimistic" previous beliefs about CEW mortality were derived from an unbounded internet search, including case series but excluding the previously identified cohort publications. A Bayesian analysis updated these previous beliefs with the published objective cohort data.

Results: Pessimistic and optimist previous beliefs with modes of 1/700 and 1/7000, respectively, and upper limits (< 2.5% probability) of 1/100 and 1/1000, respectively, were constructed. Three cohort studies formed the objective data source and their combined mortality was 1 in 2728 cases or 3.67/10,000 (95% confidence interval,

RÉSUMÉ

Introduction : Les armes à impulsions (AI), communément connues sous le nom de Taser, sont des armes réputées non mortelles par les forces de l'ordre. Néanmoins, des cas très médiatisés ont suggeré un lien de causalité entre le Taser et la mort cardiaque, mais l'ampleur de tout risque putatif n'est pas élucidée.

Méthodes : Une revue systématique électronique de toutes les études de cohortes réelles de cas consécutifs d'AI a été réalisée. Les croyances « pessimistes » et « optimistes » précédentes sur la mortalité liée à l'AI provenaient d'une immense recherche dans internet, y compris les séries de cas, mais à l'exclusion des publications de cohortes précédemment identifiées. Une analyse bayésienne a actualisé ces croyances précédentes par la publication de données de cohortes objectives.

Résultats : Les croyances pessimistes et optimistes précédentes par valeurs dominantes de 1/700 et de 1/7000, respectivement, et limites supérieures (probabilité < 2,5 %) de 1/100 et de 1/1000, respectivement,

Conducted energy weapons (CEWs) are one of several options along the use-of-force continuum used by law enforcement officials to facilitate arrests of uncooperative, violent individuals. These devices use electrical energy to inflict pain, immobilize, and ultimately incapacitate human subjects. Online video examples of CEW use associated with nonlethal and lethal outcomes have gone "viral."[1,2] Despite their purported design as nonlethal weapons, considerable debate is ongoing not only in the popular press/media but also in the medical literature[3-6] concerning the potential danger of CEWs to precipitate sudden cardiac arrest/death.

In 2008, Amnesty International summarized many in-custody deaths that were proximate to CEW exposure.[7] Recently, 8 cases of sudden cardiac arrest/cardiac death after CEW exposure have been reported in a high-impact cardiovascular subspecialty journal,[3] although any link to causality has been vigorously contested.[8] Based on these data and animal studies, it has been opined that CEW stimulation can cause cardiac electrical capture and provoke cardiac arrest resulting from malignant ventricular arrhythmias.[3] This interpretation of these recent and past cases has been called into dispute by noting underlying health issues in some of the victims and the lack of evidence for induced arrhythmias in numerous volunteer and epidemiologic studies.[4-6] In response to this debate, there has been a call "to transform the argument" from if CEW-induced mortality can occur to how often it occurs.[9] The goal of this report was to quantify the CEW mortality risk, as best possible, using probability models and to explicitly acknowledge the effect of previous beliefs in light of the paucity of quality objective data.

Methods

An electronic systematic review of all clinical studies was executed using the PUBMED, EMBASE, and Cochrane databases. The PUBMED query string used was: (((conducted OR conductive) AND (energy OR electric* OR electronic) AND (weapon* OR device*)) OR ((electric* OR electronic) AND (control OR discharge) AND (weapon* OR device*)) OR "stun gun" OR taser* OR "Conducted Energy Weapon

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1/107,751 - 1/490). The maximum a posteriori estimated risks of CEW mortality for the pessimistic and optimistic prior distributions were 5.3 and 2.2 deaths per 10,000 exposures, respectively. The upper limits (< 1% probability of occurrence) of the posterior distribution were 1 death per 408 and 982 CEW exposures for the pessimistic and optimistic previous beliefs, respectively.

Conclusions: Limited available evidence can be used to construct approximate boundaries for CEW mortality risk and suggests that the population risk of CEW mortality is likely small but not negligible. More high quality data are required to refine these estimates and extreme caution must be exercised before applying these population risks to individual cases.

ont été élaborées. Trois études de cohortes formaient la source objective de données et leur mortalité combinée était de 1 sur 2728 cas ou 3,67/10 000 (intervalle de confiance à 95 %, 1/107 751 - 1/490). Les risques estimés a posteriori maximaux de la mortalité liée à l'AI des distributions pessimistes et optimistes précédentes étaient de 5,3 et de 2,2 morts par 10 000 expositions, respectivement. Les limites supérieures (probabilité de survenue < 1 %) de la distribution postérieure étaient respectivement de 1 mort par 408 et de 982 expositions à l'AI pour les croyances pessimistes et optimistes précédentes.

Conclusions : Les rares données probantes disponibles peuvent être utilisées pour établir les limites approximatives du risque de mortalité liée à l'AI et montrent que le risque de mortalité liée à l'AI de la population est possiblement faible, mais non négligeable. Plus de données de haute qualité sont nécessaires pour affiner ces estimations. Il faut également faire preuve d'une grande prudence avant d'appliquer ces risques pour la population à des cas individuels.

Injuries"[Mesh]) AND ("Law Enforcement"[Mesh] OR "Police"[Mesh]) AND ("Retrospective Studies"[Mesh] OR "Prospective Studies"[Mesh] OR "Review"[pt] OR "Meta-Analysis"[pt]). Because consecutive real world (not volunteer) cohort studies represented the highest quality real world safety evidence available (no randomized trials having been conducted), only such studies in adults that also measured mortality were retained and formed the objective database. Specifically, animal, volunteer, modelling, case series, pediatric, and duplicate studies were excluded. Data were abstracted and validated by both authors. Only mortalities and total number of exposed individuals in the retained articles were abstracted. Mortalities in these studies were represented by binomial distributions, which are parameterized by the number of successes (deaths) in a sequence of independent yes/no experiments.

Direct probability statements can only be made if the objective data are conditioned on previous beliefs. This is the correlate of clinical decision-making in which test results are only sensibly interpreted in a clinical context. To determine the final (posterior) probability that CEWs are associated with mortality these objective data (likelihood) must be combined with previous beliefs about CEWs according to the following equation:

$$\text{Posterior distribution} = \frac{\text{Likelihood of data} \times \text{previous distribution}}{\text{Normalizing constant}}$$

Although Bayes' Theorem as expressed in the preceding formula follows the formal rules of probability in an uncontested and irrefutable mathematical manner, the difficulty becomes in choosing a previous distribution. One approach to this difficulty is to accept that no single previous belief will reflect everyone's beliefs. Therefore "pessimistic" (belief in high CEW mortality risk) and "optimistic" (belief in low CEW mortality risk) previous beliefs for putative CEW mortality might be established.[10] For example, a "pessimist" might believe the risk of CEW-related mortality is far from rare because of the many incidents reported in the media and the "optimist" might believe that the safety information supplied by the manufacturer concerning volunteer and animal studies is reassuring. Medical electronic and unbounded internet searches were also performed to find all reports, excluding the objective cohort studies already mentioned for the likelihood of CEW-associated mortality and this was used to derive transparent explicit previous probabilities for CEW mortality.

Although a large range of potential previous beliefs is to be expected initially, as more objective data accumulate, the effect of the previous beliefs will reduce and the posterior beliefs (distributions) of the "optimist and "pessimist" will converge. These previous distributions can be fully characterized by specifying 2 parameters; the mode and a measure of the spread or variation, typically an estimate of an upper limit delineating the point at which there is a less than 2.5% probability that the result would fall. For the mathematical convenience of simple closed-form calculations for the posterior distribution, we used Beta prior distributions, the conjugate family for the binomial likelihood. A Bayesian analysis is thus essentially an updating of the "pessimistic" and "optimistic" previous beliefs with the best objective data available.

To determine the effect of future studies on the estimate of CEW mortality and to assess how quickly our subjective previous estimates become dominated by newly observed high-quality prospective data, we performed an additional analysis that assumed that a new cohort with 4 times the currently available data were to become available.

Computations were done using the R software.[11]

Results

The objective data

The literature search identified 41 studies via PubMed, 105 from EMBASE, and none in the Cochrane library. From this sample only 3 large high-quality independent multicentre cohort studies that recruited consecutive patients were retained. The first study reported no CEW-attributed deaths in 1201 consecutive cases of CEW deployment.[12] There were in fact 2 fatalities that were judged by medical examiners not to be causally related to the CEW. However, 1 fatality occurred within 5 minutes of CEW deployment and we will