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Forensic medical aspects of sudden cardiac death caused by commotio cordis due to the impact of a tear gas bomb during manifestations in Venezuela in 2017
Original Article

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SUMMARY

Purpose: The objective of the study was to visualize the sudden cardiac death generated by the Commotio Cordis phenomenon, due to the impact of a tear-

gas bomb direct to the precordial area of a protester's thorax, fired by law enforcement officers, in street protest manifestations for economic political and social claims in Venezuela in 2017. Likewise, it seeks to know the legal

regulations and the forensic approach that derives from this, as well as the legal consequences that face the public order agents; we analyzed the legal medical responsibility of the forensic pathologist in the autopsy report necessary to exercise the criminal legal actions that are perceived under the charges of homicide with treachery or for futile or ignoble motives.

Materials and methods: *We report the case of a young adult who died due to the impact of a tear gas bomb in the thoracic precordial area, triggered by law enforcement officers during the social political manifestations that took place in the city of Caracas-Venezuela in the year 2017. He underwent forensic evaluations (autopsy) by the National Service of Medicine and Forensic Sciences (SENAMECF).*

Case description. *A 20-year-old young adult impacted by a tear gas bomb that was fired directly by law enforcement officers on the thorax at the level of the precordial area, which caused sudden cardiac death also known as commotio cordis.*

Results: *We analyzed the result transcribed in the death certificate issued by the forensic pathologist of the prosecution and the National Service of Medicine and Forensic Sciences (SENAMECF) attached to the Criminal*

Scientific and Criminal Investigation Body (CICPC), who performed a forensic autopsy; the following postmortem diagnosis was concluded: closed thoracic trauma in the left chest region that caused cardiogenic shock and cardiac contusion.

Discussion: *It is necessary to know the physiopathological mechanism that causes the sudden cardiac death product of the commotio cordis and the revision of the current regulations of security and control of the manifestations by the national and international public order agents; we analyzed the problems of legal medical forensic significance due to the diverse implications related mainly to criminal and / or civil law, in which the figures of homicide (fraudulent or negligent) and professional responsibility arise.*

Conclusions: *Sudden cardiac death by commotio cordis due to the impact of a tear gas bomb on the precordial area is an uncommon but very devastating event, which is why it must be distinguished as a crime against humanity due to the violation of human rights of the victims, which is typified in the Rome Statute in international criminal law.*

Key words: *Sudden cardiac death, commotio cordis, ventricular fibrillation, tear gas, impact, thorax, precordial, medical, forensic, manifestation.*

INTRODUCTION

Thoracic trauma as an extra-cardiac event that usually causes a lethal arrhythmia and sudden cardiac death is called "commotio cordis" or "blow of death"; this refers to an event triggered after an impact in the precordial region, of

low energy and apparently trivial, producing a ventricular fibrillation (VF) and a cardiorespiratory arrest (CRP) [1].

The victims are usually very young; it usually occurs in the context of sports practices, although its appearance has also been described during daily

activities. The pathogenesis seems to be related to a phenomenon of "R on T" at a particularly vulnerable moment of cardiac repolarization, which triggers a cardiorespiratory arrest (CRP) due to ventricular fibrillation.

If we go back in history, the term *commotio cordis* appears for the first time in medical literature in the 19th century, although the essence of *commotio cordis* (cardiac concussion) was already described in the millenary writings of the Chinese martial arts such as Dim Mak or "touch of death"; in Western society of the eighteenth century, written accounts are recorded that show episodes of sudden cardiac death (MSC) after minimal thoracic impacts, mostly by accident during the workday [2].

Schlomka was the first author who described the conduction alterations and arrhythmias caused by the impact on the chest wall, causing ST segment alterations, ventricular extrasystoles, ventricular branch and atrial blocks, ventricular tachycardia (VT) and ventricular fibrillation (VF); he identified three factors that influence the appearance of arrhythmias: the type of projectile, the force and the location of the impact; it must be differentiated from another term, *Contusio cordis*, which is observed in the absence or presence of structural lesions; the absence of macroscopic lesion due to impact differentiates the *commotio cordis* from cardiac contusion, in which a high energy collision (for example in the polytraumatized thorax over the precordial region) produces myocardial lesions and overlying the thoracic cage [3].

Commotio cordis as a pathology receives little attention in medical scientific literature and there are few cases reported. Currently, this term restricts its meaning to sudden cardiac death after an

impact and not to the totality of mechanically induced arrhythmias [4]. In the 1990s the term *commotio cordis* was accepted outside the forensic field as an eminent cause of sudden cardiac death in the absence of findings of thoracic injury and a structurally normal heart in the finding of the necropsy, with the known antecedent of a non-harmful impact; the episodes of sudden cardiac death by *commotio cordis* were appearing in the form of isolated clinical cases in the clinical medical literature [5].

Since then, in the medical community, the relevance of *commotio cordis* as a cause of sudden cardiac death has been observed in healthy individuals who are usually children, adolescents or young adults, and who mostly practice some kind of sports for competitive or distraction purposes, although its appearance has also been described during routine activities (Table 1).

So far the death of individuals in street demonstrations for social, economic and even political changes has not been reported, cases when the security forces repress the masses firing tear-fire projectiles directly on the corporal surface, specifically at the level of the rib cage over the precordial area.

It is likely that *commotio cordis* as a cause of sudden death in the protesters who were hit by tear gas bombs, has been underestimated by the forensic doctors who carried out the autopsy protocol.

Approximately 50% of the cases of sudden cardiac death by *commotio cordis* occur in the development of competitive organized sports, in relation to the impact of a projectile (baseball, softball, lacrosse, ice hockey) or the physical impact against other players (rugby, American football,

soccer, karate, among others). 25% of the cases of commotio cordis occur in apparently dangerous activities such as recreational sports at home, in family gatherings, in children's games, among others. The majority of the commotio cordis in children under 10 years of age occurred under these circumstances. And finally, the other 25% of cases are not

related to sports practices of any kind, but may be triggered by everyday activities.

The use of rubber balls by riot police has also been described as a cause of death by commotio cordis after a thoracic impact. But in this investigation we describe the impact of a tear gas bomb on the thorax region as a cause of sudden cardiac death by commotio cordis [5].

<p>Baseball, softball, cricket, lacrosse</p> <p>Batter hit by a ball thrown by the pitcher. Pitcher hit by a ball thrown by hand or batted. Player hit by batted ball. Catcher, referee or spectator hit by ball failed. Catcher hit by a bat. Body collisions in the bases. Player fallen on a softball after collecting it</p>
<p>American Football</p> <p>Players hit by helmet, shoulder pads, knees or elbows of opponents. Collisions during melee or interceptions. Collisions against posts. Impacts of the ball against the thorax when trying to block a point.</p>
<p>Football</p> <p>Impact of a kick in the chest. Balonazo in the chest of the goalkeeper. Player hit against the post.</p>
<p>Hockey</p> <p>Goalkeepers or other defensive players hit by a goal shot. Multiple collisions between players. Players hit by sticks.</p>
<p>Fights and aggressions</p> <p>Psychiatric guardian beaten by a patient. Professor beaten after mediating a fight between teenagers. Diverse impacts during games. Impact by fist of boxer (with glove) doing sparring. Children beaten by parents or kangaroos (physical punishment). Child hit by snowballs. Adolescents and young people involved in fist fights. Demonstrators scattered with rubber balls. Baby beaten during a diaper change. Adult beaten in a prison ritual.</p>

Kick kick on child's chest.
<p>Other circumstances</p> <p>Child hit by a horse kick. Young man hit by the recoil of a rifle during big game. Young man hit against the steering wheel of his vehicle in low energy accident. Child hit by a swing. Child fallen frontally from a slide or more height. Young man hit by a tennis ball filled with coins. Child hit by the head of a dog of 20 kg. Child hit by a frisbee (frisbee). Teen who received a slap on the chest to cut the hiccups. Boy hit by the handlebar when falling off the bicycle.</p>

Tabla 1. U.S. National Commotio Cordis Registry. Some situations that have triggered a sudden cardiac death by commotio cordis

The biomechanics of the impact and the pathophysiological mechanism of sudden cardiac death by commotio cordis, unleashed after a confrontation or violent situation with a blunt object (tear bomb), are arrhythmic events unleashed when the kinetic energy as a result of the impact of a blow abruptly affects the thorax region in the precordial area and profoundly alters the stability of the electrical conduction of the myocardium, leading to a ventricular fibrillation that can cause sudden death.

This event occurs when victims are hit by projectiles considered as standard implements or game objects (balls, balls, chips, among others) or by common implements (blunt objects) or by a direct blow to the precordial area; nevertheless the object product of the investigation is unusual since it is the impact of a tear gas bomb fired by a firearm [6].

In the biomechanics of the impact that triggers the pathophysiological mechanism, crucial variables have been identified that include the speed of the impact, the location of the impact, the intensity of the impact and the hardness of

the impact object. The objects launched at different speeds have demonstrated the existence of two determining factors in the appearance of the commotio cordis. The first circumstance has to do with the location of the impact, this has to occur directly on the center of the cardiac silhouette at the level of the left parasternal line (precordial area) [7]. The second determining circumstance is related to the exact moment after the impact on the chest wall, which must occur with a narrow margin of 10 to 20 milliseconds; the rapid rise in left ventricular pressure after impact is likely to cause the activation of ion channels through mechanoelectric coupling, in which there is a scattering of repolarization, an increase of this and, as a consequence, an electrical heterogeneity; the generation of inward current through ion channels sensitive to mechanics probably causes an increase in repolarization and non-uniform myocardial activation, and is the cause of premature ventricular depolarizations that are triggers of "direct" ventricular fibrillation, without being preceded by premature ventricular contractions or

ventricular tachycardia (configuring a "R on T phenomenon") [8]. Figure 1.

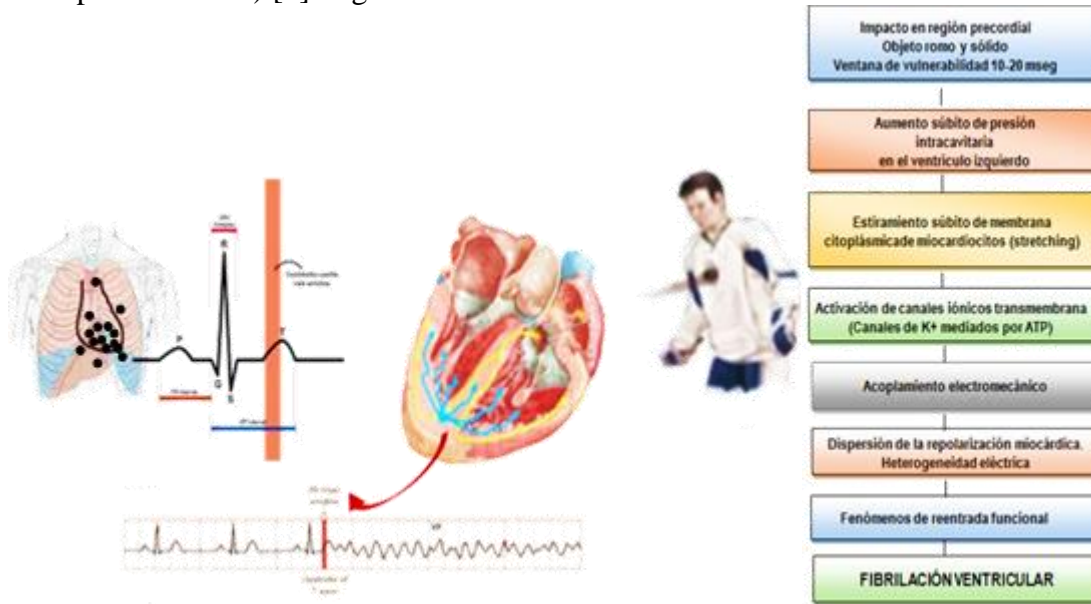


Figure 1. Exact location of the impact and the time it occurs are the determinants of ventricular fibrillation caused by commotio cordis. Ventricular Fibrillation is triggered immediately after the impact when it occurs in the vulnerable area of repolarization (10-20 msec before the peak of the T wave). Scheme of the subcellular physiopathological sequence responsible for the phenomenon of the commotio cordis

Although the cardiovascular collapse in the commotio cordis is really instantaneous, up to 20% of the victims remain physically active and with a level of consciousness preserved after the impact (being able to walk, returning the object that has impacted them, even speaking, among others), which is attributed to the individual tolerability of adolescents or healthy young adults or sustained ventricular tachycardia, before it degenerates into ventricular fibrillation.

The kinetic energy supplied in the impact varies enormously by virtue of the type, speed, mass, shape, size, weight, hardness and orientation of the projectile trajectory, biological plausibility, as well as the morphology and deformability of the thoracic cage. Projectiles, such as tear

gas bombs fired by a driving firearm, have a probability of triggering ventricular fibrillation (commotio cordis) when they progressively increase to an impact speed of 64 km per hour. At speeds greater than 80 km per hour, the risk of structural damage to the chest and heart, such as hematoma and rupture of the myocardium, which are characteristic of concussion rather than commotio cordis, increases.

The importance of the hardness, location of the impact, internal structure of the projectile and speed at the time of inducing a ventricular fibrillation is in relation to the intracavitary pressure induced in the left ventricle after the impact, which would generate the activation of ion channels, which it would in turn lead to a dispersion of the

repolarization and an electrical heterogeneity of the myocardium capable of generating a ventricular fibrillation; this is currently the most accepted hypothesis, due to the selective activation of potassium channels mediated by adenosine triphosphate (ATP), which contribute to the establishment of ventricular fibrillation in myocardial ischemia; it is currently considered the most likely pathogenic substrate in the appearance of the commotio cordis [9, 10].

METHODS

The case of a young adult, who died due to the impact of a tear gas bomb in the thoracic precordial area, is reported; the most plausible hypothesis is that it was fired directly on the victim's humanity by law enforcement officers of the security forces in charge of maintaining internal order, such as the Bolivarian National Guard (GNB) and the Bolivarian National Police (PNB), during the demonstrations of peaceful protests for economic, political and social demands that emerged in the city of Caracas-Venezuela in the year 2017; the individual was subjected to forensic evaluations (autopsy) by the National Service of Medicine and Forensic Sciences (SENAMECF).

CASE REPORT

It was a 20-year-old male economics student from the Metropolitan University of Caracas, who was in a peaceful collective protest for socio-economic and political demands in the Chacao municipality of the city of Caracas; he received the direct impact of a tear gas bomb on the thoracic region at the precordial area, fired by the shotgun of a member of the internal order body of the Bolivarian National Guard; after the impact, the young man remained active, with a preserved level of consciousness, but then he collapsed on the pavement and was helped by his partner; he was transferred to a medical center but he had no vital signs; to the physical examination is appreciated in the precordial region, at the level of the fifth space, a concussion tattoo product of the object that impacted him; the public ministry states that it is about the impression of a blunt object, like a tear gas bomb.

The young man was hit by a three-phase tear gas bomb fired 2 to 3 meters away; the tear gas bombs, when detonated correctly with a shotgun, reach a distance of 56 to 70 meters; when they are fired directly and horizontally they become a lethal projectile. The impact received by the victim is similar to being hit by a blunt 80 kg object at a speed of approximately 270 km / h (Figure 2)

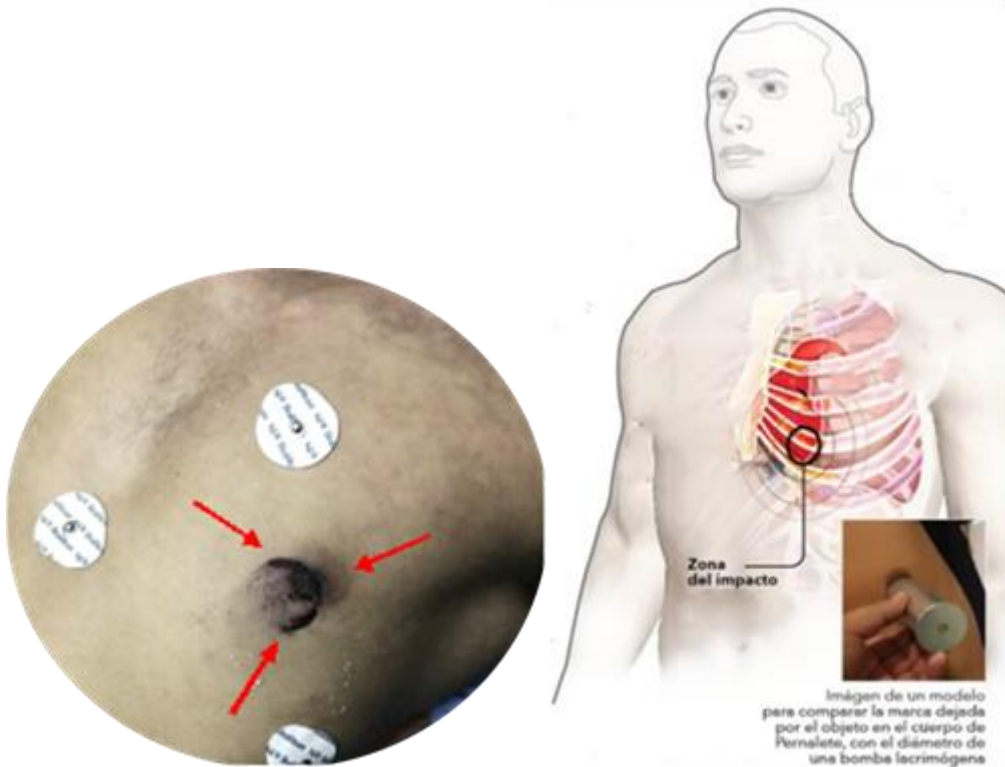


Figure 2 Infographics. A Contusion halo is seen in the area of impact of a blunt object on the body of the victim (red arrows). B. Tear-off cartridge 37 to 40 mm three-phase CAVIM.

RESULTS

Evaluating the results of the autopsy protocol performed by the forensic pathologist attached to the Office of the Prosecutor and the National Service of Medicine and Forensic Sciences (SENAMECF) of the Criminal Scientific and Criminal Investigation Body (CICPC), the following causes of death diagnosis were established: Closed thoracic trauma in the left chest region that caused a Cardiogenic Shock and Cardiac Contusion.

The investigation established that the violence executed by law enforcement agents of the Venezuelan State security forces, with the use of firearms and chemical agents during the demonstrations or peaceful protest of the Venezuelan population, has its origin in resolution N

8,610; In January 2015, the Ministry of the Popular Power for Defense authorized the use of force by means of firearms and chemical agents by the military agent for functions of control of public order in order to disperse peaceful protests.

This resolution gives a nuance of legality to the performance of military personnel in peaceful demonstrations according to the principle of proportionality; This principle is controversial since it contradicts a constitutional precept contained in Article 68 of the constitutional text which it wields. "Citizens have the right to demonstrate, peacefully and without weapons, without other requirements than those established by law." Based on this, it is speculated that the military personnel violate the Human Rights of the demonstrators by shooting them directly at

the body with a firearm (shotgun), even in the case of a tear gas bomb; This can be lethal if it impacts on the thorax region in the precordial area, which can trigger a sudden cardiac death by the commotio cordis. The national and international regulations according to the Venezuelan Public Ministry prohibits tear gas bombs from being thrown or fired at point-blank range (<10 cms) or short distance (10 to 70) centimeters directly on people.

When the analysis of the case presented from the forensic medical legal point of view is made, the type of projectile, the force and the location of the impact, as well as the kinematics or biomechanics of the impact, it is necessary to differentiate a contusio cordis from the commotio cordis; in contusio cordis there is presence or absence of structural injuries; The absence of macroscopic injury due to impact is what differentiates commotio cordis from cardiac contusion, given that a high-energy collision, such as thoracic trauma over the precordial region, produces myocardial and overlying damage to the thoracic cage.

It is necessary to study the biomechanics of the impact or biomechanics of the injuries. The damage can be a solution of continuity in the material, as in this case a bone fracture (rib, sternum), muscle rupture, or a functional lesion in this case heart [11]. Impact biomechanics is not a science with accuracy and scientific rigor, so many times it is necessary to address many of the problems from the probabilistic level. In spite of this, legal and forensic medicine needs the application of this biomechanical knowledge, fundamentally those where the purpose is the valuation of the corporal damages by the traumatic injuries to the people; an example of this is the impact of a tear-gas canister fired by a

firearm in the region of the thorax at the level of the precordial area and that can cause sudden cardiac death [12].

The biomechanical knowledge for the forensic pathologist at the time of performing the autopsy is very useful, since they can explain the mechanism of production of the injury. It distinguishes between injuries that are the result of direct trauma, those that are the result of inertial damage or those that may occur as consequences of both mechanisms due to the impact of a tear gas bomb [13].

After a thoracic trauma, an individual presents a sudden cardiac death; in the assessment, it must be determined if it is a single trauma or if it has been due to a direct trauma on the precordial area to justify this injury or damage. Therefore, from the perspective of biological plausibility, it can be argued that it is possible that after an isolated thoracic trauma the commotio cordis occurs leading to this fatal outcome, as happened in the case presented [1-3].

DISCUSSION

The sudden death of cardiac origin by the commotio cordis, is in general, although not invariably fatal; it has been considered in the legal medical field due to its rapid presentation, its character and its violent origin.

Sudden violent death is defined, with medical legal criteria, as due to an accidental, suicidal or homicidal mechanism. It usually obeys to traumatic mechanisms or to strange forces that erupt violently in the organism. There is the existence of an exogenous mechanism that has set in motion the process of death and,

as a result, may be the responsibility of the person or persons who originated it [4,5].

Deaths that occur during or immediately after a violent confrontation associated with social, economic or cultural claims are especially complex and controversial cases within the forensic pathology.

It is well known in forensic practice that many individuals who suffer sudden cardiac death from the impact on the thorax of a blunt object (tear gas), if they are standing at the time of suffering the fatal arrhythmia, may fall unconscious, unable to protect themselves, hitting the ground or surrounding objects, even on the face. Bruised wounds sometimes suggest a traumatic death. Therefore, in these cases should try to distinguish between the injuries suffered and those produced by the impact mechanism.

Commotio cordis is rare, but it has a high mortality. Documenting and recording it in countries such as the United States of America (USA), requires that the trauma, well documented, be followed by immediate cardiovascular collapse, as well as the absence of thoracic fractures and / or cardiac contusion [3] .

The Code of Forensic Medical Instruction in its Article 77 states: "When individuals who have suffered violence die from consequences of them, the Judge will decree the autopsy...". It is for all this that the autopsy is the only procedure that will determine the cause of death and grants the death certificate. All autopsies in cases of sudden cardiac death by commotio cordis should follow an orderly sequential examination.

As deaths by commotio cordis are infrequent, they have generated scant

attention in the medical scientific field; at present it is a pathological term that is restricted to sudden cardiac death after an impact and not to the totality of mechanically induced arrhythmias. It is probable that in the cases recorded, in which the triggering mechanism was the impact of a blunt object, commotio cordis is not ruled out as a cause of sudden cardiac death.

Article 3 number 2 of the Law for the disarmament and control of weapons and ammunition defines Firearm as "the mechanical instrument that uses an explosive material that propels one or multiple projectiles by means of gas pressure, which are thrown at great speed, product of the deflagration of gunpowder, which give off high pressure gas after a chemical reaction of combustion". However, in numeral 22 of the commented article, it exposes the concept of non-lethal weapons, which "include those weapons or technologies that have been specifically designed to incapacitate or immobilize one or more persons, minimizing the possibility of causing death or permanent injuries, as well as damage to property and the environment". Taking this definition into account, tear gas bombs fall into this category; However, when a tear gas bomb is used as a projectile that impacts the precordial region, it can trigger a commotio cordis resulting in sudden cardiac death.

Although it is an unusual occurrence, it gives rise to a series of problems and medical and legal forensic consequences that tend to have a considerable transcendence; Outstanding those related to Criminal Law, in the figure of intentional or intentional homicide typified in Article 407 of the Venezuelan criminal code in force. "Whoever has intentionally killed any person will be

punished with imprisonment from twelve to eighteen years." In the cases listed below, the following penalties shall be applied: "1. Fifteen to twenty-five years of imprisonment for the person who commits the homicide by means of poison or fire, submersion or another of the offenses provided for in title VII of this book, with treachery or for futile or ignoble reasons".

This code defines other crimes against public order, such as illegal association or criminal association, that is, the union of two or more people to carry out an illegal activity; This is stated in article 287: "When two or more persons are associated with the purpose of committing crimes, each of them shall be punished, by the mere fact of the association, with imprisonment of two to five years." Article 288 establishes that "if the conscripts cross the fields or roads and if two of them, at least, carry weapons or have them in a certain place, the penalty shall be imprisonment for a period of eighteen months to five years." Finally, article 289 states that "the promoters or heads of the sheaf shall incur the penalty of imprisonment from eighteen months to five years, in the case of article 287 and from thirty months to six years, in the case of Article 288."

Article 255 defines the crime of concealment. Establishing that "those who, after committing an offense punishable by imprisonment or imprisonment, without prior agreement to the crime itself and without contributing to carry it to further effects, will nevertheless help to ensure their benefit, to avoid the inquiries of the authority". The Rome Statute of the International Criminal Court states:

1. The jurisdiction of the Court shall be limited to the most serious

crimes of concern to the international community as a whole. The Court shall have jurisdiction, in accordance with this Statute, with respect to the following crimes: a) The crime of genocide; b) Crimes against humanity; c) War crimes; d) The crime of aggression.

2. The Court shall exercise jurisdiction over the crime of aggression once a provision is approved in accordance with articles 121 and 123 in which the crime is defined and the conditions under which it will be established. That provision will be compatible with the relevant provisions of the Charter of the United Nations.

The International Criminal Court, in its article 7, defines crimes against humanity as "any of the following acts when committed as part of a generalized or systematic attack against a civilian population and with knowledge of said attack: a) Murder ... "Also in part III of this Statute are established the general principles of criminal law in Article 22 states the following:" Nullum crimen sine lege: No one shall be criminally liable in accordance with this Statute unless the conduct of which it is, at the moment in which it takes place, constitutes a crime within the jurisdiction of the Court "

The element of intentionality of these crimes is reflected when:

1. Except as otherwise provided, a person shall be criminally liable and may be punished for a crime within the jurisdiction of the Court only if the material elements of the crime are carried out with intent and knowledge of the material elements of the crime.

2. For the purposes of this article, it is understood that acts intentionally who:
 - a) In relation to a conduct, it is proposed to incur in it;
 - b) In relation to a consequence, it is proposed to cause it or is aware that it will occur in the normal course of events.
3. For the purposes of this article, "knowledge" means the awareness that there is a circumstance or a consequence will occur in the normal course of events. The words "knowingly" and "with knowledge" shall be understood in the same sense, as stipulated in article 30.

Finally, when the crime against humanity is committed in compliance with superior orders and legal provisions article 33 states:

1. Anyone who has committed a crime within the jurisdiction of the Court in compliance with an order issued by a government or a superior, be it military or civil, shall not be exempt from criminal liability unless:
 - a) He was obliged by law to obey orders issued by the government or the superior in question;
 - b) I did not know that the order was illegal; Y
 - c) The order was not manifestly unlawful.
2. For the purposes of this article, it will be understood that orders to commit genocide or crimes against humanity are manifestly unlawful.

Crimes against humanity are conducts typified by the International Criminal

Court, since they are part of the core crimes of international criminal law. Crimes against humanity are defined as certain behaviors that are committed in the context of an attack with certain characteristics: it must be generalized or systematic and must be directed against the civilian population. The basic criteria for determining when one is in the presence of a crime against humanity are already established in international criminal law in the Rome Statute. For the Venezuelan criminal law, in its domestic law this type of crime remains a novum, because although the criminal code is not classified as such, however, by this immersed the Venezuelan State in international conventions, treaties or treaties, it has to take advantage of said statute of international criminal law, as established in article 23 of the Venezuelan constitutional text, which refers to:

"The treaties, pacts and conventions related to human rights, subscribed and ratified by Venezuela, have a constitutional hierarchy and prevail in the internal order, to the extent that they contain rules on their enjoyment and exercise more favorable to those established in this Constitution and in the laws of the Republic, and are of immediate and direct application by the courts and other organs of the Public Power".

Article 29 of the Rome Statute refers to the non-applicability of statutory limitations to crimes within the jurisdiction of the Court.

CONCLUSION

The impact of a tear gas bomb over the precordial area as a trigger of the commotio cordis, brings about the alteration in the stability of the electrical

conduction of the myocardium, leading to a ventricular fibrillation that can cause sudden death cardiac. This event can occur when the victim was hit by a tear gas bomb fired by the security forces of the internal public order.

Two situations must be distinguished: the first is that sudden cardiac death by the commotio cordis is a rare event, but at the same time very devastating. And the second is that there is a crime against humanity due to the violation of the human rights of the victims, which is typified in the Rome Statute in international criminal law, so it must be prosecuted and penalized.

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