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Areas of the Head and Neck Most Affected by Firearm Projectiles

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ABSTRACT

Introduction: firearm projectiles are the cause of head and neck injuries of large proportions. Therefore, investigating and describing the areas of the head and neck that are mostly affected by firearm projectiles is essential to determine a pattern of these injuries. This kind of investigation can be useful in forensic medicine to help elucidate and differentiate self-inflicted injuries compared to those accidental shots or homicides.

Materials and Methods: systematic review based on the analysis of studies published in Portuguese, English, and Spanish, between 1989 and 2022, collected in the following databases: PubMed, Scopus, Embase, Web of Science, and Lilacs.

Results: the search identified 47 articles, of which six studies met the inclusion criteria and were, therefore, used for data collection. In general, the literature indicates that the head and neck areas mostly affected by firearm projectiles are directly related to the cause of death.

Conclusions: the present study provides evidence that proves the variation in the areas of the head and neck mostly affected by firearm projectiles according to the cause of death.

Keywords: Gunshot wounds; Wounds and injuries; Penetrating wounds; Gun violence; Firearms; Forensic ballistics; Head; Neck.

Introduction

The patterns of injuries caused by firearm projectiles are globally used as essential evidence for criminal investigations, as they provide data such as the type of weapon and the shot direction, which are indispensable to unraveling the cause of death of an individual[1]. Among the injuries caused by firearms shot, traumas in the head and neck regions have a significant incidence rate and are related to several consequences, not only physical but also psychological and social disorders in individuals affected by these injuries.

Another important consequence of firearms injuries is the high expenditure on health services. In Brazil, injuries in the head and neck region, caused by firearm projectiles, usually demand very high costs in the Unified Health System[2], since this violence was responsible for 967,851 deaths between 1980 and 2014, being the primary cause of homicides. In this scenario, according to studies by Maia *et al*. (2021)[2], the anatomical distribution of injuries caused by firearms was 10.7% in the face region, 10.3% in the head region, and 2.5% in the neck region, totaling 23.5% of affected areas.

In the same context, in the United States of America, firearms injuries-related expenses, in the health system, are projected for approximately US$1 billion costs[3]. It is important to point out that firearm violence affects different age groups, including children and adolescents, in a harmful way, which is the second leading cause of death in the pediatric trauma sector in this country. According to Swendiman (2020)[4], younger patients are often more affected in the upper body, given that about 23.8% of injuries affect the head and neck. Among these young patients aged between 13 and 16 years, 73.2% are African-American and black, while 15.6% are white, thus evidencing the profile of victims affected by firearm projectiles[4].

For the victimology studies, race and ethnicity are fundamental characteristics for analyzing regional demography correlated with firearm violence rates since firearm violence varies according to the availability of weapons and local legislation, as well as financial differences of the population[5]. In California (USA), for example, one-third of the cases from the emergency department database for facial fractures were Hispanics, the reason being the larger population of Hispanics in that state compared to others[3]. As in

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Brazil, the black population is 2.6 times greater than white victims of firearms[2], with men being more affected.

Despite women having low rates of injuries caused by firearms, data show that, among the female population affected by firearm projectiles, the proportion of homicides drastically exceeds the distribution of suicides. In Scandinavian studies, female suicide by firearms corresponded to only 1-3%, while 10% of the cases of female victims were due to homicide[6]. These indexes highlight another fundamental aspect of the analysis of injuries in the head and neck region: the data help to distinguish between suicide and homicide.

Given the considerable incidence in the head and neck areas, the data obtained by injuries investigation, and also the harmful consequences for the population, it is essential to understand which areas of the head and neck are most affected by firearm projectiles.

Materials and Methods

The strategy used in this systematic literature review was the PICO methodology, in which the patient population is gunfire victims; the intervention/exposure constituted by the injuries by firearm projectiles; comparison involved the regions of the head and neck, and the expected outcome is the most affected locations. Thus, the scientific question raised is what are areas of the head and neck mostly affected by firearm projectiles.

To answer the proposed question, a systematic review process used a combination of keywords. The proposed descriptor arrangement, in English, consisted of Gunshot Wounds AND Forensic Ballistics AND Wounds and Injuries OR Penetrating Wounds AND Gun Violence AND Firearms AND Violence AND Head OR Neck; in Portuguese: Ferimentos por Arma de Fogo AND Balística forense AND Ferimentos e lesões OR Feridas penetrantes AND Violência com Arma de Fogo AND Armas de fogo AND Violência AND Cabeça OR Pescoço; and, finally, in Spanish language: Heridas por Arma de Fuego AND Balística forense AND Heridas y lesiones OR Heridas penetrantes AND Violencia con Armas de fuego AND Armas de fuego AND Violencia AND Cabeza OR Cuello. Results from the following databases were used: PubMed, Scopus, Embase, Web of Science, and Lilacs. In addition, the screening (Figure 1) covered publications between the years 1989 and 2022.

A total of 47 studies were analyzed by 3 previously trained examiners. Given the established selection criteria, those studies that were not related to the proposed question were excluded. In consequence, 1 document was excluded due to duplicity, and 38 articles were excluded, being classified as "unrelated to the topic", when the document disagreed with the central question, and/or "unspecific", when the data referred to the head and neck broadly, presenting statistical data about other anatomical areas, but

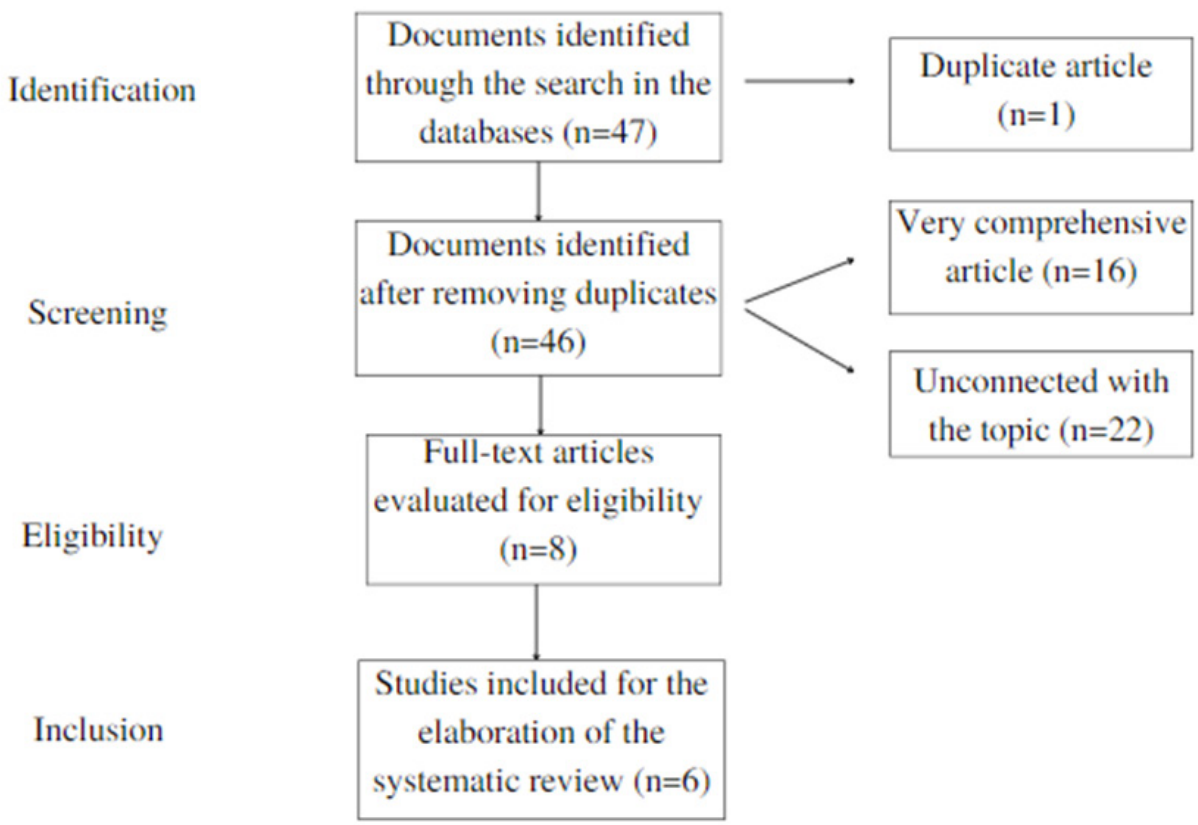

Figure 1. Flowchart of screening and selecting articles.
Source: Prepared by the author*.

without answering the structured question of the present study. Ultimately, 6 studies were selected for the development of this article, which is detailed in Table 1.

Results

The six articles used for the elaboration of this systematic review were based on case reports and cross-sectional studies based on data from institutes, departments, and hospitals, ensuring the reliability of the information. Corresponding data contains information on the proportion of shots according to the affected region, the direction of the projectile, the number of gunshots, and the relationship between incidence and sex.

Among the studies, 624 autopsies (577 cases of suicide and homicide) were performed by the "Institute of Forensic Medicine" at the University of Münster (Germany) (n = 302 from 1967 to 1997) and the "Institute of Forensic Medicine" at the University of Hamburg (Germany) (n = 322 from 1985 to 1997). In this review, 1,006 gunshot wounds were analyzed, of which 484 were wounds with entry to the head (252 due to suicide and 232 due to homicide) and 41 wounds with the entrance in the neck and back of the head (3 due to suicide and 38 due to homicide). The study by Karger *et al.*[6] showed that the most frequent entry points for gunshot wounds in suicide cases are the temporal region (36%), mouth (20%), and forehead (11%), as shown in Figure 2, and left chest (15%); while in homicides, the main targets are the head (30-50%) and thorax (25-45%), mainly in the victim's dorsal region.

The distribution of head wounds in suicide cases in this study was 111 wounds in the right and 14 in the left temporal region, 61 injuries in the mouth, 33 in the

Table 1. Characteristics of the articles.

Author	Year	Title	Study	Results
Pavelites JJ, Prahlow NA, Landrum JE, Zollinger D, Vermillion D	2011	Na Unusual Case of Lead Snowstorm Caused by Fragmentation of Buckshot	Case report	2 cases with gunshots forming radiographic images similar to a snowstorm.
Karger B, Billed E, Koops E, Brinkmann B.	2002	Autopsy features relevant for discrimination between suicidal and homicidal gunshot injuires	Cross-sectional study	624 autopsies performed by the Institutes of Forensic Medicine in Münster and Hamburg. 577 were caused by firearms, of which 284 were suicides and 293 homicides.
Thomsen A, Leth P, Hougen H *et al.*	2021	Gunshot homicides in Denmark 1992 – 2016	Cross-sectional study	1,417 homicides occurred in Denmark between 1992 and 2016, 315 (22.2%) caused due to gunshot wounds. The head (58.1%) and chest (46.7%) were the most affected areas, with head injuries being more common in contact or near-contact shots.
Moore PL, Selby G, Irving RM.	2003	Gunshot injuries to the temporal bone	Case report	Patient shot in the head and neck region by a firearm projectile, hitting the temporal bone. High-resolution computed tomography (CT) showed the trajectory of the projectile: it entered the right maxillary sinus through the medial wall, exited through the posterior wall, crossed the right infratemporal fossa and lodged in the tip of the ipsilateral mastoid.
Rampa S, Wilson FA, Tak HJ, Roy S, Wani RJ, Markiewicz MR, Allareddy V	2019	Patient Characteristics and Cause of Facial Fractures in the State of California	Cross-sectional study	198,870 emergency room visits for facial fractures between 2005 and 2011 in the State of California. The most frequent fractures were: closed fractures in nasal bones, facial bones, orbital floor, malar and jaw bones, and jaw bones.
Oliva A, Grassi S, Grassi VM, Pinchi V, Floris R, Manenti G, Colosimo C, Filograna L, Pascali VL	2021	Postmortem CT and autopsy findings in nine victims of terrorist attack	Case report	9 victims of terrorist attack with injuries to the head and neck areas, 7 of which were caused by firearms.

Source: Prepared by the author.

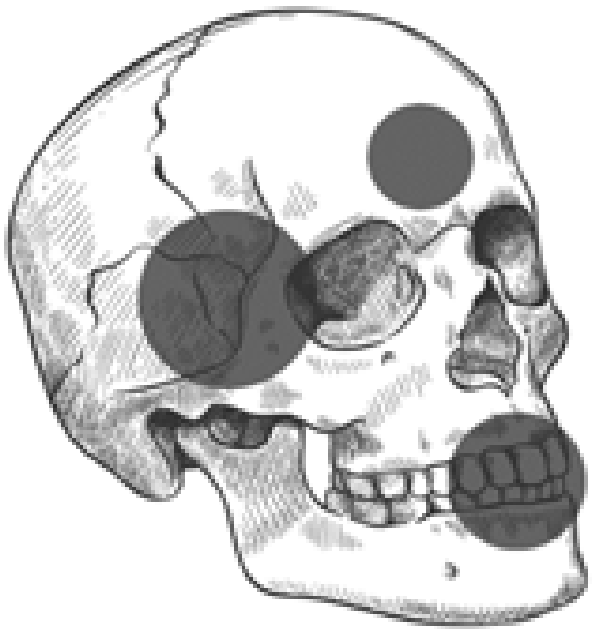

Figure 2. Illustration of the head and neck areas most affected in suicide cases. Source: Prepared by the author*. Representation from tools available on the Canva website via canva.com

forehead, 11 in the mouth floor,5 in the eyes, 4 in the back of the head, 4 in the vertex area (highest point of the skull) and 2 in the back of the neck. For homicides, the distribution of injuries entering the head was 57 in the back of the head, 29 in the cheek, 24 in the left temporal region, 22 in the back of the neck, 19 in the forehead, 19 in the right temporal region, 16 in the eyes, 15 in the vertex area, 3 in the mouth and 3 in the mouth floor.

According to the direction of the projectile, in cases of suicide, most of the shots were contact shots or close-range shots (97%), in addition to having a stable hand position. In homicides, 92.5% of the gunshots were of intermediate or distant range, indicating the victim's distraction or a possible execution scenario. Additionally, among 61 cases of suicide with shots inside the mouth, only 1 pointed the weapon downwards, being the most frequent in an upward direction. In shooting situations with entrance into the neck and back of the neck, the majority of homicides were caused by bullets with a horizontal trajectory, and in suicide cases, the direction of the bullet travel was upwards.

As for the number of shots, 53% of the homicide cases had multiple injuries caused by firearm projectiles, with the number of wounds in these cases limited by the capacity or time of the gun magazine and the availability of ammunition. On the other hand, the suspicion of suicide can be eliminated solely if the shot of a non-automatic firearm affects the indispensable centers of the central nervous system since when affected, the individual is immediately incapacitated[6].

Studies by Thomsen *et al.* (2021)[1], in Denmark, between the years 1992 and 2016, showed that there were 1,417 homicides, 315 of which were caused by trauma from firearm projectiles, the head (58.1%) and the thorax (46.7%) the most affected regions. Among these cases, there were 762 perforations, of which 600 (78.4%) affected the head, neck, thorax, and abdomen, thus causing brain and lung injuries. The distribution of affected areas was 57.8% in the skull, 54% in the brain, 9.5% in the blood vessels of the head and neck region, including 8.9% in the neck organs. In addition, the most common path of firearm injuries was right posteroinferior (9.3%) and left posteroinferior (7.7%)[1].

Focusing on the incidence of firearm projectile injuries in the temporal bone, More *et al.* (2003)[7] point out, the significant consequences of these injuries, such as facial paralysis, intracranial damage, and critical vascular injury. The case report was of a 31-year-old African man who had a gunshot in the face on the right side and presented, two days later, with ipsilateral facial weakness, edema, and bloody otorrhea, associated with right-sided deafness and severe vertigo. Computed tomography showed the projectile path, which entered the right maxillary sinus through the medial wall and exited through the posterior wall, crossing the right infratemporal fossa. Consequently, there was trauma to the facial nerve from the geniculate ganglion to the stylomastoid foramen, laceration, and thrombosis of the sigmoid sinus, associated with trauma to the tympanic membrane and the entire ossicular chain, which were absent in this case. A fallopian canal rupture and neural degeneration have also been identified. Because of its extensive course in the temporal bone, the facial nerve can be affected in several places or a long segment of the nerve can be injured, the vertical segment and the stylomastoid foramen being frequently affected areas[7].

A study by Rampa *et al.* (2019)[3] about the characteristics of patients and causes of facial fractures in the State of California (United States) showed that, among 64,653,918 hospital emergency visits, 198,870 were due to facial fractures during the period from 2005 to 2011. In addition, data show that cases increased by 35% from 2005 to 2011, with the average age of victims treated in the emergency department being 35.7 years. Firearms are the 6th most frequent cause of these injuries, affecting the nasal bones, orbital floor, cheekbones, and jawbones, as well as the mandible.

Concerning post-mortem computed tomography, Oliva *et al.*(2021)[8] developed a study on nine victims of a terrorist attack who had injuries in the head and neck region, with 7 victims having injuries caused by firearms and 2 victims with cuts from sharp weapons. Among the cases resulting from firearm projectiles, the injured regions showed wounds, represented in Figure 3, with: (1) entry into the left occipital bone and exit into the right orbit; (2) entry into the left posterior parietal bone and exit into the right temporoparietal area; (3) arrangement in the right frontoparietal, left temporoparietal and right occipital regions;

Figure 3. Illustration of the head and neck areas most affected in homicide cases. Source: Prepared by the author*. Representation from tools available on the Canva website via canva.com

(4) perforations in the region above the external acoustic meatus, in the right zygomatic bone, in the superficial tissues of the neck and in the mandibular and occipital regions; (5) perforations in the parieto-occipital, left temporoparietal and forehead areas; (6) entry into the occipital region, fracture extending from the C1 vertebra to the left occipital condyle, metallic fragments above the left frontal bone and under the mastoid process, whose projectile located in the anterolateral wall above the maxillary sinus; and finally, (7) entry into the left cheek and exit under the left ear, in addition to a multifragmentary fracture of the right cranial vault extending to the temporal pyramid and mandibular ramus.

Post-mortem CT scans showed that the skull lesions have conical shapes compared to entry and exit wounds. In addition, the study reveals that the severity of injuries caused by firearms varies according to the kinetic energy with which the projectile is launched and can be highly destructive since they are capable of reaching about 300 m/s (revolver) at 720 m/s (AK-47)[8].

Another harmful consequence of firearm projectiles in the head and neck region reported by Pavelites *et al.* (2011)[9] is the unusual snowstorm due to buckshot fragmentation. The study consists of a case report, which evidences a pattern in the radiographic image, named snowstorm, in which the charges of buckshot, coated with copper, fragmented into small shards. In this case, the victim was stricken by firearm projectiles in the upper region of the right eye and anterior neck. When piercing the subcutaneous tissues of the area superior to the right eye, the projectile reached the supraorbital crest of the basilar skull.

After murdering a co-worker, the individual committed suicide, showing the same radiographic pattern as a snowstorm. The projectiles hit the head, chin, neck, and left chest. Perforations in the skin and subcutaneous tissues with subarachnoid hemorrhage and cerebral contusions were revealed. With exit to the right side of the face, one of the projectiles presented an ascending path, from left to right and posteroanterior direction. In addition to causing injury to the lower chin, with mandible perforation and fractures of facial bones, it also caused laceration of the right external carotid artery[9].

Discussion

Assessing characteristics such as the number of injuries, the direction of entry and exit of the projectile, as well as the distance of the shot is fundamental to substantiate the cause of death of an individual[10–12]. Based on the results of the studies analyzed to carry out this systematic literature review, it became clear that there are important discrepancies between injuries resulting from homicide and suicide, which impact the determination of the most frequently affected body regions[13]. In this sense, to define the areas of the head and neck most affected by firearm projectiles, it is necessary to analyze the origin of the occurrence of the shooting.

The heterogeneity of the samples in the present study made it difficult to compare and develop a standard pattern regarding the areas most affected by firearm projectiles. The six studies were performed in different geographic locations. Hence, divergences were identified since studies carried out in Turkey and New Zealand indicate fractures in the jaw bones as the most frequent, while studies carried out by Rampa *et al.* (2019)[3] in the State of California indicate the nasal bones to be more affected.

In homicide cases[13–15], the studies show that the head and neck area most affected by firearm projectiles is the neurocranium, mainly in the frontal, parietal, occipital, and temporal bones. According to Karger *et al.* (2002)[6], among the 232 wounds caused by homicide found by the German institutes of the Universities of Münster and Hamburg, 57 were in the back of the head and 24 in the left temple. In the article by Thomsen *et al.* (2021)[1], 57.8% of the 315 homicide cases motivated by firearms showed trauma to the skull.

In agreement with these results, 9 cases of homicide, due to a terrorist attack, were investigated by Oliva and Grassi *et al.* (2021)[8] through the analysis of post-mortem computed tomography scans and showed 7 injuries from firearm projectiles in the

head and neck area. Of these 7 victims, only one presented no lesion in the neurocranium region. Thus, in this specific study, 85.7% of the cases had injuries in the neurocranium area.

In the study by Karger *et al.* (2002)[6], in suicide situations, the head and neck area most affected by firearm projectiles is the face. Among 252 injuries in cases of suicide, 111 were in the right temple, which is, therefore, the most affected region, followed by the mouth (61) and forehead (33). In addition, most shots are classified as contact or near-contact, with a stable hand position.

Conclusions

In conclusion, the present study supports, through results obtained in bibliographic surveys carried out in PubMed, Scopus, Embase, Web of Science, and Lilacs databases, that the head and neck area most affected by firearm projectiles varies according to the occurrence situation. In homicide cases, the region primarily affected is the neurocranium, especially the occipital, parietal, and temporal bones. Whereas, in suicide situations, the most frequently affected location is the face, specifically the temple, mouth, and forehead.

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