Gunshot Injuries to the Face and Cranium: A Radiologic Review

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Introduction:

People own guns for a myriad of reasons, including hunting, sport shooting, and collecting. Guns are also owned, at least in part, for self-defense. Fear of crime is widespread, and many consider keeping a gun in the home a reasonable precaution. Forty percent of American homes contain one or more firearms. Studies show that people who keep guns for self-defense are more likely to keep at least one gun loaded and unlocked than people who keep guns for other purposes.

The United States leads industrialized nations with the highest numbers and rates of firearm deaths. Each year, firearms cause approximately 38,000 deaths and 99,000 non-fatal injuries in the U.S. The incidence of penetrating head injury in the United States is about 12 per 100,000 population, the highest of any developed country in the world.

In the United States, firearms are the implement of choice for the commission of both homicide and suicide, and the favored target is the craniofacial region.

Material and Methods:

Initial patient selection was performed using a computerized search of the database cataloging University of Michigan CT examinations. The keywords used were "gunshot", "gun", "shotgun", "bullet", "face", "maxillofacial", "orbits", "cranium", and "brain". The search was limited to head, maxillofacial, orbital, and neck CT's performed at the University of Michigan between January of 1998 and December of 2002. A total of 39 patients were identified. The caseload was then examined and patients with gunshot injuries to the face and cranium were retained while patients with gunshot injuries solely to the neck were excluded. Patient electronic medical records were then examined retrospectively to identify lethality, the firearm used, the location of the injury (including entry and exit sites), the place at which the injury occurred (home, etc.), and existence of co-morbid factors.

Injuries were stratified into one of four categories: accidentally self-inflicted, intentionally self-inflicted, accidentally inflicted by another, and intentionally inflicted by another. Pertinent imaging studies were reviewed and representative examples of various injuries photographed. Detailed 3D reformats and reconstructions of these injuries were created using a GE Advantage 4.0 workstation. The "Reformat", "SolidFacial", and "CT Soft" reconstruction algorithms were employed.

Results:

39 patients were identified with gunshot injuries to the face and cranium. Of the 39 cases, 20 were intentionally self-inflicted, 16 were intentionally inflicted by another, 1 accidentally inflicted by another, and 2 had no pertinent information to determine who inflicted the injury. Of 20 intentionally self-inflicted injuries, 12 were by handguns, 5 by shotguns, 2 by rifles, and 1 by BB gun. Of 16 injuries intentionally inflicted by another, 14 involved handguns and 2 involved shotguns. The sole accidental injury inflicted by
another was a non-lethal hunting accident involving a shotgun. For the 2 unknowns, 1 involved a handgun and 1 a BB gun.

13 fatalities occurred among the 39 patients. 7 of 20 intentionally self-inflicted injuries were fatal, all employing handguns. 5 of 16 injuries intentionally inflicted by another were fatal, again, all involving handguns. 13 of 20 self-inflicted injuries were non-lethal: 5 used handguns, 5 used shotguns, 2 used rifles, and 1 used a BB gun. 11 of 16 injuries intentionally inflicted by another were non-lethal: 9 involved handguns and 2 involved shotguns. Of 2 unknown cases, 1 was lethal (handgun) and 1 was not (BB gun).

All fatalities resulted from handguns. No shotgun or rifle injuries were lethal. All 7 patients with intentionally self-inflicted shotgun and rifle blasts devastated facial soft tissue and bone. Injury extent was determined, at least in part, by position of the muzzle inside the mouth or under the chin.

**Tissue Effects:**

A penetrating missile transfers energy to the surrounding tissues. Impact imparts a temporary pressure wave perpendicular to the path of the bullet, accelerating tissue forward and sideways. The force generated is such that the tissue particles, because of inertia, continue moving after the missile passes. This expands the tract into a temporary cavity up to 30 times the original cross-sectional area. This quickly collapses on itself.

Superimposed on these pressure waves are shock waves directly related to the velocity of the missile. Tissue elasticity, hemorrhage, and edema are the factors influencing cavity collapse. All structures in the bullet track are destroyed or pushed aside. A smaller permanent pathway marked by vapor bubbles, hemorrhage, bullet fragments, and sometimes bone chips is left behind.

Shotgun wounds differ somewhat from handgun and rifle wounds. As with other firearms, the velocity of pellets as they strike the intended target is the primary determinant of wounding capacity. Additional variables include the pattern of pellets, the number of pellets, the size of the pellets, deflection of the pellets, and the distance of the target from the muzzle blast.

**Wound Ballistics:**

When projectiles penetrate living tissue, the injury is directly related to the amount of energy transferred to the target. This is expressed by the equation:

\[ E = \frac{1}{2}mv^2 \]

where \( E \) = energy transferred, \( m \) = mass of the missile, \( v \) = velocity of the missile. Thus, wounding capacity is most directly related to the energy imparted by the missile's velocity as it violates tissue. Bullets are lead projectiles covered by a copper or brass jacket. Jacketed bullets are more likely to fragment on impact. A fully jacketed round travels further and is more accurate than a "dum-dum", which is designed to deform on impact, increasing its effective diameter. The shape and consistency of a bullet greatly influence the nature of the wound. Hollow, soft type bullets will deform on impact, thus increasing their area of contact with tissue. The release of energy to tissue is
enhanced, thus causing more extensive damage. This type of bullet is less likely to exit from the target.

Co-Morbidity:

Numerous co-morbidities were identified within the 4 patient populations. The preponderance were manifest in the intentionally self-inflicted population and included a history of significant mental illness, such as Bipolar Disorder, Schizophrenia, Depression, and psychosis not otherwise specified. These patients also possessed histories punctuated by alcohol abuse, alcoholism, and poly-substance abuse. Alcohol abuse, alcoholism, and ADHD were identified within the patient population intentionally injured by another.

Conclusion:

Gun violence remains a leading cause of morbidity and mortality in the United States. Many factors contribute to the high incidence and prevalence of gunshot injuries in the U.S. including, but not limited to, widespread gun availability, social and socioeconomic factors, and significant mental illness. Firearm injuries to the face and cranium will continue to be devastating injuries which pose significant long-term physical and mental health consequences for patients and substantial reconstructive and restorative issues for clinicians.

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References:


Legends:

Fig 1 A-C. Lethal intentionally self-inflicted handgun injury. Right temporal entry wound and left parietal exit wound. Reformatted paraxial image traces the path of bullet, outlined by hemorrhage, bone fragments and vapor bubbles. Massive edema with poor grey-white differentiation and sulcal effacement is seen. There are subdural, intraparenchymal, and intraventricular hemorrhages with pneumocephalus and blood in the interhemispheric fissure.

Fig 2 A-C. Lethal close-range handgun injury intentionally inflicted by another. Right frontal entry wound. Bone fragments, vapor bubbles, bullet fragments, and hemorrhage are left in the bullet's wake. The bullet is lodged in the fractured left frontal bone. Massive edema with basal cistern effacement and transtentorial coning is identified. Massive edema and coning were seen in all cases of lethal close-range handgun injury where bullet penetrated the skull and traveled through brain parenchyma.

Fig 3 A-C. Long-range handgun injury intentionally inflicted by another. There is no skull penetration. Bullet deforms primarily against the petrous temporal bone. There is a depressed fracture of the right parieto-occipital bone above the petrous region with countercoup contusion and a small subdural hemorrhage in the left frontal region. No brain edema is identified.

Fig 4 A-C. BB gun injury, accidentally self-inflicted. Trace the path of the BB through the right eye with ruptured orbital globe demonstrating irregular contour, vapor bubbles, and vitreous hemorrhage. The low-velocity BB penetrated the right orbital roof, stopping at the base of the right frontal lobe. No brain edema or intracranial hemorrhage is identified.

Fig 5 A-C. Intentionally self-inflicted rifle injury, barrel-in-mouth. There are fractures of the anterior maxilla, hard palate, nasal bones, numerous ethmoid septae, bilateral medial orbital walls, and anterior walls of the frontal sinuses. The soft tissue of nose has been avulsed. Due to lack of yaw movement in a rifled bullet, the field of injury is small compared to a shotgun wound and is limited to the central face. There are no injuries of the lateral midface, mandible, orbits or lateral cranium. Due to the high velocity, however, the destruction in the path of the bullet is extensive.

Fig 6 A-D. Intentionally self-inflicted shotgun injury, barrel-under-chin. Explosive injury to a large area of the mandible, midface, orbit, and cranium. Innumerable BB's are seen from the jaw to the forehead. Explosive blast effect on the left side with soft tissue lacerations, hemorrhage, torn vessels, and vapor bubbles. Fractures of the mandible, maxillary sinuses, orbit, frontal sinuses, and calvarium are visualized with significant displacement of bony fragments from blast effect typical of low velocity projectiles.

Fig 7 A-C. Intentionally self-inflicted handgun injury across the orbits. Projectile path across the frontal bones with the bullet traveling extra-cranially in the posterior orbits, severing the optic nerves, and causing extensive soft tissue laceration and hemorrhage.
Due to shock-wave effect of high energy (high-velocity) projectile, numerous fractures of the bones of the midface, paranasal sinuses, and orbits are identified.

Fig 8 A-C. Intentionally self-inflicted shotgun injury, barrel under the chin. There is a large zone of injury involving the mandible, lower, middle, and upper face, including the right orbit. No injury to the cranial vault is identified. The calvarium and brain are intact. Close-range gun-barrel effect from rapidly expanding gases mutilates the soft tissues and fractures the facial bones in a large area beyond the visible tract of missiles (bullets). Fractures and soft tissue injuries are also appreciated on the left. Numerous bullet fragments are seen over a large area due to the high-energy blast effect.

Fig 9 A-C. Long range shotgun injury intentionally inflicted by another. A frontal blast at long range covers a large area of face with direct penetrating injury at both orbits. However, the missile fragments are stopped by the zygoma and orbital bones. Only one bullet penetrates the calvarium and lodges in to right superior orbital fissure in to right temporo-occipital lobe trailing bone fragments and hemorrhage.

Fig 10 A-C. Intentionally self-inflicted BB gun injury. Barrel was pointed medially and superiorly at the inner canthus of right orbit. The orbital globe is intact. Soft tissue and orbital muscle injury were seen. Low-velocity BB is lodged in the roof of the sphenoidal sinus on the right side with fracture and dural tear resulting in extensive pneumocephalus, but no direct brain injury.

Fig 11 A-C. Intentionally self-inflicted 12 gauge shotgun injury, barrel below the chin. This is a follow-up study after a maxillary reconstruction plate seen in 3D reformats. Note the total lack of mandible, maxilla, hard palate, ethmoids and frontal sinuses in the midline. Orbits are well preserved bilaterally.

Fig 12 A-C. Intermediate-range lethal handgun injury intentionally inflicted by another. Left frontal entry wound with the bullet lodged just below a fractured right parietal bone. Bone fragments, bullet fragments, vapor bubble, and hemorrhage seen along the path of the bullet. Interhemispheric, intraventricular, and subdural hemorrhages are seen with a low-attenuating swollen brain. There was effacement of the basal cistern with transtentorial herniation.

Fig 13 A-C. Close-range lethal intentionally self-inflicted handgun injury. Right frontal entry wound with fracture of the frontal bone in the midline, but bullet ricocheting off the skull and lying at left temporo-parietal lobe. Note extensive parenchymal, subdural, subarachnoid, and interhemispheric hemorrhage. Bone fragments at right frontal lobe.

Fig. 14 A-C. Close-range intentionally self-inflicted handgun injury. Entry wound over right temple, but gun was pointed anteriorly. It blew off the right orbital globe completely and lodged in the nasal cavity, sparing the brain. Note bullet fragments at right orbit with a bony defect of entry wound at superior part of lateral wall.
Fig 15 A-F. Intentionally self-inflicted hunting rifle (.36 caliber) injury, barrel below the chin. The path of the bullet is oblique, starting below right mandible and almost completely destroying the face and both the orbits. There are numerous fracture starting with the right mandible, bones of the midface, paranasal sinuses, and bilateral bony orbits. Bullet fragments are seen at left orbit. However, compared to a shotgun injury damage is greater but over a smaller area. There was no brain injury.