Articles

Blunt and penetrating injuries caused by rubber bullets during the Israeli-Arab conflict in October, 2000: a retrospective study

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Summary

Background Low-velocity rubber bullets were used by Israeli police to control riots by Israeli-Arabs in early October, 2000. We aimed to establish the factors that contribute to severity of blunt and penetrating injuries caused by these missiles.

Methods We analysed medical records of 595 casualties admitted. We assessed relation of severity of injury to type of bullet, anatomical region of injury, and final outcome. Severity of injury was established by the abbreviated injury scale, and we calculated injury severity score.

Findings 151 males and one female (age range 11–59 years) were included in the study, in whom 201 proven injuries by rubber bullets were detected. Injuries were distributed randomly over the body surface and were mostly located in the limbs (n=73), but those to the head, neck, and face (61), chest (39), back (16), and abdomen (12) were also frequently noted. 93 (61%) patients had blunt injuries and 59 (39%) penetrating ones. Severity of injury was dependent on ballistic features of the bullet, firing range, and anatomic site of impact. Two casualties died after a penetrating ocular injury into the brain and one died as a result of postoperative aspiration after a knee injury.

Interpretation Resistance of the body surface at the site of impact (elastic limit) is the important factor that ascertains whether a blunt or penetrating injury is inflicted and its severity. Inaccuracy of rubber bullets and improper aiming and range of use resulted in severe injury and death in a substantial number of people. This ammunition should therefore not be considered a safe method of crowd control.

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Introduction

Rubber bullets were used for the first time by British forces in Northern Ireland in 1970.[1–4] These missiles are intended to inflict superficial painful injuries, thereby deterring demonstrators from continuing further hostile activities, while at the same time avoiding serious injuries and deaths that arise with conventional firearms. The missiles are blunt-nosed, with a low muzzle velocity of 73 m/s and a muzzle kinetic energy of 402 J. The recommended safety range of these missiles is more than 40 m, but inaccuracy of the bullets makes it difficult or impossible to avoid hitting the face, head, and chest. Children and teenagers have been reported to have the most severe injuries from these bullets, particularly skull fractures and brain injuries, along with trunk injuries to the lungs, liver, and spleen.

To reduce the number of serious trunk and brain injuries inflicted by rubber bullets, more accurate plastic bullets composed of polyvinyl chloride, with a muzzle velocity of 71 m/s and a muzzle kinetic energy of 325 J, have been introduced.[2,4,5] The enhanced accuracy and stability in flight of these bullets results in less frequent head and chest injuries than rubber bullets, but more severe skull and brain injuries, and often death.[2]

Between 1970 and 1975, over 55 000 rubber bullets were fired in Northern Ireland, with an estimated death rate of one in 18 000 rounds used, and serious injury rate of one in 1100 rounds.[2] Plastic bullets were also used by the South African Security Force during the civil unrest in 1984, leading to a substantial number of severe facial injuries.[6] During the Intifada between 1987 and 1993, the firing of rubber and plastic bullets by Israel Defence Forces resulted in several hundred significant injuries.[7–10] Although designed to avoid serious wounds and death, the firing of rubber and plastic bullets has resulted in a large number of extensive penetrating injuries and more than 20 deaths, mostly by injuries to the brain.[10,11]

The Israeli Police Force also used rubber bullets to control demonstrations by Israeli-Arabs during early October, 2000. Police forces were instructed to fire the rubber bullets from a safe range of more than 40 m and to aim exclusively at the lower limbs of the demonstrators. We investigated casualties with injuries induced by rubber bullets, who were treated at a frontline clinic, two regional hospitals, and a level I trauma centre, to establish the factors associated with generation of blunt or penetrating injuries by a rubber bullet. We postulated that the major determining factor leading to blunt or penetrating injury by the rubber bullet, and its severity, was surface resistance to injury of the body area that was injured.

Methods

Study population

During riots by Israeli-Arabs in early October, 2000, several hundred people sustained injuries caused by conventional ammunition and rubber bullets. 13 people died as a result of those injuries. We analysed the medical records of 595

Range	Bullet dispersion	Number of hits of target out of 90 attempts
40 m	164 cm	82 (91·1%)
50 m	216 cm	73 (81·1%)
60 m	242 cm	58 (64·4%)
70 m	250 cm	55 (61·1%)

Table 1: **Experimental firing of RCC-95 rubber bullets by the Israeli police force**

casualties who were admitted to a frontline clinic in Umm el Fahem, two regional hospitals in Nazareth, and the level I trauma centre at Rambam Medical Center in Haifa. We included in our study 152 casualties with proven injuries induced by rubber bullets.

Ballistic details

Rubber bullets used during the riots were of two types:

RCC-95—this bullet is a blunt cylindrical missile composed of three metal cores that are coated by a hard rubber shell 0·2 cm thick with a diameter of 1·8 cm. The bullet is mounted in a special canister that fits on the muzzle of an US-manufactured M-16 assault rifle. Its weight is 48 g, with a muzzle velocity of 130 m/s and muzzle kinetic energy of 46 J/cm^2. The missile dissociates into its three components after shooting. The recommended range of the missile is 40–70 m (table 1). A special propellant cartridge, which is mounted in a conventional canister, is used to propel the fired missiles. The bullets are recommended by the manufacturer (TAAS, Israel Military Industries) for selective control of individual rioters.

MA/RA 88—this bullet is composed of 15 rubber balls with a metal core, each weighing 17 g, with a calibre of 1·7 cm. The missile is stored in a special canister mounted on the muzzle of the assault rifle. Its muzzle velocity is 78 m/s and muzzle kinetic energy 33 J/cm^2, with an effective range of 30–80 m. When fired, the bullets form a circle with a diameter of 7 m at a range of 50 m. The bullets produce a low energy of impact and are therefore recommended by the manufacturer (TAAS) for control of groups of rioters with minimum potential of physical injury, but with substantial psychological impact.

Procedures

We documented distribution of injuries by body region, mechanism of injury (blunt or penetrating), severity of injury, surgical procedures, and final outcome for every patient. We assessed severity of injury with the abbreviated injury scale (AIS; 1990 revision, 1998 update; Association for the Advancement of Automotive Medicine, Des Plaines, IL, USA). An AIS score of 1 was judged mild injury, 2 was moderately severe, and 3 or more was severe. We based our calculation of injury severity score (ISS) for every patient on the sum of the squares of the highest AIS code in each of the three most severely injured body regions. An ISS of 1 or 2 was judged mild severity, 3–9 moderate severity, and 10 or more severe.

Role of the funding source

The sponsors of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Of 152 patients with 201 proven rubber-bullet injuries, 35 were treated at the frontline clinic in Umm el Fahem, 101 were admitted to two regional hospitals in Nazareth, and 16 were referred to the Rambam Medical Center in Haifa. There were 151 males and one female, with an age range of 11–59 years (figure 1). 20 (13%) patients had more than one bullet injury, and in one (0·6%) individual, 13 bullet injuries were noted (figure 2).

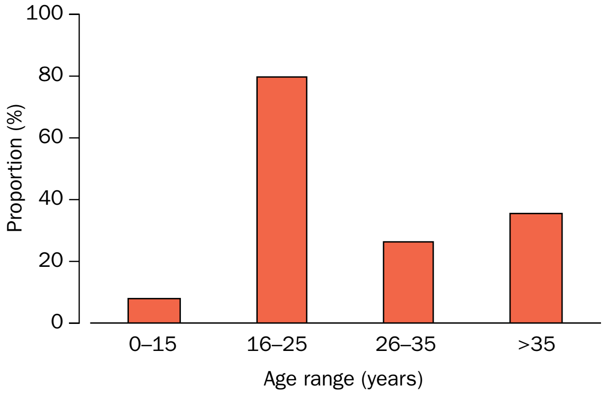

Figure 1: **Age distribution of 152 wounded casualties**

The 201 rubber-bullet injuries were randomly distributed all over the body (figure 3). Injuries were mostly located in the limbs (n=73), but those to the head, neck, and face (61), chest (39), back (16), and abdomen (12) were also frequently noted. In accordance with ISS score, 92 (46%) injuries were mild, 71 (35%) were moderately severe, and 38 (19%) were severe. 116 (58%) of 201 sites of impact were detected above the umbilicus, whereas 85 (42%) were noted below this area. 123 (61%) injuries were blunt, whereas 78 (39%) were penetrating.

84 (55%) people were treated as outpatients and 68 (45%) were admitted. Most mildly injured casualties (72) were treated as outpatients and released after first-aid treatment, whereas most of those with moderately severe (52) and severe injuries (28) were admitted. Surgical procedures under general anaesthesia were done in 11 (7%)

Figure 2: **Rubber-bullet injuries induced by MA/RA 88 bullet**
In this patient, 13 blunt bullet injuries were detected on the back.

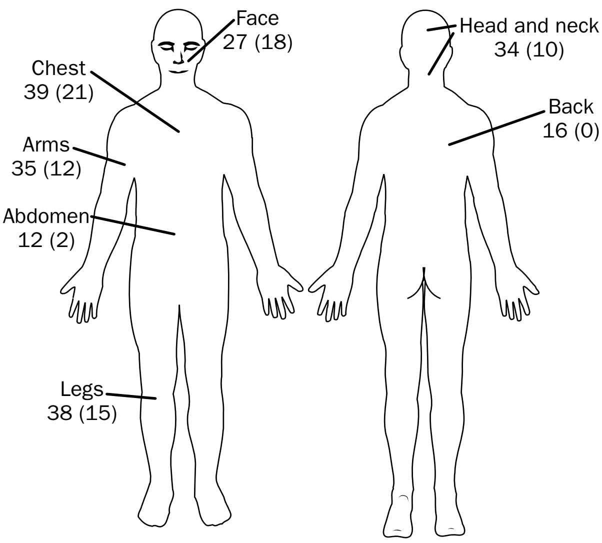

Figure 3: **Distribution of rubber-bullet injuries**
Penetrating injuries are shown in brackets.

patients with head, neck, and facial injuries, ten (7%) with chest injuries, three (2%) with abdominal injuries, and 11 (7%) with limb injuries. Patients with moderately severe injuries were admitted for 1–10 days (median 1), whereas those with severe injuries were in hospital for 4–28 days (median 6).

Three people died of their injuries: one after a severe penetrating ocular injury into the sphenoid sinus; the second as a result of severe diffuse brain damage caused by penetrating ocular injury; and the third as a result of postoperative aspiration after knee surgery for a moderately severe rubber-bullet injury. Long-term morbidity was noted in one patient with head and neck injury (post-traumatic psychosis), in three with facial injuries (blindness), and in two with abdominal injuries (repeated intestinal obstruction because of adhesions).

Type of rubber bullet could not be ascertained in most mildly injured patients from history or skin marks. In most patients with moderately severe injuries, and in all those severely injured, RCC-95 bullets were recovered.

Firing range could not be established accurately in most people by information obtained from the individual themselves or from bystanders. However, in 42 patients with 57 moderately severe or severe injuries (18 skull injuries, 11 chest, three abdominal, and 25 limb), severe contusion, bone fractures, and penetrating injuries in body areas with high elasticity, viscosity, or both were noted, suggesting that bullets were fired from close range.

Injuries to arms and legs (table 2) were generally less severe than injuries to the face, head and neck, or chest. Most injuries to limbs were blunt (n=48), causing superficial contusion (bruise) and swelling, with or without superficial laceration. In some patients, the shape of the bullet was imprinted in the skin. More severe injuries to limbs caused deep lacerations or closed or open bony fractures of the ulna, metacarpus, phalanges, femur, and tibia. All people with superficial injuries were treated as outpatients and were immediately released without further results. All nine patients with open knee lacerations and open bony fractures of the limbs were immediately operated on at admission.

34 (17%) injuries were to the head and neck and 27 (13%) to the face (table 3). Injuries to the head and neck were more frequently blunt (24/34), with or without superficial laceration of the skin, sometimes with brief loss of consciousness for a few seconds. In more severe head injuries, depressed fractures of the skull, fractures of the base of the skull, subarachnoid haemorrhage, and epidural and subdural haematoma were noted (figure 4), with extended periods of unconsciousness and loss of memory. Glasgow coma scale on admission was 3 in two patients, 12 in three, 13 in one, 14 in one, and 15 in the remaining 20 patients with head injuries. All patients responded to conservative treatment and were discharged after several days of observation.

Injuries to the face were usually more severe and penetrating than those to other areas of the body, with gross ecchymoses, orbital and periorbital oedema, bruising and deep lacerations of the face and eyelids, and fractures of the orbital floor, zygoma, mandible, and maxilla. Injuries to the eyeball were especially severe, causing brain penetration and death in two patients, and visual loss or complete blindness when there was no penetration into the brain (figure 5).

	Type of injury		Severity		
	Blunt	Penetrating	Mild	Moderate	Severe
Type of arm injury (n=35)					
Laceration/contusion or closed fracture	23	7	23	7	0
Open fracture of humerus	0	1	0	1	0
Open fracture of ulna	0	1	0	1	0
Open fracture of metacarpus	0	1	0	1	0
Open fracture of phalanges	0	1	0	1	0
Tear of tendons of hand	0	1	0	1	0
Type of leg injury (n=38)					
Laceration/contusion or closed fracture of thigh	17	5	17	5	0
Laceration/contusion or closed fracture of leg	7	3	7	3	0
Open fracture of femur	0	1	0	1	0
Open fracture of tibia	0	2	0	2	0
Laceration/ contusion of knee	0	1	2	1	2*

*One patient with an open knee laceration died after surgery.

Table 2: **Injuries to the arms and legs caused by rubber bullets**

	Type of Injury		Severity		
	Blunt	Penetrating	Mild	Moderate	Severe
Type of head and neck injury (n=34)					
Laceration/ contusion of head	16	0	9	4	3
Laceration/ contusion of neck	7	0	6	1	0
Depressed skull fracture	0	3	0	1	2
Simple skull fracture	1	0	0	1	2
Fracture of base of skull	0	3	0	1	2
Subarachnoid haemorrhage	0	2	0	0	2
Epidural haematoma	0	1	0	0	1
Subdural haematoma	0	1	0	0	1
Type of facial injury (n=27)					
Laceration	9	3	4	6	2
Fracture of mandible	0	2	0	2	0
Fracture of zygoma	0	1	0	1	0
Fracture of maxilla	0	1	0	1	0
Fracture of orbital floor	0	3	0	1	2
Total haemophthalmia	0	2	0	0	2*
Evisceration of eyeball	0	3	0	1	2
Foreign body in face	0	3	2	1	0

*Both patients died of the injury.

Table 3: **Specific head and neck and facial injuries caused by rubber bullets**

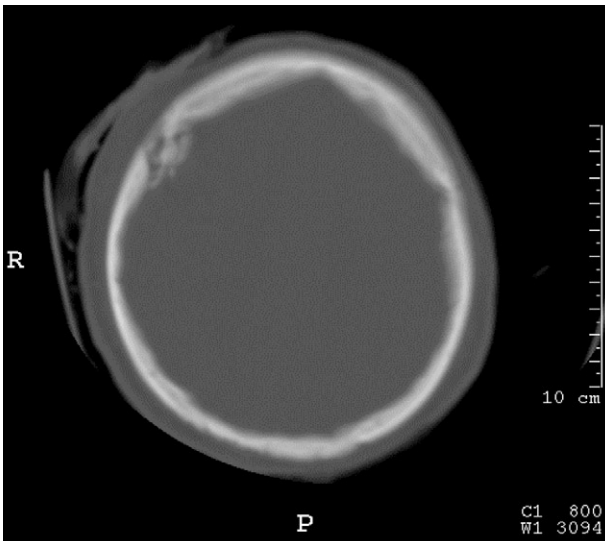

Figure 4: **Computed tomography scan of 27-year-old man with blunt rubber-bullet injury of skull**
Bullet caused open fracture of the parietal bone with subarachnoid haemorrhage. Patient was discharged after 2 days of observation.

Figure 6: **Computed tomography scan of 26 year-old man with penetrating rubber-bullet injury of face**
Bullet caused mandibular fracture. At surgery, plating of the mandible was done. Postoperative course was uneventful.

Injuries to the face were most frequently penetrating (18/27), leading to severe local injuries, bone fractures (figure 6), and intracranial injuries that resulted in significant permanent disability.

Of 39 injuries to the chest, about half were blunt (table 4). When the rubber bullet struck the chest wall over a rib, only superficial lacerations and contusions were inflicted. More severe bullet injuries to the chest wall (n=8) caused skin penetration with rib fractures and lung contusions, without penetration into the pleural cavity. In these moderately severe chest contusions, patients initially showed striking respiratory distress with bloody sputum, but they responded to conservative treatment within a few days. In ten patients, rubber bullets penetrated the chest wall in between the ribs with no rib fracture, leading to pneumothorax, haemothorax, pericardial tamponade, myocardial contusions, and tear of subclavian artery. Five patients needed urgent thoracotomy (figure 7), and in the other five, bullets were extracted after the patient had stabilised. Minimum or no lung damage was typically noted at thoracotomy, with the rubber bullet found free-floating within the pleural cavity, showing that it had penetrated the chest wall and transferred its kinetic energy to this wall, causing minimum intrathoracic injury to the lungs, pericardial cavity, or blood vessels.

There were 12 (6%) injuries to the abdomen and 16 (8%) to the back (table 4). All back injuries were blunt, usually with only mild contusion or superficial lacerations (figure 2). Ten of 12 abdominal injuries were blunt. Two injuries in the upper abdomen close to the chest wall penetrated the abdominal wall, leading to splenic and large

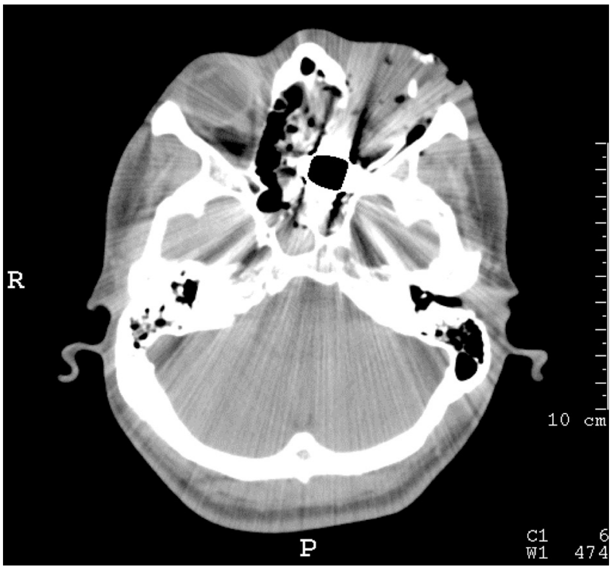

Figure 5: **Computed tomography scan of 18 year-old man with penetrating ocular rubber-bullet injury**
Bullet caused fractures of base of skull, intracerebral bleeding, and subarachnoid haemorrhage. Surgical decompression was done soon after admission, but patient died the day after.

	Type of injury		Severity		
	Blunt	Penetrating	Mild	Moderate	Severe
Type of chest injury (n=39)					
Superficial laceration/ contusion of chest wall	18	0	10	8	0
Rib fractures and contusion of lung	0	8	0	2	6
Pneumothorax	0	6	0	2	4
Haemothorax	0	4	0	1	3
Contusion of heart	0	1	0	0	1
Pericardial tamponade	0	1	0	0	1
Tear of subclavian artery	0	1	0	0	1
Type of abdominal injury (n=12)					
Contusion of abdominal wall	7	0	4	3	0
Laceration of spleen	0	1	0	0	1
Ruptured small bowel	1	0	0	0	1
Ruptured large bowel	0	1	0	0	1
Ruptured mesentery	1	0	0	1	0
Contusion of testicles	1	0	0	1	0
Type of back injury (n=16)					
Contusion of back	11	0	6	5	0
Laceration of back	3	0	1	2	0
Contusion of buttock	2	0	2	0	0

Table 4: **Specific chest, abdominal, and back injuries caused by rubber bullets**

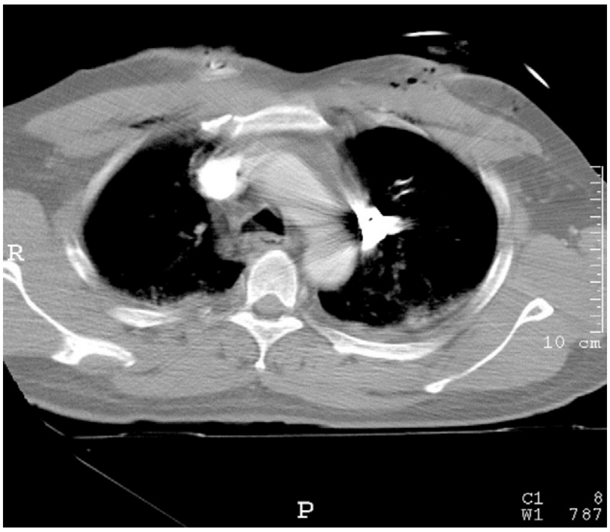

Figure 7: **Computed tomography scan of 45 year-old man with penetrating rubber-bullet injury of left chest**

Bullet caused pneumohaemothorax. At thoracotomy free-floating bullet was found in left pleural space with minimum injury to lung. Only extraction of bullet and tube thoracostomy was done. Patient recovered uneventfully.

bowel injury with intra-abdominal haemorrhage treated by laparotomy. Patients with blunt abdominal injury usually showed local tenderness and guarding, which was managed by close observation, with repeat computed tomography for suspected intra-abdominal injury. Only one patient with blunt abdominal injury underwent exploration because of peritoneal signs that arose on observation. At laparotomy, perforation of several segments of bowel loops was noted, and segmental resection, reanastomosis, and temporary diverting colostomy were done.

Discussion

Both conventional ammunition and rubber bullets were used by the Israeli Police Force to control public disorders by Israeli-Arabs in early October, 2000. This use resulted in several hundred casualties and 13 deaths. 201 rubber-bullet injuries in 152 patients resulted in a substantial number of severe injuries and three deaths (2%), of which two were a direct result of injury and one was caused by postoperative aspiration after knee injury.

Our results show that the factors that most affect penetration and severity of injury inflicted by a rubber bullet are elastic limit, viscosity, or both of the body area that was injured. In body areas with low elastic limit, such as the face and eyes and the intercostal regions, severe penetrating injuries were frequently detected, whereas in body areas with high elastic limit, such as the limbs, back, and skull, blunt injuries were usually inflicted.

The major concerns our study highlighted are: safety of use of rubber bullets for control of civil riots; range of firing by the police (more or less than 40 m); and police aiming towards the lower half of the body. Inaccuracy of rubber bullets resulted in random injuries all over the body surface. However, our observation that more than half the injuries were inflicted above the umbilicus suggests improper use of the weapon by the police. Moreover, evidence for close range of firing can be assumed from the 57 injuries in 42 patients, in whom penetration or fracture by the rubber bullet was detected in body areas with high elasticity, viscosity, or both, such as skull bones, long bones of the limbs, and ribs of adult patients. The finding of 13 MA/RA 88 bullet injuries on one patient's back (figure 2) is also supportive evidence for close range of firing.

In three of ten people studied by Hiss and colleagues,[10] blunt injuries by rubber bullets induced lethal brain damage (n=2) or cervical spinal injury (1) without penetrating internal structures. Of the seven penetrating injuries, five bullets penetrated the thin facial bones of young adults, one the occipital bone of a 13-year-old boy, and one the chest wall, leading to a fatal injury to the heart and lung.

Ballistics of fired missiles can be divided into several phases, including internal (missile movement within the weapon), external (flight of missile from rifle to victim), and terminal (missile injury to the victim).[12–14] Wound ballistics, the interaction of the missile with the target tissue, is established by many factors, making actual prediction of wounding potential very difficult. Factors that affect type, magnitude, and depth of wound include weight (mass), shape, and velocity of the missile, kinetic energy of the missile at impact, surface viscoelastic properties (tension), resistance to penetration of the body surface in the area of impact, and drag coefficient of the missile. Wounding potential of a particular missile is established to a large extent by the efficiency with which its kinetic energy is transferred to tissue in the area of impact. The kinetic energy of a missile is defined as the mass of the missile multiplied by the square of its velocity. Velocity of the missile on impact, which is dependent on range of firing, is the major factor determining severity of injury.[15,16] An important factor in velocity of impact is the missile's ballistic coefficient, which is an expression of its ability to overcome air resistance. The ballistic coefficient is a function of mass, shape, and diameter of the projectile.

Rubber bullets are made so that low kinetic energy is imparted to the victim at the so-called safe range of 40 m when aimed at the lower limbs. This low ballistic coefficient results in unstable flight of the missile, which tends to tumble end over end, leading—in several of our cases—to markings showing that the missile had struck the skin sideways. Also, the low coefficient results in inaccurate erratic flight, which makes it difficult or impossible to avoid hitting the face, head, and upper torso.

Tissue damage induced by rubber bullets is largely attributable to direct compression—or a crushing-type mechanism—of tissues by the blunt tip of the bullet, and to the shockwave generated by the impact, which creates lacerations and fractures distant from area of impact. Force of impact is controlled by several factors, including magnitude (proportional to mass of the missile, acceleration-deceleration, and area of application), duration of application, and rate of onset.[16] This force produces various physical strains on the victim's body, including tensile (stretching), shear (opposing forces to direction of the missile), and compressive (crushing). When strains applied by the blunt rubber bullet deform tissue beyond its limits of elasticity (tendency to regain its original state) or viscosity (resistance to change in shape during motion), cohesion of tissue surface is lost, and disruption with penetration of the missile into the body takes place.

The tolerance limit exceeded at disruption is also known as the elastic limit or break point.[16,17] When the break point was not exceeded, the resulting superficial skin lesions usually included contusions, sometimes with skin markings of the shape of the bullet, abrasions, noticeable swelling, and superficial lacerations. In tissues with high elasticity, viscosity, or both (posterior and lateral parts of the skull of adults, middle and lower part of the abdomen, back, and limbs), injuries inflicted by rubber bullets with high kinetic energy that were shot from short range were usually blunt, with fracture of bones and visceral ruptures but without penetration. In thin-walled tissues with low elasticity, viscosity, or both (thin bones of the face, eyes, skulls of youngsters, chest, and upper abdomen), risk of penetration was greatly increased, even when bullets were shot from a safe range, leading to penetration into body cavities inflicting serious or mortal injuries. An exit wound was never detected after rubber-bullet injury, because of the low kinetic energy and shape of the missile.

Millar and colleagues[1] stated a mortality rate of one in 16 000 fired rounds in Northern Ireland, with a serious injury ratio of one in 800 and a disability ratio of one in 1900. The three factors attributed to fatal outcome in their series were short range, young age, and point of impact. In our series, only 38 (19%) injuries were incurred in the lower limbs, with 78 (39%) penetrating. In 80 (53%) patients, moderate or severe injuries were inflicted that needed admittance and extensive medical and surgical treatment. The fact that 117 (58%) injuries were detected above the umbilicus suggests that a high aiming point was used by the police. In Millar's study[1] of 90 patients, 76% of rubber-bullet injuries were inflicted in the head, neck, and chest, also suggesting a high aiming point or selection of severe injuries. Our observation of 57 injuries in 42 patients that were inappropriately severe in relation to elasticity, viscosity, or both of the anatomical site of injury suggests improper aiming and range by the police, and therefore questions the use of rubber bullets in civilian conflicts.

This type of inaccurate ammunition—one missile that breaks into three components immediately after firing—and the resulting ricochets evidently make it difficult or impossible to avoid severe injuries to vulnerable body regions such as the head, neck, and upper torso, leading to substantial mortality, morbidity, and disability.

The body region most vulnerable to fatal penetrating rubber-bullet injury was the anterior part of the face with its thin bony structures, with particular susceptibility of the eyes.[7] Gross ecchymoses with orbital, periorbital, or facial oedema were present in all 27 patients with facial injury, with 18 having penetration leading to neurological damage and death in two because of penetration into the brain through the eye. In a series of ophthalmic injuries described by Jaouni and O'Shea[18] from east Jerusalem, 567 eye injuries were inflicted from 1987 to 1993, mostly in young adults. Severe ocular injuries were noted in 43·1%, loss of perception to light in 25·2%, vision less than 6/60 in 12·6%, and enucleation needed in 15·1%.

The body area most vulnerable after the face to severe penetrating injury was the chest,[8] because of its extensive surface area, low viscosity, and low elastic limit between the ribs, resulting in penetration of the missile into the lung and heart, causing pneumohaemothorax, cardiac contusion, pericardial tamponade, and large-vessel injury. The upper part of the abdomen, with its low elasticity, was also vulnerable to penetrating injury, whereas rubber-bullet injury to the lower two-thirds of the abdomen usually resulted in blunt trauma without penetration, even when severe intra-abdominal injuries were inflicted.

Imaging in people with injuries from rubber bullets has two goals: to locate the bullet and to identify internal injuries caused by this missile. Localisation of penetrating rubber bullets is of special importance, because the nonsterile, low-velocity rubber bullet can cause local infection, and its rubber shell might gradually disintegrate inside the body and release toxic materials.[19] It is therefore recommended that the bullet be immediately located and removed during surgery. Plain radiographs have only a minor role in early workup of the wounded individual, mainly to confirm presence of a bullet. Computed tomography with thin sections is the major tool used to identify exact location of the bullet and injuries caused by it.

The need for authorities to control civil disturbances is well acknowledged. Techniques used by police forces to deter such activity must be effective and able to keep serious injuries to demonstrators to a minimum. We reported a substantial number of severe injuries and fatalities inflicted by use of rubber bullets when vulnerable upper-body regions such as the head, neck, and upper torso were struck. This type of ammunition should therefore not be considered a safe method of crowd control. New types of ammunition with higher accuracy and less force of impact than those currently in use are urgently needed for control of civil demonstrations. Meanwhile, to prevent serious blunt and penetrating injuries and fatalities, the anatomic target area should be rigorously limited to the lower limbs, and the minimum firing range should always be kept above 40 m.

Contributors

All authors treated the patients and helped in study design. A Mahajna and M M Krausz wrote and corrected the report.

Conflict of interest statement

None declared.

Acknowledgments

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References

1 Millar R, Rutherford WH, Johnston S, Malhotra VJ. Injuries caused by rubber bullets: a report on 90 patients. *Br J Surg* 1975; **62:** 480–86.

2 Rocke L. Injuries caused by plastic bullets compared with those caused by rubber bullets. *Lancet* 1983; **1:** 919–20.

3 Shaw J. Pulmonary contusion in children due to rubber bullet injuries. *BMJ* 1972; **4:** 764–66.

4 Whitlock RIH, Gorman JM. Some missile injuries due to civil unrest in Northern Ireland. *Int J Oral Surg* 1978; **7:** 240–45.

5 Ritchie AJ, Gibbons JR. Plastic bullets in Northern Ireland. *BMJ* 1990; **301:** 1332.

6 Cohen MA. Plastic bullet injuries of the face and jaws. *S Afr Med J* 1985; **68:** 849–52.

7 Balouris CA. Rubber and plastic bullet eye injuries in Palestine. *Lancet* 1990; **335:** 415.

8 Yellin A, Golan M, Klein E, Avigad I, Rosenman J, Lieberman Y. Penetrating thoracic wounds caused by plastic bullets. *J Thorac Cardiovasc Surg* 1992; **103:** 381–85.

9 Schnitzer JJ, Fitzgerald D. Peripheral vascular injuries from plastic bullets in children. *Surg Gynecol Obstet* 1993; **176:** 172–74.

10 Hiss J, Hellman FN, Kahana T. Rubber and plastic ammunition lethal injuries: the Israeli experience. *Med Sci Law* 1997; **37:** 139–44.

11 Hiss J, Kahana T. The fatalities of the Intifada (uprising): the first five years. *J Forensic Sci Soc* 1994; **34:** 225–29.

12 Bellamy RF, Zajtchuk R. The physics and biophysics of wound ballistics. In: Bellamy RF, Zajtchuk R, eds. Conventional warfare: ballistic, blast, and burn injuries. Washington DC: Office of the Surgeon General, Department of the Army, 1990; 107.

13 Feliciano DV. Patterns of injury. In: Feliciano DV, Moore EE, Mattox KL, eds. Trauma, 3rd edn. Stamford, CN: Appleton and Lange, 1996; 85–103.

14 Ordog GJ, Wasserberger J, Balasubramanium S. Wound ballistics: theory and practice. *Ann Emerg Med* 1984; **13:** 1113–22.

15 Mendelson JA. The relationship between mechanisms of wounding and principles of treatment of missiles wounds. *J Trauma* 1991; **31:** 1181–87.

16 Barach E, Tomlanovich M, Nowak R. Ballistics: a pathophysiologic examination of the wounding mechanisms of firearms—part I. *J Trauma* 1986; **26:** 225–35.

17 National Research Council Committee on Trauma Research. Injury biomechanics research and the prevention of impact injury. In: Committee on Trauma Research, eds. Injury in America: a continuing public health problem. Washington DC: National Academy Press, 1985; 48.

18 Jaouni ZM, O'Shea JG. Surgical management of ophthalmic trauma due to the Palestinian Intifada. *Eye* 1997; **11:** 392–97.

19 Guo W, Willen R, Andersson R, et al. Morphological response of the peritoneum and spleen to intraperitoneal biomaterials. *Int J Artif Organs* 1993; **16:** 276–84.