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Clinical Article

Epidemiological, Forensic, Clinical, and Imaging Characteristics of Head Injuries Acquired in the Suicide Attempt with Captive Bolt Gun

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Summary

The captive bolt gun (slaughterer's gun) is a tool used in the meat industry for "humane killing" of animals. Used with the intent of suicide, the captive bolt gun causes very serious injuries.

We analysed 19 self-inflicted head injuries with captive bolt gun during the past 20 years. Autopsy of 20 pigs killed by this method was also performed.

All 19 cases were middle-aged men from rural areas, with low level of education, and without a previous psychiatric history. Five of them used the captive bolt gun daily in their professional activities, while the remaining 14 handled it only sometimes. In seven cases suicide was primarily successful, while in five patients, despite intensive medical care, serious craniocerebral injuries eventually resulted in death. Total mortality was 63.2%.

The clinical appearance of the entrance wound and the imaging characteristics of the cranial trauma are very specific, and can be easily differentiated from firearm or other penetrating injuries. These wounds were always primarily infected with mixed bacterial flora from the skin. Therefore, besides radical primary wound care, especially of the wound canal with removal of foreign bodies, it is important to administer high doses of wide spectrum antibiotics.

Keywords: Penetrating head injury; suicide; captive bolt gun; slaughterer's gun.

Introduction

Twenty years ago we admitted to our Neurosurgery Department an unconscious patient, with a penetrating wound in the right temporal area, surrounded by powder tattoos. The X-ray of the skull, and the computed tomography (CT) of the brain, showed a wound canal directed frontally, with some bone fragments at the end of the canal. However, no metal foreign bodies (bullets) could be detected. We consulted senior colleagues who were also unable to explain the mechanism of this injury.

The father of the patient, who arrived with the patient, trying to disguise the suicide attempt, claimed that his son fell and hit his head on a protruding metal piece of a farmer's machine. After surgery, we found out from the police that it was a suicide attempt with a captive bolt gun, and we were shown this unusual device which was hard to define as a weapon or a tool.

In severely depressed states people may reach for various tools with the intent of suicide. Often these tools are within the reach of their hand, such as guns, poisons or a hanging rope. The properties of wounds caused by unsuccessful suicides are mostly known, which allows for a straightforward treatment strategy. Gender, occupation, place of living, and the psychological state of a person who attempts suicide have influence on the choice of the mode of suicide. Sometimes the methods and tools for suicide are very bizarre and hard to recognize, hence treatment of such wounds may be very difficult.

The captive bolt gun or captive bolt pistol, is a device used by butchers and vets to kill large animals in a painless manner, the so called "humane killing". By shooting the head one can daze the animal, and then in the second act, without resistance, finish the killing by

a different method. This technique is mostly used in Middle European countries, so the reports of injuries with captive bolt guns in professional literature are mostly from German speaking countries and those neighboring Germany, while in English and American literature they are rare. One of the reasons for this fact is a relatively strict license policy for such tools in English speaking countries, because, by law, they are equal to any other weapon. Only farmers and vets can legally obtain them [18]. Hunt and Kon described a few models of guns for "humane killing of animals" as well as the characteristics of the accompanying wounds, but these models are rarely seen in our area [9]. In many European countries the captive bolt gun is considered a tool and its purchase is quite liberal, so they are available to a wide range of users. The captive bolt gun is a metal device of cylindrical shape, 30 cm long. On the market there are two kinds: "Kerner" and "Schermer", but there are also anonymous copies of listed models with very similar technical properties.

Powder filling pushes out a bolt the frontal area of which is concave and with sharp edges. The bolt breaks the skull of an animal penetrating some 7–10 cm into the brain, and then a spring pulls it back. Powder gases escape through two or four openings on the frontal side of this device. These openings are symmetrically placed, with a 30 degrees angle divergent to the bolt. Powder filling is a 9 mm caliber cartridge without a bullet. There are various power fillings, depending on the size of the animal being stunned, or the thickness of the skull. The bolt of Kerner's gun is a 10.5 mm caliber, and the part that comes out on firing is 9 cm long. The Schermer's bolt is a 12 mm caliber and 7.5 cm long. Maximal firing velocity is 50 m/sec [11, 15] (Fig. 1).

The constructional characteristics of captive bolt guns cause specific injuries. If the frontal side of the gun is directly pressed to the surface at a right angle, on firing the sharp edge of the muzzle cuts the skin and takes it like a plug into the depth of the wound, together with hair and all other skin elements. The diameter of the skin piece is always smaller than the bolt caliber. The edges of the wound created under such conditions are sharp, and pigmented with residues of powder gases, which partially enter along the bolt. Symmetrically on both sides of the wound, 15 to 20 mm from the center, there are two round or oval powder tattoos, formed by gases escaping through openings on the frontal side of the gun. The edges of the tattoos closer to the wound are sharp and clear,

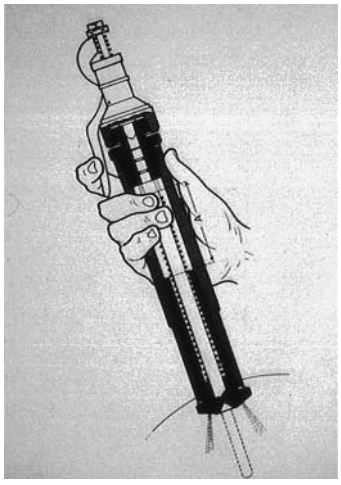

Fig. 1. A scheme of the captive bolt gun mechanism (slaughterer's gun, ger. Bolzenschussapparat)

Fig. 2. Entry wound with typical position and appearance of the powder rings (tattoos)

while the outer edges are less well defined and light (Fig. 2). If the captive bolt pistol is fired at a sharp angle this picture changes. The edge of the wound on the side of the smaller angle is sharper, while on the side of the larger angle it is irregular and dull. The same is true for the appearance of powder burns. If the captive bolt gun is at a distance from the surface, the diameter of the wound is the same but the powder burns are wider and of lower intensity. The outer appearance of the wound is very typical and recognizable on first sight. However, even with the same tool, the outer appearance of the wound may differ, depending on modifying factors [12]. Knowing the outer appearance of the wound may be very important in solving unclear circumstances of injury (suicide or homicide) [5].

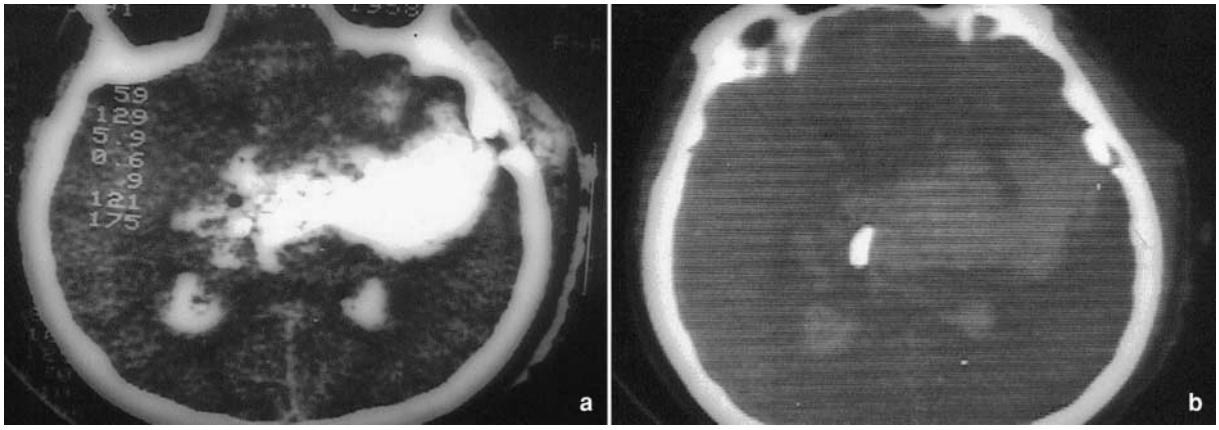

Fig. 3. (a) Brain CT scan shows a bone defect at the entry site and the wound canal, which is typically wider near the entry site. Bone fragments and air are located at the end of the wound canal. There is also blood in the lateral ventricles, and diffuse cerebral edema. (b) Wide window brain CT scan at a slightly higher level shows the entry site with a bone fragment from the inner table of the skull. A large bone fragment at the end of the wound canal is now well visualized

Defects on the tabula externa of the skull are practically identical to the caliber of the bolt, but the diameter of the wound on the tabula interna is considerably larger due to bone fragments punched out by the bolt, and dispersed around the firing canal as secondary projectiles. At the end of the wound canal there is always a piece of skin, sometimes with corresponding hair, and the central part of the bone defect. The length of the wound canal is always longer than the penetrating bolt due to the effect of bone fragments, which act as secondary projectiles. The damage of bone fragments to the brain parenchyma, and especially to the blood vessels, is considerably larger than the direct destructive effect of the bolt [7].

Such an injury, according to the experience obtained in experimental animals, usually causes loss of consciousness, visually evoked potentials, and corneal reflex, depending on the location of the injury [4]. This explains the possibility of repeated use of the captive bolt gun in suicidal attempts [14]. Such brain injuries usually do not cause rapid death, but the overall prognosis is poor – according to the literature the mortality is 80 to 90%. Besides immediate brain parenchyma injuries, and damage to the large blood vessels, impacted pieces of skin and skin elements determine the prognosis. These wounds are primarily contaminated with a surface skin bacterial flora, and proliferation of bacterial micro-organisms can be found within six hours. This leads to development of purulent meningitis, cerebritis and death. Therefore, it is essential not only to remove all devitalized tissue, but to undertake complete exploration of the wound to find potential foreign bodies deep in the wound, in order to decrease the risk of infection [18].

Methods and Patients

This study included a group of 19 people who attempted suicide with a captive bolt gun during a 20 year period. At our Neurosurgery Department we treated 12 (63.2%) patients who attempted suicide with this tool from 1981 to 2000. At the Institute for Forensic Medicine and Criminology, we have found autopsy data of seven patients (36.8%) for whom these injuries were primarily lethal. All the available data – anamnestic, hetero-anamnestic, or available medical documentation, were analysed. Age, place of living, occupation, educational level, and history of prior psychiatric illness were recorded. Clinical examinations, CT scans, intra-operative findings, and postoperative course were also assessed.

Autopsy of 20 pig heads killed by this method was also performed. Immediately after the injury a sample of the macerated brain was taken from the beginning of the firing canal, approximately 25 mm from the skin level, and from the end of the firing canal.

Results

All 19 injured persons were men from 21 to 64 years old, with the average age of 40.5 years. All came from rural areas. Four were butchers, and one was a veterinary technician. The remaining 14 were of different occupations, but in their primary occupation they worked with farm animals and in the meat industry for personal needs. The captive bolt gun was owned as a working tool, as described above. In this group there were no highly educated people. From the available data, no evidence of previous psychiatric treatment

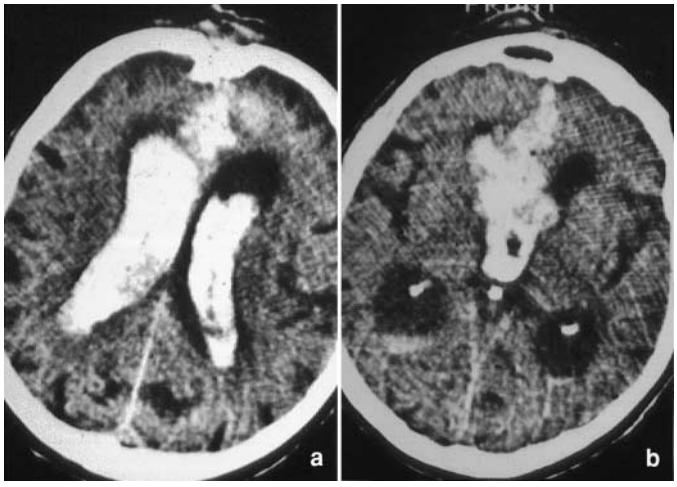

Fig. 4. (a) Brain CT scan shows a displaced bone fragment at the forehead entry site. The wound canal is extending into the lateral ventricles, causing intraventricular haemorrhage. (b) Brain CT scan at a lower level again shows the wound canal, with a large bone fragment at the end of the canal in the posterior aspect of the third ventricle, just anterior to the calcified pineal gland

was found in the entire group. There was no notice of any accidental injuries, nor attempts at homicide.

During the period from 1980 to 1991 there were 10 suicide attempts and 6 successful suicides using the captive bolt gun, which is 84.2% of the whole series. During the war and aggression on Republic of Croatia from 1991 until the end of 1995 no new cases of self-aggressiveness with the captive bolt gun were recorded in our institutions. Since the end of the war, from year 1996, a rise in the number of suicides with the captive bolt gun has been evident. Two unsuccessful suicide attempts and one case of successful suicide with captive bolt gun happened in the period 1996–2000, which is 15.8% of the entire analysed series.

Nine patients had entrance wounds in the right fronto-temporal region, one in the left temporal region (left-handed), one in the projection of the frontal sinus, and one in the parieto-occipital region, two centimeters to the right from the median line. In the group of successful suicides, the entrance wound in four cases was in the right temporal region, and in three cases frontally in the median line.

The entry site was identified in all the patients. These wounds were round, partially with sharp and partially with uneven skin powder marks throughout the whole circumference of the wound. At the poles of the circular wound, about 2 cm from its center, there were round or oval powder burns, which gave a very specific and recognizable appearance to this kind of injury. In one case these tattoos were in four different positions around the wound.

On CT these injuries showed characteristics typical of penetrating head injuries: entry site with large defect of the tabula interna, hyperdense wound canal due to haemorrhage, which was typically wider near the entry site, and small bone fragments along the canal. Associated brain edema, hemorrhage into the ventricular system, and extra-axial haematomas were sometimes encountered. Intracranial metal foreign bodies were not detected in any of the cases, and an exit site was never seen. At the end of the wound canal a large bone fragment, approximately 1 cm in diameter, was identified in all patients.

Intra-operatively, the wound canal was 7 to 10 cm long, and at its limit bone fragments with pieces of skin and hair were always found. Smaller bone fragments were shattered around the firing canal as secondary projectiles as well.

In four cases with exceptionally poor general and neurological status, wound and firing canal were primarily treated, and foreign bodies within reach were removed. All four patients from this group died.

In the remaining eight cases osteoclastic craniotomy was performed, with the intent of removing the bone fragment, whose edges were primarily infected. In the temporal region in addition to the round bony defect, a comminuted fracture of the temporal squama was found in two cases, and irregular linear or star-shaped fractures of surrounding bones in three cases. After removal of the bone, tears or irregular defects of the dura were found which were excised up to the healthy area. Besides detailed exploration of the firing canal, the entire destroyed brain tissue was removed, along with bones and other foreign material, especially skin and hair, which were pushed to the end of the firing canal. Haemostasis was established, and the dura was exactly reconstructed. Reconstruction of the dura was done using periosteal flaps, or temporal fascia, with

Table 1.

Pt.	Age	EW	GCS	CD	BFendWC	BFWC	GOS/30d	GOS/3m	DNS
1.	30	Tr	10		yes	yes	5	5	PO
2.	21	F	6		yes	no	3	3	RH
3.	36	Tr	3	SyV	yes	yes	1		
4.	41	Tr	DOA	SyV	yes	yes	1		
5.	34	F	DOA	RA	yes	no	1		
6.	36	Tr	9		yes	no	3	5	PO
7.	64	Tr	9	HT	yes	yes	1		
8.	46	F	DOA	ICA	yes	no	1		
9.	47	Tr	10		yes	yes	3	4	PO
10.	35	Tr	DOA	SyV	yes	yes	1		
11.	44	Tl	3	SyV	yes	yes	1		
12.	49	O	6		yes	yes	2	2	PVS
13.	41	F	DOA	HT	yes	no	1		
14.	27	Tr	3	SyV	yes	yes	1		
15.	35	Tr	9		yes	no	3	3	PO
16.	56	Tr	DOA	SyV	yes	yes	1		
17.	38	Tr	3	SyV	yes	no	1		
18.	35	Tr	DOA	SyV	yes	yes	1		
19.	54	Tr	10		yes	no	3	5	PO

F Frontal; *Tr* Right Temporal; *Tl* Left Temporal; *O* Occipital; *DOA* death on appearance; *EW* localization of entrance wound; *GCS* Glasgow Coma Scale on appearance; *CD* Cause of death; *BFendWC* Bone fragments at the end of wound canal; *BFWC* Bone fragments in the wound canal; *GOS/30d* Glasgow Outcome Scale at 30 days; *GOS/3m* Glasgow Outcome Scale at 3 months; *DNS* Definitive neurological status; *SyV* Lesion of fissura Sylvii vessels; *HT* Lesion of hypothalamus; *ICA* Lesion of ICA; *RH* Right hemiplegia; *PO* Psycho-organic Syndrome; *PVS* Persistent vegetative state.

local application of fibrin glue (Beriplast®P). Since these were primary infected wounds, high doses of wide spectrum antibiotics were administered.

Autopsy findings of the seven successful suicides revealed lesions of large blood vessels in the Sylvian fissure in five cases as the cause of death, a lesion of the infraclinoid internal carotid artery in one case, and choking with inhaled vomit in one case. Four patients who were brought to our clinic in a moribund state had massive tamponade of the ventricular system in two cases, and destruction of the hypothalamus and surrounding structures in another two cases, in addition to injured large blood vessels in the Sylvian fissure. One patient with the lesion of right frontal lobe died on the eighth post-operative day due to development of purulent meningitis. The total mortality with self-inflicted injuries employing captive bolt gun was therefore 63.2% (12 out of 19 cases).

Seven patients (36.8%) survived. Three had a relatively low grade of handicap, in the form of a psycho-organic syndrome, which corresponded to predominantly frontal lobe injuries. Two patients had discrete hemiparesis and psycho-organic syndrome upon the completion of treatment, and one patient had residual hemiplegia. A patient whose entry site was in the parieto-occipital area, and the wound canal reached the pineal region and quadrigeminal plate, postoperatively developed meningitis, and remained in coma.

Autopsy of 20 pig heads killed by this method found identical morphological characteristics of the skin entrance wounds. As firing was always done at a standard location, at the right angle on the skull bones of pigs, there were no linear or star-like fractures, as noticed on human skulls. The largest fragment with pieces of skin and hair, was found deep at the end of the firing canal in all of the 20 cases, while throughout the canal smaller fragments were detected. In all 20 cases, the sample from the end of the firing canal contained identical bacterial flora as on the skin of the animal.

The results are summarized in Table 1.

Discussion

Injuries with captive bolt guns are a rarity in our area, so that a number of neurosurgeons might never see such a bizarre injury. Since many suicide attempts with captive bolt guns are successful, corpses are transported directly to the Institute for Forensic Medicine and Criminology. Clinicians, therefore, rarely have an opportunity to learn the morphological features of such injuries, and how to undertake adequate

treatment measures. We have performed a retrospective study and were therefore unable to gain data concerning the cerebral pathophysiological status of patients, as in the work of Valadka *et al.* [19].

In some countries a license is not required to obtain a captive bolt gun. It is rather treated as a tool used by vets and butchers in industrial plants for so called "humane killing" of large animals. Therefore, their purchase is legalized, they are relatively easily obtainable and hence misuse is possible [10, 16]. It is evident from the literature that suicides are the most frequent among captive bolt gun injuries, while accidental injuries or homicides are much less common [5, 7, 10, 14, 15, 17, 18].

In the group we analysed, the wounded were middle-aged men, which correlates well with the data in the literature [7, 10]. Patients who survived (7/19) were somewhat younger (average 38.8 years) in comparison to the twelve patients that died (average 40.8 years). To our knowledge, previous psychiatric treatment has not been described in any of the reported cases. Although this study did not include the psychological and psychiatric profile of suicides, there seems to be an auto-destructive pattern in the survivors, without the "cry for help" function of the suicide. The male predominance of this destructive and aggressive means of suicide is probably in relation to the innate characteristics of the male gender as the more active and aggressive [1, 3]. Another common finding in all the analysed cases is that they are all from rural areas, as opposed to urban communities, and that they were all with a low level of education.

Five cases from the group (26.3%) almost daily handled this device as their professional tool (four butchers and one veterinary technician). The remaining 14 cases (73.7%), occasionally handled a captive bolt gun, or owned it as a tool. Therefore, it is easy to conclude that they reached for this tool as a convenient means of suicide [13, 18].

Sixteen out of 19 (84.2%) analysed suicide attempts with a captive bolt gun occurred in the first 10 years of our study. During the second ten-year period, there were only 2 attempts and one successful suicide with a captive bolt gun (15.8%). It is important to mention that during the war period (1991–1995) there were numerous suicides, many of them with fire weapons. However, there were no reports of self-aggression with captive bolt gun. This may be explained by increased availability of firearms during that period.

Wounds were very typical and recognizable, so that after the first experience with such a wound, it was almost impossible not to recognize it again. The most frequent place of injury was the right temporo-occipital region, in 13 (68.4%) cases. These were mostly right-handed persons. In four cases (21%) the entrance wound was in the projection of the frontal sinus. In one case (5.23%) the entrance wound was in the left temporal region (left-handed) and in one (5.2%) in the parieto-occipital region (indicative of a possible homicide). The most common wound locations (fronto-temporal and frontal region) are probably the result of ergonomical properties of the captive bolt gun. The direction and the depth of bolt invasion and impacted bone fragments mostly affected large vascular structures, predominantly in the Sylvian fissure, causing high primary mortality and serious morbidity.

The radiological findings were also easily recognizable and similar to clinical experience. Penetrating head injuries are most commonly caused by firearms, and their appearance on CT images may be very similar to the cases we described, however bullet fragments, exit site, or both are inevitably present [6]. Penetrating injuries may also be inflicted by other metal objects, ice-pick being a relatively common example, however, typically with homicidal intent. Those injuries show a relatively small bone defect at the entry site, and no evidence of large fragments along the wound canal [6]. We propose that the distinguishing features of captive bolt gun injuries are a large bone defect at the entry site, a corresponding bone fragment at the end of a long wound canal, and absence of an exit wound and intracranial metal objects. We have seen a somewhat similar appearance in two cases of attempted homicide with a hammer; however the bone fragments were only a few centimeters deep, and the wound canal was not clearly formed.

All nineteen patients have had bone fragments at the end of the wound canal. Bone fragments along the wound canal were present in ten patients, and eight of them died. Primary wound contamination with mixed skin flora caused meningo-encephalitis in two patients, although high doses of wide spectrum antibiotics were administered. One of these patients died on the eighth post-operative day and the other remained comatose after the treatment of the infection was completed.

These findings were confirmed by bacteriological study of animal brain tissue samples. These samples were taken from the firing canal at a depth of 25 mm from the skin surface in 16 cases (84.2%), and showed flora identical to the animal's skin surface. In all cases

(100%) taken from the firing canal bottom, where a skin piece was impacted, a large quantity of skin bacteria were detected.

This experience allows for a very aggressive approach in the primary wound treatment, with the excision of all devitalized or suspicious soft tissue parts. This includes osteoclastic craniotomy, as well as excision of the dura into the healthy tissue. Special care should be given to detailed exploration of the wound canal and in particular to removal of all foreign bodies, especially impacted skin and hair pieces and bone fragments from the bottom of the canal. We recommend closing the dura defect with periosteal flaps, and avoiding devascularized autotransplants (fascia lata). In such an environment it is contra-indicated to use lyophylized dura or similar implants. Also it is recommended to close the dural defect with very little sewing material, mostly monofilamental. Watertightness should be achieved with fibrin glue, which has proved to be a good material for contaminated wound closure or in wounds with a large infection risk.

Conclusion

Self-injury with suicidal intent with a captive bolt gun is a relatively rare incident with a number of characteristic findings that are important for recognition of injury mechanisms, as well as for the approach to treatment of survivors. Once seen, this entrance wound is so specific that it is almost instantly recognizable in later encounters, and the imaging features are very characteristic.

As the captive bolt gun is primarily used to daze animals, with intention of ''humane killing'', the suicidal person mostly uses it for injuring their own head. These injuries are often primarily lethal. Due to extensive lesions of brain structures, primarily large vessels, and superimposed infection, the total mortality rises to 63.2%, despite surgical treatment and high doses of wide spectrum antibiotics. Survivors are seriously handicapped with a psycho-organic syndrome as a dominant neurological finding.

References

1. Betz P, Pankratz H, Penning R, Eisenmenger W (1993) Homicide with a captive bolt pistol. Am J Forensic Med Pathol 14: 54–57
2. Biro M (1979) O poreklu suicidalnog ponašanja: teze za etiološku studiju. Soc Psihijat 7: 133–141
3. Carey ME (1995) Experimental missile wounding of the brain. Neurosurg Clin N Am 6: 629–642
4. Daly CC, Kallweit E, Ellendorf F (1988) Cortical function in cattle during slaughter: conventional captive bolt stunning followed by exsanguination compared with scechita slaughter. Vet Rec 122: 325–329
5. Faller-Marquardt M (1991) Zur analyse von bolzenschußstanzverletzungen. Beitr Gerichtl Med 49: 193–200
6. Gean AD (1994) Penetrating injuries. In: Gean AD (ed) Imaging of head trauma. Raven Press, New York, pp 189–203
7. Gerlach J (1955) Über bolzensußverletzungen des gehirns: eine typische suizidart der metzger. Zentralbl Neurochir 2: 83–89
8. Gnjidić Ž, Kubat M (1996) Forensic and clinical characteristics of head injuries in suicide attempts with ''bolzenschusapparat''. Book of abstracts: the first congres of the croatian neurosurgical society. Zagreb, Croatia, pp 73–74
9. Hunt AC, Kon VM (1962) The patterns of injury from humane killers. Med Sci Law 2: 197–203
10. Lignitz E, Koops E, Püschel K (1988) Tod durch bolzenschußgeräte. Arch Kriminol 182: 83–93
11. Mosdal C (1985) Cranio-cerebral injuries from slaughter's gun. Acta Neurochir (Wien) 74: 31–34
12. Pollak S (1977) Zur morphologie der bolzenschußverletzung. Z Rechsmedizin 80: 153–165
13. Pančić I (1978) Preživeli suicidi. Psihijatrija danas 3–4: 399–403
14. Schliermeyer H (1973) Suizid durch zweimaligen Bolzenschuß in der Kopf. Arch Kriminol 151: 87–90
15. Sellier K (1982) Schußwaffen und Schußwirkungen; Balistik, Medizin und Kriminalistik. Schmidt-Romhild, Lubeck, pp 82–88
16. Simon G (1958) Suicide, Tötungen und Verletzungen durch Viehschußapparate. Arch Psychiatr Zeit Neurolog (Arch Psychiatr Nervenkr) 197: 124–147
17. Sulla I, Fagul'a J, Santa M (1990) Penetrierende Kopfverletzungen mit Viehbetäubungsgeräten. Zentralbl Chir 115: 219–222
18. Tordrup PJ, Kjeldsen SR (1994) Accidental injuries from captive-bolt guns (Slaughterer's gun). Injury 25: 497–499
19. Valadka AB, Gopinath SP, Mizutani Y, Chackop AG, Robertson CS (2000) Similarities between civilian gunshot wounds to the head and nongunshot head injuries. Trauma 48: 296–302

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