

Assessment of a specifically developed bullet casing gun for the stunning of water buffaloes

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28 **Abstract**

29 To meet the demand for genuine mozzarella and meet, keeping of water buffaloes has
30 become increasingly popular in Switzerland. Concomitantly, close to 400 buffaloes are
31 being slaughtered every year. Irrespective of their close relatedness, anatomical
32 characteristics of the heads of water buffaloes and cattle differ considerably. As a result,
33 standard captive bolt stunners fail to reliably produce adequate loss of consciousness in
34 water buffaloes and, thus, do not fulfill animal welfare requirements. The goal of the
35 present study, therefore, was to develop a new stunning device for water buffaloes meeting
36 all animal welfare and occupational safety requirements and to pave the way for
37 corresponding regulations. This newly designed bullet casing gun was assessed under
38 practical conditions in an abattoir as based on widely accepted criteria. Stunning resulted in
39 deep unconsciousness in all the water buffaloes slaughtered but for one male individual
40 over 9 years of age. Excepted for old bulls, the device presented herewith provides a means
41 to stun water buffaloes of both sexes effectively and reliably while keeping occupational
42 hazards to a minimum.

43 **Keywords:** *water buffalo, skull anatomy, stunning assessment, bullet casing gun*

44 **1. Introduction**

45 Water buffaloes were first introduced into Switzerland in 1996 to allow for the domestic
46 production of genuine mozzarella. Since then, the number of animals has increased
47 continuously with the result that approximately 360 animals are slaughtered every year for
48 stock management and meat production (Dr. A. Briner, Federal Food Safety and
49 Veterinary Office FSVO, personal communication).

50 Animal welfare legislation (Tierschutzgesetz, 2014; Verordnung des BLV über den
51 Tierschutz beim Schlachten, 2014) stipulates deep concussion as a prerequisite for
52 bleeding and further slaughtering. Concussion is usually accomplished by producing
53 severe brain damage with penetrating devices in order to produce deep unconsciousness.
54 Conscious perception is linked to the cerebral cortex. Prior to reaching the primary cortex
55 areas, however, all the sensory information but olfaction is relayed in the thalamus.
56 Damage to the thalamus thus is an effective way to prevent conscious perception making
57 this region of the diencephalon an effective target for stunning.

58 Irrespective of the close relatedness of the two species, water buffaloes have distinctive
59 anatomical head features compared to cattle (Schwenk, 2014). Therefore, standard captive
60 bolt stunners fail to produce loss of consciousness and, consequently, stunning procedures
61 commonly used for cattle may not be applied to water buffaloes. This is basically due to
62 the width of the frontal sinus, the skin thickness and the hardness of the bone plates which
63 together prevent captive bolts from reaching the cranial cavity (Alsaify, El-Gendy, & El
64 Sharaby, 2013; Kamel & Moustafa, 1966; Moustafa & Kamel, 1971; Saigal & Khatra,
65 1977). Attempts to improve the situation by increasing the bolt length and using stronger
66 propellant charges have failed to resolve the issue satisfactorily. For these reasons, various
67 handguns are currently being used by butchers. Though they are dependable and effective
68 in many cases, stunning with free bullets from a distance of 5 to 15 centimeters does not

69 meet other requirements such as occupational safety, applicability and affordability. Thus,
70 a legally underpinned standard procedure for the stunning of water buffaloes taking into
71 account the exigencies of both animal welfare and work safety is urgently needed.

72 The goal of the present study, therefore, was to develop a new stunning device for water
73 buffaloes meeting all animal welfare and occupational safety requirements and to pave the
74 way for corresponding regulations. After in-depth analysis of ballistic parameters,
75 usability, effectiveness and reliability of a newly designed bullet casing gun were assessed
76 under practical conditions in an abattoir. Assessment of widely accepted criteria
77 (Anonymous, 2013b; Grandin, 2002; Gregory, Lee, & Widdicombe, 2007; Verhoeven,
78 Gerritzen, Hellebrekers, & Kemp, 2014) showed that stunning resulted in deep
79 unconsciousness in all the water buffaloes but for one male individual over 9 years of age.
80 Except for old bulls, the device presented herewith provides a means to stun water
81 buffaloes of both sexes effectively and reliably while keeping occupational hazards to a
82 minimum.

83 **2. Materials and Methods**

84 All the experiments were performed with a bullet casing gun which was specifically
85 designed and built for stunning water buffaloes (Fig. 1). The device was made of two 9
86 mm-bore rifled gun barrels with a barrel length of 150 mm, both of which were loaded
87 with .357 Magnum 10.2g Hollow Point (.357 Mag./10.2g HP) ammunition from Geco
88 (Ruag Ammotec Group, Germany) to provide a backup means for an immediate second
89 shot in case of failure of the first attempt. As a safeguard, the device needs to be unlocked
90 ahead of firing. The contact point was slightly lateral to the intersection of two lines
91 connecting the upper and contralateral lower edges of the horn base.

92 The heads of six water buffaloes were collected after regular slaughtering to conduct
93 preliminary ballistic experiments prior to assessing the bullet casing gun on live animals in
94 an abattoir. The unskinned heads were numbered from 1 to 6 according to the animals'
95 ages. Five heads (h1-h5) were from bulls aged 26, 28, 30, 35 and 107 months. Head six
96 (h6) originated from a 114 month-old female water buffalo. In four out of the six heads
97 (h1-h4), the base of the skull was cut away with a band saw and the brains were removed
98 thus yielding front plates.

99 Up to four shots were fired on any given head (h1-h4) and four different ammunitions were
100 tested in order to assess whether the projectiles reached the cranial cavity. Ammunitions
101 tested on front plates included

102 • the .357 Mag. 10.2g Hollow Point (.357 Mag./10.2g HP) bullets from Geco (Ruag
103 Ammotec Group, Germany),

104 • the .357 Mag. 8g Semi Jacketed Hollow Point (.357 Mag./8g SJHP) bullets from
105 Remington (Madison, North Carolina, USA),

106 • the .357 Mag. 8g Semi Jacketed Soft Point bullets (.357 Mag./8g SJSP) from Union
107 Metallic Cartridges (UMC, Madison, North Carolina, USA) and

108 • the .38 Special 10.2g Semi Jacketed Soft Point (.38 Spl./10.2g SJSP) from Geco (Ruag
109 Ammotec Group, Germany).

110 After every shot, the front plates were inspected from the inside to determine whether the
111 bullet had completely penetrated the skull. The two best suited ammunitions, i.e.
112 .38 Spl./10.2g SJSP and the .357 Mag./10.2g HP, were then tested on the two intact heads
113 h5 and h6. The .38 Spl./10.2g SJSP was fired to the right half and the .357 Mag./10.2g HP
114 ammunition to the left half of the head, respectively. Both heads underwent computed
115 tomography with a dual-source CT scanner with 2x128 slices (SOMATOM
116 FlashDefinition, Siemens, Forchheim, Germany) to track the projectile's pathway through

117 the brain. Data reconstruction was performed with 0.6 mm slice thickness in a soft (B30)
118 and a hard (B70) reconstruction algorithm. Multiplanar and 3-dimensional reconstructions
119 were performed at a multimodality workstation (LEONARDO, SynGo, Siemens Medical
120 Solutions, Forchheim, Germany). Data were analyzed with the Osirix® software (Pixmeo,
121 Bernex, Switzerland).

122 Thereafter, the effectiveness of the bullet casing gun loaded with .357 Mag./10.2g HP
123 bullets was assessed on 20 water buffaloes in a standard slaughtering environment with the
124 approval of the [State Veterinary Office Aargau](#) (permit 75661). All the animals were
125 stunned by the same butcher and in the same setting. To record the entire slaughtering
126 process from stunning to exsanguination, a High Definition Video Camera (Panasonic,
127 HC-V727, Rotkreuz, Switzerland) was used. Depth of concussion was judged at the
128 abattoir during routine slaughtering according to a detailed checklist including a broad
129 spectrum of established criteria (Anonymous, 2013b; Grandin, 2002; Gregory, Lee, &
130 Widdicombe, 2007; Panel on Euthanasia, 2013) as given in Table 1. Every single criterion
131 was graded with 1 when it was indicative of loss of consciousness and with 0 when it was
132 not compatible with concussion. On-site evaluation was double-checked by viewing the
133 video recordings upon return from the slaughterhouse. To ensure proper handling of the
134 bullet casing gun, computer tomograms from two heads (Nr 10 and 16, Table 1) were
135 produced as reported above in order to track the bullet's pathway and to review the brain
136 lesions produced (Schwenk, 2014). As a backup, the butcher always had his "Ruger GP
137 100 Double Action" Revolver at hand in case of failure of the first shot. The revolver was
138 loaded with .357 Magnum 10.2g Semi Jacketed Soft Point Flat Nose ammunition (.357
139 Mag./10.2g SJSP-FN). The decision to rely on the previously used stunning method as a
140 backup was part of the approval from the Swiss Federal Food Safety and Veterinary
141 Office. Immediate collapse, instant onset of apnoea and of spontaneous blinking as well as

142 the absence of any vocalisation (during the entire slaughtering process) were considered as
143 main criteria for loss of consciousness (Anonymous, 2013a, 2013b; Grandin, 2012;
144 Verhoeven, Gerritzen, Hellebrekers, & Kemp, 2014). These criteria were complemented
145 with additional benchmarks. Tonic and clonic spasms were considered normal immediately
146 after stunning (Gregory et al., 2007). Their presence was graded with 1 and specified as
147 being mild or vigorous. A fully relaxed, atonic state, in turn, was rated with 0 as being
148 anomalous. Adequate stunning was expected to abolish nystagmus as well as evoked
149 corneal and palpebral reflexes. Furthermore, eyes were required to have a wide blank stare
150 and not to be rotated (Grandin, 2002). In addition, absence of the nasal septum reflex was
151 assessed with forceps. Agonal breathing, defined as gasping, was graded with 0 when
152 present and with 1 when absent. As soon as the animal was hanging on the bleeding rail,
153 the tongue was assessed with respect to both its position (straight) and its tone (limp). A
154 clearly protruding tongue hanging straight and limp was considered indicative of loss of
155 consciousness and assessed with 1. In contrast, a stiff or curled tongue as well as active
156 tongue movements were interpreted as a sign of possible return to sensitivity and assessed
157 with 0 (Grandin, 2002; Gregory, Lee, & Widdicombe, 2007). When the tongue was
158 concealed within the oral cavity, assessment of corresponding parameters obviously was
159 not feasible. The head, the ears, the tail and the back were expected to hang straight and
160 without targeted or directed motility or righting reflexes. A general loss of muscle tone in
161 the second phase, i.e. prior to bleeding, was judged as based on head, ears, back and tail
162 hanging straight and limp and was also considered a required sign of adequate stunning.

163 **3. Results**

164 In the preliminary ballistic experiments with front plates and two complete heads, the
165 .357 Mag./10.2g HP bullets infallibly punched through both bone plates and reached the

166 cranial cavity. Analysis of CT data sets from the two whole heads (h5 and h6) confirmed
167 the destruction of the thalamus (data not shown). The .38 Spl./10.2g SJSP ammunition
168 produced penetrating shots as well, but CT images revealed only limited brain damage as
169 the bulk of the projectile fragments were absorbed in the frontal sinus prior to reaching the
170 brain. The preliminary experiments revealed that fragmentation was less and the
171 penetration considerably better for the heavier projectiles (.357 Mag./10.2g HP and
172 .38 Spl./10.2g SJSP) than for the lighter ones (.357 Mag./8g SJSP and the .357 Mag./8g
173 SJHP). The .357 Mag./8g SJSP produced an unwanted blowback.

174 Assessment of the stunning effectiveness of the bullet casing gun used with the
175 .357 Mag./10.2g HP ammunition is summarized in Table 1. Stunning was considered
176 effective in 19 of 20 animals and complete loss of consciousness resulted from a single
177 shot. Analysis of CT data from the animals Nr. 10 and 16 revealed the point of contact to
178 be perfectly adequate as the target region was precisely hit. Notwithstanding, animal Nr.
179 10, a 161 months old female water buffalo, did not collapse immediately but with some
180 delay. However, all the other indicators of deep concussion were fully met.

181 Only a 118 month old male water buffalo (Table 1, Nr. 20) had to be reshot because he did
182 not collapse after the first shot. The animal was immediately stunned again with the
183 “Ruger GP 100 Double Action” Revolver. Because of limited accessibility to the head, the
184 second shot had to be fired with an occipital contact point. Thereafter, the bull collapsed
185 hesitantly. Breathing, gasping, vocalization, spontaneous blinking, eye movements and the
186 nasal septum reflex were absent. The corneal as well as the palpebral reflex were absent
187 but the eyeballs were rotated downwards (as under general anesthesia). When hanging on
188 the rail, the animal’s back was straight, muscle tone was lost but for the stiff ears. The head
189 and tail were hanging loose and limp. The tongue was not visible and, thus, could not be
190 assessed. The animal did not react to the bleeding. Careful analysis of the CT data set

191 revealed that the brain had essentially been spared. Neither of the two bullets had reached
192 the cranial cavity and brain damage was limited to minor hemorrhagic lesions.

193 After the stunning, tonic and clonic spasms were observed in 16 water buffaloes. In 13
194 cases out of these, the spasms were mild while the remaining 3 animals showed vigorous
195 spasms. Four out of the 20 buffaloes did not exhibit any spasms and were assessed with
196 score 0. In these cases, assessment of spasm intensity was not applicable and entered as x
197 (Table 1). A mere tail switch from one side of the body to the other or vigorous tail
198 movements were noted in 3 animals. In one out of the three, tail movements were
199 combined with vigorous spasms. In 16 animals, the tongue was protruding and was
200 invariably hanging out straight and limp. Thus, no curling or tongue movements were ever
201 observed. In 4 animals, the tongue was not visible and could not be assessed. Neither of
202 these 20 animals showed positive eye and nasal septum reflexes or a response to a nose
203 pinch. Similarly, gasping, spontaneous blinking, nystagmus as well as vocalisation were
204 absent in all the water buffaloes including the old bull.

205 **4. Discussion**

206 This study provides a detailed description of a newly designed bullet casing gun to stun
207 water buffaloes as well as a thorough assessment of its usability under practical
208 conditions. We recommend this method to be used in regular slaughterhouses as it is
209 effective, reliable and safe to handle.

210 Conventional captive bolt stunning devices (Schermer KL, Cash Magnum 9000S) comply
211 with standard safety requirements but because of their inadequate penetration power and
212 insufficient bolt length, even the high-performance systems (Schermer KL) do not ensure a
213 dependable stunning effectiveness in water buffaloes. In addition to the mere width of the
214 frontal sinus, the skin and the bone thicknesses add to restrict the effectiveness of such

215 systems in this species. In order to shorten the distance to the brain, captive bolt devices
216 were assessed from an occipital contact point. Irrespective of a sufficient bolt length and
217 lesser resistance of the occipital bone as shown in ballistic tests (results not shown), further
218 assessment revealed that the occipital approach is not suitable for practical reasons. The
219 animals' interest in the stunner inevitably prevented a dependable positioning of the
220 captive bolt device. Therefore, such an approach would require a complete immobilization
221 of the head in a bent position which is not feasible with water buffaloes in a standard
222 setting without unwanted considerable stress for the animal.

223 Notwithstanding, regulation to come into effect by August 2015 requires slaughter cattle to
224 be confined in such a way as to allow a stunning device to be placed to the forehead
225 reliably and accurately (Dr. A. Briner, Federal Food Safety and Veterinary Office FSVO,
226 personal communication). Although this will definitely facilitate the use of stunning
227 devices in a frontal position, this is not enough to allow their use in an occipital position.

228 The attempt to develop a specialized and more powerful captive bolt stunner with an
229 adequate penetrating bolt length of 18 cm to be used in a frontal position was abandoned
230 due to the prohibitive energy consumption of the return system. An increase of the
231 propulsive energy would not solve the issue as the recoil would dislodge the device from
232 the head at the expense of propelling the bolt towards the brain. Therefore, a device with a
233 free projectile was developed.

234 The custom-built bullet casing gun presented herewith combines the advantages of
235 handguns and captive bolt stunners. The bullet casing gun may be pressed against the
236 forehead like a captive-bolt stunner. Besides providing a standard handling, this further
237 minimizes operational hazards. However, the bullet casing gun may also be fired from a
238 distance of five to ten centimeters should the animal not tolerate physical contact. The
239 .357 Mag./10.2g HP provides a deformable bullet which delivers its energy in the target

240 tissues. It was expected, therefore, to provide an effective and reliable stunning impact
241 without bearing the risk of through and through shots.

242 Eighteen criteria were used to evaluate the loss of consciousness in 20 animals from a one
243 year old male calf up to a thirteen years old cow including a ten years old breeding bull. In
244 order to come to a final judgment on the stunning effectiveness, several criteria were taken
245 into account. “Failure to collapse or delayed collapse”, “regaining posture”, “active
246 breathing”, spontaneous blinking or “vocalisation” were considered crucial elements
247 (Anonymous, 2013b; Grandin, 2012; Gregory, Lee, & Widdicombe, 2007; Verhoeven,
248 Gerritzen, Hellebrekers, & Kemp, 2014). Other criteria such as “nystagmus”, “positive eye
249 reflexes” or “rigid muscle tone of the animal’s body” were seen as being less compelling
250 as single features and, thus, were assessed within a broader context. But for the breeding
251 bull which had to be reshot, all the animals were ascertained to have been stunned
252 properly. This also applies to the 13 year old cow which did not fully collapse
253 immediately. When reviewing the video tape, it became obvious that the animal had
254 become wedged within the stun box due to its mere size. Although the animal was not
255 stunned again, all the other criteria were fully met, thus indicating complete loss of
256 consciousness. CT further corroborated that the brain target had been hit by the bullet.

257 Tonic and clonic spasms are expected after captive bolt stunning (Gregory et al., 2007)
258 whereas a fully relaxed physical state raises concerns about a potential resumption of
259 consciousness (Gregory et al., 2007). Absence of muscle spasms was noted in 4 animals. In
260 two out of these, all the other indicators of deep concussion were met. In one of the
261 remaining animals, the tongue was not protruding and could not be assessed. As for the
262 fourth animal, it was the old breeding bull which did not collapse immediately and in
263 which the tongue was not protruding. It also showed rotated eyeballs and stiff ears.
264 Variable tail movements were observed in 3 animals during lifting but could not clearly be

265 differentiated from general spasms in all the instances. However, when suspended to the
266 bleeding rail, the tail was hanging limp in all the 3 animals. Whereas a stiff and curled
267 tongue is a sign of possible return to sensitivity (Grandin, 2002), a protruding tongue
268 hanging straight and limp closely depends on a completely relaxed jaw and, thus, is
269 considered a reliable sign of deep unconsciousness (Grandin, 2002). The latter was the
270 case in all the animals in which the tongue was visible. On the other hand, failure of the
271 tongue to protrude is not an indicator of residual consciousness (Grandin, 2002) and, thus,
272 was not taken into account. This applied to 4 animals. As for the old breeding bull, it
273 collapsed slowly after the second shot only. Although the majority of the other criteria
274 indicating loss of consciousness were met, some parameters were indicative of a shallow
275 concussion. These included rotated eyeballs, lack of spasms and stiff ears. This is in
276 agreement with the computer tomography findings of the head which revealed that the
277 brain had been spared. Therefore, one must part on the assumption that stunning was
278 shallow only.

279 Taken together, the assessment of the loss of consciousness clearly supports the contention
280 that the bullet casing gun is an adequate means for stunning water buffaloes. In congruence
281 with the ballistic studies (Schwenk, unpublished results), no through and through shots
282 were observed in live animals, nary in the youngest calves. On the other hand, the bullet
283 casing gun reliably and reproducibly provided a complete loss of consciousness but for the
284 old breeding bull. Thus, particular solutions should be considered for old males. Our data
285 show that the bullet casing gun provides an adequate stunning for male buffaloes up to 5
286 years and is likely to work for somewhat older males as well. This is corroborated by the
287 preliminary experiments which were conducted to test the ammunition. One of the heads
288 used originated from a bull that was almost 9 years old and all the bullets regularly reached
289 the cranial cavity. However, for lack of more bulls between 5 and 10 years of age, the

290 threshold age may not be defined more accurately. But for the exception of very old bulls,
291 the bullet casing gun presented herewith provides a highly reliable stunning device in
292 combination with .357 Mag./10.2g HP ammunition both from an animal welfare as from an
293 occupational safety point of view.

294 **5. Acknowledgments**

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297 **6. References**

298 Alsafy, M. A. M., El-Gendy, S. A. A., & El Sharaby, A. A. (2013). Anatomic reference for
299 computed tomography of paranasal sinuses and their communication in the Egyptian buffalo
300 (*Bubalus bubalis*). *Anatomia, histologia, embryologia*, 42(3), 220–231. doi:10.1111/ahe.12005

301 Anonymous. (2013a). *Gute fachliche Praxis der tierschutzgerechten Schlachtung von Rind und*
302 *Schwein* (bsi-Schwarzenbek). Retrieved from http://www.bsi-schwarzenbek.de/Dokumente/bsi_gute_Praxis_4_13.pdf

304 Anonymous. (2013b). Scientific Opinion on monitoring procedures at slaughterhouses for bovines.
305 *EFSA Journal*, 11(12), 1–65.

306 Grandin, T. (2002). Return-to-sensibility problems after penetrating captive bolt stunning of cattle
307 in commercial beef slaughter plants. *Journal of the American Veterinary Medical Association*,
308 221(9), 1258–1261.

309 Grandin, T. (2012). *How to Determine Insensibility in Cattle, Pigs, and Sheep in Slaughter Plants*.
310 Retrieved from <http://www.grandin.com/humane/insensibility.html>

311 Gregory, N. G., Lee, C. J., & Widdicombe, J. P. (2007). Depth of concussion in cattle shot by
312 penetrating captive bolt. *Meat science*, 77(4), 499–503. doi:10.1016/j.meatsci.2007.04.026

313 Kamel, S. H., & Moustafa, M. S. (1966). A detailed description of the skull of the Egyptian
314 buffalo, *Bos (bubalus) bubalis* L. with a comparative study of that of the cow. *Zentralblatt für*
315 *Veterinärmedizin. Reihe A*, 13(8), 746–752.

316 Moustafa, M. S., & Kamel, S. H. (1971). Sinus paranasalis of the Egyptian buffalo,
317 *Bos(Bubalus)bubalis* L. *Zentralblatt für Veterinärmedizin. Reihe A*, 18(6), 530–535.

318 Panel on Euthanasia. (2013). *AVMA Guidelines for the Euthanasia of Animals: 2013 Edition*.
319 Retrieved from <http://www.uccaribe.edu/research/wp-content/uploads/2011/05/AVMA-Guidelines-on-Euthanasia.pdf>

321 Saigal, R. P., & Khatra, G. S. (1977). Paranasal sinuses of the adult buffalo (*bubalus bubalis*).
322 *Anatomischer Anzeiger*, 141(1), 6–18.

323 Schwenk, B. (2014). *Assessment of different stunning methods used for water buffaloes by means*
324 *of MRI and CT* (Diss. med. vet.). Universität Bern, Bern.

325 Tierschutzgesetz SR 455, Swiss Federal Convention 2014.

326 Verordnung des BLV über den Tierschutz beim Schlachten SR 455.110.2, Swiss Federal Food
327 Safety and Veterinary Office 2014.

328 Verhoeven, M. T. W., Gerritzen, M. A., Hellebrekers, L. J., & Kemp, B. (2014). Indicators used in
329 livestock to assess unconsciousness after stunning: a review. *Animal (Animal: an international*
330 *journal of animal bioscience)*, 1–11. doi:10.1017/S1751731114002596

331 **Table 1:** *Assessment of the loss of consciousness in 20 water buffaloes stunned*
332 *with the bullet casing gun loaded with .357 Mag./10.2g HP ammunition.*

333 The table provides a compilation of the criteria used to assess the
334 concussion and their rating for every single animal. All the animals were
335 fully stunned but for the bull Nr. 20 which did not collapse immediately and
336 which was reshot with a handgun loaded with .357 Mag./10.2g SJSP-FN.
337 Nonetheless, concussion was shallow only. BCG: bullet casing gun; HG:
338 handgun (Ruger GP 100 Double Action Revolver); shaded cells: main
339 criteria; 1: the criterion was met; 0: the criterion was not met, x: not
340 applicable; v: vigorous; m: mild.

Nr.	Sex	Age	Months	Days	Stunning device	Ammunition	Spasms		Clinical signs										Tongue	Number of shots fired	Deep concussion (overall assessment)										
							Spasms	Spasms	Immediate collapse	Tonic and clonic	Intensity	Instant onset of apnoea	Absence of gasping	Absence of spontaneous blinking	Absence of nystagmus	Wide blank stare	Absence of palpebral reflex	Absence of corneal reflex	Absence of nasal septum reflex	Loss of muscle tone (on bleeding rail)	Protruding	Straight and limp	Head hanging straight and limp	Ears hanging straight and limp	Back straight, no righting reflex	Tail hanging straight and limp	Absence of any vocalisation				
1	Females	1	16	508	BCG	.357 Mag/10.2g HP	1	1	1											0	x	1	1	1	1	1	1	1	1	1	
2		2	17	537			1	0	x	1	1	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1	1	1	1
3		3	18	567			1	0	x	1	1	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1	1	1	1
4		4	19	590			1	1	m	1	1	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1	1	1	1
5		5	19	592			1	1	m	1	1	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1	1	1	1
6		6	22	689			1	1	m	1	1	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1	1	1	1
7		7	38	1162			1	1	m	1	1	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1	1	1	1
8		8	58	1789			1	1	m	1	1	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1	1	1	1
9		9	113	3467			1	1	m	1	1	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1	1	1	1
10		10	161	4898			0	1	m	1	1	1	1	1	1	1	1	1	1	1	0	x	1	1	1	1	1	1	1	1	1
11	Males	11	13	418	BCG	.357 Mag/10.2g HP	1	1	v	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1		
12		12	21	659			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13		13	21	669			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14		14	31	963			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15		15	33	1008			1	1	v	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16		16	35	1090			1	0	x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17		17	36	1106			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18		18	39	1201			1	1	v	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19		19	53	1617			1	1	m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20		20	117	3576	BCG	.357 Mag/10.2g HP	0	0	x	1	1	1	1	1	1	0	1	1	1	1	0	x	1	0	1	1	1	2	0		
					HG	.357 Mag/10.2g SJSP-FN																									

341 **Figure 1** *The bullet casing gun prototype with its two 9 mm-bore rifled gun barrels*
342 *and protected trigger.*

343 Both barrels are loaded with .357 Mag./10.2g HP to provide a backup means
344 for an immediate second shot in case of failure of the first attempt. A shifter
345 allows for a rapid switch between the barrels. The safety lever locks both
346 barrels and needs to be released ahead of firing. 1: Trigger; 2 Safety lever.



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