Euthanasia of whales: the effect of .375 and .485 calibre round-nosed, full metal-jacketed rifle bullets on the central nervous system of the common minke whale

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ABSTRACT

The effect of rifle projectiles used for the euthanasia of stranded or hunted whales has been an issue for debate, in particular in the International Whaling Commission (IWC) and the North Atlantic Marine Mammal Commission (NAMMCO). In the Norwegian hunt for common minke whales, 9.3mm, .375 or .458 calibre rifles are used as backup weapons to euthanise whales that are not deemed dead after being hit with a harpoon grenade. When using the rifle, the hunters aim at the brain of the animal. The present study investigates the effects of the two rifle calibres .375 and .458 and round nosed, full-metal jacketed bullets in 29 common minke whales. The whales were examined *post mortem* shipboard and 22 of the brains were fixed *in situ* and later subjected to gross and light microscopic examination. The results show that the two types of bullets are fully capable of penetrating the skull and spinal bones of common minke whales and fatally damaging the central nervous system, resulting in immediate or very rapid loss of consciousness.

KEYWORDS: WHALING-MODERN; EUTHANASIA; BRAIN; HISTOLOGY; COMMON MINKE WHALE

INTRODUCTION

When animals are to be euthanised and several methods are applicable, the one resulting in most rapid death should be used. However, there will always be some animals that will survive the primary killing attempt, regardless of the method employed or precautions taken. For example, the captive bolt pistol used for stunning cattle and sheep is regarded as a highly effective weapon if applied correctly. However, Grandin (1998) has reported that of 11 federally inspected beef plants in the USA, only four were able to render 95% of the cattle insensible with a single shot by the captive-bolt stunner. A study of cattle from British abattoirs demonstrated that 53% of young bulls had to be re-shot (Kestin, 1992). An experienced operator is prepared for such situations and will have backup weapons and substitute equipment at hand in case of an emergency. The veterinarian has an extra syringe ready, in abattoirs a secondary or substitute weapon is available, and during hunting an extra round is in the gun or the pocket.

The gear of choice for different types of hunts is influenced by several factors. Today, a wide selection of both weapons and ammunitions are produced by a variety of manufacturers, but in many rural districts the selection of hunting gear is limited and the hunters have to use what is commercially available. Little scientific data have been published on the wounding effect of different types of hunting ammunition used on various game. Comparative gunshot data are, however, available from studies of ballistic injuries in experimental animals and from human civilians and military personnel (for reviews see e.g. Abdolvahabi *et al*., 2001; Finnie, 1993; Karger *et al*., 1998).

The legislative demands and regulations concerning weapon specifications and ammunition for various hunts between different countries vary considerably. In fact, remarkably few countries seem to have such regulations (IWC, 1988; Knudsen, 2005). In Norway, where about 50 different species of birds and wild games are hunted by about 200,000 hunters per year (Statistics Norway, 2002), the authorities have developed a list which specifies the minimum requirements for weapons and ammunition for each species including marine mammals (Gjems *et al*., 2003). All hunters must pass a theoretical and practical exam to obtain a licence to hunt. Additionally, big game hunters must pass annual shooting tests. Minimum requirements for weapons and ammunition for seals and common minke whales (*Balaenoptera acutorostrata*) have been in force for decades in Norway. Marine mammal hunters are obliged to pass annual shooting tests and they have attended obligatory training courses since the early 1990s.

In the Norwegian hunt for common minke whales, which is carried out from small fishing boats using harpoon guns of 50 or 60mm calibre and harpoons equipped with explosive penthrite grenades, a rifle of minimum calibre 9.3mm is required as the backup weapon for rapid re-shooting of whales that are not judged by the hunters to be dead from the shock of the penthrite detonation. The ammunition is restricted to round nosed, full-jacketed bullets with minimum impact energy of 3,433 Joules $100m^{-1}$. However, during the training courses, larger and heavier rifle calibres such as .375 and .458 have been demonstrated and their use encouraged, and consequently the 9.3mm calibre is now used less often.

During hunting, the rifle is kept beside the marksman and the whales are to be hauled in rapidly for control after the impact of the harpoon. The rifle is usually fired from close range and when the whale's head is out of the water. The hunter aims at the brain (Fig. 1), which, depending on the size of the animal, lies 55 to 75cm behind the blowhole (Knudsen *et al*., 1999). An illustration chart with the position of the brain and aiming point from different shooting angles and directions has been distributed to all Norwegian whaling vessels. Rifle shots are fired at any whales that show movement, if the flippers or jaws are not relaxed or if the hunters suspect it may still be alive. In 2001, 79.6% of the animals were recorded instantaneously dead from the grenade detonation (Øen, 2002).

Nevertheless, the hunters used the rifle on 45% of the whales as many use the rifle as a matter of routine when the whale is alongside the boat (Øen, 1995;2002).

In the International Whaling Commission (IWC) and the North Atlantic Marine Mammal Commission (NAMMCO) killing methods for marine mammals have been debated in meetings and several workshops (IWC, 1981;1988; 1992;1995;1997;2000;2002;2003;2006; NAMMCO, 1999;2001;2004). The effectiveness of different weapons and hunting methods used for marine mammals has been thoroughly discussed, including the effect of rifle ammunition on common minke whales. Øen (1995b) reported on the effect of 9.3mm round nosed, full-metal jacketed bullets on the central nervous system (CNS) of 10 common minke whales. The study showed that the 9.3mm bullet went completely through the skull and caused damage and bleeding in the brain tissue along the wound canal and large haematomas, in certain cases covering most of the surface of the brain. Results from the Japanese trials on the use of .375 calibre in the Japanese whale research programme have also been reported (Ishikawa, 1999; IWC, 1997). Norwegian studies on rifle bullet performance on the CNS of common minke whales continued with the two larger calibres of .375 and .458 and progress reports and preliminary results were presented during IWC Workshops in 1999 and 2003 (Øen, 1999; Øen and Knudsen, 2003).

This article presents and discusses the final results of the Norwegian studies on the wounding effect on the CNS of the .375 and .458 calibre round nosed full-metal jacketed bullets on common minke whales.

MATERIAL AND METHODS

The present study included 29 common minke whales (12 males and 17 females) taken during regular hunts in 1997-99 that were re-shot with rifles due to the hunters judging the whales to be still alive after grenade detonation. All rifle-shot animals were chronologically sampled during the time period when the scientists where present on the different hunting vessels. A Brno® hunting rifle calibre .375 (9.5mm) and H&H Magnum® 19.4g/300gr round nosed full metal-jacketed bullets with an estimated muzzle velocity (V_0) of 769 ms^{-1} and estimated impact energy at muzzle (E_0) of 5780J were used on eight whales. For 21 whales, a Browning® hunting rifle, calibre .458 (11.6mm) and Win Magnum® 32,4g/500gr round nosed full metal-jacketed bullets with V_0 and E_0 of 622 ms^{-1} and 6264J was used.

The shooting range was estimated visually and the number of rounds and the whale's reaction to the shot were recorded. During flensing (butchering), post mortem inspections were conducted. The head was thereafter parted from the body at the atlantooccipital joint, the skull was inspected after removal of the overlying blubber and musculature, and 22 of the brains were fixed *in situ* and thereafter excised as described in detail in Knudsen *et al.* (2002). For logistical reasons, the first three brains were only grossly examined in the fresh state onboard and not fixed, and for one whale only the spinal vertebrae and cord were examined. Additionally, three brains were too severely lacerated by the projectile to be excised and further examinations were not regarded purposeful. Thus, the full process was followed for 22 whales.

After excision, the whole brain was put into a perforated plastic bag tagged with an identification number (in running order) and stored in 30l containers with 8% neutral formalin for at least two months. Before further examination all fixed brains were randomised and given a new identification number, so further analyses were conducted blind. The code was not opened until all samples had been analysed. At the gross examination of the fixed brains, representative samples of tissue blocks for microscopy were collected from the same anatomical site in cerebrum, cerebellum, brainstem and cervical spinal cord (totally about 40 specimens from each brain) as described in Knudsen *et al.* (2002). Additional tissue blocks were sampled when pathological findings were evident in areas that were not covered by the routine sections. The blocks were embedded in paraffin wax, sectioned at 5μm with a microtome, and stained with hematoxylin/eosin (H&E) after standard protocols (Culling *et al*., 1985). Photomicrographs of the micro slides were taken and mounted using a Zeiss Axioscop (Carl Zeiss Vision GmbH, Hallbergmoos, Germany), a Sony Power HAD Camera Adapter (Sony Corporation, Tokyo, Japan), and Matrox Imaging Intellicam (Matrox Electronic System Ltd, Dorval, Canada). Adobe *Photoshop 7.0* (Adobe System Inc., San Jose, USA) was used for digital processing of the illustrations.

RESULTS

Fifteen of the 29 whales had received one single round with the rifle, while 14 had received two or more bullets (Fig. 2). In 10 of the 14 cases, where more than one shot was fired, it was recorded that the first bullet(s) hit the head in front of the blowhole or the musculature in the neck/back. The

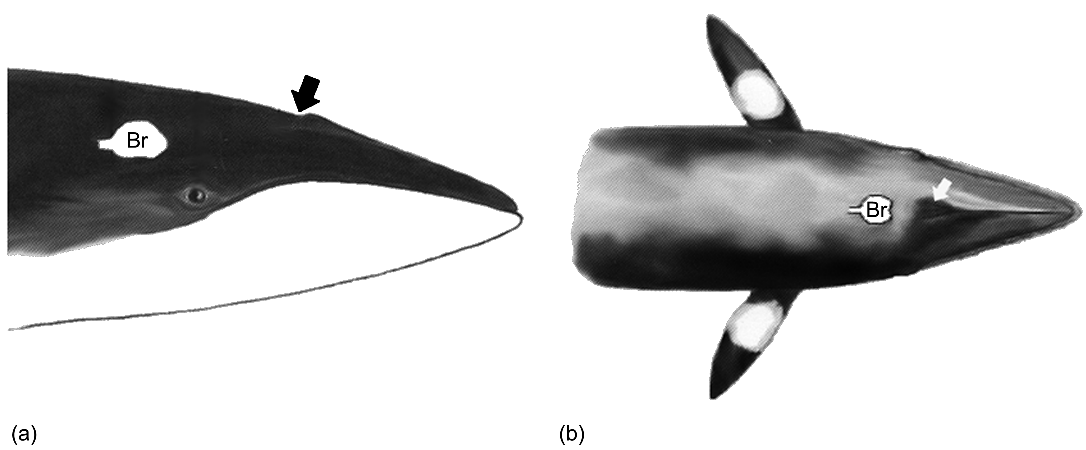

Fig. 1. Schematic drawings showing the position of the brain in the common minke whale viewed (a) laterally and (b) dorsally. The brain (Br) is situated behind the eyes and blowhole (arrow).

maximum number of rounds used was six on one whale that had become entangled in the harpoon line and had its head under water. The mean number of rounds for the remaining 28 was 1.6 (95% CI: 1.2-1.9; Range: 1-3). The mean shooting range was 9.3m (SD: 4.9; Range: 3-25m).

Fig. 2. Number of rifle rounds used on 29 common minke whales.

In 20 whales, the rifle bullet had hit and penetrated the head (Table 1). In 10 of these, the bullets had passed into the cranial cavity and through the brain. In seven cases it had passed the cranium less than 20cm either rostrally, laterally or caudally to the cranial cavity. In two cases the projectile had penetrated the skull about 30cm laterally to the brain. One whale was hit in the head from behind at an oblique angle and the bullet had passed over the skull and was retrieved in the soft tissue rostrally to the blowhole.

The entrance wounds into the cranium varied in size for both .375 and .458 bullets from about 1.5-4cm round holes (Fig. 3(a)), with fissures radiating in different directions on the skull bone surface, to 10-30cm wide craters with displaced bone fractures (Fig. 3(b)). Both bullets had penetrated the skull completely and as with the entrance wounds, the exit wounds could vary in size and shape (Figs 3(c) and (d)). In some cases, the wound canal could be traced and probed with a scalpel shaft along its whole length under the skull and in some whales the bullets had penetrated the whole head and exit holes were evident in the blubber on the ventral side of the whale. A few bullets were found in the blubber ventral to the jaw. They had no signs of deformation or damage after passing through the bones and soft tissues.

For the ten animals in which the projectile had passed through the brain (Table 1), the bullet had caused massive gross haemorrhages on the brain surface and in the brain tissue along the wound canal. Severe tissue laceration (Fig. 4) and displaced bone fractures were demonstrated. Three brains were so damaged that they had fallen apart and were not fixed for further analyses. At the microscopy of the remaining seven fixed brains, perivascular haemorrhages were common at several neuroanatomical sites distant from the wound canal (Fig. 6(a)). All movement ceased and the body relaxed (including flippers, jaw and tail) immediately

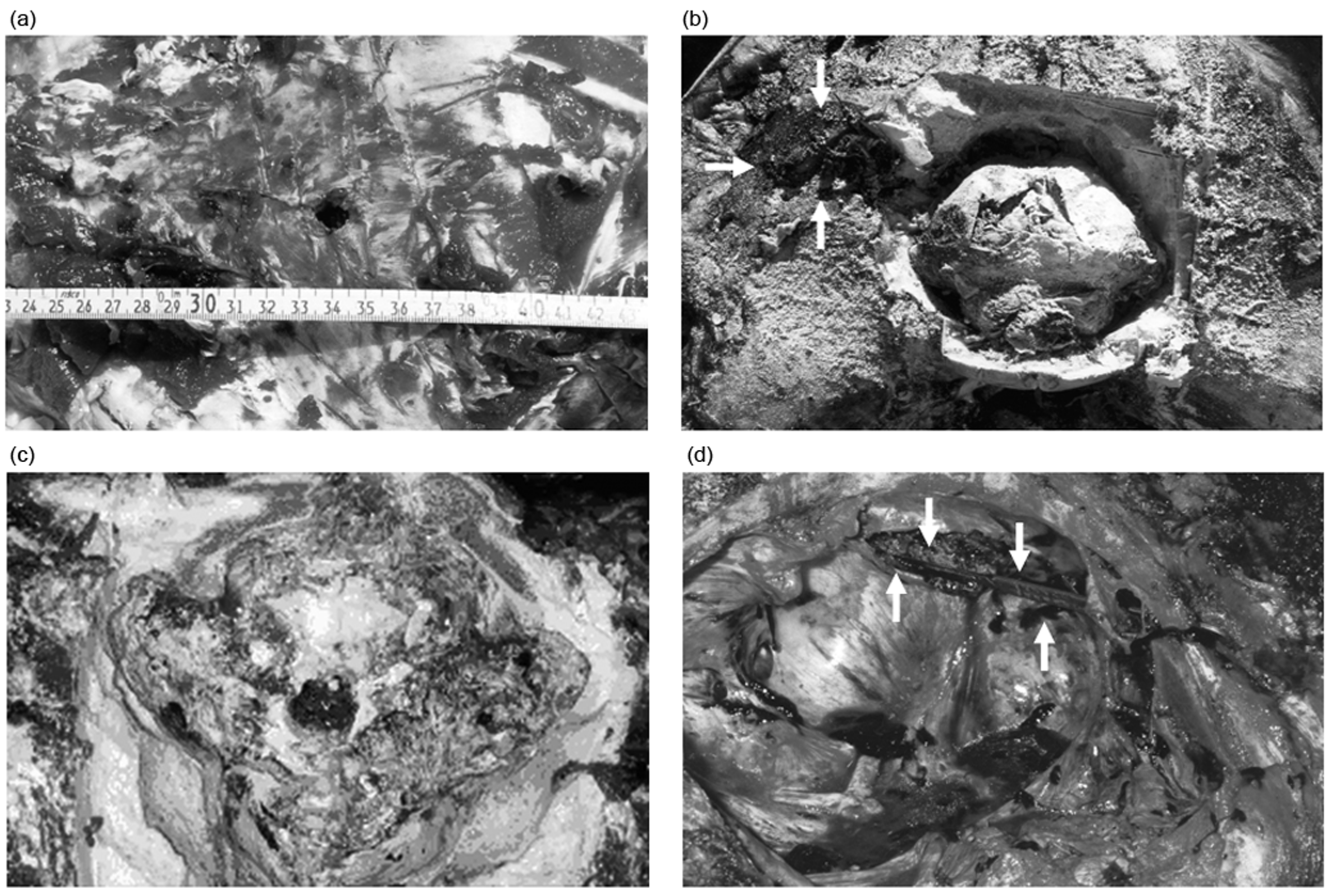

Fig. 3. Entrance and exit wounds in the skulls of four common minke whales after infliction of round nosed full metal- jacketed bullets of calibre .375 or .458. (a) A round entrance wound of about 2cm in the skull over the brain (.375). (b) A crater-formed entrance wound (arrows) in the skull less than 20cm from the brain with displaced bone splints penetrating into the brain (.375). (c) Round exit wound ventrally in the cranial cavity (brain excised) (.458). (d) Bullet path and exit wound (marked with a scalpel and arrows) in the frontal cranial cavity (brain excised) (.458).

after the rifle bullet struck in seven of the ten whales, two flapped their tail a couple of times until all movement stopped, while the jaw remained closed in one (Table 1).

The seven animals for which the bullet had hit the cranium less than 20cm from the brain (Table 1) had massive gross epidural, dural and subdural haemorrhages which covered large parts of the brain (Fig. 5(a)). At microscopy perivascular haemorrhages were visible in most brain regions. Complete and immediate body relaxation occurred after the rifle bullet hit in five of the seven whales (Table 1). In the remaining two, movement of the tail was registered for a few seconds after the rifle shot in one whale, while the other animal relaxed its flippers immediately but thrashed its tail violently for about one minute until all movement ceased (Table 1).

The two whales hit in the skull approximately 30cm laterally to the brain (Table 1) were both shot with the rifle because their flippers were held out at an angle, the jaw was closed and weak movements could be seen in the tail. The animals showed no apparent reaction to the first bullet, but the flippers relaxed and the weak movements ended after a second round. No gross haemorrhages or other pathological changes could be demonstrated in these brains, despite the fact that all bullets had hit the cranium. Microscopy, however, revealed perivascular haemorrhages in the white matter of cerebellum and in the upper brainstem. In both whales, the grenade had detonated in the thoracical spine and also damaged the lungs and it is likely that the blood circulation had already collapsed and the whales were dead when the rifle bullets struck, which may explain why no gross haemorrhages were detected in the brains.

The whale in which the projectile was retrieved in soft tissue in front of the brain (Table 1) immediately turned over and all movement ceased when the bullet struck. At gross examination a few, small demarcated dural haemorrhages were found on top of the hemispheres, while microscopy revealed haemorrhages in thalamus, the whole brainstem and upper cervical spinal cord.

For the four whales for which the shot had been directed towards the spinal vertebrae (Table 1), three had been hit in the 1st or 2nd cervical vertebra and all movement ceased immediately after the rifle bullet struck. The cervical bones were damaged and fractured and gross haemorrhages could be observed in the bone and soft tissue. In one of the three, displaced bone fragments from the atlantooccipital joint had penetrated into the caudal part of the brain. Gross examination of all three brains revealed massive subdural and subarachnoid haemorrhages, most extensively under the base of the brain. During microscopy, additional haemorrhages, especially deep in the cerebrum and cerebellum and in the brainstem and spinal cord, were seen (Fig. 6(b)-(d)). The fourth whale was hit in the 2nd thoracical vertebra with a single .375 bullet. It instantly rolled over onto its back and sank. Massive haemorrhages were

Table 1

Summary of hitting areas, brain injuries, behaviour and diagnostic inference in 29 minke whales after rifle shot of calibre .375 or .458 round nosed full-metal jacketed bullets.

Hit region (*n*)	Site of impact (*n*)	Brain injuries (*n*)	Behaviour of whales (*n*)	Diagnostic inference
Head (20)	Brain (10)	Massive gross changes	Instant relaxation (7)	Instantly dead
			Weak tail movements (2)	
			Instant relaxation; closed jaw (1)	
	Skull[a] (7)	Massive gross changes	Instant relaxation (5)	Instantly dead
			Weak tail movements (1)	
			Instant relaxation followed by seizure (1)	
	Skull[b] (2)	Histological changes	Gradual relaxation (2)	Likely dead before rifle shot
	Skull[c] (1)	Minor gross changes	Instant relaxation (1)	Instantly dead
Spine (4)	Upper cervical (3)	Massive gross changes	Instant relaxation (4)	Instantly dead
	Thoracical (1)	Not examined		
Not detected (5)	Not detected	Massive gross changes (3)	Instant relaxation (3)	Instantly dead
		Histological changes (2)	Instant relaxation (1)	
			Gradual relaxation (1)	Likely dead before rifle shot

[a]<20cm from the brain. [b]Approx. 30cm from the brain. [c]>30cm from the brain.

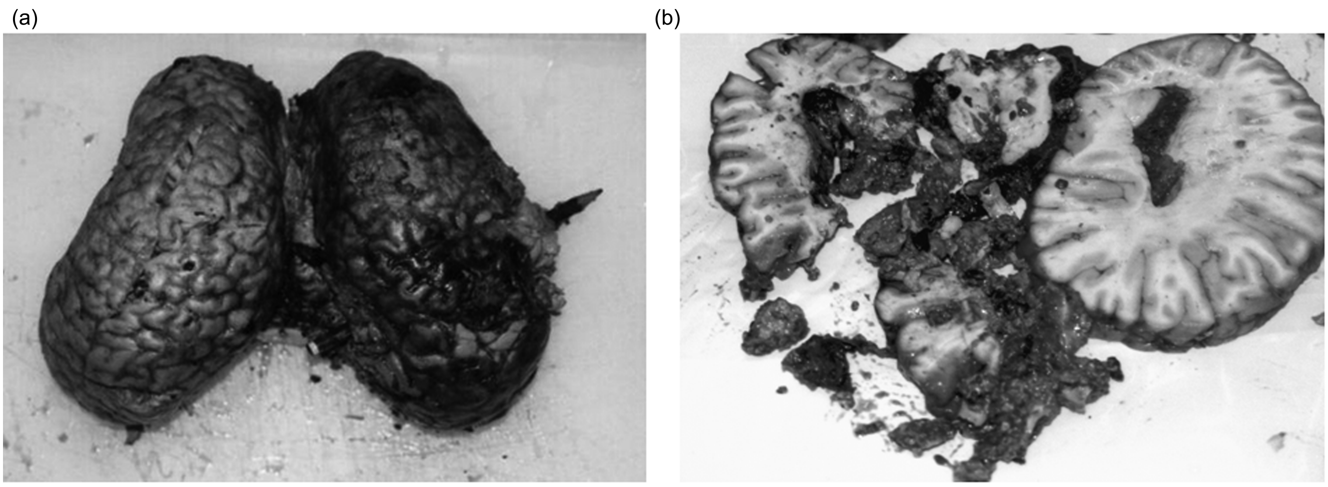

Fig. 4. Gross pathology in a common minke whale shot with rifle in the brain. (a) The pencil marks the projectile trajectory through the caudal right hemisphere. (b) Destructive damages in the caudal part of the brain. The cerebrum has been sliced into 1cm thick disks.

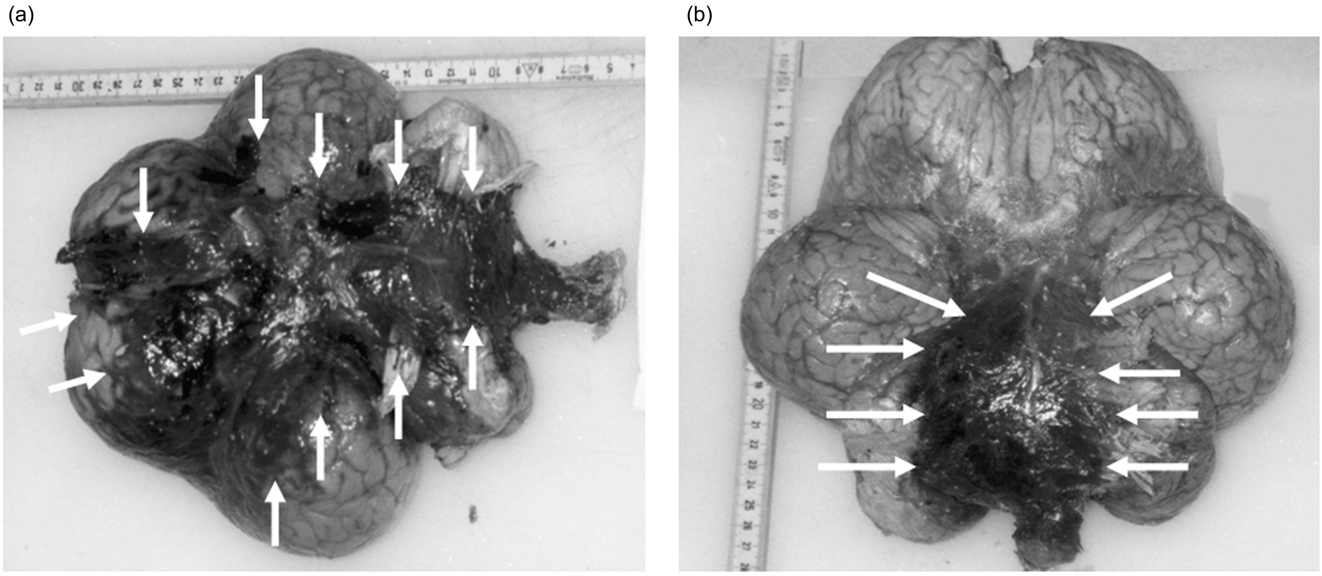

Fig. 5. Gross findings in common minke whale brains after rifle projectile impact outside the cranial cavity. (a) Massive subdural and subarachnoid haemorrhages (arrows) are covering major part of the brain. Ventral view. (b) Extensive subarachnoid haemorrhages (arrows) under the caudal base of the brain. The cranial nerves are embedded in blood.

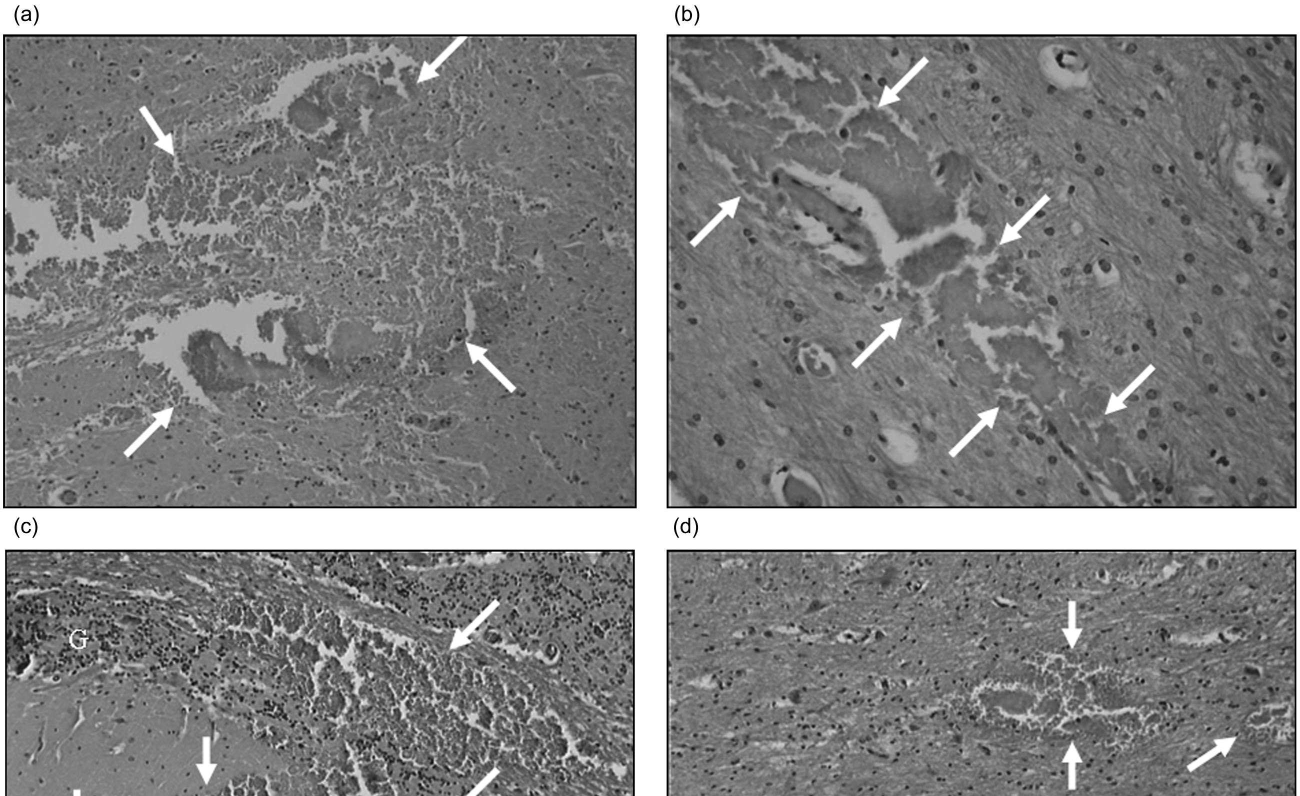

Fig. 6. Microphotographs showing intracerebral haemorrhages (arrows) from whales hit in the brain (a) or in the spinal cord (b-c) with rifle, visualized using hematoxylin and eosin (H&E) staining technique. (a) Multiple haemorrhages in the ventral horn (grey matter) of the cervical spinal cord (10/0.25). (b) Haemorrhage in thalamus (40/0.65). (c) Multiple haemorrhages in the molecular (M) and granular (G) cell layer of the cerebellar vermis (10/0.25). (d) Multiple haemorrhages in the medullary obex adjacent to the 4th ventricle (10/0.25).

demonstrated in the spinal canal ascending to the foramen magnum. This brain was not examined and the state of the brain is unknown.

In three of the five whales, the bullet path was not detected during flensing (Table 1) and multiple and massive bleeding was evident intracerebrally (Fig. 5(b)). The whales immediately stopped moving and passively sank after the rifle shot. The grenade had detonated dorsally in the musculature over the abdomen in all three whales and it is most likely that it was the bullet that caused the damage to the brains. In the last two whales (Table 1), multiple haemorrhages were found in the brainstem and in deeper parts of the cerebrum during microscopy. In one of these, the grenade had failed to detonate and the harpoon had not caused damage to any vital organs or greater vessels. The animal immediately turned over when the bullet struck, and the brain haemorrhages were obviously caused by the rifle shot. Although the projectile path could not be demonstrated for these five animals, the distributions of haemorrhages in the brains were similar to those found in whales that were hit with rifle bullets in the spinal cord. In the second whale, the grenade had detonated and torn open the spinal canal over the thorax and damaged the aorta. It was re-shot because some weak movements were observed in the tail and the flippers were partly erect. This whale showed no apparent reaction to the rifle shot, but the flippers gradually relaxed. It is assumed that this whale was likely dead before the rifle was used and that the pathological changes found in the brain can be attributed to the detonation of the penthrite grenade.

DISCUSSION

Many factors decide the wounding capabilities of a rifle bullet (Amato *et al*., 1974; Bellamy and Zajtchuk, 1990; Berlin *et al*., 1976; Charters and Charters, 1976; Harvey *et al*., 1962). The kinetic energy, which is the relationship between its velocity and mass, is highly important. Another decisive factor is the ability to penetrate, which is related to the bullet shape, weight, design of the core and jacket and the sectional density. The sectional density is the relationship between the weight and the cross section of the projectile. Generally, a heavy projectile penetrates deeper than a lighter one and a pointed projectile penetrates soft tissues easier than a blunt one. However, pointed bullets splinter more easily or ricochet when hitting hard tissue such as bone than butt bullets that indulge larger forces to the front. A full-jacketed projectile consists of a soft core surrounded by a capsule (jacket) of hard metal. The nose can be sharp pointed, rounded or even blunt. Soft point and hollow point bullets also have a soft core surrounded by a hard metal jacket, but the jacket is not fully closed in the front, exposing the core. When such bullets hit an object, the jacket is torn open as it penetrates, and the projectile expands and rapidly stops. The expanded projectile creates wide wound canals, but it easily splinters when it hits hard bones. A full-jacketed bullet is designed to penetrate solid objects and deep into animals without being damaged or deformed.

The caudal part of the skull bones of a common minke whale, like for other baleen whales, is relatively thick and sloping (Knudsen *et al*., 2002). A sharp pointed bullet may therefore easily ricochet, deviate or tumble when it hits the skull. Øen has reported on the use of military ammunition calibre 7.62 pointed, full-jacketed bullets and soft nosed bullets on gray whales, *Eschrichtius robustus* (IWC, 2000), where several rounds were fired at the whales. At a post mortem of the skulls he found that none of the soft point bullets had penetrated the skull bones and most of the pointed full-jacketed bullets had ricocheted or capsized when hitting the sloping bones and were retrieved on the skull surface partly deformed and with emptied jackets. However, wounds in the cranium were registered, which indicated that some pointed bullets had penetrated into the skull. None of these brains could be examined due to logistical reasons.

The different structure and qualities of organs also affect the mechanism of wounding. In organs with no room for expansion, the sudden energy transformation from a passing projectile will cause an almost explosive rise in the internal pressure (Bellamy and Zajtchuk, 1990). The brain will therefore be particularly vulnerable as it is inelastic and enclosed by rigid bones. When a high-velocity bullet passes into the brain, the pressure inside the cranial cavity will therefore increase dramatically resulting in damages that becomes grossly destructive and ‘explosive’ in character (Bellamy and Zajtchuk, 1990; Clemedson *et al*., 1973; DiMaio and Zumwalt, 1977; Finnie, 1993; Karger *et al*., 1998; Watkins *et al*., 1988). The whole brain, or parts of it, might be blown away (‘Krönlein’ shots) or pressed through natural openings like the sinuses or the foramen magnum (Betz *et al*., 1997; Harvey *et al*., 1962; Thali *et al*., 2002). The cranium may often crack, resulting in secondary injuries to the brain tissue from the fractures and bone splinters (Bellamy and Zajtchuk, 1990; Thali *et al*., 2002;2003).

The principal gross and histopathological features found in the brains of the common minke whales subjected to direct hits in the brain were skull fractures, severe brain parenchyma laceration, in-driven bone fragments and massive haemorrhages on the brain surface and along the projectile trajectory. Intracerebral haemorrhages were demonstrated in neuroanatomical sites distant from the bullet tract. These findings concur with other studies of gunshot wounds to the skulls and brains of other species (Allen *et al*., 1982; Finnie, 1993; Karger *et al*., 1998). Projectiles penetrating the cranium near the brain (< 20cm) or in the upper cervical spinal canal generally produced extensive gross intracranial haemorrhages and in some cases displaced skull fractures. The brainstem and central areas of the brain were frequent sites for the haemorrhages (Figs 6 (b)-(d)) and vascular injuries in these sensitive and vital areas may be expected to cause serious and immediate effects on brain function or ‘brain stem effects’ (Carey *et al*., 1989; Crockard *et al*., 1977a; 1977b; Karger *et al*., 1998; Levett *et al*., 1980).

Based on the behavioural observations and pathological examinations it appears fair to conclude that three of the 29 whales included in this study were probably dead or irrevocably unconscious before the bullet struck (Table 1). In all three whales, the penthrite grenade had detonated in the spine and based on previous reported studies (Knudsen and Øen, 2003) it is highly likely that these animals were irreversibly unconscious regardless of the fact that they showed weak movements after the detonation.

During regular hunting of wild terrestrial game with rifles, the projectiles are usually directed at the thorax area to damage the circulatory system by injuring the heart, lungs and/or main thoracic vessels. The animal loses consciousness and subsequently dies from the impact shock and/or the rapid fall in blood pressure by puncture of the circulatory system. However, this method cannot be successfully used for euthanasia of whales during hunting as the thorax is under water and water has a considerable braking effect on a rifle projectile. In trials on dead common minke whales, Øen (1995a) found that a 20mm × 66mm high-velocity bullet with impact energy of 60kJ, which is about ten times the impact energy of the rifle projectiles used in the present study, travelling 1m or more through water before hitting the whale, stopped in the blubber. Only direct hits went sufficiently deep into the animal to give the potential to kill. A rifle bullet will therefore hardly penetrate the blubber if it hits water first. However, for euthanasia of stranded whales, which in many cases have the thorax area out of the water, a rifle shot through the heart or main vessels with sufficient ammunition, will probably kill the animal rather quickly, although not instantaneously.

Consequently, for the euthanasia of whales in water, the primary target area for rifles is the brain and for a whale of the size of a common minke whale a heavy, round nosed or semi butt, full-jacketed bullet with high impact energy and sectional density is recommended to avoid splintering, ricocheting and deviation by passing hard tissue. The brain of a common minke whale is approximately 20cm in length, 20cm in width and 15cm in height (Knudsen *et al*., 1999). This is a relatively small target as it is exposed over water only for a couple of seconds at a time. However, the shooting range is usually short and the results from the present study demonstrated that the .375 and .458 missiles caused fatal damage to the brain, and killed the animal instantaneously or very rapidly also when it hit and penetrated the skull as far as 20cm from the brain. Consequently, when using the recommended .375 and .458 calibre bullets, the lethal hitting area will be larger than the brain itself, increasing the potential for rapid kills. Additionally, the study also demonstrated that hits in the spine in the neck resulted in brain damage and very rapid death. This was demonstrated even when the whale was hit as far back as to the 2nd thoracical vertebrae.

In previous studies, Øen (1995b; 1999) demonstrated that 9.3mm calibre round nosed, full-jacketed rifle bullets were effective when the bullet hit the brain or very close to the brain. As the brains from these animals were not subjected to histological examination, the results cannot be directly compared with those from the present study. It is, however, the authors' opinion, based on empirical knowledge and experience from several seasons on board whaling vessels, that the two higher calibres are superior to the 9.3mm calibre for the euthanasia of common minke whales. However, marksmanship is still imperative for the result, and it is essential that the marksmen have sufficient and proper anatomical knowledge regarding the position of the brain and cervical spine and have proper training using the gun. For the .375 and .458 calibres it appears that calibre choice is not critical. The most important issue with these calibres is that the marksman chooses the weapon with which he feels most comfortable.

CONCLUSIONS

The study shows that round nosed full-metal jacketed bullets of calibre .375 and calibre .458 are fully capable of penetrating the skull of a common minke whale and cause severe and massive damage to its CNS, immediate loss of consciousness and subsequent death of the animal. The fatal effect can be achieved also from hits and penetration of these bullets into the skull in close proximity to the brain (< 20cm) and into the upper spinal cord.

ACKNOWLEDGEMENTS

The grant sponsor of this study was the Norwegian Research Council (Project no.: 17377/140). We wish to thank the Directorate of Fisheries (Bergen, Norway) for permission to conduct this study during regular whale hunting. We thank the skippers and crews on the different whaleboats for assistance and practical arrangements onboard. We also thank Arild Leithe, Kirsti Johnsen and Turid Kaino for technical assistance, and two anonymous reviewers for their useful comments.

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Date received: October 2006.
Date accepted: March 2007.