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Bowhunting deer

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Abstract

There are conflicting views about the humaneness of the handbow as a recreational hunting method for deer. Some claim that it is the most humane hunting method, whilst others report higher wounding rates and crippling losses than with the rifle. This commentary summarises the factors affecting the likelihood of a quick death, the types of equipment commonly used, the vital target areas, the influence of blood loss on blood pressure and brain function and the prevalence of wounding during routine bowhunting. Some requirements in Bowhunters Association Codes of Conduct are also described. It is concluded that where bowhunting is allowed, Codes of Conduct should emphasise the hunters' responsibility to track and despatch injured animals, and adherence to the Codes should be encouraged, if not enforced.

Keywords: *animal welfare, deer, haemorrhage, hunting, suffering, trauma*

Introduction

This review focuses on the welfare issues associated with recreational bowhunting for deer. Many of these issues apply to bowhunting in other species, which presently include elk, moose, wild boar, kangaroo, fox, feral camel plus a range of game species in Africa. The main feral deer species that are hunted by bow for recreational purposes are white-tailed deer, red deer, hog deer and samba deer.

Bowhunting is a recreational sport in many countries. Two exceptions are Senegal and the UK, where it is illegal (D Hepworth, personal communication 2004). It is a method favoured among poachers because of its quietness. Its popularity varies with wild deer numbers, its adoption rising when wild deer are plentiful. Most bowhunting is by handbow. Crossbow hunting is legal in some countries and states and illegal in others. In certain cases where crossbow hunting is prohibited but handbow hunting is allowed, physically disabled hunters may use a crossbow if they have a doctor's certificate that confirms their permanent disability.

Crossbow hunting has a poorer image in terms of sportsmanship among hunters, whilst handbow hunting is often looked upon as an 'art' and as a form of 'natural hunting'. In general, bowhunting requires a high level of patience and perseverance, and the success rate can be remarkably low. In one report, from Iowa, 1657 bowhunters spent 62 453 h to kill 251 deer (Mustard 1960). This works out at approximately 250 h per animal.

In many regions of the USA the off-take of deer by hunters is recorded. With firearm hunting this is usually done by inspecting the shot deer at country check stations, but in the case of bowhunting it is usually through reports submitted to the appropriate authority. The number of deer shot by bow is probably under-reported (McPhillips *et al* 1985); consequently it is not possible to give a reliable estimate of the total number of deer killed by bowhunting in North America. In the European Union it is thought to be less than 10 000 head per year (Lecocq 1997).

Equipment and its use

Three types of handbow are used in recreational hunting: the compound bow, the recurve bow and the longbow. Most hunters use the compound bow but, traditionally, the longbow was the main type of hunting handbow (Foley *et al* 1985). The recurve handbow is used in target archery as well as hunting. The traditional longbow is lightweight, has a quiet action and is popular among sportsmen who set a high value on the craft of hunting.

Modern compound bows are made from laminated wood, glass and carbon fibre. The back and front surfaces of the bow can be reinforced with glass or carbon fibre to improve its power and durability. In the past this was done using the *ligamentum nuchae* taken from carcasses. The modern compound bow also has a strung cam at the end of the bow limb, which allows the draw to pass the highest draw weight before full extension. The full draw weight is often 50–65% less than peak draw and this enables the hunter to hold the bow at full draw for considerably longer when aiming (Eriksson *et al* 2000).

The crossbow is used less frequently for hunting, although it has several practical advantages. It offers a greater range in distance and a flat-launch trajectory; it requires less skill, the bolt can be kept in a ready-to-fire position without any effort, and telescopic sights can be used. Typically, military crossbows had a draw weight of 550 kg when throwing an 85 g bolt (Foley *et al* 1985), whereas military longbows

Table 1 Time to onset of pain after an injury (after Melzack *et al* 1982).

Type of injury	Time to onset of pain (min)
Fracture	5
Cut	13
Bruise	15
Laceration	21
Sprain	105

were usually limited to about 45 kg draw weight, which reduced their range to less than 275 m. The disadvantage of the crossbow is that it has a slower firing rate in comparison with the handbow. Hunting handbows and crossbows typically have draw weights of 20–30 kg and 65–70 kg respectively. Flight velocities within 1 m of a compound bow are of the order of 55–65 m s^{-1}, with kinetic energy of about 60 J. Many hunting compound bows are capable of breaking a deer's leg bone or vertebra (Eriksson *et al* 2000).

Arrows are made of wood, aluminium, graphite or some combination of aluminium and graphite. Three types of arrow head are used: (1) field points (plain pointed heads) that are generally used for target archery or stump shooting; (2) judo points (four wire fingers) for shooting into bushes and grass so the arrow does not disappear below the grass as it would with field points; and (3) broadheads used for big game hunting. Field points and judo points are sometimes used for shooting fish and small game such as rabbits. However, field point arrows are inappropriate for hunting deer as they produce less tissue or organ damage, and in general they are reserved for target shooting in archery.

Reports based on practical experience

Many bowhunters argue that bowhunting is one of the most humane forms of hunting and that part of the reward comes from a sense of achieving a humane kill. According to bowhunters, the animal is often unaware of being hit because the bow is so quiet. The struck animal will continue to feed or walk, and will then lie down as blood is lost. If the animal becomes aware that the hunter is nearby when the arrow is fired, it will run away, but this may be through fear of human presence rather than trauma caused by the arrow (B Warburton, personal communication 2003).

One argument used to support the humaneness of bowhunting is that provided the tool is used correctly, death by broadhead arrow is among the least painful and thus the most humane ways for an animal to die. Petersen (2000) recalls instances where two deer were shot through the chest. The arrows passed through the animals and hit the ground on the other side. In both cases, the deers' reactions were to run and look back towards the arrows that had gone through them. Both deer died within a few yards of where they were shot and there were no outward signs of alarm. However, other reports indicate that when deer have been chased or are alarmed, they are difficult to kill with an arrow. It has even been reported that an excited deer can run hundreds of yards whilst carrying an arrow in its heart (Rue 1978).

There are anecdotes in humans that arrow injuries are not immediately painful (Petersen 2000). This is consistent with experience at emergency clinics in hospitals, where severe lacerating injuries have been reported as being painless at the time of the injury (Table 1) (Melzack *et al* 1982). The depth of an injury influences whether it will be immediately painful. When injuries are deep (eg fractures, crushes, amputations, and deep stabs), 72% of subjects experience prompt pain. When injuries are limited to skin (eg lacerations, cuts, abrasions, burns), 53% of subjects have a pain-free period immediately following the injury. In the fracture cases where there is no immediate pain, there is instead an initial feeling of numbness at the wound. Persistent pain develops later when the pressures associated with haemorrhage, oedema and inflammation develop, and when pain receptor agonists released from the injured tissue accumulate at the wound (Gregory 2004). These types of pain would be relevant in bowhunting cases where shot animals have survived for days.

Anecdotal information on the prevalence of wounding rates has been published (Mayer & Samuel 1992), although it would be helpful if there were more studies which included the nature and extent of the wounds. The main findings so far have been as follows. Non-retrieved crippling losses from arrow and gunshot injuries have been estimated from the number of shot deer found injured or dead. In a study in Illinois, the prevalence of crippling losses from gunshot wounds was between 21% and 24%, whereas the prevalence of crippling losses from arrows was on average 39% (Nixon *et al* 1991). The prevalence was higher in hinds, because trophy hunters put less effort into searching for wounded animals that were not bearing antlers.

The number of deer that are wounded and not immediately killed has also been estimated from the hit-but-did-not-retrieve (HBNR) returns submitted by bowhunters to regional authorities. Between 12% and 20% of bowhunters reported at least one HBNR during a season (McPhillips *et al* 1985). In a separate postal survey of 840 deer bowhunters in South Dakota, 21% reported at least one deer HBNR, and one hunter reported five deer HBNR. The wounding rate by bowhunters was 0.92 deer HBNR per deer harvested. In other words, for every animal that was killed there was approximately one animal wounded without being retrieved (McPhillips *et al* 1985). In a study in Purdue, four deer were wounded by rifle per 100 hunter days, whereas six were wounded by arrow per 100 hunter days (Stormer *et al* 1979). This suggests that the wounding incidence (per hunter day) during bowhunting was 1.5 times greater than during hunting using rifles.

Injuries caused by arrows

Death from an arrow injury depends on haemorrhage from the blood vessels that are cut by the arrow head. A penetrating arrow causes limited wound cavitation, unlike a rifle bullet. Instead, broadhead arrows cause radiating incised wounds in the internal organs (Hain 1989), and the more blades there are on the arrowhead, the greater the potential

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tissue comminution in the arrow track. If the arrow falls out or is removed, the rate of haemorrhage is likely to increase. Experience with emergency cases in humans has shown that it is inadvisable to remove a deeply embedded arrow if procedures are not in place to control subsequent bleeding.

The likelihood of a shot being lethal also increases with the depth of penetration of the arrow (Ashby 1997). Depth of penetration depends on arrow weight, bow energy-storing capacity, draw length used in a given shot, bow tuning, release technique, target distance, broadhead construction and blade sharpness. During penetration, an arrow occasionally changes direction and this can add to the unpredictable nature of organ damage (Georén 1990).

It is thought that the depth of penetration is reduced if the animal is moving; for example, if the aim is at the chest, body movement may introduce lateral pressure and greater friction on the arrow shaft. It has also been suggested that a squeezing effect by the ribs on the shaft may be exaggerated if the animal is moving. In addition, the chances of not striking a vital area are increased if the target is moving because of the difficulty of synchronising the aim with movement of the animal. Some hunters have a policy of not shooting at a moving target because of these three factors.

The broadhead arrow leaves a distinctive pattern in the skin of the animal. These arrows have between two- and six-bladed tips, usually two or three. The shape of the penetrating edges of the wound reflects these designs. For example, a four-bladed tip leaves a cross whereas a five-bladed tip leaves a five-limbed star. Field tip arrows leave a less characteristic elliptical slit in the skin, and their depth of penetration is usually lower (Eriksson *et al* 2000). From superficial inspection in deer, it can be difficult to distinguish between a field tip arrow wound and a bullet wound (Randall & Newby 1989). If a broadhead arrow grazes the skin without completely penetrating the hide, it leaves a serpentine or polygonal skin injury, often with a characteristic divot removed by two adjacent blades (Rogers *et al* 1990).

Vital areas in the target

The vital areas that should be struck during hunting are those that lead to rapid unconsciousness and death. Hofmann and Schotz (1968) described these areas for deer and other game species. When using a rifle, the 'vital centres' include the spinal cord, brain, heart and major blood vessels in the neck and chest. In the case of bowhunting, the heart and lungs are usually considered the appropriate targets. If the heart or a large artery is struck, the chances of a quick kill are high, whereas, if the arrow lodges in muscle or the abdomen without severing a major artery, death will be delayed. In humans, it has been reported that a heart strike can result in massive intrathoracic haemorrhage, with 1200–2100 ml blood being present in the pleural cavity plus about 100 ml in the pericardial sac (Cina *et al* 1998; Eriksson *et al* 2000). Puncturing a lung will not necessarily cause rapid bleeding because pulmonary artery pressure is only about 15 mm Hg. It is inadvisable to include the head as a target site because of its small size, and, when struck by an arrow, penetration is by no means certain. In a human case, penetration of the skull with a low velocity arrow did not guarantee unconsciousness (Opeskin & Burke 1994). There are differences in view about whether the liver should be included as a 'vital area' in bowhunting. Stab wounds in the liver do not always result in prolific bleeding, except when the incision reaches deep into the organ. Because depth of penetration cannot be predicted, the safest policy is to exclude the liver as a target area.

Some hunters take the view that the target deer must present itself side on, before a chest shot can be taken. Others prefer the animal to have just passed the hunter before the arrow is released. The difference depends on whether the intention is to rupture one or more ribs with the arrow, or to penetrate the thorax via the abdomen and diaphragm.

Loss of consciousness, distress and death

There is no direct information on the time to loss of consciousness and death during bowhunting or during haemorrhage in deer. However, there are some general principles that apply to terrestrial mammals including deer.

The time to loss of consciousness and the time to death depend on which tissues are damaged and, in particular, on the rate of blood loss and hence the rate of induction of cerebral hypoxaemia. Anecdotal evidence in humans suggests that loss of consciousness and death can be very rapid when subjects have been struck in the heart by an arrow. One subject was found lying face down, holding the arrow in one hand and with little sign of body movement (Eriksson *et al* 2000). The impression was that loss of consciousness had been prompt.

In other cases, where cardiac puncture did not result in immediate death, the following signs have been observed: extreme restlessness, 'air hunger' (ie sense of breathlessness), cold and clammy skin, and venous hypertension (extended jugular veins). Cardiac tamponade can occur if the right side of the heart is punctured and more than 150 ml blood accumulates in the pericardial sac. This leakage leads to a gradual, rather than abrupt, failure of heart function, especially if bleeding is contained by the pericardial sac without substantial flow into the pleural cavity (Asfaw & Arbulu 1977).

When a human or animal undergoes haemorrhage, an autoregulatory mechanism is activated that helps maintain cerebral blood flow. This mechanism fails when mean arterial pressure falls below 50 mm Hg (Kovách & Sándor 1976). When mean arterial pressure falls below 40 mm Hg, oxidative metabolism in the brain starts to become compromised, and pressures below 30 mm Hg lead to irreversible neuronal damage.

The blood pressure changes during haemorrhage correspond to the amount of blood that is lost, but the exact relationship may vary between species. In rats there is a critical threshold in the amount of blood lost before blood pressure catastrophically plummets. This threshold corresponds to about 3.5 ml blood lost per 100 g body weight, which in turn represents about 60% of total blood volume (Crippen *et al*

Table 2 Relationship between the % total blood volume lost in a 20 min period, and mortality rate and time to death in rats that died within 2 h.

Blood loss (% total blood volume)	Mortality at 2 h (%)	Time of death (min ± SD)
35	0	–
43	26	56 ± 35
48	33	81 ± 26
52	65	37 ± 33
61	100	11 ± 2

1991). Suppression of consciousness, as seen in changes in the electroencephalogram, was thought to set in when mean arterial pressure fell to less than 50 mm Hg, and electrocerebral silence occurred only when apnoea had set in and systolic pressure was less than 30 mm Hg. Time to death was reproducibly prompt when rats lost 60% or more of their total blood volume (Table 2) (Crippen *et al* 1991; McGlew *et al* 1991). If this finding applies to deer, the blood volume that would need to be lost during haemorrhage from a red deer hind would be more than 2 l.

In monkeys, the corresponding minimum mean arterial pressure needed to support consciousness is thought to be more than 35 mm Hg (Bar-Joseph *et al* 1989). At pressures below 35 mm Hg the animals were almost always stuporous or comatose. This critical value may vary according to the rate of blood pressure decline; for example, in dogs and cats allowed to haemorrhage through an indwelling arterial cannula, mean arterial pressures as high as 40 mm Hg have been linked with unconsciousness when those pressures occurred for long periods (about 30 min) (Kovách 1961). Similarly, the loss of somatosensory evoked potentials in the cerebral cortex depends on the duration of hypotension as well as its severity (McCutcheon *et al* 1971).

Kirimli *et al* (1970) bled sedated dogs through an aortic cannula and noted that the time to relaxation of the jaw muscles was 6 min. Relaxation of the jaw muscles is sometimes used to measure depth of anaesthesia, with jaw relaxation indicating that the animal is in a surgical plane of anaesthesia. If the carotid arteries are severed, unconsciousness and loss of brain function are likely to be quicker, and, provided that the arteries do not occlude during bleeding, loss of evoked potentials and unconsciousness can occur within 15 sec (Gregory & Wotton 1984).

The transition from consciousness to unconsciousness during haemorrhage is not always a smooth progression. When the femoral artery has been cut in dogs, the bulk of the haemorrhage occurred in the first 3–5 min, after which it slowed to a drip or ceased (Milles *et al* 1966). In 43% of cases, there was a spontaneous second haemorrhage, which occurred 2–40 min after the end of the first episode. This second haemorrhage was due to secondary vasoconstriction in combination with a shift in fluid from the extravascular to the intravascular space, and the additional blood lost varied from 15 ml to 200 ml. In primates, these second haemorrhages have been associated with transient blood pressure rises and with a resurgence of consciousness (Bar-Joseph *et al* 1989).

There are three anatomical features that could delay the rate of induction of unconsciousness and death during haemorrhage in deer. First, the vertebral artery in deer is connected with the basilar artery, at least in young animals (Du Boulay *et al* 1973). This means that if an injury causes blood loss from a carotid artery, blood could continue to flow to the Circle of Willis and from there to the cerebral cortex, via the vertebral artery–basilar artery–Circle of Willis route. The contribution that this route would make may not be large, but the implication is that a ventral neck shot in deer may take slightly longer to induce unconsciousness than in species that do not have this anatomical feature. Second, the veins in deer lungs are well endowed with thick muscle bundles in comparison with many other species, and presumably this enables the veins to constrict during injury and haemorrhage (Ferencz & Greco 1969). Third, the deer's spleen has a bilayered capsule and trabeculae that are rich in smooth muscle (Hartwig & Hartwig 1985). These features would allow increased expansion of the spleen when storing red blood cells, and the rapid release of stored red blood cells during haemorrhage, which together may extend the duration of consciousness and survival during haemorrhage.

It has been suggested that in humans, a gradual decrease in blood volume of 20–25% produces anxiety, a decrease of 30–35% is associated with restlessness, and a decrease of 35–40% can cause depression (Kovách & Sándor 1976). This indicates that protracted haemorrhage may in its own right cause mild forms of distress. In addition, during haemorrhage there is likely to be tachypnoea and hyperventilation, which, when severe, would indicate that there is a sense of breathlessness before the loss of consciousness. Experimental work in monkeys that were bled from an open iliac artery has shown that increased ventilation occurs at mean arterial pressures greater than 40 mm Hg and that the increased ventilation was severe enough to lower p_aCO_2 (Bar-Joseph *et al* 1989). The monkeys were comatose when mean arterial pressure was less than 35 mm Hg. Taken together, this confirms clinical experience in humans that respiratory distress can occur during haemorrhage.

Some deer bowhunters strive for a double-lung hit so that the lungs collapse, producing impaired oxygenation of blood. In some situations this may accelerate time to death, but collapse of the lungs could be distressing for the animal. In humans, collapse of the lungs during open pneumothorax can create unpleasant sensations if the subject is unable to perform breathing actions through failure to generate negative intrathoracic pressure. The subject comes to a standstill and struggles for breath from a sense of 'air hunger'. The sense of breathlessness during lung collapse is partly due to failure in mechanoreceptor activation that would normally occur with expansion and relaxation of the thorax during breathing. However, if a tension pneumothorax develops either from failure to blow off air that escapes from the lungs into the chest or from air drawn into

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the chest through the arrow hole, death may occur relatively rapidly from failure in venous return to the heart as well as from compromised ventilation (Lewis 1982). The size of the hole has to be quite large for this effect to occur. It has been found in the human that small perforations of the chest wall can be tolerated reasonably well, but when the hole in the chest wall is larger than the diameter of the trachea (3–4 cm in adult humans), air is readily inspired through the hole and effective ventilation is abruptly terminated (Jantz & Pierson 1994).

Codes of practice

Various bowhunting clubs and organisations have Codes of Conduct which aim to support sportsmanship and acceptable animal welfare practices (eg www.ndbowhunters.org/code). In some regions there is a legal requirement to sit a test of competence before the individual can bowhunt. Some Bowhunters Association Codes of Conduct require hunters to:

• use razor-sharp broadheads;

• not shoot at big game unless the hunter can reasonably expect to put an arrow into a vital area;

• use equipment that is adequate for the size of the hunted animal. When hunting adult deer, select single-blade heads rather than multi-blade heads. Single-blade heads penetrate deeper than multi-blade heads, and the deeper the arrow penetrates the more likely it is to kill;

• limit the shooting distance to within the individual's marksmanship;

• be aware that the most lethal shot angle is with the animal quartering away from the bowhunter, and that this approach is to be preferred;

• pursue and recover any wounded animal as soon as practicable;

• always trail quietly;

• continue the search for an arrow-hit animal until there is no longer any possibility of finding it;

• have the skills of tracking a wounded animal;

• assist other bowhunters in finding animals that have been hit by an arrow;

• approach cautiously and quietly when a shot animal is found lying on the ground, so as not to alarm the animal and provoke flight. If possible approach from the back of the animal. If the animal is obviously alive try to get close enough for another shot, which should be aimed at the chest. Quietly back off so as not to alarm the animal, and wait silently to assess the situation and decide on the next course of action.

Animals that are not killed by the first strike have to be followed and killed appropriately. A good blood trail helps when tracking those animals and this in turn is assisted if the arrow either passed through the animal or fell out. It is said that most bagged deer are shot at a distance of 18 m or less, and only a few are brought down at ranges of 35 m or more. On account of this, it is often recommended that the shooting range should not exceed 20 m. A useful edict is that bowhunters consider any game animal wounded by an arrow and not recovered as a reproach to the sport of bowhunting. However, the level of humaneness no doubt depends on the skill, awareness and desire of the individual to be humane.

Besides the above, there are rules on fair game hunting, such as not shooting at animals that are swimming or held by a snowdrift or trap, and not hunting from a vehicle or boat. Where those standards have implications for the welfare of the animal, they could also be considered in Codes of Welfare on Bowhunting.

Animal welfare implications

It has been argued that most forms of hunting will cause suffering for some of the hunted animals. The points discussed in this commentary provide the basis for those concerns in the case of bowhunting. Suffering could include the failure to produce an immediate kill resulting in debilitation and death from predation or septicaemia, and respiratory distress from non-fatal chest injury. The prevalence of such suffering is not known. However, reports on crippling losses indicate that between 12% and 48% of shot deer may escape whilst injured. This is substantially greater than for hunting by rifle, and so on animal welfare grounds the rifle is to be preferred.

Where bowhunting is permitted, it is the responsibility of the recreational hunter and the hunting associations to minimise the suffering that occurs in crippled animals. They need to ensure that standards of humaneness are upheld, irrespective of their cultural outlook towards hunting in general (Kellert 1993). This can be implemented through adoption of Codes of Conduct that the hunters voluntarily accept as the correct course of action.

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