CONCLUDING STUDIES ON THE FAILURES OF ELECTRICAL LANCING OF WHALES

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Final Acceptance: 16 February 2000

Abstract *Animal Welfare 2000, **9:*** 433-441

Electrocution of an animal is inhumane if it is not rendered instantaneously insensible by the application of sufficient current density within vital centres of the brain. Application of electric current which does not achieve this, is likely to cause severe pain. The humane aspects of electrical lancing have aroused widespread concern and debate.

For an electrically lanced whale of the size of those currently hunted, previous research has indicated that the current densities produced in the heart and brain are unlikely to reliably render the animal insensible or stop its heart. This study supports these findings and demonstrates that the presence of salt water/immersion may further reduce current densities. Evidence for the failure of the electric lance includes the necessity for multiple and prolonged applications of electric current.

Reasons for the failure of the electric lance include non-optimal current injection sites, insufficient current injected, the presence of salt water, and the trauma caused by the explosive harpoon. The efficacy of the electric lance may be falsely exaggerated for reasons associated with blood loss and misdiagnosis of death. All evidence clearly indicates that attempts to stop the heart by electrocution will cause severe pain to an already traumatized animal.

We suggest that the use of the electric lance is clearly inhumane, and are pleased to announce that its use in Japanese whaling operations was reportedly discontinued as from 1997.

Keywords: *animal welfare, electric lance, euthanasia, whales*

Introduction

Electricity for killing whales was in use as early as the 1850s (Anonymous 1853). Early methods of electrocution involved the use of one electric harpoon injecting electric current into the body of the whale. The return path of the current was believed to be through the mouth, then via sea water to the catcher vessel. It was thought that the blubber constituted an electric insulating barrier, preventing current leakage (Mitchell 1986). The use of electricity as a primary method of killing whales was abandoned through lack of success (in spite of the use of large currents of up to 56A), and inadequate financial support (Tonnessen & Johnsen 1982). A modified approach using electricity as a secondary killing method (electrical lancing) was introduced by the Japanese in 1971 (Anonymous 1993).

The humane aspects of electrical lancing have aroused widespread concern (Blackmore 1992; Kestin 1995; McLachlan 1995; Blackmore *et al* 1996; Van Liere *et al* 1996) and debate (Hayashi 1995; Ishikawa 1996; Walloe 1996; Kestin 1999).

Our previous research on dry whale carcases indicated that the current densities achieved in the heart and brain of electrically lanced larger whales (ie those greater than 3m in length) were unlikely to reliably cause electroanaesthesia and cardiac fibrillation. These are estimated to require 10mA cm^{-2} and 0.5mA cm^{-2} respectively, as noted in the *Discussion* (Barnes *et al* 1996; Blackmore *et al* 1996). The results of the same studies suggest that to reliably achieve a humane kill of hunted whales, an electric current of at least 50A must be applied to the animal. The operation of specialist equipment used to produce such currents would impose a considerable risk to people. Electric generators on whaling boats typically deliver currents of approximately 5A.

Under practical whaling operations, electrocution occurs with the animal in sea water. Whereas our previous research was on dry whale and dolphin carcases, this study in addition examines current densities in the heart of a recently dead dolphin partially submerged in salt water.

Materials and methods

The carcase of a dry, 3.4m, adult, female common dolphin, *Delphinus delphis*, was placed on its side in a large plastic tank approximately 24h after the death of the animal during a stranding. Current densities in the heart were determined by methods previously described in detail by Barnes *et al* (1996). The same procedures were used to determine current densities when the surface of the animal was uniformly moistened with salt water applied by an atomizer. The experimental procedure was repeated with the carcase partially submerged in salt water, with a little over half of its girth immersed and the lance insertion sites either approximately 5cm above or below immersion level. The salt water used in these experiments was made to simulate sea water by adding sodium chloride to tap water to make a 2.7 per cent solution.

As fully described in our previous studies (Barnes *et al* 1996), and shown in Figure 1 and Figure 2, a constant current of $5A_{rms}$ (root mean square) at 50Hz was applied by stainless steel current application electrodes (250mm in length, 10mm in diameter). These were almost fully inserted at optimal positions B1 and B3 (Figure 1).

In each of the four experiments in the present study, the current was measured between pairs of sensing electrodes at three levels (with 30mm spacing) within the heart using the same probe as employed in our previous experiments. Three readings were made at each level, averaged, and the mean currents converted to current densities (see Barnes *et al* [1996] for a detailed description of the methodology).

Results

The results of the four experiments carried out on a 3.4m common dolphin are presented in Table 1.

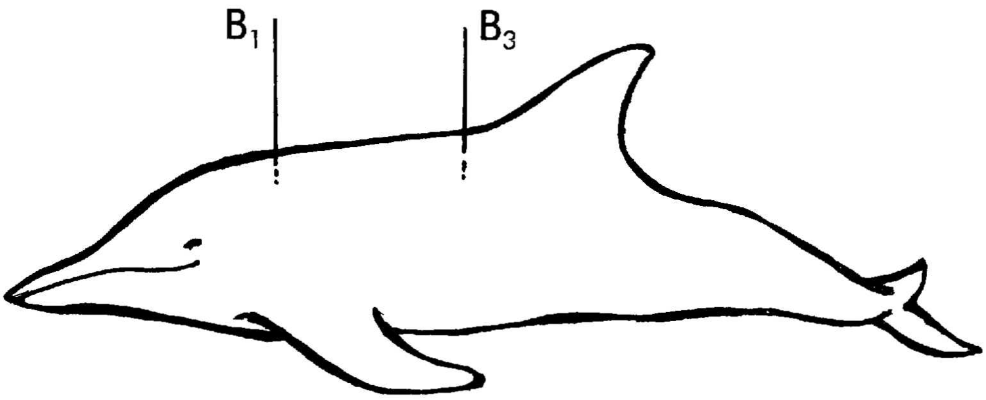

Figure 1 **Routine experimental positions of the current-application electrodes lateral to the dorsal midline.**

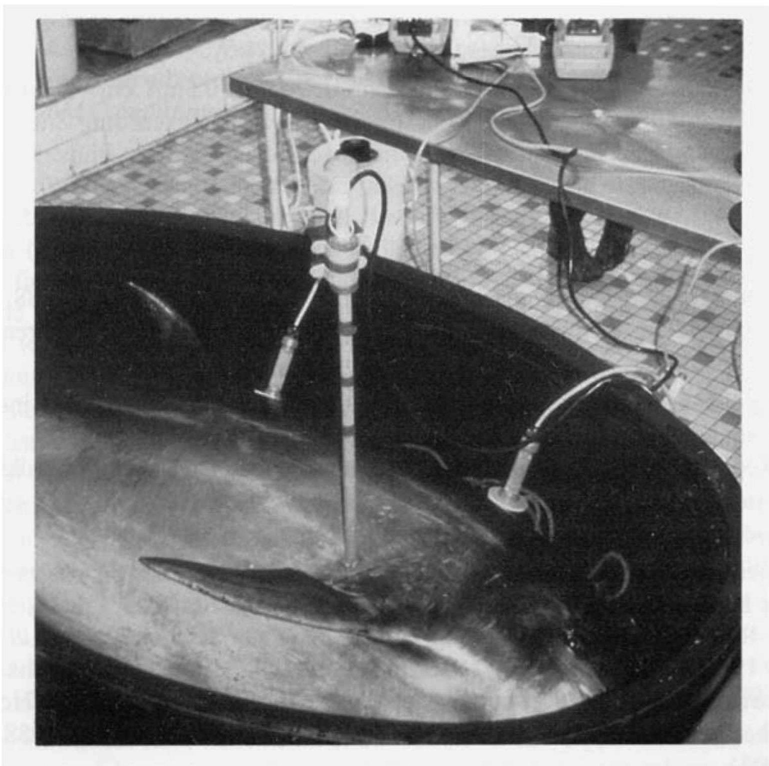

Figure 2 **Positions of the current density probe and the two current application electrodes connected to the electrical supply and sensing equipment.**

https://doi.org/10.1017/S0962728600023010 Published online by Cambridge University Press

Table 1 **Comparison of current densities in the heart of a common dolphin under various experimental conditions.**

Experimental condition	Current densities (mA cm^{-2}) at three levels within the heart[1]			Mean current densities in the heart (mA cm^{-2})	Ratio[2] experimental: dry
	Level 1	Level 2	Level 3		
Dry	1.43	1.71	1.91	1.68	1.00
Moist	1.43	1.66	1.85	1.65	0.98
Wet (a)[3]	0.84	1.02	1.13	1.00	0.59
Wet (b)[4]	0.74	0.96	1.01	0.90	0.54

1 Mean of three readings at each level (see Barnes *et al* [1996]). Readings differed from the mean by 1–2 per cent.

2 Ratio of mean current density in the heart under experimental conditions as compared to mean current density under dry conditions. Pearson product-moment correlation coefficients between Dry vs Moist, vs Wet (a) and vs Wet (b) treatments were, respectively, $r = 0.999$, $r = 0.999$ and $r = 0.968$ (all $P < 0.001$).

3 Water surface c 5cm below electrodes.

4 Water surface c 5cm above electrodes.

These results show that mean current densities in the heart are reduced by the presence of salt water. The mean current density of 1.68mA cm^{-2} determined in the dry dolphin carcase, compares favourably with that of 1.70mA cm^{-2} reported in the 3.2m minke whale, *Balaenoptera acutorostrata*, by Barnes *et al* (1996). For comparison, Figure 3 plots data from that paper, together with the results of the present study.

Figure 3 indicates that the threshold current density of 0.5mA cm^{-2} required for cardiac fibrillation (Roy 1980) is unlikely to be reached in whales exceeding 8m in length. This unlikelihood would be increased if the whale were even partially immersed in sea water and/or if the lances were placed in non-optimal positions (Barnes *et al* 1996).

Discussion

There is general agreement (Gregory *et al* 1983; Blackmore and Delany 1988; Kestin 1995) that for electrocution to be a humane method of killing animals, three requirements must be fulfilled:

i) Application of sufficient current to the brain to induce insensibility instantaneously, lasting until brain death from anoxia caused by cardiac arrest.

ii) Application of sufficient current to immediately and irreversibly fibrillate the heart.

iii) Simultaneous application of both of the above; or application of the current through the brain, followed immediately by the current through the heart.

It has been previously shown that the current density in the brain of whales resulting from an electric lance current of $5A_{rms}$ at 50Hz is well below the 10mA cm^{-2} that is estimated to be necessary for an effective stun resulting in immediate insensibility (Lang *et al* 1969; Sances & Larson 1971; Barnes *et al* 1996; Blackmore *et al* 1996; 1997). Applications of significant electric currents which do not result in immediate insensibility, or currents which do not pass through the brain, are likely to cause severe pain (Blackmore & Delany 1988; Jones 1990; Kestin 1995).

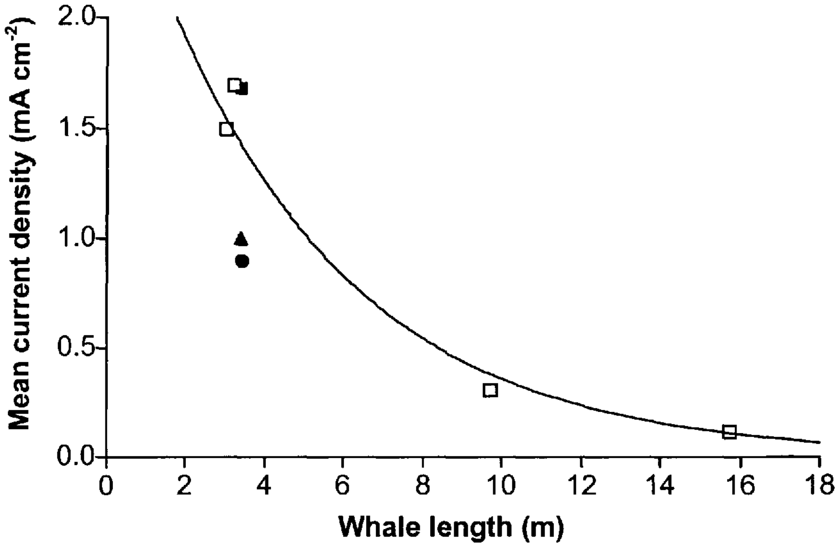

Figure 3 **Mean current density in the heart as a function of body length (using optimal positions of the current injection electrodes). Open symbols □ refer to previous measurements on dry cetacean carcases (Barnes *et al* 1996). Solid symbols refer to the results of the present study: ■ Dry; ▲ Wet (a); ● Wet (b). (Modified from Figure 6 of Barnes *et al* [1996] and reproduced with permission of *Medical and Biological Engineering and Computing*.)**

According to Japanese heart-centred concepts and definitions of death (Gavin 1995), the purpose of electrical lancing as a secondary method for killing whales is to cause cessation of heart function (Hayashi 1980). If permanent, this results in circulatory collapse, cerebral anoxia and, finally, brain death (Stephenson 1969; Huszar 1982). Under laboratory conditions, the application of adequate current for 3–5 s was sufficient to cause cardiac fibrillation in various animal species (Sugimoto *et al* 1967; Roy 1980; Tacker & Geddes 1980). Therefore, one would assume that if adequate current density were established in the heart of a whale being electrocuted, current application times as short as 5s should suffice – not least because the animal is already traumatized. Since reported lancing times are generally well in excess of this figure (Hayashi 1980; Walloe 1996), and multiple electrocutions are required (Anonymous 1993), it is obvious that fibrillation rarely, if ever, occurs as a result of the first current application. Reasons for this failure of the electric lance include non-optimal current injection sites (Roy *et al* 1986; Anonymous 1993; 1995a; Barnes *et al* 1995; Hayashi 1995; Ishikawa 1996) and application of insufficient current (Kestin 1995; Barnes *et al* 1996). In addition, a reduction in current density caused by the presence of salt water has been postulated (Anonymous 1993; Ishikawa 1996; Van Liere *et al* 1996; Walloe 1996; Blackmore *et al* 1997) and demonstrated by Gregory and Wotton (1992).

Since previous studies have indicated that the current usually applied to the brain and the heart during electrical lancing was insufficient to incapacitate hunted whales (Barnes *et al* 1996), electrical lancing as a secondary killing method does not fulfil any of the three stated requirements for humane electrocution.

The present study confirms our findings from previous experiments (Barnes *et al* 1996). It also demonstrates that the presence of moisture on the skin reduces the current density detected in the heart, to 98 per cent of the dry skin value. Immersion of the cetacean in salt water and immersion of both the cetacean and current application electrodes, further reduces the detected current densities in the heart (to 59% and 54% respectively).

Therefore, during practical whaling operations, the presence of sea water will, inevitably, lessen the efficacy of electrical lancing even if the lances are not immersed. This finding seems to be supported by an article submitted to the International Whaling Commission (IWC) by the Government of Japan (Anonymous 1993), which states that to prevent 'the electric power from dissipating in the sea water' the body of the whale is lifted 'slightly above the water' – presumably by the harpoon. However, our study has clearly demonstrated that there is substantial leakage of electric current through the skin. Thus, lifting the whale 'slightly above the water' is pointless, and, without guarantee of a humane despatch, must surely aggravate the pain that the animal is already suffering.

Successful cardiac dysfunction is achieved when the current density imposed in the heart exceeds the threshold for fibrillation – which is about 0.5mA cm^{-2} in healthy animals (Starmer & Whalen 1973; Roy 1980). In severely traumatized and haemorrhaging animals the threshold value is likely to be progressively lowered because of the tachycardia (rapid heartbeat) resulting from hypovolaemia (reduced blood volume) and a subsequent fall in blood pressure (Sugimoto *et al* 1967). The extent of the fall in threshold is not known, but the decrease could improve the chances of cardiac fibrillation being triggered by electrical lancing and this would reduce the time-to-death. However, in spite of this possible increase in the vulnerability of the heart, which should necessitate only a brief, single electrocution, reports indicate (Kestin 1993; Walloe 1996) that multiple electrocutions over an extended period of time are generally required to cause cardiac dysfunction.

Unsuccessful electrocution of whales is unlikely to be due to spontaneous cardiac defibrillation as suggested by Kestin (1995). Where defibrillation has been described, in small animals such as rabbits, rats, mice and hedgehogs, it has been found that the ability of a heart to defibrillate spontaneously is inversely related to its mass (Geddes 1985). On this basis, a relatively large whale heart once fibrillated by electrical lancing is highly unlikely to spontaneously defibrillate and resume normal activity which would require repeat electrocution. The multiple electrocutions which are routinely carried out on cetaceans (Anonymous 1993) must be necessitated by the application of inadequate current densities to the heart – rather than by spontaneous cardiac defibrillation.

Reports of the efficacy of the electric lance may have been exaggerated for the following reasons: first, death or immobility due to the effect of hypovolaemic shock, and second, immobility caused by muscular fatigue or spinal discharge resulting from prolonged electrical stimulation. In the first case, death may not be due to electrical lancing and in the second case, immobility may be falsely diagnosed as synonymous with death (eg some reports of shorter times-to-death with the electric lance may be associated with the electrocution of unconscious animals as reported by Hayashi [1980]). In both cases, a relatively short time to death would be erroneously attributed to the electric lance. One further factor that falsely implies reduced time-to-death by electrical lancing, is the way in which time of death is defined, ie the last time that application of current elicited a response by the animal (Anonymous 1993). It is contradictory and misleading to associate death with both the presence and the absence of a reaction to the application of an electric current.

Extended times-to-death by electrocution may be associated with several factors, separately or in combination. These include non-optimal placement of the electric lances (McLachlan 1995), inaccurate strike of the harpoon (Kestin 1999), and a delay in (or absence of) lowering of the threshold for ventricular fibrillation (Sugimoto *et al* 1967).

Conclusions

The present paper supports our previous findings (Barnes *et al* 1995; 1996; Blackmore *et al* 1996; 1997) regarding the inadequacies of current densities in the heart of cetaceans produced by simulated electrical lancing. In addition, we have shown that the presence of salt water diverts current from the target organ by leakage through the skin. Therefore, under practical whaling conditions, attainment of cardiac fibrillation thresholds in cetaceans by electrical lancing would be greatly impeded if not impossible.

Animal welfare implications

The stated objective of electrical lancing is to cause permanent cardiac arrest. Available data and our research indicate that immediate and irreversible cessation of heart function is unlikely to be achieved by present methods of electrical lancing which employ multiple and prolonged applications of electric current. Since electrical lancing also fails to simultaneously disable brain function, which would render the animal unconscious and insensible to pain, attempts to stop the heart by electrocution must surely cause severe pain to an already traumatized animal.

Electrical lancing, as a secondary method of killing whales, cannot be considered humane. The few reports that exist on the efficacy of firearms as a secondary method of killing whales (Anonymous 1995b; Kestin 1995; Borodin 1996) would also apparently discount this alternative on animal welfare grounds. There thus appears to be no practical humane secondary killing method.

Acknowledgements

The authors wish to acknowledge the support of J K McLay, New Zealand Commissioner to the IWC and M Donoghue, delegate to meetings of the IWC. The assistance of the New Zealand Department of Conservation, the Ministry of Foreign Affairs and Trade, and Massey University and its technical and professional support staff, is also gratefully acknowledged; as is the cooperation of the Maori tribes (iwi).

Epilogue

At the 49th Annual Meeting of the IWC in Monaco in October 1997, Japan undertook to trial the use of a rifle as the main secondary killing method for harpooned whales, and stated that during these trials, the electric lance would only be employed in emergency situations, for example if the crew member trained in the use of the rifle were not available. At the 50th Annual Meeting of the IWC in Oman in May 1998, Japan reported that all harpooned minke whales that had required a secondary killing method in the 1997/1998 Antarctic season had been shot with a rifle, and that the times-to-death were broadly comparable to those obtained in previous seasons with the electric lance. Japan stated that it would continue to use the rifle as the preferred secondary killing method (M Donoghue 1999 personal communication). At the 1999 meeting of the IWC in Grenada, Ishikawa (Japanese delegate) reported that 'on no occasion since the introduction of the rifle as the secondary killing method had the electric lance been deployed' (Anonymous 1999).

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