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A tool to facilitate implantation of electrodes for electromyographic telemetry experiments

C. M. Bunt

Waterloo Biotelemetry Institute, Department of Biology, University of Waterloo, Waterloo, Ontario, N2L 3G1 Canada

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Conventional techniques for implanting electrodes into axial swimming musculature of fish are reviewed. A new device is described that reduces time for electrode implantation, ensures constancy in electrode orientation, implantation depth, and separation distance. This device is inexpensive, simple to build, and easy to use.

Key words: electromyogram telemetry; electrode positions; standardization; surgical techniques.

Electromyographic (EMG) telemetry involves implantation of transmitters in fish that relay muscular activity to aerial or submerged antennas and receiver systems. Muscular activity rates in free swimming fish are then used to describe physical output associated with fishway use (Bunt, 1999), upstream migrations (Hinch *et al.*, 1996), spawning behaviour (Kaseloo *et al.*, 1996; Weatherley *et al.*, 1996), swimming performance and oxygen consumption (McKinley & Power, 1992; Booth *et al.*, 1995; Økland *et al.*, 1997), diel activity (Demers *et al.*, 1996), activity associated with stressors such as pollutants (Weatherley *et al.*, 1980) and temperature changes (Booth *et al.*, 1997; Beddow & McKinley, 1998), metabolic rates (Rogers & Weatherley, 1983; Briggs & Post, 1997), and to test bioenergetic models (Hinch & Rand, 1998).

Typically, EMG transmitters consist of a cylindrical package composed of a printed circuit board and surface mounted components, wrapped around a battery and sealed in epoxy. Trailing from one end of a radio (as opposed to ultrasonic) telemetry package are three leads. One is a broadcast antenna and the other two are electrode attachment wires for the detection of biologically relevant data. Traditionally, electrodes at the end of the attachment wires are implanted into target musculature using a variety of techniques that require several minutes to complete. Usually, these techniques involve two independent needles that are inserted carefully into red musculature beneath the skin and below the lateral line for measurement of aerobic activity, or within glycolitic, white musculature to measure anaerobic, or burst activity. Transmitters accumulate (i.e. integrate) bio-electrical energy from target muscles in a capacitor. When a preset threshold is achieved (e.g. 150 μV), the device transmits a pulse from the broadcast antenna, with a rate that is dependent on the rate of loading of the capacitor. Therefore, radio pulse rates are inversely proportional to muscular activity. The strength of EMG signals is not correlated with electrode separation distances between 5–12 mm; however, Beddow & McKinley (1998) indicated that abrupt signal differences occurred when electrodes were >30 mm apart. They also indicated that transmitters malfunctioned when electrodes contacted one another (Beddow & McKinley, 1998). Electrode positions within muscle fibres may affect the electrical potential difference between electrodes. In fish, twitch contraction times and EMG signals vary with longitudinal position (Wardle & Videler, 1993; Jayne & Lauder, 1995) and muscle type (Jayne & Lauder, 1994). Therefore,

Tel.: 519 893 2530; email: cbunt@sciborg.uwaterloo.ca

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inconsistent electrode implantation could cause biologically irrelevant variation in EMG data.

There is no standard separation distance between electrodes [1 mm—Weatherley *et al.* (1982); 5 mm—McKinley & Power (1992) and Booth *et al.* (1997); 10 mm—Hinch *et al.* (1996); 20 mm—Briggs & Post (1997); 7 mm—Beddow & McKinley (1998)]. Most studies use electrode separation distances between 5 and 10 mm. However, conventional techniques for electrode placement result in variable electrode positions and variable implantation depths within target musculature that are difficult to control. Moreover, if the distance between electrodes is not consistent, signal accumulation and capacitor loading may be affected. Inconsistencies in electrode placement may contribute to EMG data variation among groups of fish. Inconsistencies in electrode placement among research projects make it difficult to compare results accurately from different studies. This paper describes a simple device that may be used to reduce significantly the time required for electrode implantation, and that ensures constancy in electrode orientation, implantation depth and separation distance.

The following examples are based on implantation of EMG transmitters into anaesthetized *Micropterus dolomieu* Lacépède (350–500 mm L_T). These techniques have also been used with largemouth bass *M. salmoides* Lacépède (Demers *et al.*, 1996; Kaseloo *et al.*, 1996), Atlantic salmon *Salmo salar* L., (Booth *et al.*, 1997; Beddow & McKinley, 1998), sockeye salmon *Oncorhynchus nerka* (Walbaum) (Hinch *et al.*, 1996), lake sturgeon *Acipenser fulvescens* Rafinesque (McKinley & Power, 1992), rainbow trout *Oncorhynchus mykiss* (Walbaum) (Weatherley *et al.*, 1982; Briggs & Post, 1997), and lake trout *Salvelinus namaycush* (Walbaum) (Kaseloo *et al.*, 1996; Weatherley *et al.*, 1996). Traditional methods of implanting transmitter electrodes into target musculature involve the use of sewing needles (Kaseloo *et al.*, 1992), or two grooved needles (*c.* 150 mm long, 21-G) and sharpened metal plunger inserts (McKinley & Power, 1992). Electrodes are loaded into the grooves and the needles are inserted through the body wall, to beneath the epidermis from inside the body cavity. This eliminates problems associated with abrasion, tangling or angling damage that may occur when electrodes are completely inserted through the body wall and anchored externally (Kaseloo *et al.*, 1992; Demers *et al.*, 1996; Briggs & Post, 1997). Needles are guided visually from above a ventral body cavity incision that, secondarily, facilitates placement of the transmitter within the body cavity. Placement and spacing of the electrodes is accomplished through palpation of the epidermis adjacent to the side of electrode implantation. Alternatively, electrode placement could be guided by radiography, but this is exceptionally costly. Once the electrodes are in place, excess electrode wire is pushed posteriorly, away from the incision, and the broadcast antenna is threaded from a puncture near the urogenital pore using a modified shielded needle technique as follows. A small puncture is made through the skin near the antenna exit point using an 18-G needle. Then, a 150-mm blunt-tip spinal-tap needle with a solid steel insert is introduced into the puncture and guided carefully past the viscera so the tip protrudes from the ventral incision. The solid insert is removed, the transmitter antenna is pushed into the tip of the spinal-tap needle, and the needle is withdrawn from the puncture, leaving the antenna threaded in its place. The transmitter is inserted carefully into the body cavity and pushed posteriorly away from the incision. In some cases, antibiotic solutions may be applied before the body cavity incision is sutured closed and fish are allowed to recover prior to experimentation. The average time required for electrode placement and transmitter implantation using this technique is *c.* 10 min, but could be up to 30 min from initial incision to final suture.

The newly developed device (Fig. 1) consists of two fused syringes and plungers that expel preloaded transmitter electrodes from modified large gauge needles. Since fish size is often correlated with thickness of the body wall, longer needles and plunger inserts are required to implant electrodes in larger fish.

To expel the electrodes accurately into the target musculature, the syringe plungers were modified to include a length of surgical steel that fitted into the shafts of the grooved needles [steel plunger insert; Fig. 1(a)]. To build the device, plungers were removed from the syringes and the rubber tips were detached. A length of 20-G surgical steel (*c.* 3 cm long, depending on fish size and needle length) was heated with a Bunsen burner and

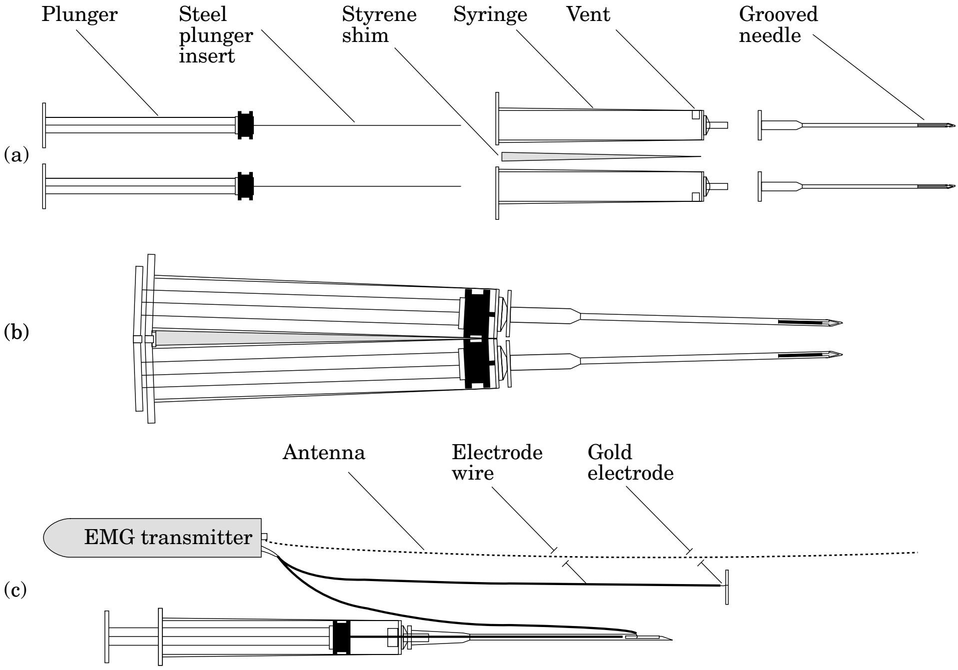
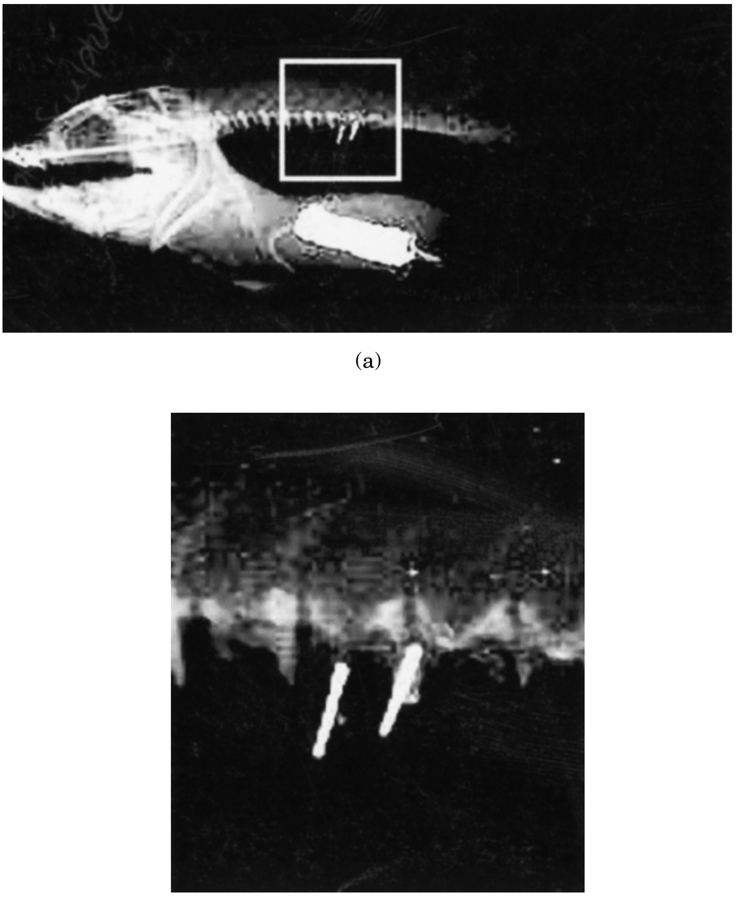


FIG. 1. (a) Components of the tool used to facilitate implantation of EMG electrodes (exploded view). (b) Assembled tool (plan view) with syringe and shim held together with hot glue. (c) Transparent lateral view of the implantation tool showing EMG electrode loaded into needle groove.

melted into each syringe plunger tip, parallel with the syringe plunger. Surgical steel inserts were secured in place with a small amount of epoxy glue. Then, the rubber tips were forced carefully over the ends of the surgical steel inserts and back onto the syringe plungers. The distal ends of each plunger were glued together so that they functioned as one unit rather than two independent plungers. Then, the plungers with surgical steel inserts were placed into the syringes. The inserts were guided into the needle shafts, and pushed snugly against the ends of the electrodes when they are loaded into the needle grooves. Transmitter electrode wires were held parallel to the electrode needles prior to insertion from inside the body cavity into the axial musculature beneath the epidermis.

To prevent gas bubbles from entering the implantation sites, rectangular vents measuring 4 × 4 mm were cut with a scalpel blade towards the lower end of each syringe. The vents discharge air before it enters the needle shafts. Different sized shims made from styrene foam may be glued between the two syringes so that the distance between needle tips may be varied. Industrial-strength hot glue is the recommended adhesive. The prototype tool consisted of two 40-mm 16-G hypodermic needles that were aligned and glued to the syringe tips with a small amount of epoxy. The needle tips were also slightly blunted with a sharpening stone to prevent puncture of the epidermis and infection (Beddow & McKinley, 1998). In this model, needle tips were spaced 7 mm apart and a groove was created in the tip of each needle using a hand-held power rotary tool [Fig. 1(b)]. These longitudinal grooves measured *c.* 1 × 10 mm and permitted insertion of 9 K gold electrodes that measured 0·75 × 7 mm. Each electrode was composed of a cylindrical shaft with a hole for the transmitter electrode wire midway along the length [Fig. 1(c)], rather than at one end (Hinch *et al.*, 1996). With electrodes loaded into both needle tips, and transmitter attachment wires pushed to the apex of the needle groove, the electrode/needle combination creates a relatively streamlined shape



(a)

(b)

FIG. 2. (a) X-ray image of *Micropterus dolomieu* (*c.* 350 mm) implanted with electrodes from a typical EMG transmitter using the new tool. (b) Enlargement (electrodes 7 mm long); note relative electrode positions.

[Fig. 1(c)]. When the electrodes are ejected from the tool, they become hooked into the target muscle like an anchor tag.

Guiding the needles through the body cavity incision, past viscera and into axial swimming muscles requires care. During experimentation with traditional needles and the new device, muscles often twitched as physical damage occurred in the muscle mass between the body cavity and target musculature beneath the skin. When it is clear that electrodes are placed properly, a 2–3-mm withdrawal of the needles prevents puncture of the skin after plunger depression. Using the new device, needles are guided into place quickly, and plunger depression releases the electrodes into the muscles that are to be monitored. The device is then removed from the incision, the antenna is threaded through the body wall, the transmitter is inserted carefully into the body cavity and the incision is sutured closed. Average time required for electrode placement, transmitter implantation and suturing of the incision is *c.* 5 min. In trials with the new device, electrodes were implanted quickly and average anaesthetization times for *M. dolomieu* were reduced by a factor of two. In each trial, electrodes were oriented and spaced consistently (Fig. 2). High-quality EMG data from several *M. dolomieu* implanted with this technique have been used in a variety of experiments (Bunt, 1999). X-ray imaging and post-mortem examinations indicated that electrode placement was well controlled and visual observations showed that post-surgical behavioural effects were negligible. Occasionally, the traditional technique of electrode placement leads to movement of the electrodes and resultant contact between them (Beddow & McKinley, 1998). This results in loss of biologically relevant EMG data and waste of a transmitter if the fish has been released for observations of natural behaviour and activity. There was little variation in electrode positions when the new tool was used to implant EMG electrodes. Overly dulled or damaged needles may simply be replaced and the life expectancy of the tool is virtually unlimited. The newly described device is inexpensive and simple to build, easy to sterilize and use, and will allow researchers to compare the results of physiological telemetry experiments accurately by ensuring that electrode placement techniques are standardized.

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