MFR PAPER 1047

Investigation of Blubber Thickness in a Gray Whale Using Ultrasonography

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ABSTRACT

A captive juvenile gray whale, Eschrichtius robustus, *was studied with ultrasound using A-mode technique. Measurements of blubber and fat thickness by means of selected tissue interfaces were made. Suture implantation depths were also measured. Ultrasound would be a reliable method for measuring blubber and fat thicknesses to give insight to a marine mammal's nutritional status.*

PROBLEM

A captive yearling gray whale was considered for ultrasound study 1) to measure blubber and fat thickness to reflect on nutritional status, and 2) to measure depth of polyethylene suture implantations being used for an attachment of a radio transmitter device on the animal's dorsal surface.

PROPOSAL

Using an ultrasound beam with A-mode technique, it was proposed to measure skin, blubber, fat, and muscle depth. Tissues of varying density will reflect ultrasound echoes from their respective interfaces. A porpoise, *Tursiops truncatus*, model was proposed for correlation.

BACKGROUND

Ultrasound is a relatively new science which is meeting with intense interest and enthusiasm for medical diagnostic and research purposes. It has proven effective in detecting brain midline shifts with the echoencephalogram. Examinations of the heart to predict cardiac output, mitral valve activity, and presence or absence of pericardial effusions are made. B-scan examination of the abdomen to localize and characterize various masses and organs in the peritoneal cavity and retroperitoneal space is accepted practice. Obstetrics has found valuable use for ultrasound in evaluating gestational age, placental location, and pelvic masses.

In the field of veterinary medicine this technique has made it possible to select breeding stock by determination of the fat and muscle interfaces, allowing identification of those animals with the best commercial potential. This latter application suggested measurements for marine animals to evaluate nutrition.

MATERIALS AND METHODS

Utilizing commercially available pulsed ultrasound equipment designed for medical application, multiple measurements of the echo interfaces of the gray whale were obtained at selected positions along the dorsal-lateral aspect and axilla. Additional measurements were obtained over the polyethylene sutures to determine the suture depth. All of this material was displayed on a cathode ray oscilloscope with a linear scale divided into millimeter increments. As an in vitro correlation to provide information as to which structures were providing the echo interfaces observed in the live mammal, a porpoise model with necropsy section was obtained. Using a direct visual placement of the transducer in similar areas to that of the gray whale, the echo interfaces were photographed on the oscilloscope. Direct linear measurements and anatomical identification of the structures traversed were performed. These echo patterns correlated highly with the similar patterns obtained from the gray whale and indicated which structures were providing these echoes. Thin section radiographs were obtained of the porpoise model, further demonstrating the density differences of tissue between the skin lines, blubber, areolar fat, muscle, and fascial surfaces. In all cases the measurements corresponded exactly to the visual interpretation of the fascial, fat, bone, and skin interfaces.

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DISCUSSION

Elementary Ultrasound Physics

Although ultrasonic technology in medicine is relatively new, the earliest experiments date back to the 1800's when attempts to produce high frequency sounds were performed. In 1883 Galton developed an ultrasound whistle which was capable of producing vibrations as high as 25,000 cycles per second. In modern terminology, the frequency of vibrations is assigned the term "Hertz" and 25,000 cycles per second is abbreviated as 25 kilohertz (25 kHz). In 1929 Sokolov described an ultrasonic method for detecting flaws in metals. Following this, in 1947, this new modality was utilized in medical diagnosis when early workers such as Keksell, in Sweden, demonstrated the ability to detect the midline of intracerebral structures.

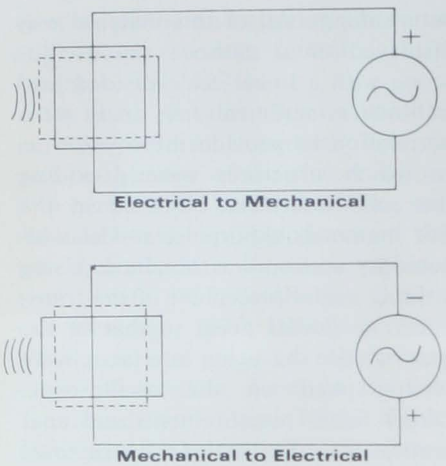


Figure 1.—Piezoelectric effect.

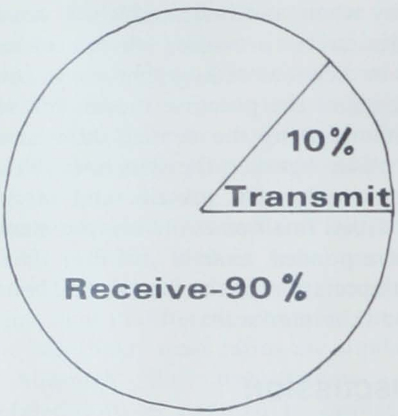


Figure 2.—Split function concept. Pulsed ultrasound from transducer is transmitted 10% of the time and received 90% at 400 pulses/sec.

Ultrasonics, the technology of high frequency sound waves, deals with the transmission of sound or pressure waves through a medium. Sound waves, unlike electromagnetic waves, cannot be transmitted through a vacuum. The generation of sound waves from a transducer depends on a phenomenon known as piezoelectric effect. This effect is produced when electrical energy is applied to a crystal which, when distorted by this electrical energy, will produce a mechanical pressure wave. In reverse, the piezoelectric effect occurs when mechanical energy distorts the crystal, producing an electrical potential which can be measured. The technique of recording reflected ultrasound results from this reversible behavior. (See Figures 1 and 2.) Sound waves travel through various materials with characteristic velocities. The product of the density of the material and the velocity of sound through the given material is called "characteristic acoustic impedance" (Z). When the two substances adjacent to each other transmit sound at a different velocity, the ultrasonic reflection (R) at the boundary is determined by the ratio of the two acoustic impedances as described in the formula

$$R = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$$

If the two substances have the same acoustic impedance, the numerator becomes zero and there is no reflection. On the other hand, if there is a large difference between the acoustic impedances, the result approaches unity, and almost all of the energy is reflected. In between these two extremes some of the sound energy is reflected while that remaining passes through the interface. Since most soft tissues have acoustic impedances that are quite similar, there are relatively weak reflections at the boundaries. The air-tissue interface is the strongest biological reflector. The bone-tissue interface, likewise, produces a very strong reflection. As most reflections are relatively weak, sensitive equipment is required to detect those boundaries with the less strongly reflected echoes and interfaces such as fat-muscle.

What is the resolution of the system? The frequency of sound determines its wavelength. The resolution is likewise dependent on the wavelength in the axial direction. The higher the frequency, the smaller the wavelength; thus, we have a better resolution capability as determined by the formula $v = \lambda f$ where v is the velocity of the sound in the medium, λ is the wavelength, and f is the frequency. We assume that the minimum distance between two objects for discrimination must be equal to at least 1½ wavelengths. (See Figure 3.) By going to higher frequencies, however, we lose penetration in tissue due to sound attenuation; therefore, a compromise must be made and the frequency selected which gives adequate axial resolution, yet adequate penetration through the tissue thickness. For the mammalian models studied the frequency varied between 1 and 2 megahertz, which was adequate for penetration through the structure studied.

$$v = \lambda f$$

$$\lambda = \frac{v}{f} \quad \frac{1500 \ ^{m}/_{sec}}{5{,}000{,}000 \ ^{cyc}/_{sec}}$$

$$= 3 \times 10^{-4}$$

$$= 0.3 \text{ mm} = \lambda$$

$\lambda \times 1.5 =$ **Minimum Distance Between Two Objects for Discrimination.**

$= 0.45$ **mm For 5 mhz**

Figure 3.—Formula for resolution.

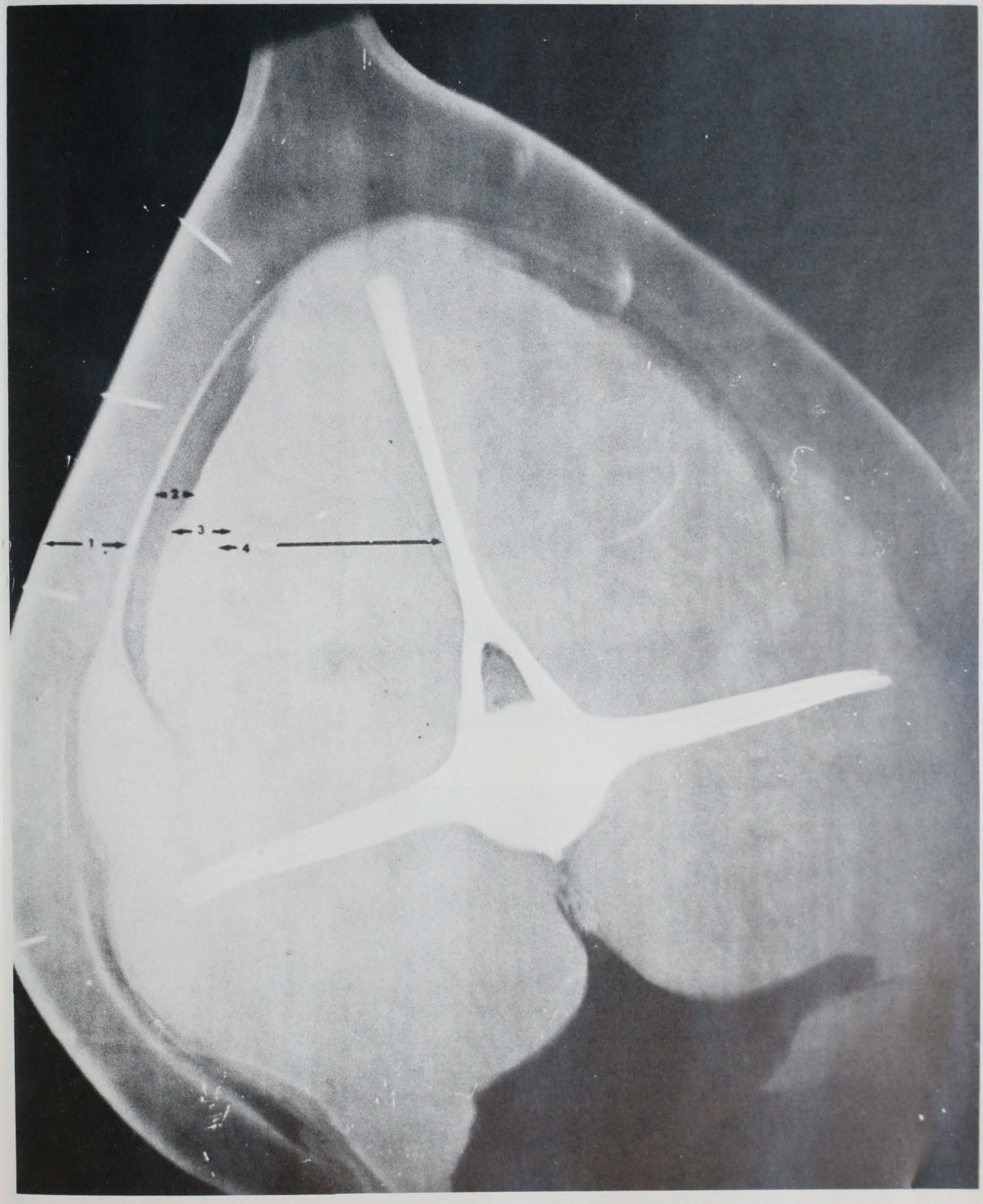
Findings

Although the size difference between the 28 foot captive gray whale and the captive Atlantic bottlenosed dolphin (*Tursiops truncatus*) necropsy model is somewhat different, the anatomical structures of the mammals are known to be similar.

During periods of illness or malnutrition, marine mammals of these species are noted to develop a depression in the dorsal contour posterior to the axilla. It is thought that this depression is due to catabolism of blubber, areolar fat, and/or muscle mass loss.

Presuming that areolar fat diminishes in volume prior to muscle loss,

Figure 4.—Radiograph of *Tursiops* cross section demonstrating (1) blubber, (2) areolar fat, (3) muscle group to fascial layer, and (4) second deep muscle group to dorsal spinous process.



2
1
3
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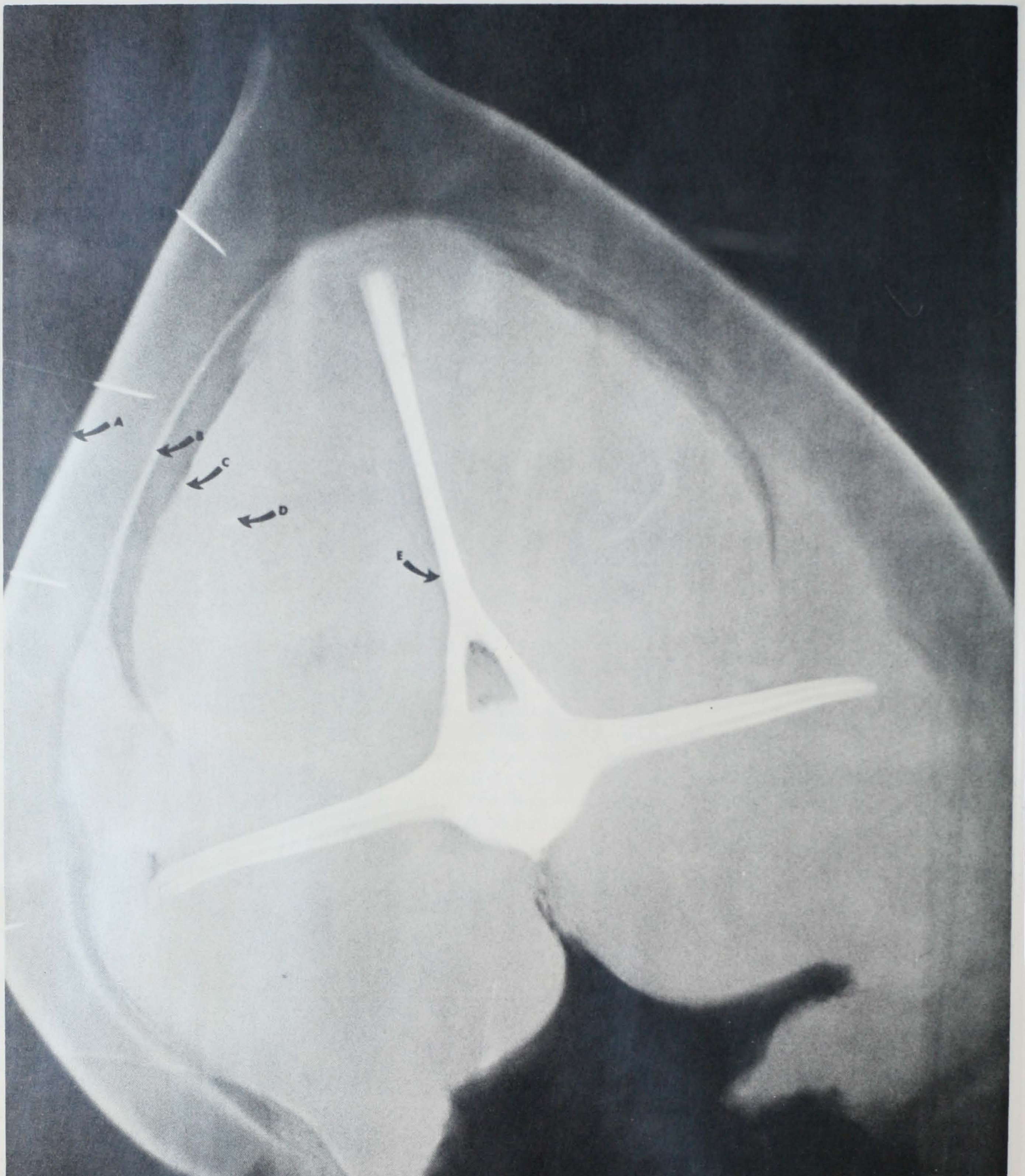
A
B
C
D
E

one could measure the normal thickness in healthy mammals and compare with abnormal animals and any available necropsy specimens.

As a pilot program, echographic measurements were made in both the gray whale, *E. robustus*, and the porpoise, *T. truncatus*. Necropsy correlation in *Tursiops* showed that the measurements were easy to perform and were highly accurate. (Figures 4-8.)

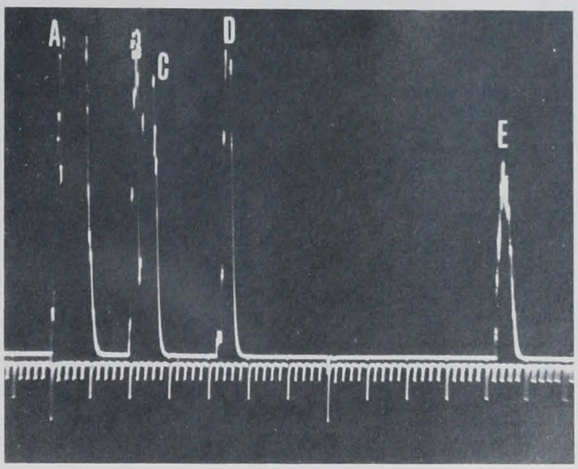

Figure 6.—A-scan of *Tursiops* cross section. Lettered spikes conform to radiographs and tissue boundaries as measured in necroscopy section: (A-B) blubber thickness = 2 cm, (C-D) fat thickness = 1 cm, and (D-E) muscle thickness = 8.2 cm.

Applications

Ideally, to make this method most useful, measurements should be made and necropsy correlation measurements obtained whenever these mammals are found deceased. Due to the expense and shortage of the species, flying a small team to the animal site with the easily portable battery or generator operated scanning equipment should be the most effective means of collecting this invaluable data.

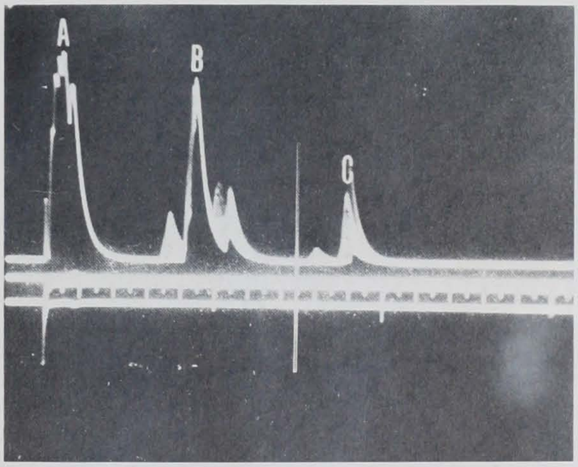

Figure 7.—A-scan of gray whale dorsal-lateral surface posterior to axilla demonstrating blubber thickness of 4.1 cm (A-B) and fat thickness of 4.6 cm B-C). C represents fat-muscle interface.

Further observations on the nutritional status during development comparing captive and free animals, as well as disease effects, should prove to be a new approach to the study of marine mammals. Such research data, if accumulated, may be of great benefit in the protection and treatment of valuable, trained marine mammals and their free swimming counterparts.

CONCLUSION

A-mode echography is an effective means of measurement of tissue layers and should be an effective tool in the study of marine mammal nutrition and health status.

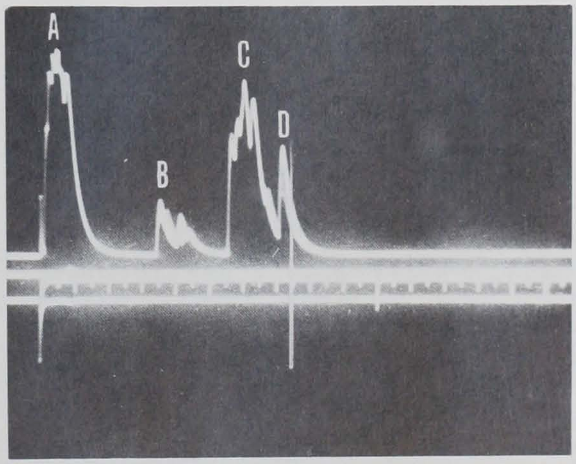

Figure 8.—A-scan of gray whale for polyethylene suture localization. (A) Skin. (B) Blubber-fat interface at 3.5 cm. (C) Polyethylene suture at 5.5 cm. (D) Fat-muscle interface at 7 cm.

Figure 5.—Radiograph of *Tursiops* cross section demonstrating (A) skin-blubber interface, (B) blubber-fat interface, (C) fat-muscle interface, (D) muscle-fascial layer interface, and (E) reflective bone (dorsal spinous process).

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MFR PAPER 1048

Surgical Attachment of a Telemetry Device to the Dorsal Ridge of a Yearling California Gray Whale, *Eschrichtius robustus*

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ABSTRACT

Surgical attachment of an instrument package mounting device onto the dorsal ridge of a yearling female California gray whale, Eschrichtius robustus, *was accomplished through the utilization of four large polypropylene sutures. Use of polypropylene and polyester fabric meshes to induce tissue growth around the sutures was not successful. Post-operative therapy was beneficial in insuring adequate healing at the suture sites. The original polypropylene sutures were replaced the day before release by polyvinyl chloride coated stainless steel.*

INTRODUCTION

In March 1971, an infant female gray whale was captured within Scammon's Lagoon, Baja California, and subsequently transported by boat to Sea World, Inc. in San Diego, Calif. The animal was captured for research purposes, and for the year following her capture, various studies were undertaken.

As the animal approached 1 year of age, the financial burden to Sea World in holding facilities, personnel, and food made it necessary to design a plan for her release. At that time, W. E. Evans, of the Naval Undersea Center, San Diego, proposed (with the support of the National Oceanic and Atmospheric Administration) that the whale be released carrying a telemetry device for tracking and recording.

Evans (1971) has reported the use of radiotelemetry devices attached to the dorsal fin of dolphin, using a bolt placed through the fin. Martin, Evans, and Bowers (1971) have utilized a harness for the fixation of a device onto a pilot whale. A gray whale has no dorsal fin for bolt fixations, and the growth rate of this animal left the harness method undesirable. Therefore, a surgical fixation was considered the method of choice.

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MATERIALS AND METHODS

Sutures composed of 3 mm diameter polypropylene were swaged onto a stainless steel needle made from 3 mm diameter rod shaped into a 10 cm diameter half circle. Polypropylene was chosen because of its inert nature in mammalian tissues (Usher et al., 1962) and because of its availability in the dimensions required. Two types of prosthetic mesh were used in conjunction with the sutures, polypropylene (Marlex®[1]) mesh and polyester fiber (Mersilene®[2]).

Five weeks before the scheduled release, an attempt was made to place polypropylene mesh pads (2 cm × 2 cm) subdermally at the entrance and exit sites of the four proposed sutures at positions on a longitudinal plane 10 cm to either side of the dorsal ridge and 10 cm apart. The intention was to induce collagen fiber infiltration within the fabric to add strength to the skin and to prevent infiltration of water once the sutures were in place. The skin was closed with simple interrupted nylon sutures.

Four weeks before release the four polypropylene sutures, each having had a sheet of polyester fabric attached to it using Eastman 9-10 adhesive,[3] were placed at the proposed sites. Depth of penetration of the sutures was later confirmed by ultrasonography to be from 4 to 6 cm (Curran

[1]Cavol, Inc., Providence, R.I. Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.
[2]Ethicon, Inc., Somerville, N.J.
[3]Eastman Chemical Products, Kingsport, Tenn.