Computed Tomography (CT): A Non-Invasive Technique for Assessing Trauma and Disease in Stranded Marine Mammals

Cramer, S. R.[1], D. R. Ketten[1, 2], J. Arruda[1, 2] M. Yamato[1], R. S. Williams[3], C. Merigo[4], K. Touhey[5], A. Mooney[1]

(1) Woods Hole Oceanographic Institution (WHOI), 266 Woods Hole Road MS 50, Woods Hole, Massachusetts, 02543, USA (2) Harvard Medical School, 243 Charles Street, Boston, MA, 02114, USA (3) National Marine Life Center, 120 Main Street, Buzzards Bay, MA, 02532, USA (4) New England Aquarium (NEAq), Central Wharf, Boston, MA, 02110, USA (5) International Fund for Animal Welfare (IFAW), 290 Summer Street, Yarmouth Port, MA, 02675, USA

INTRODUCTION: Computed Tomography (CT) is an exceptional tool for understanding internal anatomical structure. Two and three-dimensional visualizations of internal structure are valuable data for researchers and clinicians interested in functional anatomy, pathology or forensics. This poster presents an overview of CT scan techniques developed over the last decade for imaging stranded marine mammals. It also provides special protocols for maximizing detection and diagnosis of a range of pathologies, including blunt trauma, hemorrhage, fractures, parasites, temporal bone pathology, emboli and lung pathology. Images with case histories are presented for each condition.

RESULTS:

BLUNT TRAUMA

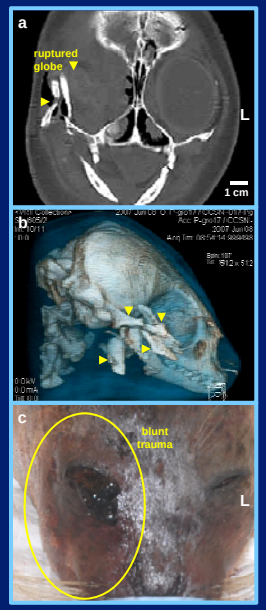


Figure 1. Transaxial CT (a) (bone window; 3mm slice) through the head of a harp seal (*Phoca groenlandica*) with multiple fractures of the right mandible and orbit, and right eye rupture. Volume Rendering Technique (VRT) reconstruction (b) (1 mm slice; 3 mm spiral CT) of the head showing the fractures (arrows) of the zygoma, mandible, and malar bones. Seal (c) prior to CT. Note the edema and ecchymosis along the right mandible and eye and vitreous humor oozing of the right eye. (Specimen courtesy of NMFS/NOAA)

DISCUSSION: BLUNT TRAUMA – This harp seal (*P. groenlandica*) presented post mortem with evidence of blunt force trauma to the side of the head: a ruptured eye, swelling, and contusion. CT scans confirmed underlying fractures.

HEMORRHAGE

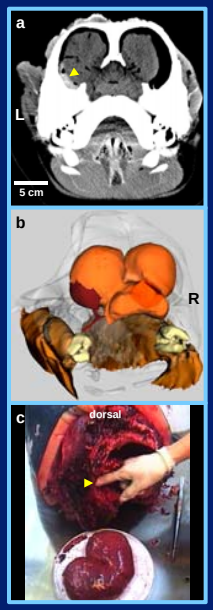
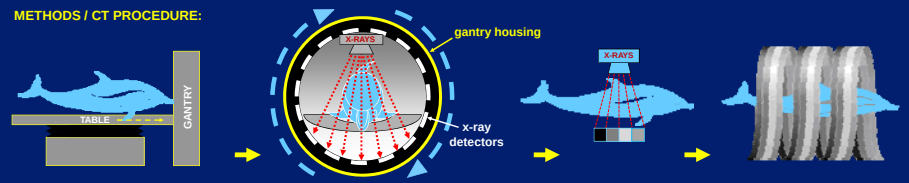


Figure 2. Transaxial CT (a) (soft tissue window; 3 mm slice) through the head of a Blainville's beaked whale (*Mesoplodon densirostris*) with a left temporal fossa intracranial hemorrhage (arrow) (Ketten, 2005a). Tissue reconstruction (b) of the head using 3D Slicer® software shows the hemorrhage (red), the brain (orange), the ear bullae (beige), and the jaw fats (bronze) (Ketten, 2005a). Removal of the brain (c) confirmed the hemorrhage. (Specimen courtesy Bahamas Stranding Network and NMFS/NOAA).

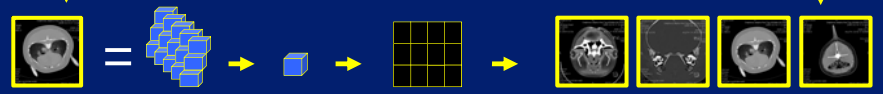
DISCUSSION: HEMORRHAGE – This animal died in a stranding associated with a Naval sonar exercise. The mechanism behind this hemorrhage is unknown at this time but has been reported in beaked whales stranding under similar circumstances.

METHODS / CT PROCEDURE:



The table moves; the gantry spins; x-rays are emitted in a fan array and collected by detectors on the opposite side of the tube; x-rays pass through the body in the form of a helix generating "Attenuation Profiles" (a collection of the signals obtained from all the detector channels at a given angular position of the tube detector unit)

DATA OBTAINED ARE PASSED ON AS ELECTRICAL SIGNALS CORRESPONDING TO THE ACTUAL X-RAY ATTENUATION. SIGNALS ARE DIGITIZED AND TRANSMITTED TO THE IMAGE PROCESSOR



1 CT SLICE | .....a matrix of 1024 x 1024 or 512 x 512 volume elements called "voxels" | .....x-ray attenuation values are calculated for voxels | .....viewed image is reconstructed from a matrix of picture elements (pixels) | .....pixels are assigned a CT number or Hounsfield Unit (HU) based on attenuation values of the voxel ranging from white (densest tissue) to black (least dense/air)

FRACTURES / PARASITES

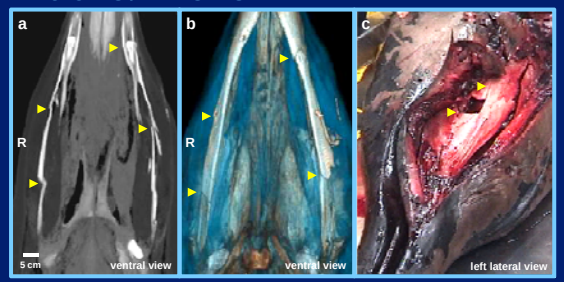


Figure 3. Coronal CT (a) (bone window; 1 mm slice) of a Blainville's beaked whale (*M. densirostris*) with bilateral compound mandibular fractures (arrows) (Ketten, 2002). VRT reconstruction (b) (1 mm slice; 3 mm spiral CT) of the head highlighting the fractures (Ketten, 2002). Jaw fractures were confirmed during necropsy (arrows). (Specimen courtesy Caribbean Stranding Network)

DISCUSSION: FRACTURES – Necropsy of the beaked whale confirmed multiple bilateral, parallel mandibular fractures (Ketten, 2005a). Adjacent contusions on the ventral surface suggested blunt trauma from post mortem handling.

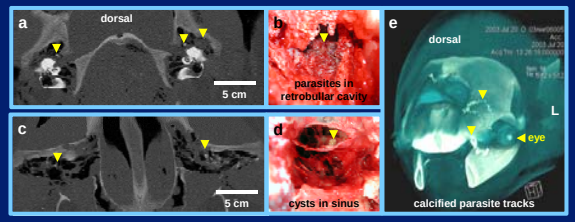


Figure 4. Transaxial CT (a) (bone window; 0.5 mm slice) through the head of a post mortem Risso's dolphin (*Grampus griseus*) with a parasitic infestation (arrows) of the peribullar sinuses. Extraction of the right ear (b) revealed nematodes and cysts (arrow) in the retro bullar cavities. Transaxial CT (c) (bone window; 0.5 mm slice) through the sinus region of the same animal. Dissection revealed calcified cysts (d) (arrow) in the pterygoid sinuses. VRT reconstruction (e) (1 mm slice; 3 mm spiral CT) of the head of a harbor porpoise (*Phocoena phocoena*) with a > 0.5 m calcified parasitic track invading the blubber, muscle, melon and orbital tissues (arrows) (Norman et al, 2004). (Specimens courtesy Woods Hole Aquarium and NWMFS)

DISCUSSION: PARASITES - The parasites observed in the Risso's dolphin (*G. grisseus*) were identified as two species of *Metastrongyles spp*. (T.P. Lipscomb, AFIP). Zucca et al., (2004) also reported findings of *Crassicauda grampicola* infestation in the pterygoid sinuses and peribullar regions of a Risso's dolphin (*G. griseus*). In the harbor porpoise (*P. phocoena*) parasite species identification is pending.

TEMPORAL BONE PATHOLOGY

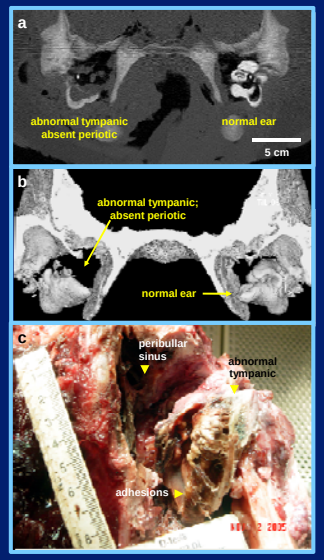


Figure 5. Transaxial CT (a) (bone window; 1 mm slice) through the head of a post mortem beluga whale (*Delphinapterus leucas*) with a right ear anomaly (Ketten, 2005b), including absence of a right periotic bone. Shaded Surface Display (SSD) reconstruction (b) (0.5 mm slice; 1 mm spiral CT) of the right and left ears *in situ*. Right tympanic bone (c) during necropsy. (Specimens courtesy Woods Hole Aquarium, Center for Whale Research, D. Rotstein, and New England Aquarium)

DISCUSSION: AUDITORY PATHOLOGY - The absence of a right periotic bone in this beluga whale (*D. leucas*) may be due to non-development or a lytic process. The normal left ear argues against but does not rule out a congenital defect. The absence of the periotic bone, the pitted and corrupted right tympanic, the extensive calcified adhesions, and dense granular material in the peribullar sinus suggest protracted infection (Ketten, 2005b).

CONCLUSION: The value of CT as a non-invasive, fast, and accurate imaging tool for research and clinical exams increases. We can assess normal and abnormal anatomy with the fidelity required for accurate diagnoses. If more studies team modern imaging with gross observation, dissection, and histological analyses, we can substantially improve our ability to apply this technology to the diagnosis and treatment of conditions in rehabilitation cases. Resolution and speed are improving and with the increasing availability of wider bore machines, better imaging of larger species is becoming feasible for both *in vivo* and necropsy studies.

EMBOLI

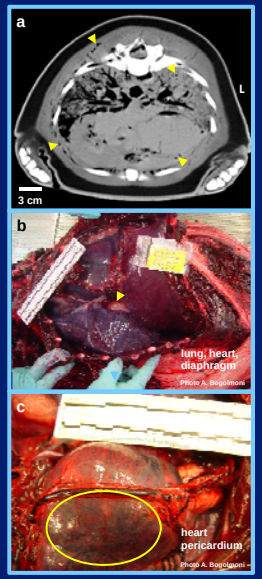


Figure 6. Transaxial CT (a) (soft tissue window; 3 mm slice) through the thorax of a harp seal (*P. groenlandica*). Gas bubbles were observed on CT (a) and in necropsy (b, c) in blood vessels, muscle, lungs, heart, brain, and kidney (Bogomolni, 2007) (Specimen courtesy NMFS/NOAA).

DISCUSSION: EMBOLI - This harp seal (*P. groenlandica*) was entangled in a commercial fisheries gillnet (NOAA/NMFS, 2007). The seal was scanned within a few hours of its recovery. No anaerobic organisms were reported from thoracic and abdominal tissues (Bogomolni, 2007). It cannot be determined whether these emboli formed pre or post-mortem.

LUNG PATHOLOGY

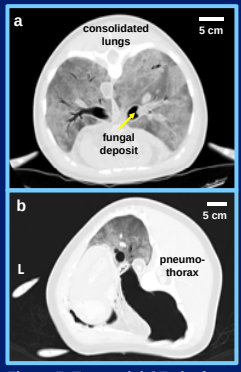


Figure 7. Transaxial CTs (soft tissue windows; 1 mm slices) through the thoracic cavities of a harbor porpoise (a) (*Phocoena phocoena*) with evidence of parenchymous inflammation (arrow) and bilateral lung consolidation and an Atlantic white-sided dolphin (b) (*Lagenorhynchus acutus*) with a pneumothorax (Specimens courtesy Cape Cod Stranding Network and NWMFS).

DISCUSSION: LUNG PATHOLOGY – A significant proportion of cetaceans diagnosed with bacterial or viral respiratory tract problems exhibit pulmonary abscesses subsequent to heavy parasite infestation (Dunn, 2001). Pneumonia and or pneumothorax may also be secondary pathologies to inhalation of chemicals, trauma to the chest wall, and a small minority to rickettsiae, fungi, and yeasts.

REFERENCES: References listed on poster handout

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