Arteriovenous patterns in beaked whales

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LONG-TERM GOALS

There were two discrete research goals:

1) To provide a clear picture of the vascular anatomy in beaked whale heads that will enhance our understanding of the basic biology of beaked whales and act as a baseline from which future morphological (e.g. acoustic pathways), pathophysiological (e.g. decompression sickness and embolus formation) and mathematical modeling (e.g. diving nitrogen kinetics) research can evolve. To conduct a preliminary histologic examination of tissues associated with the extramandibular fat body (EMFB), intramandibular fat body (IMFB) and pterygoid venous lake.

2) To describe the vascular morphology of the pulmonary system in bottlenose dolphins and investigate the presence of anatomic intrapulmonary shunts. Results may help inform future models of pulmonary shunting used for mathematical modeling of diving nitrogen saturation levels in cetaceans.

OBJECTIVES

The first objective of the research was completed. The objective was to describe and better understand the gross morphology of the blood vessels in the heads of beaked whales. Gross anatomical findings and contrast angiographic imaging obtained during the first year of the research were to be supplemented with microscopic examination of vascular structures of interest (e.g. pterygoid venous lake and intramandibular fat body). The final products were to be published in a peer-reviewed scientific journal and presented at the Society for Marine Mammalogy 20th Biennial Marine Mammal Conference, Dunedin, NZ.

The second objective of the research was to investigate the vascular morphology within the lungs of bottlenose dolphins (and beaked whales if specimens allowed). The purpose of this investigation was to determine the presence or absence of anatomic intrapulmonary shunts as well as to examine the branching patterns of the pulmonary vasculature.

APPROACH

The approach for the first objective was unchanged from the original report and primarily involved completion of research and publication goals.

The second objective required the acquisition of high quality lungs specimens from bottlenose dolphins (and beaked whales when possible). Lungs specimens were to receive traditional anatomical preparation for vascular corrosion casting, involving flushing of blood clots from the vascular system and injection of casting compound followed by corrosion of soft tissue. Resulting vascular casts were to be imaged via scanning electron microscopy (SEM) and micro-computed tomography (microCT).

WORK COMPLETED

Objective 1
Owing to the large number of findings resulting from the research conducted for Objective 1, the findings were prepared as two companion manuscripts and submitted to the Journal of Morphology for publication. Following peer-review, both manuscripts have been accepted for publication and because of their size will be published as companion papers in an issue dedicated to them and including the coverpage (Costidis and Rommel, 2016a; 2016b).

Objective 2
The second objective of the research was started but encountered significant delays. Due to a prolonged and geographically extensive morbillivirus mortality event plaguing bottlenose dolphins along the East coast of the U.S., quality lung specimens were not accessible. Primary tissue targets for morbillivirus infections are the lungs and central nervous system. Pulmonary sequelae observed in specimens commonly involved severe pulmonary congestion, bronchopneumonia and moderate to severe diffuse to coalescing, multifocal emphysematous bullae. Vascular congestion often resulted in extensive blood clotting of pulmonary vasculature. These pulmonary pathologies rendered all fresh specimens obtained unusable. Due to these complications, a no-cost extension was requested to facilitate continuation of the research to completion. Due to the extended nature of the mortality event, salary funds were exhausted and the PI was forced to relocate, after which additional challenges where encountered regarding the use of appropriate facilities at which to conduct the research. The PI has since resolved those challenges and has obtained a no-cost extension to allow for completion of the research. To date, the PI has performed a corrosion cast on one bottlenose dolphin lung and imaged it using microCT. Data obtained from microCT were post-processed using Amira software to examine the level of resolution and the success of the casting compound in perfusing alveolar blood vessels. Two additional lung samples have been obtained and are awaiting injection of casting compound. With the remaining funds the PI will purchase the materials required to complete the research and continue the research protocols over the duration of the no-cost extension.

RESULTS

Objective 1
Costidis, A.M. and Rommel, S.A. (2016a) The Extracranial Arterial System in the Heads of Beaked Whales, with Implications on Diving Physiology and Pathogenesis (In press: Journal of Morphology).

Costidis, A.M. and Rommel, S.A. (2016b). The Extracranial Venous System in the Heads of Beaked Whales, with Implications on Diving Physiology and Pathogenesis (In press: Journal of Morphology).

Objective 2
Owing to the preliminary nature of the pulmonary research, the only results obtained thus far are procedural improvements for corossion casting of the remaining samples.

IMPACT/APPLICATIONS

The findings from the research conducted for Objective 1 could have wide ranging applications. The two publications currently in press will provide the most comprehensive information published to date on vascular patterns in the heads of any cetacean, including the most commonly studied delphinid species. The anatomical details about the vascular anatomy can provide researchers with vascular access points for future physiological, medical or functional experiments. The detailed knowledge of the vascular anatomy can also allow for more informed interpretations of circulatory-related pathologies (e.g., embolization) and more targeted sampling of tissues. We were able to identify novel vascular structures previously undescribed in cetaceans such as what appears to be a cavernous tissue body within the bony nasal passages that may be capable of engorging with blood. We also identified expansive pterygoid venous lakes unique to beaked whales and demonstrated their dynamic response to inflation of the adjacent pterygoid air sacs as a possible functional role in pressure equilibration during diving.

Owing to the preliminary nature of the pulmonary research, its impact cannot yet be assessed.

RELATED PROJECTS

A grant proposal was submitted requesting funds to study the gross morphologic and histologic details of the extensive endotracheal venous plexus of cetaceans. This plexus has only received cursory mention through histologic imaging. The pathways and/or mechanism of filling and emptying of the plexus are unknown, as are other important characteristics such as it's volume and extent. Such data are crucially important as they have the potential to affect numerous pulmonary processes such as pulmonary airway compliance, gas absorption, and volume of pulmonary "dead" space.