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Case Report

Nebulization Therapy in a Rehabilitated Florida Manatee (*Trichechus manatus latirostris*): Thermoregulatory Support and Possible Ecological Applications

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Abstract

Florida manatees (*Trichechus manatus latirostris*) are susceptible to morbidity and mortality from cold exposure, known as Cold Stress Syndrome (CSS), when their aquatic environments measure below 20°C for extended time periods. Clinical data from a rehabilitated Florida manatee affected by CSS demonstrate how a novel nebulization therapy was used to increase the efficacy in delivering antibiotic and bronchodilation drugs resulting in clinical resolution and eventual release of a manatee with secondary pneumonia and persistent hypothermia. Treatment in the nebulization chamber over the course of several weeks also resulted in the manatee normalizing its body temperature in addition to specifically resolving the respiratory disease. Based on the resolution of the hypothermia, we hypothesized that the respiratory system may be an under-appreciated modality of thermoregulation in manatees. Data obtained from the rescue staff also support the concept that respiratory heat exchange plays an essential role in the thermoregulation of manatees in Florida. As a result of these clinical and anecdotal findings, a floating polyurethane portable greenhouse prototype has been constructed that will passively warm the air above the surface of the water. Preliminary findings show that a simply constructed floating greenhouse can elevate the ambient air temperature that the manatee could potentially breathe by approximately 4 - 5°C. Expanding this floating greenhouse concept to an environmental scale, it is possible that a warm air refuge, in contrast to a warm water refuge, can be designed and implemented to mitigate excessive morbidity and mortality due to CSS in Florida manatees. With fossil fuel powered electrical plants being phased out in Florida, this passively powered refuge can have significant conservation impacts on manatee populations.

Keywords: *Florida Manatee; Trichechus manatus latirostris; Cold Stress Syndrome; Thermoregulation; Nebulization; Warm Air Refuge; Warm Water Refuge; Manatee Conservation*

Abbreviations

TLPZ: Tampa's Lowry Park Zoo; FWC: Florida Freshwater Fish and Game Commission; CSS: Cold Stress Syndrome; UME: Unusual Mortality Event

Introduction

Florida manatees (*Trichechus manatus latirostris*) are susceptible to morbidity and mortality from cold exposure, known as Cold Stress Syndrome (CSS), when their aquatic environments measure below 20°C for extended time periods.

Case Report

In December 2014, a 141 kg, juvenile female Florida manatee presented to Tampa's Lowry Park Zoo (TLPZ) in poor body condition, with epidermal sloughing, and hypothermia with an oral temperature of 87°F (30.6°C) with 96°F (35.6°C) considered normal [1]. The manatee was treated according to standard protocols at TLPZ that consisted of ceftiofur crystalline free acid (7 mg/kg SQ; Excede™, Pfizer, Inc. 235 East 42d St. New York, NY 10017) and ketoprofen (2 mg/kg; Ketofen™, Zoetis Inc., Kalamazoo, MI 49007). This and all manatees diagnosed with CSS are housed in a pool of freshwater heated to approximately 86°F (30°C). Several days after admittance follow up biochemistry and haematology revealed an elevated high white blood cell count (12530/uL; in house reference 5700 - 9000/uL), hypoglycemia (39 mg/dl; in house reference 55 - 80 mg/dL), hypoalbuminemia (2.9 mg/dL; in house reference 4.2 - 5.3 mg/dL), hyperglobulinemia (5.0 mg/dL; in house reference 2.25 - 2.85 mg/dL), hypocalcemia (8.5 mg/dL; in house reference 10.35 - 11.36 mg/dL), and hypophosphatemia (8.6 mg/dL; in house reference 4.2 - 5.5 mg/dL). Radiographic and ultrasonographic exam of the lungs were consistent with pneumonia. The manatee appeared heavy in the water and surfaced to breath with an exerted effort. Tulathromycin was administered (2.5 mg/kg x3 q7d SQ; Draxxin™ Zoetis Inc., Kalamazoo, MI 49007) and is a standard therapy for resistant pneumonia in manatees at TLPZ, but this did not result in clinical improvement. Danofloxacin (2.5 mg/kg x7 q3d SQ; Avocin™, Pfizer, Inc. 235 East 42d St. New York, NY 10017) was also added to the therapy. Eggs of the trematode *Moniligerum blairi* [2] were noted on parasitological evaluation. Treatment consisted of 20 mg of moxidectin (Quest Gel, Zoetis 10 Sylvan Way Parsippany NJ, 07054) given *po* at diagnosis and 14 days later. Despite a slight improvement of food intake, there was no resolution of hypothermia nor improvement of body condition. Furthermore, nasal discharge was frequently observed.

Several sheets of Plexiglas™ (122 cm X 244 cm) were taped together in accordion fold fashion to provide a cover over the one meter deep channel connecting two medical pools shown in figure 1. A lettuce feeder was placed directly below the insertion of an off the shelf vaporizer to allow the manatee to breathe the medication more directly when surfacing. A combination of five mL n-acetylcysteine (Acetylcysteine 20%, Cumberland Pharmaceuticals, Inc, 2525 West End Ave, Suite 950, Nashville, TN 37203) 500 mg amikacin (Amikacin, Bedford Laboratories, Bedford, OH 44146), and 1 mL albuterol (Albuterol sulfate Inhalation Solution, 0.5%; Bausch and Lomb, Bausch and Lomb Incorporated, Tampa, FL 33637) was nebulized for one hour twice daily for three weeks. During this time there was a marked decrease in nasal discharge, normalization of haematological and serum biochemistry values, and a normalization of core body temperature. Weight gain occurred during this treatment and continued to increase exponentially. Nasal discharge completely resolved as well as radiographic ultrasonographical evidence of respiratory disease. The manatee was evaluated for release per standard protocols and was returned to the wild after 8 weeks of therapy.

Figure 1: *Plexiglass taped together and placed over transfer channel connecting medical pools. Condensation demonstrates the trapped warm air provided by the heated pool originating from the pool in the lower right corner of the picture (not shown). Nebulizer shown is commercial over the counter product readily available in pharmaceutical outlets.*

A nebulization chamber may provide a practical, inexpensive adjunctive therapy to non-responsive pneumonia in manatees, and perhaps other marine mammals. In addition to delivering medication deep into the respiratory tract, the trapped air is warmer than the ambient during the time of year when CSS affects manatees. The rehabilitation pools are heated and in this instance the water was warmed to 86°F (30°C). During this case the typical ambient air temperature was 57°F (13.9°C). The ambient air measured approximately 2.5 cm above the surface of the heated pool was 63°F (17.2°C) while the air at the same distance above the water in the nebulization chamber was 73°F (22.8°C). The resolution of hypothermia in this manatee because of the nebulization therapy raises some intriguing concepts about thermoregulation via respiratory exchange in this species that may prove useful in clinical settings and perhaps in larger scale cold stress events in manatees. Previous evaluations of thermal exchanges between manatees and their environment focused on cutaneous exchange and heat flux windows [3]. Additional support for a larger role of the respiratory system can be found during the rescue and transportation of cold stressed manatees. Approximately 90% of the manatees presented to TLPZ are rescued and transported by the Florida Freshwater Fish and Game Commission (FWC) from the Sarasota, Charlotte, Lee, Collier and Monroe counties in southwest Florida [4]. The response team in that area have adopted a rescue method in which they will cover the affected manatee with an emergency thermal blanket. These thermal blankets serve as an additional insulatory layer and shield the patient from conductive heat exchange with the environment. These blankets are used in field responses and in the transport vehicles (Figure 2). During transport the ambient air is warmed with the vehicle's heater. Oral temperatures are collected routinely at the time of rescue, during transport and again upon arrival to TLPZ. Table 1 shows a subset of manatees rescued and transported in such a fashion. The thermal blankets as applied have negated the heat flux described in manatees [3] and the only explanation for the consistent increase in body temperature is via ventilatory air exchange. Further exploration into the role of ventilatory heat exchange has begun by measuring nostril temperatures of manatees [5]. Temperature measures of the air exchanged may be more valuable but technically challenging. Esophageal temperatures have recently been described as providing a more reliable indicator of core body temperature in manatees [1]. Previous to this, oral temperatures had been the accepted standard and if done consistently provide relative temperature changes as noted here.

Figure 2: *Left image: Florida manatee rescued due to CSS with emergency rescue blanket in the field awaiting transport. Right image: Florida manatee with emergency thermal blanket in heater transport vehicle with oral temperatures monitored. Photos courtesy D. Boyd.*

Manatee Identification	Oral temperature at rescue	Oral temperature at admission
102883	78°F (25.5°C)	83°F (28.3°C)
102884	82°F (27.8°C)	89°F (31.7°C)
102885	86°F (30°C)	91°F (32.8°C)
102898	87°F (30.6°C)	91°F (32.8°C)

Table 1: *Oral temperatures of a subset of Florida manatees rescued from the southwest coast of Florida and transported to TLPZ. All manatees were rescued and transported with emergency thermal blankets as described above.*

In addition to the clinical utility of using trapped warm air in a clinical setting, trapped air may be applied on a landscape level and could provide a warm air-refuge for Florida manatees. Currently power plant discharges are leading sources of warm water refuges for manatees in southwest Florida and along the Atlantic coast [6]. Many of these power plants are due to close due to outdated technology or high operating costs and manatees who have relied on these warm water refuges are not likely to move long distances to find other warm water sites [6]. Wildlife managers have been tasked to enhance protection for other warm water sites. One possibility based on the clinical experiences with warm air and manatees with CSS is to develop a warm air refuge for manatees associated with existing warm water refuges. The concept of chamber nebulization can now be expanded into a floating greenhouse.

Method

A pilot project was conducted to measure the potential change in ambient air temperature that a passively heated greenhouse could develop while floating. A 68 cm X 68 cm X 79 cm commercially available indoor/outdoor greenhouse (EcoDauer Mini Pop-Up Greenhouse Cover for Outdoor Indoor Backyard Grow Tent Small Portable (27''x 31'') was retrofitted with pool noodles to allow it to float. Waterproof tape was used to seal all the connections between cloth and polyurethan as well as all zippered margins. A 4.5 kg anchor was tethered to the greenhouse and it was moored in 1m of water off the beach (Figure 3). Air temperatures and humidity were measured remotely (Inkbird Wireless Thermometer Humidity and Temperature Monitor, IBS-TH2 Freezer Thermometer Bluetooth Temperature Sensor Smart, with APP for Android and iOS Temperature and Humidity Sensor) and water temperatures collected with a commercial aquarium thermometer (Zacro LCD Digital Aquarium Thermometer Fish Tank Water Terrarium Temperature). Data was collected at five-minute intervals on two separate days in the Gulf of Mexico waters of Ft. DeSoto County Park in Pinellas County Florida.

Figure 3: *Floating greenhouse as modified and anchored just offshore at Ft. DeSoto Park, Pinellas County Florida.*

Results

Data is summarized in table 2. Water and air temperatures remained constant during the data collection period, so the data is truncated to 10-minute intervals for display purposes. The temperature difference between inside the greenhouse and the ambient air temperatures was between 4 - 5°C. Humidity increased on both testing days with a greater increase on the colder day. Condensation was noted in both study days at approximately 20 minutes elapsed time.

1/30/2022 Start time 4:15:00 PM								
Time Intervals (minutes)	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**Average**
Surface water temp. (°C)	13.9	14.1	14.2	14.1	14.1	14.1	13.9	14.0
Water temp. 33 cm deep (°C)	13.3	13.4	13.4	13.4	13.4	13.4	13.2	13.3
Inside greenhouse air temp (°C) @15 cm	15.2	16.4	16.3	16.8	16.5	16.4	16.3	16.3
Outside air temp. (°C)	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
Outside greenhouse humidity %	34.0	35.0	35.0	36.0	36.0	38.0	38.0	40.0
Inside greenhouse humidity %	77.5	74.2	74.2	73.8	74.6	76.3	75.6	75.2
2/12/2022 Start time 14:20								
Surface water temp. (°C)	18.1	17.7	17.6	17.6	18.2	17.7	18.2	17.9
Water temp. 33cm deep (°C)	16.4	16.6	16.5	16.6	16.7	16.8	16.9	16.6
Inside greenhouse air temp. (°C) @15 cm	24.9	24.5	24.4	24.5	24.8	24.6	25.1	24.7
Outside air temp. (°C)	20.0	20.0	20.6	20.6	20.6	20.6	20.6	20.4
Outside greenhouse humidity %	53.0	52.0	52.0	52.0	52.0	52.0	51.0	52.0
Inside greenhouse humidity %	63.2	65.8	66.3	65.7	66.3	65.7	65.1	65.4

Table 2: *Temperatures in degrees celsius and humidity (%) on two separate days collected from floating greenhouse. Air temperatures from inside to outside the greenhouse are approximately 4 - 5°C. Data was collected every five minutes, but only 10-minute intervals are shown.*

Discussion and Conclusion

The combined experiences of utilizing thermal blankets and transporting manatees in heated vehicles as well as treating manatees in a modified nebulization chamber demonstrate the potential that ventilation has in the thermoregulatory management of Florida manatees. This underappreciated modality of heat exchange in manatees has led to the concept of providing a passive source of warmed air for manatees in the winter. The simple pilot project presented here demonstrates that a floating greenhouse will in fact raise the air temperature inside it. A manatee then breathing this warmed air can potentially stave off the effects of CSS longer if such a buffer was not available. This raising of the ambient air available to a manatee has the distinct advantage of not involving any fossil fuels to heat water. In a manatee rehabilitation center trapping this warm air as it rises off heated water can translate into less energy utilized to warm water. On an ecological scale a floating greenhouse as conceptualized in figure 4, placed in the current warm water refuges provided by power plant can complement the warmth provided. A mobile structure can then be moved further away seasonally to allow manatees to acclimate to a new warm air refuge. This would then accommodate the concerns that manatees are reluctant to move away from learned warm resources.[6] Such floating structures could also be used in natural warm water refuges to expand capacity at these sites. These structures could be designed and constructed to be used on temporary basis during extended cold events to provide sanctuary from CSS during unusual mortality events (UME) related to cold. Before implementing on such a scale consideration to air exchange and respiratory pathogens needs to be considered. Additions such as fans, ventilations exhaust, and air flow design considerations should be explored to allow for room air exchange. This would balance warm air with potential pathogen accumulation and buildup of carbon dioxide. Forced heated air could even be utilized in some situations. Nebulization chambers, and especially neonatal intensive care units, have these design components in place and could be used as models to adapt on a larger scale.

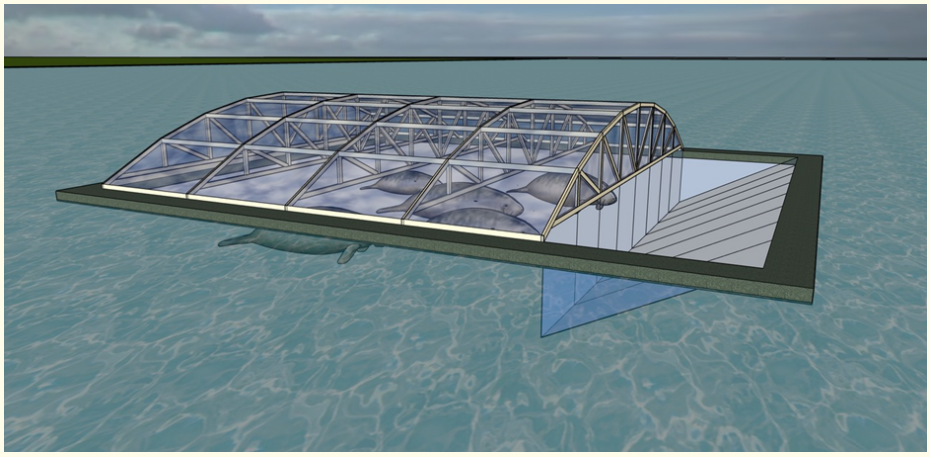

Figure 4: *Conceptual rendering of floating greenhouse designed to provide warm air refuge for Florida manatees.*

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