1964 #13

ACID-BASE CHANGES DURING DIVING IN THE HARBOR SEAL, Phoca vitulina

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Six young female harbor seals were studied following a period of training to adapt them to diving under laboratory conditions. An arterial catheter was placed in a branch of femoral artery and advanced into the aorta, using procaine for local anesthesia. Arterial blood was sampled at intervals during the control period, during six minute dives, and during the post-dive period. Measurements of arterial $PaCO_2$, pH, PaO_2, SaO_2, and lactate concentrations were obtained sequentially. During the dive, there is a small but progressive rise in PCO_2 and fall in pH. Arterial oxygen tension and saturation decrease. Lactate concentrations show minimal degrees of elevation. Thus the major acid-base abnormality during the dive is respiratory acidosis. In the immediate post-dive period there is marked hyperventilation and CO_2 is lost in excess of its metabolic generation and in excess of the CO_2 accumulated during the dive. Blood O_2 stores are rapidly replenished during the immediate post-dive period so that blood PO_2 rapidly returns to normal. Lactic acid levels rapidly rise as perfusion is restored to peripheral vascular beds. The vector effect on pH between the respiratory alkalosis caused by hypocapnia and the metabolic acidosis caused by lactate accumulation is a net decrease in arterial pH.

These complicated changes in respiratory gas and acid-base metabolism do not return to pre-dive levels following a six minute dive for periods up to one hour. This finding suggests a substantial time lag between occurrence at intracellular sites where gas metabolism actually occurs and the reflection of these events in arterial blood.

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STUDIES IN THE DIVING SEAL, GAS PATTERNS IN EXTRADURAL VEIN BLOOD

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The large extradural vein found in the harbor seal, Phoca vitulina, was described by Harrison (School Science Review, 1957) and has been thought to be the route of venous return from the head. By this route venous blood draining the cranial vault would return to the inferior vena caval system via the renal venous plexus. Attempts were made to obtain dye dilution cardiac output curves during diving by injecting Indocyanine green as a bolus into the extradural vein. Blood samples from an aortic catheter did not inscribe a dye dilution curve. Accordingly it did not appear that the extradural vein system was in the active circulatory circuit during diving, or that the dye entered into such a large reservoir that the recording of a dye dilution curve would have been masked.

To evaluate the anatomical function of the extradural venous system aortic blood samples and extradural vein blood samples were collected in the control state, during diving, and during the post-dive period. The arterial-venous oxygen difference remained unchanged or decreased during the period of diving. During the post-dive state arteriovenous oxygen difference increased

in all three seals studied. The magnitude of the arteriovenous oxygen differences were so small that it appeared unlikely that blood in the extradural vein was draining a site of active oxidative metabolism during diving.

In addition, the lactic acid concentration in one of the seals showed a rise in the extradural vein samples indicating that the site of origin of blood in the extradural vein had been a locus of anaerobic glycolysis.

These findings suggest that the extradural venous system is not the major route of venous drainage for the brain. The precise anatomy of this venous system and its function require further elucidation.

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CARDIAC OUTPUT DETERMINATIONS IN THE DOGFISH, Squalus acanthias, USING INDICATOR DYE CURVE TECHNIQUE

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Although the functional aspects of gas exchange in an aquatic media are of considerable biological interest, progress in quantitation of these parameters has been limited by methodological problems. A number of techniques have been utilized to approximate cardiac output in fish but have been handicapped by requiring unwarranted assumptions or by the necessity of manipulations of the animal that alter physiological status.

A modification of the dye dilution technique for measuring the cardiac output of the elasmobranch, Squalus acanthias makes available a method for quantitation of cardiac output in fish without altering the physiological state of the animal. In the present studies arterial blood was sampled via a catheter inserted into the dorsal aorta through a thin-walled excentrically tipped needle. Venous injection was performed into the duct of Cuvier. Indocyanine green was injected as a bolus into the duct of Cuvier and arterial blood was sampled by the dorsal aortic catheter using an automatic sampling and recording densitometer (Gilford). Cardiac output was calculated from the down slope of the dye dilution curve.

A total of 26 fish weighing between 1.3 and 7.0 kilograms were studied shortly after being obtained by trawl. The mean "resting" cardiac output was 1.60 ± 1.00 L/Kg/Hr. The oxygen consumption averaged 48.1 ± 34 ml/Kg/Hr, and carbon dioxide production averaged 33.3 ± 26 ml/Kg/Hr. The respiratory exchange ratio averaged 0.98 ± 0.1. "Resting" data were designated instead of "basal" conditions since the animals were swimming in place in an upright position. Accordingly the work of breathing and the work of maintenance of position must be considered in these "resting" values.