OVERVIEW OF THE NAVY DIVING BIOMEDICAL RESEARCH AND DEVELOPMENT PROGRAM

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Summary

The objectives of the Navy Diving Biomedical Research and Development Program are to provide biomedical technology to support all Navy manned diving operations, to increase the safety and efficiency of divers at current operational depths, and to provide physiological information that will allow Navy divers to perform useful work at deeper depths for longer periods of time. The major thrusts of the program are:

- o Development of safe and efficient decompression procedures for air, mixed gas, and saturation diving.
- o Development of biomedical criteria for design of underwater breathing apparatus and for thermal protection of divers.
- o Development of improved therapies for decompression sickness and air embolism, and the development of improved capabilities for the safe use of oxygen in diving and in treatment of diving accidents.

Past accomplishments and future thrusts of the program are illustrated.

Objectives

The Navy program in diving biomedical research and development is administered by the Naval Medical Research and Development Command, with funds provided by the Chief of Naval Operations (OP-23), Chief of Naval Research, and Chief of Naval Development. The objectives of the program are:

- o To provide the biomedical technology to support all Navy diving operations
- o To increase the safety and efficiency of divers at current operational depths
- o To provide physiological information that will allow useful work to be performed at deeper depths for longer periods of time

Task Descriptions

This program addresses the biomedical problems of submarine rescue, salvage, underwater demolition, explosive ordnance disposal, special warfare operations, underwater construction, and other manned underwater operations. The content and priorities of the program are defined by specific Navy operational requirements. Currently, the program is divided into three major task areas. These are:

- o Decompression Procedures
- o Biomedical Criteria for Diver Equipment Design
- o Diver Health and Safety

The tasks of Decompression Procedures are to investigate the effects of inert gases under pressure on cellular and tissue systems, to define the environmental conditions that increase the incidence of decompression sickness, and to develop safer and more efficient decompression procedures for air, mixed gas and saturation diving. This work includes basic studies of inert gas solubilities in animal tissues, studies done at the small animal level to determine the effects of oxygen, temperature, etc. on the incidence of decompression sickness, and animal and human studies of inert gas uptake and elimination that are being used to construct new mathematical models for the design of decompression tables.

Tasks pertaining to Biomedical Criteria for Diver Equipment Design are to develop biomedical criteria for underwater breathing apparatus and to develop biomedical criteria for the thermal protection of divers. This work includes studies of breathing mechanics under submerged, dense gas conditions, methods to facilitate dense gas breathing, and studies to quantitate regional and total body heat loss of divers.

The tasks of Diver Health and Safety are to develop improved therapy for decompression sickness and air embolism, and to develop improved capabilities for the safe use of oxygen in diving and in the treatment of diving accidents. This program is designed to improve treatment of diving casualties through development of new treatment tables, development of new drugs to be used as adjunct therapy, and definition of central nervous system and pulmonary oxygen limits.

Facilities and Performers

The US Navy Diving Biomedical Research and Development Program is conducted at two in-house laboratories, the Naval Medical Research Institute and the Naval Submarine Medical Research Laboratory. In addition, part of the program is conducted under contract at three university centers, The State University of New York at Buffalo, the University of Pennsylvania, and Duke University. The lead laboratory for the program is the Hyperbaric Research Facility at the Naval Medical Research Institute. This recently completed facility contains a number of laboratories for animal and human research, as well as a man-rated chamber complex consisting of five interconnected pressure chambers capable of supporting prolonged human diving experiments to simulated depths of 3400 feet of sea water. This laboratory, which has been built at a cost exceeding \$22 million, presently has a staff of 22 civilian and military scientists and a support staff of 80 people, including 45 US Navy divers.

Recent Accomplishments

Some of the recent accomplishments of the program will illustrate the types of projects that are being pursued and the potential benefit to the Navy. For example, recent studies conducted at the Naval Submarine Medical Research Laboratory have established safe surface interval times for decompression from saturation air environments. These results will be used to develop safe procedures for rescue of personnel from a disabled submarine that is internally pressurized.

Work at the Naval Medical Research Institute (NMRI) has defined the effects of diving, decompression sickness, and recompression therapy on fetal development in animals. This investigation was begun because the Navy now has women divers, thus there is concern about the effects of diving on the fetus and the effects of pregnancy on susceptibility to decompression sickness. The development and validation of techniques for using cutaneous heat flow sensors to calculate accurately regional and total body heat loss of divers was also recently completed at NMRI. These results will aid the design and testing of new thermal protective garments for divers.

Other efforts at NMRI have been directed toward finding better methods to treat serious decompression sickness and air embolism. Recently, NMRI investigators found a new drug combination to facilitate the recovery of neurological function after air embolism in animals. This drug combination, now being tested in clinical trials, may be beneficial for patients suffering the effects of serious diving accidents. Yet another study has explored new recompression profiles for treating spinal cord decompression sickness. Results from this animal work have shown that the use of oxygen at shallower depths is more effective in restoring neurological function than the standard recompression therapy of air at 165 feet of sea water. Although additional work is necessary to validate these findings, we expect these efforts to lead to new and more effective treatments for decompression sickness and air embolism.

Future Thrusts

In the future, the Navy Diving Biomedical Research and Development Program will continue to pursue current program objectives and tasks, and to expand these as new operational needs are defined. The program will capitalize on technologies that are newly available to accelerate progress in each of the three task areas. Some of these new technologies and their applications are illustrated below. In the Decompression Procedures task area, the newly available techniques for creating radioactive nitrogen by high energy x-ray are being used to study uptake and elimination of inert gases in human subjects. For the first time, this new technology permits the mapping of nitrogen uptake and elimination in specific body areas in human subjects. This work, in combination with other studies of inert gas kinetics and bubble formation, will allow construction of mathematical models for decompression that are based on firm physiological

evidence rather than on the purely theoretical considerations used in the past. Safer and more efficient decompression tables for a wide variety of diving scenarios will result from this effort. In Biomedical Criteria for Diver Equipment, a new technique has been developed to study the ventilation of divers without adding additional resistance to their breathing. The system utilizes magnetometers placed on the diver's chest and abdominal walls to measure ventilation over a wide range of conditions. It is being used to measure the effects of immersion, breathing dense gas, and external resistances imposed by underwater breathing apparatus on the diver's ventilatory system. This work will provide a basis for improving underwater breathing equipment and thus, improving diver performance at depth.

Another new technique is being evaluated to facilitate breathing at deeper depths. High-frequency, low-amplitude oscillations of a diver's breathing gas are being studied as a means of decreasing the work of breathing and increasing gas exchange in the lung. This technique offers the possibility of reducing the energy requirements of breathing and increasing work tolerance at depth.

In Diver Health and Safety, new techniques are being used to map the interaction of blood components with damaged tissue in the brain following cerebral air embolism. These studies use radioactively-tagged platelets and leukocytes to determine their role in causing decreased blood flow and neurological injury following this type of diving accident. An improved understanding of the mechanisms of damage will allow more effective therapeutic measures to be developed.

New techniques are also being used to determine the effects of oxygen exposure on lung function. In both animals and human subjects, the metabolic activities of the lung are being measured as an early indicator of pulmonary oxygen toxicity. Finding a reliable indicator of oxygen toxicity would provide the scientific basis for extending the limits of oxygen exposure for divers.