EDITORIAL

Current Status of Research in Artificial Support of the Circulation

In spite of the significant advances during the last 16 years in the pharmacologic and surgical treatment of heart disease, diseases of the heart and blood vessels remain a significant cause of death and disability in the United States. In 1967, 1,002,111 Americans died from diseases of the cardiovascular system (Vital Statistics, 1967), the majority of these being due to segmental atherosclerosis. An additional datum of importance is that abnormalities of the heart and blood vessels are the most common cause of death for American men under 65, when maximum business and domestic responsibilities occur. Of equal importance is that these diseases accounted for a loss of 540 man-years, the equivalent of about $2.5 million dollars by the labor force, housewives, and others. It is as yet early to define what beneficial effect broad application of the principle of direct surgical restoration of blood flow to the heart's arteries may have on these statistics. When an acute myocardial infarction is accompanied by cardiogenic shock, the mortality remains high, ranging from 40 percent to 100 percent in spite of prompt and effective treatment. The advent of closed-chest cardiopulmonary resuscitation, as recommended by Kouwenhoven et al (1960), and the advent of continuous electrocardiographic monitoring in coronary care units have had a favorable effect on the mortality from acute myocardial infarction, in general, but not in patients with "coronary shock," in particular.

Primarily because of a limited number of suitable donors and the unsolved problem of tissue rejection, cardiac allografts (transplants) do not provide a solution to this problem. That a method for mechanical circulatory (and respiratory) support is a relevant health goal for research in the health sciences needs little justification. Several ingenious methods for mechanical circulatory support of the failing circulation have been proposed and some have been used in man with variable success. These results have suggested that no one method is applicable to all patients.

Since its introduction by Gibbon (1954), use of the heart lung machine for the correction of inborn and acquired heart diseases has become commonplace in medical centers the world over. In response to a questionnaire initiated by the American Hospital Association and reported by Glenn (1970) of 260 cardiac surgical teams in the United States, it was found that 16,000 open-heart procedures were carried out during 1969. Use of the heart lung machine for circulatory assistance rather than for cardiac surgery was first suggested by the late Dogliotti (1952) and has been a matter of abiding interest to the author and his co-workers for the last seven years. During this period, 37 patients have been seen in consultation by the group for the question of mechanical support of the failing circulation, and of these, 33 have been treated with the heart lung machine as a cardiac assistance device in the operating room, in the intensive care unit, in the emergency room, and in the patient's room. Of these, one-half could be resuscitated and one-quarter left the hospital alive. These figures would cast doubt on this technique as a method of treatment of patients were it not kept in mind that in over half the patients the indication for treatment was cardiac arrest unresponsive to usual measures. In general, the indications for this method of treatment have been progressive failure of the heart as a pump using multiparameter physiologic rather than clinical assessment. Of particular importance to surgeons is the concept of use of mechanical circulatory support devices for the preoperative preparation of patients otherwise too ill to tolerate even anesthesia. In a few centers in the country at the present time, mechanical circulatory assistance by a variety of modes has been used in patients with either impending myocardial infarction or with an uncorrectable, ineffective heart rhythm preliminary to special diagnostic x-ray studies and corrective surgery. In our own experience, in nine patients with other kinds of heart disease in whom preoperative mechanical circulatory assistance was nec-
necessary, seven could be resuscitated and four survived.

A clinical research program of this type (as a cardiac surgical program, in general) tends to improve the quality of care for patients with other sorts of illnesses in a general hospital. As these patients, for whom the concept of an intensive care unit was first necessary, has provided over the last decade insight into the needs for mechanical support of breathing, accumulation of acid wastes in the blood, and control of irregular heart rhythm and kidney function in seriously ill patients, and has accrued benefits in the quality of hospitalized patients in general hospitals, to some degree. Indeed, the now popular coronary care unit, in some respects, arose consonant with the demands of a cardiac surgery program for continuous monitoring of heart rhythm.

A program for the development of mechanical devices for short-term or long-term functional replacement of heart and/or lungs in the broadest sense has, therefore, improved survival from heart disease and perhaps more practically improved the quality for many patients who would otherwise have died. In addition, it has improved the quality of care of seriously ill patients with other kinds of medical problems, and third, particularly when extended to address the concept of longterm support (as in an artificial heart device) research and development in this field has highlighted the significant restraints to further development, particularly in the area of new materials non-injurious to blood and other body tissues, as well as that of interaction of the pumping device with the circulatory control systems of the living body. This has been particularly true when attempts to substitute the heart’s entire pumping action for long periods of time, ie, days to weeks, has been attempted. In our own program and in the three others in the country active in the field of total artificial hearts, while individual animals have survived hours to days, eventual death has regularly occurred in a state resembling cardiogenic shock in which the heart, being externally powered, did not participate. Rather than seeking longterm survival at this current state of knowledge, our own research group has sought an understanding of pathophysiologic mechanism through multi-discipline, goal-oriented laboratory investigations in animals. In our own medical center, as in several others in this country and abroad, the research has encouraged joint scientific and educational activity between engineers and physicians. A whole generation of a new type of scientist, the bioengineer, has been developed as a result of such interaction.

Contemporary heart lung machines, while useful for short-term support of breathing and heart function, have deleterious effects on the body tissues, particularly blood, when used for more than a matter of hours. Promising longterm artificial oxygenation devices have been developed and used in animals with survival for a week or longer, and those that have been approved for use in patients have been used in certain patients to support breathing in the presence of acute lung damage. In our own experience, the use of such a longterm oxygenation device permitted maintenance of respiration in one patient for almost four days without serious changes in the blood. The ideal blood-compatible material for longterm use, however, is not yet available. Polymers characteristically have a non-Newtonian stress/strain relationship and the response to chronic longterm stress depends upon molecular organization. Our own program has promoted interaction between physicians and engineers at both the basic science and applied levels in order to gain information regarding the characteristics of the ideal material for use in a biologic environment. This involves both the evaluation of naturally-occurring macromolecules in the body, the use of special laboratory techniques for the characterization of the molecular organization of specific polymer samples, including laser spectrometry, as well as an attempt toward the development of new linings for artificial heart devices, using the individual’s own tissue cells grown in the laboratory in tissue culture. To date, plastic patches in the hearts of animals in areas where normally clot formation would be common have remained free of blood clots for as long as 90 days.

Implanted plastic substances are known to induce cancers of the soft tissues in certain animals. Projecting a need for materials for clinically applicable mechanical circulatory support devices, a portion of our own program now in progress is to relate molecular organization of a given polymer to the development of soft tissue cancers in mice so disposed by heredity.

A related portion of our program of equal importance has been the effect of shear stresses on red blood cells in artificial circulation systems; while outright destruction of red blood cells has been recognized since the advent of artificial heart valves, the shortening of the life span of the formed elements of the blood has been recognized only recently.

In our colleagues’ flow dynamics laboratory, which involves faculty of three universities, work has included studies of the fundamental fluid dynamics associated with healthy, diseased, and
prosthetic heart valves, as well as basic studies of the alteration of fluid dynamics within the normal cardiovascular system. Such studies are basic to an understanding of the fluid dynamics relationships when an artificial blood tube or circulatory assist device is employed.

In the area of control theory, which has involved both engineers and physicians, techniques for recording the output of naturally occurring cardiovascular control systems in the normal animal have been employed with and without the use of artificial circulatory devices. It seems likely that this may serve as a useful control parameter in the future rather than employing arbitrary, man-made control parameters.

Mechanical circulatory assistance has been shown to be extremely relevant to patient care both at the present time and presumably in the future. As a field for further research and development, it is responsive to what remains our number 1 cause of death and disability in America. A significant investment of public funds has already been made in this area over the last decade and identifiable returns in terms of improved survival and quality of life for large numbers of patients have been realized. Further research and development is very much needed in this important field.

John Hines Kennedy, M.D., F.C.C.P.*
Houston

*Taub Laboratories for Mechanical Circulatory Support, Cora and Webb Mading Department of Surgery, Baylor College of Medicine, Houston. Supported by U.S. Public Health Service Grant HE 13330.
Reprint requests: Dr. Kennedy, Baylor College of Medicine, 1200 Moursund Avenue, Houston 77025

The Artist-Statesman Ignace Jan Paderewski (1860-1941)

Born in Kurylowka, Poland, Paderewski entered the Warsaw Conservatory of Music at twelve years of age and obtained his diploma in 1878. From 1887, his career as a pianist advanced as a continuous triumph. His engagements led him throughout Europe. He attracted many friends, including musical greats like Gounod, Saint-Saens, Massanet and Franck. Under the auspices of the House of Steinway, Paderewski landed on American shores in 1891. His debut was at Carnegie Hall. Critics acclaimed him from the start and audiences almost literally carried him triumphantly from the platform. His performances were described as "glittering brilliance of execution," "complete rhythmic awareness," "outstanding re-creative originality." Paderewski traveled across the United States, giving three hundred speeches for the cause of independent Poland. Upon the creation of resurrected Poland, he was named Prime Minister and Minister of Foreign Affairs. Paderewski returned to Switzerland and in 1922, returned to concert life. From his sojourn in Australia he brought back a parrot who made it a habit of perching on his master's foot during practice sessions, exclaiming from time to time, "Oh Lord, how beautiful."

Pilarski, L: They Came From Poland—The Story of Famous Polish-Americans, New York, Dodd, Mead, 1969