Proceedings Second World Symposium Artificial Heart

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Proceedings of the Second World Symposium Artificial Heart

with Comments and Discussions

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Copy editing: E. Hennig and Noreen Flynn

The contents were compiled from original manuscripts and transcriptions of audio tapes of the Symposium and revised in spite of the well-known difficulties of time and response from the respective authors.

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Preface

It is a great pleasure to have the opportunity to publish the proceedings of the Second World Symposium on Artificial Heart Research in the Series Advances in System Analysis.

In the past 5 years, between the First and the Second World Symposium, there have been many changes in the philosophy of Artificial Heart Research and a tremendously rise in knowledge. There have been quite a lot of clinical applications of the left ventricular assist devices, biventricular assist devices and total artificial hearts, worldwide.

In march, 1986, the chairman of the Second World Symposium on Artificial Heart Research, Professor Dr. med. E. S. Bücherl, in Berlin, had done the first implantation of the Berlin Type Artificial Heart, in a 39 years old patient. So this is the right place, and a great honour for me, to express the deepest congratulations to Professor Bücherl for his pioneer research work, in cardiac surgery and artificial heart research.

Moreover I would like to thank Dr. E. Hennig for his great deal in copy editing this book. He never despaired by the well-known difficulties of time and response from the world wide distributed authors. Also I want to thank Mrs. N. Flynn, the associate editor of Dr. Hennig, for her excellent work.

I hope that this volume will give a great stimulation for the future research activities in the field of artificial heart.

Mainz, Mai 1986

Dietmar P. F. Möller
Editor Advances in System Analysis

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Welcome

E. S. Bücherl (Berlin)

E.S. Bücherl (Berlin)

It gives me great pleasure to open the Second World Symposium on Artificial Heart Research here today in Berlin. Sometimes I feel rather like the father of this special research family - as long as Pim Kolff is not present! The big difference, I suppose, is that most members of this family are male and for a good family combination both men and women are extremely important! I think most of you would agree.

I'll try to jog my memory a little and tell you something about the history of this particular family. It was in 1955 after finishing my first extensive research program on extracorporeal circulation that I began to wonder about the next step we were going to take. I thought it was perhaps possible to come up with something more implantable than an extracorporeal heart-lung machine. I started to look around and see what was being done and to find out where I could come across some new ideas and turned to the United States.

In 1956 on my first visit to the USA, starting in Cleveland, I met a tall, good-looking - and in my opinion - quite a famous professor. You all know him, of course, William Kolff. In a room full of plastic molds I came across a rather small man. It was Tet Akutsu. I have a great deal of admiration for this man and must give him lots of credit for having started his research with so much enthusiasm and optimism and for still being very active in this field after such a long time.

Of course, when traveling across the USA, you have to stop in Houston. On my first visit, which was a very short one, I got the impression that something was really going on in that big town. I then met Denton Cooley. At least, he was at that time thinking about the future and the direction we were to go in. A very lively and impulsive fellow, Domingo Liotta, was later with him. As we all well know, they did the first implantation of an artificial heart on a human.

It would take me too long to talk about all the colleagues I met in the USA: Hastings, Kusserow, Sawyer, Kolobow, Nosé, Kantrowitz and later Bill Pierce. On another visit, again in a very small room, I

observed another student who I felt was really enjoying his work. I can now see that such enjoyment can end in success and bring about progress. This young student was, as you have already guessed, Rob Jarvik.

Of course, at that time most of the researchers working in America came from abroad, especially from Japan. The only man I know who has been working from the very beginning till now in Japan is Atsumi. I must say quite frankly that when I first heard his lectures my English was not good enough and I found it quite difficult to follow everything that was said. But in the meantime my English has improved and it has become a lot easier to understand him. Atsumi has contributed greatly to artificial heart research. But, I do believe now that Japan is calling back its researchers to do their valuable work at home.

Coming back to Europe; in the beginning I had a few problems with what was being done in Paris and with the ideas of Lapeyre. It was always difficult to put them into practice but the stimulation one got was superb.

I am very attached to Italy and always like to visit my many good friends there, for example, Luigi Sprovieri. He is not really working on artificial heart research but if you need any information about what is happening in this field from any part of the world then he is the man to ask. The only problem is finding him! He could be in Rome or Sienna or Paris or somewhere else but if you have a good secretary like Mrs Meyer then you are sure to be able to find him. He travels either by car or plane but when traveling by car he does not drive as fast as Provenzale. When I went with Provenzale from Rome to a meeting in Fuiggi I thought we were really flying! We did, however, manage to arrive safely and in one piece. When talking about Italy I should mention a man close to the Pope, Raffaello Cortesini, who unfortunately cannot be here because of other committments.

In Vienna, Wolner and Unger have been doing very good research. I have also a great deal of admiration for Professor Vasku. To work

under those conditions and to come up with such results deserves respect and admiration. I am very happy that Doctor Schlosser and Doctor Karl - two of my friends from my home town - have come to this meeting. They are not experts in this kind of research but at least I feel a little bit more at home.

Last but not least, I would like to thank my colleague, Doctor Hennig, whom you all know. I do not know really whether he is a physiologist or an engineer. But I would say a combination of both. He has contributed so much to our work and without his administrative help we would not be here today.

I think our family is a very special one. We have a lot of problems but with our energy and drive we have been able to survive and will continue to do so. We need support and we need to be optimistic. Many of us share the same outlook for the future. Many of you have shown that you are not only looking for new ideas but putting them into practice.

Sometimes in the past when I was a little depressed, perhaps close to some kind of resignation. I thought about our wonderful colleague, Theodor Billroth. Some of you know what he did. About 100 years ago he carried out the first operation on the stomach. If you read the letters from Billroth to Brahms the problems sound familiar. Problems with colleagues, problems with bureaucracy, but in the end success. I am convinced that our family will grow and with this drive and input and collaboration we will realize our idea of building an implantable artificial heart. I am very pleased that you are all here contributing to this symposium and I thank you all for coming.

I am happy to inform you that most people in the field of artificial heart research have accepted our invitation to come to Berlin. Therefore I think we will have a very effective meeting, which will give great stimulation for the future.

I look forward to welcomig you in Berlin.

Prof. Dr. E. S. Bücherl

Biomaterials

Introduction
A. S. Hoffman (Seattle)

Moderation
J. D. Andrade (Salt Lake City)

Assistance
W. Lemm (Berlin)

Allan S. Hoffmann (Seattle)

INTRODUCTION

There is a wide variety of foreign materials which are used in contact with biological fluids. These materials are known as biomaterials (1-11). The different classes of biomaterials include polymers (fibers, rubbers, molded plastics, emulsions, powders, coatings and fluids), metals, ceramics, carbons, reconstituted or specially treated natural tissues, and composites made from various combinations of such materials (Table 1.1).

Applications of such materials include invasive instruments or devices (e.g., catheters), implanted instruments or devices (e.g., pacemakers, hydro-cephalus tubes, total artificial heart), extracorporeal cardiovascular devices (e.g., kidney dialysers, blood oxygenators, detoxifiers, blood pumps), and implanted soft or hard tissue substitutes (e.g., heart valves, blood vessels, burn dressings, hip joints, dental repairs or replacements). It can be seen that many different biomaterials are used clinically, as components of implants or devices for diagnosis or therapy (12-14).

Synthetic polymers make up by far the broadest and most diverse class of biomaterials. This is mainly because synthetic polymers are available in a wide variety of compositions, properties and forms and also because they may be readily and reproducibly fabricated into complex shapes and structures (Table 1.1 and Figures 1.1-1.3). They may also be modified chemically (15-19) and biochemically (20-28), such as by immobilization of enzymes, antibodies and anticoagulants.

I)	POLYMERS	
	A) FIBERS	FILMS OR MEMBRANES
	B) RUBBERS	FIBERS OR FABRICS
	C) PLASTICS	TUBES
		POWDERS OR PARTICLES
		MOLDED SHAPES
		BAGS OR CONTAINERS, ETC.
		LIQUIDS SOLIDS (ADHESIVES)
II)	METALS	CAST OR MOLDED SHAPES
		POWDERS OR PARTICLES
		FIBERS
III)	CERAMICS	MOLDED SHAPES
		POWDERS OR PARTICLES
		LIQUIDS SOLIDS (CEMENTS)
IV)	CARBONS	MACHINED SHAPES
		COATINGS
		FIBERS
V)	NATURAL TISSUES	FIBERS
		NATURAL FORMS
		ALSO, RECONSTITUTED AS FILMS, TUBES, FIBERS, ETC.
VI)	COMPOSITES	COATINGS
		FIBROUS FELTS OR SHEETS
		FIBER OR FABRIC-REINFORCED SHAPES, TEC.

Table 1.1 Classes and forms of biomaterials (5).

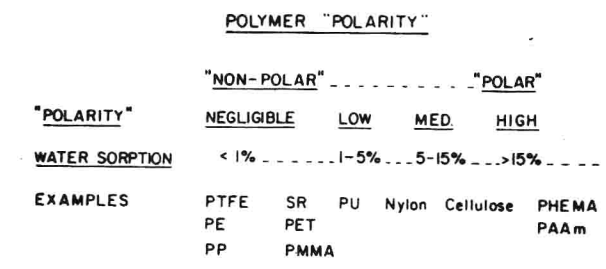

Figure 1.1 Relative "polarity," as measured by water sorption of a wide range of polymeric biomaterials (see below for symbols used).

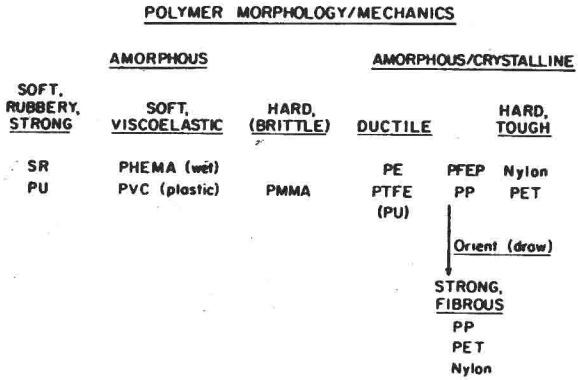

Figure 1.2 Molecular morphology and macroscopic mechanical behavior for polymeric biomaterials.

SOLID POLYMERIC BIOMATERIALS

PROPERTIES	EXAMPLES	USES
(a) SOFT (RUBBERY)		
—LOW WATER SORPTION	SR, PU, PVC	TUBES, DIAPHRAGMS, COATINGS, IMPLANTS, PACEMAKERS, ADHESIVES, BLOOD BAGS
—HIGH WATER SORPTION	PHEMA	CONTACT LENS, BURN DRESSING, COATINGS
(b) AMORPHOUS, HARD	PMMA	CONTACT LENS, IOL, DENTAL AND ORTHOPEDIC CEMENTS
(c) SEMI-CRYSTALLINE		
—LOW WATER SORPTION	PET, PP, PTFE	SUTURES, VASCULAR GRAFTS, SEWING ANCHORS, TISSUE INGROWTH
	NYLONS, PGA	SUTURES, (BIODEGRADABLE)
	PE	IUD, BONE JOINTS,
	PFEP	CATHETERS
	CA	HOLLOW FIBER DIALYSER, CONTACT LENS
—MODERATE WATER SORPTION	CELL	DIALYSIS MEMBRANE

Figure 1.3 Examples of elastomeric, plastic and semi-crystalline (fibrous) polymeric biomaterials (5).

THE ARTIFICIAL HEART AND POLYURETHANES

The total, implantable artificial heart may contain polymeric, metallic, proteinaceous and carbonaceous biomaterials. Among the polymers there may be hard or soft amorphous plastics, semi-crystalline, oriented fibers, and elastomers. Table 1.2 lists the various biomaterial components of the JARVIK 7 heart (29).

It can be seen that there are many very different materials. Sometimes the same material may be used in different components, and have different properties due to the fabrication process and/or the component dimensions, rather than due to composition.

Polyurethane (PU) elastomers are presently the most common polymeric materials used in the artifical heart (30-34). The basic chemistries of poly(urethanes) and poly(urethane-ureas) are shown in Figures 1.4 and 1.5. The PU's may vary from soft rubbery materials to hard plastics, depending on the ratio of different ingredients. Figure 1.6 shows the four most common medical grade PU's. Biomer remains the most widely used PU to date.

Other important elastomers which have been tested for use as blood pump membranes include silicone rubber (Figure 1.3) and polyolefin rubber (a copolymer rubber of 1-hexene and methyl hexadiene) (35, 36).