Preface

Nowhere in the scientific progress has the schism in the knowledge been as striking as in the case of vascular mechanics and pathology. This joint subject would serve as a classic example of science developed in two different directions. It provided the motivation to put forth this book and establish a correlation between vascular mechanics and pathology. The book focuses on the artery and arterial diseases. The most fundamental functions of the artery are (1) to serve as a conduit of blood flow and (2) to serve as a container of blood pressure. The artery carries the blood to all organs of the body and it uses pressure to drive the blood through the tissue to provide nourishment. Hence, the artery is both a pipe and a pressure vessel. The artery pulsates about 103,000 times a day along with the beating heart. In a lifetime, the artery sustains cyclic pressure for about 3.8 billion cycles. This obviously poses a significant challenge to the artery and therefore the artery must be endowed with special structure and properties to meet this challenge. In the event that additional challenges are imposed, such as high blood pressure, it would not be surprising that the artery could "break down" or become diseased. In the book, we examine the structure and properties of the artery and study the challenges imposed on it with a view to understand the survival of and the development of the diseases in the artery.

Two separate bodies of knowledge have developed in great detail, which are of interest to us. They are (1) arterial diseases, particularly atherosclerosis and aneurysm and (2) engineering analysis of pressure vessels. In arterial diseases, the most common is atherosclerotic plaque, which predominantly forms at branches, bifurcations, and curvatures. The second most common is the aneurysm, which, among other locations, also forms at the branches of cerebral vessels. Other situations concerning the artery are hypertension, use of beta-blockers to reduce the heart rate, exercise which increases and then reduces heart rate, aortic dissection, orientation of cells, and balloon angioplasty. Development of hyperplasia or aneurysm at the arterial anastomosis is also an interesting example. Why do we use veins from the lower leg for coronary artery bypass grafts is not obvious to many. These are some of the topics that need explanations and the book addresses them in terms of vascular mechanics.

The other body of information exists in the field of pressure vessel engineering. For mechanical engineers pressure vessels are the means by which outer space and ocean depths are reached, nuclear power harnessed, energy systems controlled, and petroleum processes operated. The demand for high pressure and large diameter vessels has been accompanied also by a demand for weight reduction and structure fabrication, posing a challenge for design engineers. In the body, nature has taken on a challenge for making the most efficient structures that will achieve storage, compliance, and flexibility all at once. In pressure vessels, it is recognized that the vessels fail from fatigue in locations where stress concentration occurs. The stress concentration occurs in localized regions of vessel intersections, bifurcations, curvatures, and holes. The pressure vessels are reinforced by such means as increased thickness and use of stronger materials.

For the mechanical pressure vessels, the design engineers can consider pressure as the direct cause of rupture or failure, but for the artery, a living biological material, pressure alone can seldom be considered a cause of the disease. Cellular, biochemical, genetic, and other biological processes will be intimately involved, and a mechanical entity, such as pressure, may have its consequences either directly or through these pathways. For physicians, high blood pressure in patients sends alarming signals that put all on alert, from blowout of an aneurysm in the aorta, from blowout of an aorta due to dissecting aneurysm, from blowout of a berry aneurysm in the cranium, from enhancement of atherosclerotic disease, exhaustion of the heart working harder against the pressure, and alike.

When one acquires the knowledge of these two fields, the similarity between the failure of pressure vessels and the occurrence of arterial diseases is inescapable and this book serves to point that out. It is known that the heart muscle becomes thicker in aortic stenosis and the heart chamber volume becomes larger in aortic insufficiency; both conditions are indicative of a cause and an adaptive response. It is also known that arteries become thicker in hypertension. These correlative relationships, however, have not been extended previously to the most important and pervasive diseases of the artery. The book explains that the parameters that determine the mechanical failure of the pressure vessels are also the ones that matter the most in the "failure" of the blood vessels and that the failure appears in the form of atherosclerosis or aneurysm.

The book begins with the description of previously reported mechanisms of atherosclerosis and aneurysm, and points out why these mechanisms appear incomplete. It then describes the structure of the artery and how it is suited to the dual function of the artery. For the first time, it describes the structure of the arterial branch. The principles of pressure vessels are then described and applied to the coronary arteries, carotid bifurcations, aortic bifurcations, aortic arch, etc. Both the general principles and the occurrence of stress concentration at the pressure vessel junctions are described. The orientation of endothelial cells and smooth muscle cells, and higher permeability of specific regions of the artery to low density lipoprotein are described. The proliferation of cells in balloon angioplasty as a response to strain is described. The reduction of stress and the role of beta-blockers in the reduction of atherosclerosis and/or related complications are described. The principles of reinforcements and reduction of diseases are applied to intramyocardial coronary arteries and vertebral arteries. The book describes the use of veins as the arterial grafts and the role of vein valve in graft stenosis.

The principles of stress concentration are further illustrated in case of anastomosis. The development of intimal hyperplasia at the anastomosis and the development of anastomotic aneurysms are covered once again from the point of view of vascular mechanics. The intracranial aneurysms and the aortic aneurysms are described with emphasis on the stress in the aortic wall. Aneurysm formation, growth, and rupture are described using pressure vessel principles. Finally, the aortic dissection is described and, for the first time, it is shown that the aortic root mechanics plays a very important role in the development of this pathology. Both pulling and twisting motions of the aortic root are analyzed for their role in the aortic dissection.

Overall, the two fields of science are brought together to enrich our understanding of the role of vascular mechanics in pathology. A broad range of subjects covered in the book provides one of the most comprehensive treatments of vascular pathology in a single document and makes this document four books in one. It enhances our knowledge of both engineering and medicine by pointing out the important link between them in the area of vascular pathology. It also promotes understanding of a common phenomenon in such varied subjects as atherosclerosis, aneurysms, pressure vessel, stress concentration, vein grafts, anastomosis, cell proliferation, and beta-blocker treatment, all associated with arterial diseases. It points to newer applications of engineering principles in medicine thereby opening new avenues for experimental research in both the fields. Usually, it is the philosophers' forte to try to understand "all things in terms of a single principle" but serendipitously, in this book, it is "the single principle" that has been brought to the forefront of multiple vascular diseases.

The book will be useful to cardiovascular surgeons, cardiologists, pathologists, radiologists, neurosurgeons, anatomists, and manufacturers of medical devices. It will also be useful to students in medicine and in biomedical engineering and to the researchers in various disciplines. It can serve as "the book" for a course on "vascular mechanics and pathology" in bioengineering. It is likely to open new doors for interdisciplinary research, which could lead to the reduction of vascular diseases and to the development of new treatments, thereby benefiting large number of patients.

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