# Book Reviews



## Sumner's Hemodynamic Guide to Venous Diagnosis and Intervention

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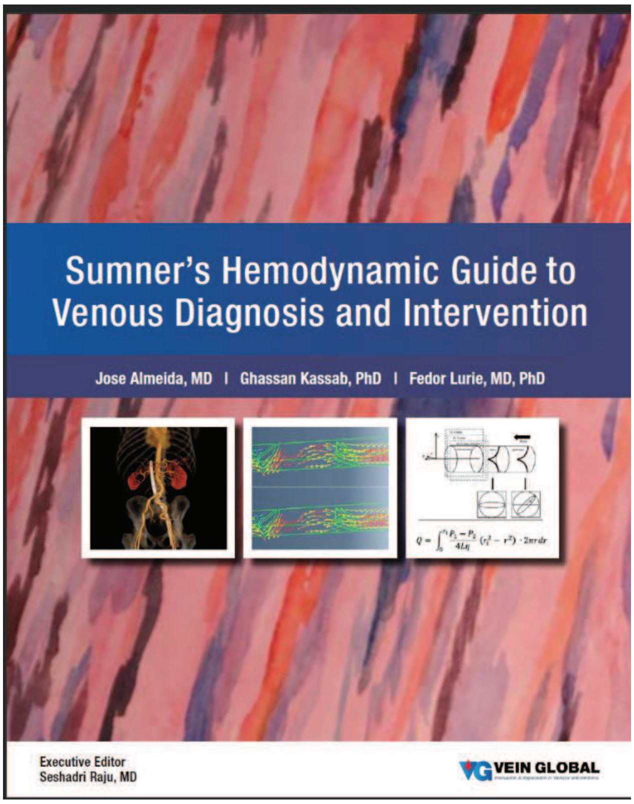
**Abstract** The 2nd Edition of 'Strandness & Sumner's hemodynamics for Surgeons' for the venous section. Editors: Seshadri Raju, Jose Almeida, Ghassan Kassab, and Fedor Lurie.




*Sumner's Hemodynamic Guide to Venous Diagnosis and Intervention*

Drs. Almeida, Kassab, and Lurie, three world authorities in this unique field of hemodynamics edited the 2nd edition of *Strandness & Sumner's hemodynamics for Surgeons* for the venous section with Dr. Raju to formulate a new guideline in the clinical aspects, hemodynamics, and diagnostic testing of venous disease, respectively; they successfully modeled to perpetuate the essence and style of the original book and named the new book after David Sumner to honor his contributions to the field of venous disease.

Among four editors, Seshadri Raju, Jose Almeida, and Fedor Lurie are such well known colleagues among the vascular specialists with no need to introduce again but the last/fourth editor, Ghassan Kassab would not be much familiar to most of the colleague clinicians but Dr. Kassab is one of the best biomedical engineers today in the country and also very well known as the final pupil of legendary Dr. Y.C. Fung who is often cited worldwide as a father of bioengineering. Dr. Kassab made such critical contribution through the first seven chapters of the book for the basic science explaining the basic bioengineering behind the behavior of various clinical conditions with mathematics and calculus in depth. He offered such unique perspective on the hemodynamics and basic science perspective on venous disease.
Indeed, the goal to preserve the spirit of the original edition was well accomplished throughout the book while introducing some modern concepts quite successfully through thirteen chapters, divided in four separate sections as following;

SECTION A: Basic Science focusing on the biomechanics foundation of hemodynamics including biofluid and biosolid mechanics.
SECTION B: Venous Pathophysiology concentrating to on the pathophysiology of reflux and obstruction from the hemodynamics perspective.
SECTION C: Venous Laboratory summarizing current imaging modalities used for venous disease diagnosis, with a hemodynamic interpretation.

SECTION D: Clinical Syndromes integrating the whole by describing the diagnosis and treatment of clinical syndromes, observed from the hemodynamics point of view.

More precisely, they made such extensive review on every topic of venous hemodynamics, item after item, to leave no stone unturned;
Chapter One: Biomechanical Principles, dedicated for the Physical Principles to illustrate Elementary Concepts of Blood Flow including the Applications of Poiseuille's Equation as well as the Deviations from Poiseuille's Equation
Chapter Two: Anatomy and Geometry of Veins; the study of venous blood flow, requiring for biomechanical understanding of both of the venous system
Chapter Three: Mechanical Properties and Microstructure; nonlinear and nonisotropic passive and active mechanical properties and nonlinear blood rheology, including non-Newtonian properties in microcirculation
Chapter Four: Venous Hemodynamics: Boundary Conditions; "Mechanical Properties and Microstructure") and of interactions with the surrounding environment (abdominal, thoracic, and skeletal-muscle pump
Chapter Five: Biomechanics of the Venous System.
Chapter Six: Homeostasis and Mechanobiology
Chapter Seven: Thrombosis, Inflammation, and Implant Interactions
Chapter Eight: Venous Obstruction
Chapter Nine: Valvular Incompetence
Chapter Ten: Venous Laboratory
Chapter Eleven: Vascular Imaging and Quantification
Chapter Twelve: Deep Vein Thrombosis

## Chapter One. Biomechanical Principles

The authors illustrated how the laws of mechanics are a foundation on which to integrate or assemble the morphometric data of the venous vasculature. Indeed, 'biomechanics' is broadly defined as mechanics applied to biology. Mechanics constitutes the study of stresses and deformations in structures and motion of bodies, whereas biology is the study of life (both within and around us). Therefore, biomechanics is the interface of these two large fields, which includes the study of venous circulation, including venous diagnosis and treatment (e.g., venous stenting, vena cava filters, and prosthetic valves). Indeed, biomechanics is fundamental to venous health and disease because venous reflux and stenosis involve biomechanical processes. Stress and strain are basic concepts in understanding the biomechanics of veins.

## Chapter Two: Anatomy and Geometry of Veins

This chapter introduces some basic anatomy of the venous system and principles that can guide a quantitative analysis of venous flow. Given the sparsity of quantitative morphometric data for the venous system, this chapter highlights the importance of future research to establish a more systematic and quantitative database of information on the anatomy and geometry of the venous system.
The morphometric data of the vasculature (arteries, capillaries, and veins) is needed to understand the circulation, to predict the pressure–flow relationship, to determine the longitudinal pressure and flow distribution from arteries to veins, to understand the distensibility of blood vessels, and to study thrombosis, stenosis, and other venous diseases.
Trying to understand the circulation without the morphometric (diameters, lengths, number of vessels, and branching pattern) data is like exploring a continent without a map.

## Chapter Three: Mechanical Properties and Microstructure

The venous system has been referred as the capacitance system because the veins contain approximately two-thirds of the total blood volume under normal circumstances. Therefore, an understanding of the mechanical properties of veins is fundamental to understanding the major compliance or capacitance chamber of the circulation. Indeed, the key determinants of venous volume regulation include passive mechanical properties, active response (e.g., myogenic), neural, regulation, and metabolic regulation. The focus of this chapter is on the passive and active properties of the venous system.
Hence, they presented general mechanical properties concepts through this chapter, including compliance, elasticity, viscoelasticity, and the stress–strain relationship of passive and active veins, including the ultrastructure that consists of collagen, elastin, and SMCs.

## Chapter Four: Venous Hemodynamics: Boundary Conditions

In a comprehensive biomechanical analysis of the venous system, the boundary conditions of the venous system must be known. The flow through the venous system is clearly affected by the inlet (postcapillary) and outlet (atrium) boundary conditions (e.g., pressure and flow). Because the venous system is highly compliant, with significant capacitance as characterized by either the pressure–diameter relationship or the pressure–volume relationship, the external boundary conditions on the venous system are also of significance.
In this chapter, the hemodynamics of normal venous flow are presented, with consideration of the effect of these various biomechanical boundary conditions.

## Chapter Five. Biomechanics of the Venous System

In this chapter, they outlined the approach of laws of mechanics as a foundation to integrate or assemble the morphometric data of the venous vasculature with the material properties of the veins and described boundary conditions to solve some boundary-value problems of venous circulation under steady-state flow. The solutions can reveal the spatial distributions of velocity, transit times, pressure, shear rate, and stress. The theory connects physical, morphometric, and rheological variables.

Following the excellent introduction of 'Hemodynamics of Venous Stenosis', they moved on the 'Venous Stenting' to dissect its issues into four separate categories: 'Post-thrombotic syndrome, Chronic venous insufficiency, Optimal venous stenting, and Effects of stenting on vessel wall' to illustrate each item quite clearly before they proceed to 'Venous Valves'.

They have made such thorough review on 'function of valves, structure and distribution of valves, role of valve sinus, and finally 'helical flow' to reach to the summary to draw the conclusion: the results of the mathematical model simulations can provide valuable insights that improve the current understanding of blood-flow patterns around native venous valves and can also help improve the design of future multiple paired prosthetic valves. These hypothesis-generating findings require further investigation regarding the disease states associated with valve pairings and novel designs for valve-pairing prostheses.

## Chapter Six: Homeostasis and Mechanobiology

The objective of this chapter is to discuss the various hypotheses regarding the CV system that

are available, because experimental data and analytical models are not available. Hence, they outlined the mechanical stimuli most closely regulated in the CV system and particularly in the venous system. They discussed the implications of these hypotheses on mechanotransduction and on vascular growth and remodeling extensively through eight separate sections: Overview of Engineering Approach to Design, The Central Hypothesis: Mechanical Homeostasis, Shear Stress, Intramural Stress and Strain, Perturbation of Mechanical Homeostasis, Limitations and Implications, Vascular Mechanobiology, and Biology of Vascular Injury.

For example, they discussed Shear Stress based on uniform shear hypothesis, and Intramural Stress and Strain based on uniform shear hypothesis and uniform tension hypothesis and further with uniform stress and strain hypothesis and biaxial stress-strain hypothesis as well. They further elucidated its Limitations and Implications through 'what is the stimulus for mechanotransduction?, Strain homeostasis, Existence of gauge length? and Other possibilities'.

## Chapter Seven. Thrombosis, Inflammation, and Implant Interactions

This chapter was dedicated to deal with;

- The role of pro-inflammatory and prothrombotic components such as mCRP and TF in atherothrombosis and venous thromboembolism (VTE)
- The roles of pro-inflammatory and prothrombotic MPs in atherothrombosis and VTE
- The roles of pro-inflammatory and prothrombotic factors in thrombogenesis in
- blood-contacting devices
- Identification of future directions in biomaterial research to minimize and prevent thrombosis on blood-contacting devices
- The mechanisms of and progression of thrombus development in the venous system versus
- those in the arterial system
- The biology of thrombosis

Through the section of Inhibition of protein and cell adsorption, they discussed various materials developed to coat surfaces that minimize these defense reaction (e.g., albumin, polyethylene oxide (PEO), pyrolytic carbon, and heparin).

Further they pointed out through Future Directions that the problem can be overcome with the use of more effective and safer antithrombotic and anti-inflammatory agents, along with less-thrombogenic biomaterial surfaces. Hence, more research and development are needed to understand biological processes involved in coagulation at the surfaces of blood-contacting devices. It is likely that biomaterials used in venous devices will be different than those used in arteries because the processes in those locations have some variations. For example, venous low shear rates can lead to regional accumulation of activated coagulation factors and thrombogenesis on a nearby surface, leading to larger thrombi and increasing the risk of thromboembolic disease.

## Chapter Eight. Venous Obstruction

The authors accommodated such many issues involved to the 'Obstruction' so extensively through ten separate sections: Venous Biomechanics and Hemodynamics, Volume-Pressure Curve, Volume and Its Relationship to Cardiac Output and Venous Return, Microcirculation and Capillary Exchange, Venous Flow through the Chest, Venous Flow through the Abdomen, Venous Flow through the Pelvis, Pathophysiology and Hemodynamics of Acute Extensive Venous Outflow Obstruction, Measurements of Venous Outflow Obstruction, and Factors Influencing Peripheral Venous Pressure: An Experimental Model.

For example, the section of Pathophysiology and Hemodynamics of Acute Extensive Venous Outflow Obstruction was dedicated to three separate issues: phlegmasia cerulea dolens, arterial pressure-flow relationships in phlegmasia cerulea dolens and phlegmasia alba dolens.

## Chapter Nine: Valvular Incompetence

The authors dedicated this chapter only to deal all the issues involved to Valvular Incompetence in eight divided sections: Venous Valves and Their Function' Valvular Incompetence, Animal Models, Human Studies, Interruption of the Fluid Column (Segmentation), Measurement of Venous Hypertension, Hemodynamic Results After Ablation, and Correction of Deep Venous Reflux. For example, the section of Measurement of Venous Hypertension made such thorough review on the valvular incompetence based on ambulatory venous pressure, plethysmography, venous filling index, ejection fraction, residual volume fraction, and Duplex ultrasound. Further, they reviewed the hemodynamic results after the ablation extensively in three different groups: Ablation of Superficial Reflux, Ablation of Reflux in limbs with Superficial and Perforating Vein Reflux and also Ablation of Superficial Reflux in limbs with Associated Deep Venous Reflux.

## Chapter Ten: Venous Laboratory

The majority of tests to obtain anatomical information are based on computed tomography, magnetic resonance imaging, venography, and intravascular ultrasound. But, their use for studying venous hemodynamics is limited to qualitative indirect information. Hence, a combination of different diagnostic modalities is used to obtain a more comprehensive picture of venous hemodynamics. But due to fundamental differences in physical principles, engineering solutions, and computational algorithms involved in each of these modalities, the basic physical principles of these modalities, their properties related to measurements of flow, identification of venous flow abnormalities, and their limitations and sources of errors are mandated for proper understanding. Therefore, the authors reviewed different test modalities that are currently used in vascular laboratories based on Diagnostic Ultrasound, Plethysmography, and Venous-Pressure Measurements. Indeed, Diagnostic Ultrasound was thoroughly reviewed in nine divided categories: Morphology, Ultrasound propagation speed, Refraction, Resolution, Patient-related factors, Physiology, Measurement of blood flow velocity, Measurement of blood flow rate (volume flow), and finally Flow imaging for Color Doppler, Power Doppler, B-Flow, Vector Mapping, for example.

## Chapter Eleven: Vascular Imaging and Quantification

As the authors properly pointed out, continuous improvements in imaging technology have created new opportunities in studying venous hemodynamics. Imaging modalities that are limited to acquiring only anatomical information, such as computed tomography venography (CTV) and intravascular ultrasound (IVUS), are now frequently used to provide information for hemodynamic inferences. Other imaging techniques have become capable of providing real-time qualitative and quantitative hemodynamic information. Recognizing limitations, measurement errors, and artifacts of these imaging modalities, they reviewed the major imaging modalities that are currently used in clinical practice and research related to venous disorders—CTV, magnetic resonance venography, and IVUS to help proper understanding of the complex engineering solutions and physical principles behind these technologies.

They described the basic physical principles of these modalities, their properties related to measurements of flow, the identification of venous flow abnormalities, and the limitations and sources of errors for the modalities, for eight separate groups: X-Ray Imaging, Contrast Venography, Computed Tomography Venography, Magnetic Resonance Venography, Intravascular Ultrasound, Computed Tomography Versus Venography, Computed Tomography Venography Versus Intravascular Ultrasound, and Venography Versus Intravascular Ultrasound. They further described their clinical use and compared these modalities to traditional venography.

## Chapter Twelve: Deep Vein Thrombosis

The authors addressed for the deep vein thrombosis (DVT) to begin with the facts that magnitude of the hemodynamic change depends on the extent of the occlusion, what vessels are involved, the relationship of the occlusion to collateral venous channels, the rapidity with which the occlusion develops, and the chronicity of the process. Indeed, the occlusion that has been present for a long time will usually produce less obstruction than will a more acute lesion of similar extent, principally because of the more extensive collateral development in the former. Further, unlike obstruction, valvular incompetence may become worse with the passage of time because

- The healing process causes fibrosis of valvular cusps
- Increased hydrostatic pressure or inherent wall defects lead to failure of healthy cusps to coapt
- Recanalized veins are functionally valveless
- Collateral vessels dilate beyond the capacity of their valves to function properly.

Hence, the authors tackled the acute DVT first through the extensive review in two divided groups: Collateralization and flow patterns in acute DVT and Treatment of acute DVT, before proceeding to the most challenging Post-thrombotic Syndrome (PTS) as the outcome of chronic DVT.

Indeed, the PTS has never received such enormous attention ever by any other reviews/authors as I know of through exhausting review under a total of nineteen topics/ issues as following;

1. Hemodynamics of post-thrombotic syndrome
2. Anatomical considerations in post-thrombotic syndrome
3. Resting versus exercise in post-thrombotic syndrome
4. Relationship between pressure in deep and superficial veins (post-thrombotic syndrome)
5. Venous blood flow in post-thrombotic syndrome
6. Venous volume in post-thrombotic syndrome
7. Edema and skin damage from post-thrombotic syndrome
8. Prevention of post-thrombotic syndrome: Primary Prevention & Secondary Prevention
9. Optimizing anticoagulation to prevent post-thrombotic syndrome
10. Venoactive agents for post-thrombotic syndrome
11. Exercise training to treat post-thrombotic syndrome
12. Compression for post-thrombotic syndrome: Intermittent Compression Devices for post-thrombotic Syndrome
13. Thrombolysis and endovascular therapies to prevent post-thrombotic syndrome
14. Surgical treatment for post-thrombotic syndrome: Post-thrombotic Infrainguinal Venous Obstruction: Saphenopopliteal or Saphenotibial Bypass & Post-thrombotic Iliofemoral Obstruction: Femorofemoral Bypass
15. Endovascular procedures for post-thrombotic iliocaval obstruction: Venous Stent Properties
16. Surgical procedures to correct reflux in post-thrombotic syndrome: Segmental Vein Valve Transfer: Axillofemoral/Popliteal Transplantation or Venous Transposition & Endovascular Approaches to Address Reflux in Post-thrombotic Syndrome
17. Complex reconstructions for post-thrombotic syndrome: Hybrid Surgical and Endovenous Iliofemoral/Venocaval Reconstruction
18. Venous ulcer management in post-thrombotic syndrome
19. Miami Experiences

## Chapter Thirteen: Chronic Venous Insufficiency

The authors reviewed this ever-challenging ‘chronic venous insufficiency (CVI)’ issue so meticulously in four divided groups of Varicose Venous Volume, Edema, Treatment, and Induration, Stasis Dermatitis, and Ulceration as the last chapter of this enormous hemodynamic book.

The first group of ‘Varicose Venous Volume’ was discussed thoroughly, divided into six groups: Blood pressure in varicose veins, Blood flow in varicose veins, Postural effects of varicose veins, Calf-pump mechanics in venous physiology, and Varicose vein treatment.
For example, ‘Varicose vein treatment’ was thoroughly discussed for the nonsurgical approach with Compression Therapy, and also surgical approach with High Ligation and Stripping, Divided Saphenectomy, Ambulatory Selective Varicose-Vein Ablation Under Local Anesthesia (ASVAL), and Conservative and Hemodynamic Ambulatory Treatment of Venous Insufficiency (CHIVA), and Endovascular Treatments with Thermal Ablation (e.g. RFA and EVLA) and Nonthermal Ablation (e.g. sclerotherapy) as well.

The second group of ‘Edema’ was reviewed so thoroughly in fifteen divided groups as following;

1. Dynamics of interstitial fluid accumulation
2. Glycocalyx
3. An improved paradigm of fluid physiology and therapy
4. Thrombosis, venous pressure, and edema
5. Venous pressure, leg position and edema
6. Lymphatic obstruction and edema
7. Hemodynamic changes in the microcirculation
8. Alteration of interstitial capillaries and edema formation
9. The glycocalyx of capillary endothelium
10. Alteration of lymphatic vessels
11. Normal skin blood flow
12. The postural venoarteriolar response
13. Skin blood flow and the venoarteriolar response in limb with venous hypertension
14. Correlation of resting flux, standing flux, and venoarteriolar response with ambulatory venous pressure
15. Correlation between venoarteriolar response, resting flux, standing flux with transcutaneous oxygen tension and transcutaneous carbon dioxide tension

The third group of ‘Treatment’ was also discussed in two divided groups: Saphenous reflux and deep obstruction and Deep reflux.

Lastly, the fourth group of ‘Induration, Stasis Dermatitis, and Ulceration’ was also so extensively to make it ‘good to the last drop’ in eight divided groups as following;

1. Alteration of skin capillaries and venous ulcer formation
2. Chronic edema
3. Incompetent perforating veins
4. Decreased capillary blood flow
5. Venous hypertension
6. Treatment of venous leg ulcers

7. Indications for intervention: *Perforator Insufficiency*
8. Wound bed preparation: *Debridement, Larval Therapy, Bacterial Colonization, Human Skin Equivalents*

Indeed, the highlight of this chapter to conclude this enormous task is a new information on the role of GLYCOCALYX for the 'revised Starling's Law'(pp 351-354) and LYMPHATIC OBSTRUCTION AND EDEMA (p358) as well as HEMODYNAMIC CHANGES IN THE MICROCIRCULATION (p359).

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