

# Renal Microvascular Disease: Angiographic-Microangiographic Correlates

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# Renal Microvascular Disease

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## Angiographic-Microangiographic Correlates

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Elkin  
RADIOLOGY OF THE URINARY SYSTEM

Bookstein & Clark  
RENAL MICROVASCULAR DISEASE

Holman & Parker  
COMPUTER-ASSISTED CARDIAC NUCLEAR MEDICINE

TO ASPECTS OF BEAUTY AND EXCITEMENT:

the beauty of renal microangiography

the beauty of angiographic-microangiographic correlates

the excitement of discovering bases for angiographic reflections of renal disease

TO THOSE OTHER SOURCES OF BEAUTY IN OUR LIVES:

Our wives, children, and parents, without whose understanding and encouragement none of this would have come to pass

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# Foreword

*Whenever a new discovery is reported in the scientific world, they say first, "it is probably not true." Thereafter, when the truth of the new proposition has been demonstrated beyond question, they say, "Yes, it may be true, but it is not important." Finally, when sufficient enough time has elapsed to fully evidence its importance, they say, "Yes, surely it is important, but it is no longer new."*

Montaigne

Bookstein and Clark have disregarded the cynicism of Montaigne, and have plunged headlong into their project with enthusiasm and ingenuity. Let us concede that the renal microvascular bed has been with us for a long time and has been thoroughly explored from both a morphologic and a functional point of view. Let us agree that there is a vast literature on this subject, which attempts to clarify the role of the renal vascular bed in promoting glomerular filtration and in supporting the critical functions of the kidney in water and electrolyte metabolism and in the elimination of nitrogenous waste. In the face of this sustained interest on the part of many investigators, the authors of this book have approached the renal microvascular bed from the vantage point of two profoundly rewarding imaging procedures: microangiography in vitro and magnified angiography in vivo. The result is a book that is a scholar's joy. It represents a careful, painstaking approach to an organ of prime importance to the normal metabolic balance—the homeostatic cadence—that constitutes health and that supports an enormous variety of diets, fluid intakes, and physical stresses embodying the normal life experience.

The renal vascular bed is unique in its complexity and functional role. It provides the kidneys with a fraction of the cardiac output far in excess of the weight or volume of the organ clearly because the blood supply to the kidneys serves more than the support role of nutrition and preservation of tissue viability. The bulk of blood delivered to the kidney, in fact, is for the purpose of producing a glomerular filtrate whereby the products of metabolism can be excreted and essential electrolytes preserved.

Given its complexity and its central role in maintaining the homeostasis of the organism, it is not surprising that a multitude of diseases should affect the kidney, some with grave consequences for the maintenance of normal life. Their functional effect can readily be measured, although not always understood. The morphologic effects of these varied diseases clearly underlie their capacity to interfere with renal function. Hence, a proper understanding of their impact on the renal vascular bed is an essential ingredient of a thorough appreciation of the pathophysiology of renal disease.

The angiographic method, initially in primitive form, was developed 50 years ago by Dos Santos. It was applied to the study of the kidneys in the forties, but with the development of transfemoral percutaneous renal arteriography in the fifties, the unfolding of the renal vascular bed and its abnormalities during life received a major impetus. Magnification angiography became a feasible and effective radiologic method during the sixties, and one of the authors of this book, Dr. Bookstein, has played an important role in defining the limits and capacities of that method.

Meanwhile, microangiography of all viscera proved to be an illuminating mirror of the nature of microvascular change in health and disease in multiple organs. Dr. Clark initiated a series of studies over a decade ago in which he developed his microangiographic technique for specific application to the renal circulation and began to explore the nature of microvascular change in both experimental and clinical settings. It is the joining of these talents, however, that provides the unique character of this volume. For each disorder that involves the kidney or of the renal vascular bed, the authors have systematically looked at the underlying microvascular changes depicted *in vitro*, have analyzed their effects on each unit of the circulation, and then have related these changes to those observed in patients studied by angiography.

The volume is organized in a logical fashion, with a description of basic concepts, the normal, and the angiographic classification of renal parenchymal disease. The next few chapters, rather than looking at disease entities, review the pathologic settings in which specific angiographic changes are visible, such as acute loss of glomerular granularity and chronic loss of glomerular granularity. There follow chapters on interlobular occlusive disease as in nephrosclerosis and polyarteritis, on pyelonephritis, hypovascular and hypervascular expanding lesions, ischemia and infarction, the transplanted kidney, and finally a series of miscellaneous conditions including amyloid disease, interstitial nephritis, and renal edema.

In each chapter the approach is consistent, with a general description of the condition and its causes, the histology, the microangiography, the clinical angiography of the condition, and finally a summary of the basic concepts covered in the section. The ability to translate the gross morphology of the magnified clinical renal angiogram into the microscopic pathology of the microangiogram enhances enormously our capacity to understand the role and meaning of clinical angiography in many conditions.

A major virtue of this book is that it is written with insistent clarity and a firm reliance on straightforward, declarative sentences that convey rather than distort the authors' meanings, in contrast to the convoluted



diction so often found in medical writing today. The authors have not only summarized the medical literature and their own wide experience, they have also integrated data from numerous experimental models, such as radiation changes in the rabbit, the microangiography of cortical necrosis due to rejection in the renal transplant in the dog, acute pyelonephritis in rabbits, and renal abscess in the transplanted dog kidney.

Is this book controversial? The answer is a resounding "yes." The authors would be the first to agree that much of the contents represent their present conclusions in continuing areas of investigation, and thus it may readily be considered a progress report rather than a final and definitive document. Nevertheless, this book represents the state of the art, which will not be modified for five or ten years in the basic core of knowledge that it expresses so vividly and so well.

Although this is a radiologic text, or more precisely, an imaging volume, its appeal goes far beyond the boundaries of radiology itself. All those who are involved in medical nephrology will find it thoroughly fascinating in its capacity to clarify many underlying changes that are barely visible at the clinical level. Those in the urologic disciplines concerned with surgical disease of the kidney will also benefit from an acquaintance with the impact of medical diseases on the microvasculature of the kidney, particularly in the degree to which the patient with urologic disease may develop ATN postoperatively or the post transplant patient may develop rejection. The clinical course of both these groups of patients is frequently directly related to the degree to which the vascular bed is irreversibly involved, or, in turn, may permit more adequate perfusion of the renal cortex than occurs at the time the disease is most acute.

Finally, beyond the radiologist, the nephrologist, and the urologist, the pathologist interested in renal disease will surely find this a provocative and immensely informative volume. Although specialized in its focus, the book will also be highly appealing to medical students, house staff, and residents in the medical, surgical, and radiological disciplines as a basic text dealing with renal pathophysiology in a large number of diseases encountered every day in the busy hospital environment.

In summary, what Bookstein and Clark have accomplished—and what warrants our admiration and appreciation—is the synthesis of the information obtainable from two critically important imaging methods: microangiography *in vitro* and magnified angiography *in vivo*. The result is a series of remarkable insights into the morphologic responses of the kidney to a host of different diseases affecting patients on every medical and surgical service in the country today.

Herbert L. Abrams, M.D.



This book was partially conceived in 1965 when we saw, in a patient with nephrosclerosis, now long deceased, a clinical angiogram demonstrating a peculiar mottled pattern. Our initial total confusion regarding the significance of this pattern was immediately dispelled by the histologic examination, which displayed innumerable microinfarcts secondary to interlobular occlusions. This case forcefully brought home the value of histologic correlation in interpreting angiograms of renal parenchymal disease. It also demonstrated the value of logical analysis of image-object relationships. Merely equating angiographic patterns with disease entities (i.e., prune-tree = glomerulonephritis) was totally sophomoric and threatened to undermine confidence in angiographic predictions of renal histology.

Our chance meeting during a presentation by one of us (R.L.C.) on the microangiography of transplant rejection further stimulated the gestation of this book. It became apparent that in addition to histologic correlates, microangiographic insights contribute greatly to angiographic interpretations, and vice versa.

And so, from that first meeting, we began to explore the relationships between a large microangiographic experience in renal parenchymal disease and a sizable clinical experience. We found the correlations frequent, fascinating, sometimes astounding, and, incidentally, clinically useful. From this experience evolved a series of lectures presented at the 1975, 1976, and 1977 meetings of the Radiologic Society of North America entitled "Angiography of Renal Parenchymal Disease." From those lectures, it was a logical next step to record our efforts and observations in book form so that any chance universal truths or lasting beauty might escape oblivion.

This book is written with the radiologist foremost in mind, but there is much that we hope will prove profitable and enjoyable also to the clinician, the nephrologist, and perhaps the pathologist. The reader will gain new insights into the morphologic correlates of renal function and dysfunction. Such insights should encourage improved angiographic interpretation and an increased awareness of the potential role of angiography in the evaluation of renal disease. The logic involved in predicting histologic features from magnification angiograms should be appreciated and will likely prove useful in analyzing the magnification angiograms of many other organ systems.

But over and above the practical aspects of this book, it seemed worthwhile, indeed compelling, to illustrate in permanent and comprehensive form the exquisite beauty and detail of renal microangiography. The angiographic-microangiographic correlations them-

selves, in their own right, are so aesthetically pleasing, they merit a permanent recording. We sincerely hope that the reader, from whatever medical discipline, finds both practical factual material and beauty in these pages, and that he enjoys reading the book as much as we enjoyed writing it.

J. J. B.  
R. L. C.

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First and foremost, we must acknowledge our debt to a vast scientific and radiologic heritage, and to the many unnamed pioneers in our field. The prime motivating force of Dr. Herbert L. Abrams during my residency years, and his continuing support since that time, have sparked and maintained my interest in angiography. Most of the clinical material was accumulated during my years at the University of Michigan, and the support of Dr. Walter Whitehouse, Department Chairman during much of that time, provided a milieu that permitted full exploitation of the case material. Drs. Stewart Reuter, Joseph Walter, and particularly Kjung Cho, who succeeded me at the University of Michigan, have continued to perform angiograms of exemplary quality and kindly have made much of this material available for the present publication. Many clinical colleagues at the University helped provide clinical material, including Drs. Sibley Hoobler, then Chief of the Hypertension Clinic, William Fry, then Chief of Vascular Surgery, and Jeremiah Turcotte, then Chief of the Transplant Service. Dr. Paul Gikas provided the histopathologic interpretations on which most final diagnoses and angiographic-histologic correlates were based.

J. J. B.

My love of anatomy and physiology, and subsequently of medicine, was engendered and fostered by Drs. Warren Walker and George Scott, Professors of Zoology at Oberlin College. During my residency at the Johns Hopkins Medical Institution, Drs. Martin W. Donner and Russell H. Morgan provided further guidance and inspiration. The fortunate association during these same years with Dr. Robert Heptinstall and his colleague, Dr. Gary Hill of the Pathology Department, catalyzed my interest in the renal microcirculation and launched my career as an experimental pathologist and microangiographer. The study of the renal microcirculation, utilizing microradiographic techniques, is not a new idea. My work has simply represented an extension of many previous elegant studies (most notably by Ljungqvist and colleagues) to more diverse pathologic conditions in both humans and laboratory animals.

My work at the University of North Carolina at Chapel Hill has been continually encouraged and supported by Dr. James H. Scatliff, Professor and Chairman of the Department of Radiology, who helped foster the unique intellectual climate that would facilitate my many collaborative efforts with the urologists, nephrologists, and pathologists. Whatever contribution my work of the past six years has made, it is due, in no small measure, to the abundance of pathologic material that has been made available through the efforts of Drs. Floyd Fried, Chief of Urol-

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R. L. C.

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# Renal Microvascular Disease

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The microvascular bed constitutes a significant fraction of the renal parenchymal mass. The glomerulus, a major component of the nephron, is primarily a capillary tuft. And the uriniferous tubule, the other major component of the nephron, is vascularized far in excess of nutritive requirements, as an essential portion of the countercurrent tubular mechanism. Logic would then suggest that a method for graphic display of vascular structures, such as angiography, might prove very useful in evaluating renal parenchymal disease.

Considerable controversy exists, however, regarding the diagnostic value of angiography. Some of this controversy can be ascribed to the limited resolution of early angiographic techniques. With modern refinements, particularly direct magnification, cortical microvascular structures may be recognized, and angiographic diagnosis can be directly related to conventional histopathologic diagnostic criteria.

Even with magnification techniques, the cortical microvascular structures are not seen with great clarity. Images of glomeruli, interlobular arteries, and other structures lack high contrast and partially overlap and obscure one another. Yet prior familiarity with clearly resolved microangiographic patterns of renal parenchymal disease permits recognition of the significance of ill-defined *in vivo* angiographic patterns. In other words, pattern recognition can be based on degraded visual information, provided there is preexistent familiarity with the nondegraded visual data. An example of this phenomenon is demonstrated in Figure 1.1.

Keeping in mind the value of prior familiarity with images of high resolution, we investigated potential relationships between *in vivo* angiograms and *in vitro* microangiograms. The remarkable and logical correlations that became apparent provide the substance and format for this book. From the book emerges an angiographic approach to the study of renal parenchymal disease based on clinical magnification techniques and angiographic-microangiographic-histologic correlates. It becomes evident that angiography not only reflects known microangiographic, histologic, and physiologic sequelae of renal disease, but in turn provides new perspectives in these same areas. At the same time, the uses and limitations of angiography are more clearly defined, and angiography becomes a more useful and reliable diagnostic method in renal parenchymal disease.

**INDICATIONS** It must be emphasized at the outset that angiography is not ordinarily indicated in evaluating nonsurgical renal parenchymal disease. Clinical