AJNR

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AJNR Am J Neuroradiol published online 7 February 2008
http://www.ajnr.org/content/early/2008/02/07/ajnr.A0932.citation

Published February 7, 2008 as 10.3174/ajnr.A0932

BOOK REVIEW

Multidetector Computed Tomography in Cerebrovascular Disease: CT Perfusion Imaging

K.A. Miles, J.D. Eastwood, and M. Konig, eds. Oxon, United Kingdom: Informa Healthcare Ltd.; 2007, 175 pages, 48 multicomponent figures and 8 tables, $129.95.

Multidetector Computed Tomography in Cerebrovascular Disease: CT Perfusion Imaging, edited by Drs. Miles, Eastwood, and Konig, is a detailed technical monograph that does for CT perfusion imaging (CTP) what *Cerebral MR Perfusion Imaging: Principles and Current Applications* (book and CD-ROM), by Sorensen and Reimer (Thieme: Stuttgart/New York, 2000), did for MR perfusion imaging (MRP). The intended audience, as indicated in the preface, is "radiologists and radiographers currently using perfusion CT or considering its introduction to their institution." Although the editors go on to state that this book "will also be valuable to clinicians treating patients with cerebrovascular disease," this is clearly a secondary consideration. Indeed, theirs is predominantly, but not exclusively, a technical treatise, and given the current rapid advances in stroke imaging indications, the reader interested in state-of-the-art clinical context is advised to look elsewhere (specifically, to relevant journals such as the *American Journal of Neuroradiology*, *Stroke*, *Annals of Neurology*, and *Radiology*). Despite multiple authors, the book is surprisingly well balanced and consistent in tone, with some overlap but limited disagreement between chapters (most notably on the topic of core/penumbra segmentation, which is treated differently in chapter 5 versus chapters 7 and 10). Many of the contributors are major pioneers and continue to be thought leaders in the field of CT perfusion imaging.

Overall, the book does a great job of introducing the background and theory essential for understanding and using CTP. The technical material is comprehensive, well formulated, and mostly up to date, including some items not yet peer reviewed at the time of publication (the blood flow/blood volume segmentation of chapter 5). Although some sections are already unavoidably dated, such as chapter 12, which compares CTP with other related imaging techniques (for example, much recent literature has emerged correlating CT with MR perfusion parameters), this book nonetheless provides a valuable framework for placing in context important issues in cerebrovascular imaging with respect to timeless underlying physiologic principles. The clinical background, though surveyed, is not as thoroughly covered as in some recent texts, including *Magnetic Resonance Imaging in Ischemic Stroke* (von Kummer and Back, eds, Springer 2006), *Acute Ischemic Stroke: Imaging and Intervention* (Gonzalez, Hirsch, Koroshetz et al, eds, Springer 2006), and the 2-volume *Neuroimaging Clinics of North America: Stroke* (Lev, ed, Elsevier 2005).

Chapter 1 offers a unique, refreshing, and engaging (if not entirely relevant) historical overview, which begins with the earliest scientific investigations of anatomy and physiology recorded in the Edwin Smith Surgical Papyrus (circa 3000–2500 BC), the document that mentions the word *brain* for the first time in history. In Huang Ti's *Canon of Medicine* (circa 2600 BC), a clear relationship between blood, pulse, and heart is delineated, which remained unconfirmed to the Western world until William Harvey in the 17th century. The development of CT perfusion imaging is subsequently traced from the anatomic studies of historical figures such as Galen and Vesalius, to the more topically relevant physics, angiographic, mathematic, and physiologic work of Röntgen, Moniz, Hounsfield, Fick, and others. This development then culminates in the Kety-Schmidt method, developed at the National Institutes of Health in the 1940s, which, to this day, remains the basis for cerebral perfusion imaging with the use of positron-emission tomography (PET) and xenon-enhanced CT. The first chapter concludes with the early deconvolution models for CT perfusion imaging developed by Leon Axel in 1980, which were limited at that time by the slow speed of commercially available scanners and data processing systems.

Chapters 2 and 3 make a concerted effort to convey to the nonexpert the mathematical models that are required for computing parameters of cerebral perfusion. Limited space is devoted to the "maximum slope" method of calculating cerebral blood flow, which is appropriate, because the deconvolution method is more complex and more accurate, and the method of choice in most commercially available CTP processing software packages. These chapters cover difficult but important material, including the confounding concepts of "delay" and "dispersion," which is best suited to readers with a strong mathematic and engineering background. Given the target audience, it may have been useful for key "take-home" points to be highlighted for the lay reader in charts or tables.

Chapter 4 describes, in very practical terms, the scanning and contrast injection protocols used in CT perfusion studies. Many important aspects of these methods are covered, and sample protocols are provided, which can be used as a starting point for those wishing to perform clinical perfusion imaging. Some concepts, such as compartmental analysis, are discussed with insufficient reference to earlier chapters, and some recently developed techniques for optimizing the contrast bolus, most notably the use of a saline "chaser" for bolus shaping, are not mentioned.

Chapter 5, titled "Image Processing," deals with segmentation of already postprocessed CT perfusion maps for the purpose of deriving clinically relevant blood flow, blood volume, and vascular data useful in stroke triage. This chapter should more logically have followed chapter 10, which surveys the practical issues involved in *creating* CTP maps, including choice of arterial input and venous outflow functions (which clearly have an impact on map quantitation). Regardless, the discussion of CTP map analysis is well written and informative, and provides the beginner with background required to interpret CTP images. Some of the details, however, such as whether to implement binomial smoothing of postprocessed pixels, may be of greatest interest to researchers because available commercial software packages do not consistently give the user control over such options. Moreover, the discussion extends beyond the expected scope of the chapter in establishing specific thresholds for distinguishing potentially salvageable from irreversibly infarcted gray and white matter. Although the novel method suggested by the authors is intriguing—they suggest basing the threshold on the product

of cerebral blood volume and cerebral blood flow values—their approach is nonstandard, has only recently been published in peer-reviewed literature, and has yet to be validated. The exploratory nature of, and context for, this schema should therefore have been noted more explicitly.

Chapter 6 offers an excellent discussion of cerebrovascular pathophysiology and the processes that affect perfusion measurements in various disease states. Although some of the details of the biochemical regulation of cerebrovascular tone and blood-brain barrier permeability are of mainly theoretic interest to clinical radiologists, an understanding of these mechanisms helps place interpretation of CTP map images in the appropriate context.

In chapter 7, the use of CTP in diagnosis of acute stroke is discussed with respect to each perfusion parameter, with the conclusion that the best approach is a combination of the parameters. In chapter 8, the authors briefly review the use of combined CTP and CT angiography (CTA) to select patients for acute stroke therapy. They explain the rationale behind the use of advanced imaging to identify patients most likely to benefit from intravenous thrombolysis beyond the 3-hour window currently approved by the US Food and Drug Administration, but they do not expand on the results of supporting clinical trials. The authors note several factors that make CTP preferable to MRP in this setting. Chapter 9 provides a similar brief overview concerning the use of CTP to evaluate vasospasm after a subarachnoid hemorrhage, in which the authors compare CTA and CTP to transcranial Doppler sonography and discuss what perfusion parameters are of greatest use in this application.

Chapter 10, "Practical Approach to CT Perfusion Scan Analysis for the Physician," is an outstanding, practical guide to CTP map postprocessing and interpretation (for both acute stroke and chronic ischemia), and is arguably the section of greatest interest to the target reader. Whereas in large academic centers on-call fellows or highly trained technologists perform CTP map postprocessing, in other facilities the interpreting radiologist may need to be comfortable with the basics of CTP map construction. Although the newest software packages have the potential to create fully automated, quantitatively reliable CTP maps (again, the text may already be dated in this regard), this chapter should, at a minimum, provide the reader with a working knowledge of the "pearls and pitfalls" required for quality control. For example, the authors discuss the difference between using an occluded versus patent artery for the arterial input function (the patent artery may lead to overestimation of transit time and underestimation of blood flow ipsilateral to a stroke).

Chapter 11 explores the relative roles of CTA and CTP in acute stroke imaging and concludes that debates about whether one or the other should be used as the sole imaging technique are ill advised, and that both should be used in a complementary fashion. There follows a brief discussion about the usefulness of CTA source images as a "poor man's perfusion" study to detect core regions of decreased cerebral blood volume, likely to be irreversibly infarcted. Chapter 12, as already noted, compares CTP with other modalities used to assess cerebral perfusion, namely, xenon-enhanced CT, MR imaging, PET, and single-photon emission CT. The authors highlight the technical advantages of CTP that support its routine use in both clinical and research settings.

In conclusion, this monograph provides a detailed and useful overview of CT perfusion imaging technology, which should be of greatest interest to radiologists and others responsible for the clinical implementation of this technique. Chapters 4, 10, and possibly 7 are potentially the most relevant for this target audience. Chapters 2 and 3 will be more appealing to advanced readers seeking an in-depth knowledge of the theoretic underpinnings. The volume is well illustrated and will be a welcome addition to the reference library of anyone involved or interested in cerebrovascular imaging.

DOI 10.3174/ajnr.A0932