CHAPTER 1

ULTRA HIGH FIELD MAGNETIC RESONANCE IMAGING: A HISTORICAL PERSPECTIVE

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1. INTRODUCTION

As one recalls the 1970s and some of the first steps in magnetic resonance imaging [1–4], it is easy to discern the great strides that have been made in this discipline over the past 30 years [5–7]. Early coarse and grainy results [4] have given way to exquisite anatomical and functional images [5–7]. The availability of MRI is now synonymous with quality of medical care, even within the rural hospital setting, and the 1.5 Tesla scanner has become a workhorse of the modern radiological exam. With the exception of CT, and this primarily in the abdomen, no other radiological modality can compete with MRI, not only in terms of the breadth of exams currently possible, but also in the future promise of the technique. Indeed, it seems that every year new clinical applications join the arsenal of MRI exams. Soon, it is anticipated that MRI will be able to fully scan the entire body [8] in great detail, including the most difficult thoracic [9–17] and abdominal locations [18–22]. Technical advancements forged and tested in the research laboratories of the world [23–40] continue to add to the versatility and power of MRI scanners. Nonetheless, what is perhaps most fascinating relative to the evolution of MRI is the seemingly untapped potential that remains. The spawning of new techniques may well open up tremendous venues for MRI in the coming decades. Thus, the clinical horizon is imperceptible. One is left only with the realization that future progress may well surpass all contributions to date.

In fact, it is clear that many aspects of MRI are, if not in their infancy, at least in their childhood. These include interventional MRI [41–44], MR spectroscopy, in-vivo EPR [45], ultra low field MRI [46], and, of course, ultra high field MRI. In addition, future discoveries in probes, molecular targeting, pharmaceutical monitoring, and contrast enhancement methods are sure to further amplify the unimaginable promise of magnetic resonance [47–56]. In the past 10 years, a revolution has slowly begun to take place in image acquisition techniques with the introduction of phased arrays [23] and partially parallel imaging techniques [24–27, 35]. The power of these new approaches has proven so phenomenal that their advent,
for now, far surpasses in importance the push toward higher fields. Indeed, technology-based improvements in imaging are far from reaching a plateau. As such, if MRI as a discipline suffers from a single affliction, it is in a lack of resources to fully pursue all of these avenues.

2. ULTRA HIGH FIELD MRI

It is anticipated that, by the beginning of 2008, at least 30 UHFMRI systems will dot the globe. Less than eight years will have elapsed from the construction of the first UHFMRI magnet [57] and the first two UHFMRI systems [58–61]. Industrial concerns are investing significant financial and human resources toward the clinical development of this modality. As a result, virtually all new UHFMRI systems are now being produced by the major MRI vendors: Siemens, GE, and Phillips. UHFMRI is being rushed into the clinical arena in a manner clearly distinct from the long and arduous experimental stage surrounding the world’s 4 Tesla systems.

Almost from the inception of UHFMRI, the 7 Tesla magnet has been destined to play a dominant role in clinical investigation [60,61]. With its 90-cm bore size, the aforementioned system results in a clinical instrument that is clearly superior to an 8 Tesla/80-cm magnet [57–59]. This is true both in terms of patient comfort and potential gradient performance. In the end, a small concession in field strength (3 rather than 4, 7 rather than 8) is made for the promise of greater bore size, and perhaps, lower production costs. The 8T system, like the 4T system, seems destined to play a purely experimental role in the development of MRI. Clinical practice will take place at 3 and 7 T.

2.1. From Concept to Reality

2.1.1. Theoretical Arguments

In retrospect, it seems like the decision to advance toward Ultra High Fields was nothing but logical. After all, the Boltzmann equation has always provided sufficient impetus for increasing field strength, at least in NMR. However, the situation in MRI was not all that clear in the late 1990s. Almost since the inception of MRI as a technique, skepticism has surrounded the increase to higher fields. This was especially true for the first UHFMRI systems. For much of the scientific community, there was real concern relative to the feasibility of such an adventure. In fact, this position made ample sense given that early warnings had always existed about RF penetration problems [62,63], RF power requirements [64–67], susceptibility artifacts, and insurmountable dielectric resonance phenomena [63,68]. Toft had advanced the notion that dielectric resonances should not play a dominant role in human MRI [69]. Yet confusion on this issue still prevailed. Concerns were uttered that fundamental dielectric resonances would produce signal voids in the