Neuroimaging Trends and Future Outlook

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KEYWORDS

• Diagnostic neuroimaging • Imaging trends • Functional imaging
• Quantitative imaging

KEY POINTS

- Imaging equipment continues to experience advances in speed, sensitivity, safety, and workflow.
- Fast acquisition methods increasingly take advantage of advances in hardware and algorithms, particularly sparse sampling methods to minimize data collection.
- There is an increasing trend toward physiologic imaging and quantitation, requiring greater consistency across manufacturers and clinics.
- The Human Connectome Project is symbolic of the drive toward combining multimodality anatomic and functional imaging with quantitation and sophisticated atlases to understand the complex circuitry of the central nervous system.
- Advanced visualization methods derived from the computer graphics and entertainment industries have become essential in the evaluation of large multidimensional data sets.
- Hybrid imaging blends advantages from multiple modalities to provide a comprehensive anatomic, functional, physiologic, and metabolic data set.
- Breakthrough clinical neuroimaging applications are derived from an alignment of scientific, engineering, clinical, and business conditions.

INTRODUCTION

Magnetic resonance (MR), computed tomography (CT), nuclear medicine, and ultrasound have been the foundation for modern noninvasive diagnostic neuroimaging during the past 4 decades. Research and innovations in engineering, algorithms, computer processing, pharmaceuticals, and the understanding of biophysical mechanisms have propelled each individually and collectively toward sophisticated visualization and quantification of disease processes. It is often the case that core ideas are developed before commercialization, subject to sometimes unpredictable solutions to nontechnical hurdles such as clinical reimbursement. Despite these

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inherent risks in prognostication, this article offers an outlook on some promising technologies that may affect clinical neuroimaging in the near future.

COMMON DEVELOPMENTS

Historical reviews[1–4] offer insights into the complex interplay of inventions and collaborations across disciplines and generations that factor into product evolution. **Table 1** summarizes general trends in neuroimaging that are common to the development and integration of individual imaging systems.

An important goal of medical imaging is preclinical detection of disease or disease progression. For example, the diagnosis of multiple sclerosis in radiologically isolated syndrome is now acceptable in the absence of clinical findings.[5] There is an increasing trend toward using more numeric data to supplement or highlight conventional image analysis because quantitative comparisons with normal ranges may detect more subtle variations that may arise early in a disease. Variability caused by the lack of robust standardization across technologists, physicians, centers, and vendors must be minimized in order to fully exploit the benefits of quantitation.[6] Automation in volume positioning, technique selection, workflow, and display processing will continue to be a development focus for the purpose of reducing variability.

The computer graphics and movie industries have accelerated the evolution of visualization tools in medical imaging. Very-high-resolution three-dimensional (3D), four-dimensional (4D) (dynamic), and multimodal data sets that are now obtained within reasonable scan times combine with interactive rendering, fly-through, and morphing algorithms and computer graphics engines to produce views of the human body that previously were unattainable. Visualization tools have become essential given the large volume of raw data collected. Obstacles to the use of sophisticated visualization

Table 1
General trends

Feature	Innovations
Connectomics	Merging functional and anatomic data from multiple modalities; large disease databases and atlases; connectivity informatics applied to understanding brain circuitry, and its relationship to cognition, development, and disease characteristics
Quantitation	Standardization and testing across vendors; age-matched controls; improved sensitivity and consistency in acquisitions; measurement and visualization of physiologic characteristics
Visualization	Multimodality fusion; integrated numerical analysis; sophisticated computer graphics to manipulate multidimensional data sets
Simplicity and repeatability	Automatic positioning and acquisitions; intervendor standardization
Patient comfort	Faster acquisitions; motion correction; gantries designed for comfort
Acquisition speed	Hardware speed; sparse sampling
Hybrid systems	PET/MR/EEG, photoacoustic, MR/HIFU

Abbreviations: EEG, electroencephalogram; HIFU, high-intensity focused ultrasound; PET, positron emission tomography.