Chapter 1
Overview and History of Image-Guided Interventions

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Abstract
Although the routine use of image-guided intervention (IGI) is only about 20 years old, it grew out of stereotactic neurosurgical techniques that have a much longer history. This chapter introduces stereotactic techniques and discusses the evolution of image-guided surgical techniques enabled by the introduction of modern imaging modalities, computers, and tracking devices. Equally important in the evolution of this discipline were developments in three-dimensional (3D) image reconstruction, visualization, segmentation, and registration. This chapter discusses the role that each has played in the development of systems designed for IGI. Finally, a number of challenges are identified that currently are preventing IGI to progress.

1.1 Introduction
At the time of writing, the modern embodiment of the field of image-guided intervention (IGI) is approximately 20 years old. Currently, the general task of IGI can be subdivided into five smaller processes and a handful of general concepts. The subprocesses are to

1. gather preoperative data, generally in the form of tomographic images;
2. localize and track the position of the surgical tool or therapeutic device;
3. register the localizer volume with the preoperative data;
4. display the position of the tool with regard to medically important structures visible in the preoperative data; and
5. account for differences between the preoperative data and the intraoperative reality.
Underlying IGI are two fundamental concepts:

1. three-dimensional position data can be used to guide a physiological or medical procedure and
2. path, pose, and orientation make the problem at least six dimensional.

Although IGI is only 20 years old, the concepts and subprocesses have been developed, tested, and refined for over a hundred years. It also is interesting to note that the first known medical application of x-ray imaging was taken with therapeutic, not diagnostic, intent. A mere 8 days after the publication of Roentgen’s first paper on x-ray imaging in 1895, J. H. Clayton, a casualty surgeon in Birmingham, England, used a bromide print of an x-ray to remove an industrial sewing needle from a woman’s hand [Burrows 1986]. Barely a month later, John Cox, Professor of Physics at McGill University in Montreal [Cox and Kirkpatrick 1896], successfully removed a bullet from the leg of a victim based upon the radiograph that had been made of the limb. Not only was the projectile successfully removed on the basis of the radiograph, it was later used as evidence during a suit against the man who had shot the victim.

1.2 Stereotaxy

Horsley and Clark [1908] published a paper on a device that embodied several concepts and methods central to IGI 12 years after Clayton’s landmark procedure. This device was a frame (Fig. 1.1) affixed to a subject’s head (in this case, a monkey), and aligned using external anatomic landmarks, such as the auditory canals and the orbital rims. Using that alignment, the device allowed electrodes to be introduced into the skull and moved to locations within a Cartesian space defined by the frame. Horsley and Clark called their device a stereotaxic frame and brought several ideas to the forefront, notably the use of an external device to define a space within an anatomical structure, and the guidance of a tool or sensor to a point within that space. Horsley and Clark also used serial sections and illustrations derived from the sections to map where they wanted to move their instruments. This idea presaged tomographic imaging by more than 50 years. Horsley and Clark also introduced the concept of a spatial brain atlas. In an atlas, the user assumes that certain structures or functions can be found at particular spatial settings on the frame. The fundamental flaw in their system was that they assumed the monkey brains possessed a constant structure; that is, that one monkey’s brain is the same as another. This led them to believe that external structures (auditory canals and orbital rims) could be used to accurately predict the location of internal structures.

To resolve these issues, and for stereotaxy to progress from physiological experiments on monkeys to medical procedures on humans, a methodology for obtaining patient specific information about internal structures