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Since the invention of X-rays in 1895, there has been a steady progression of angiographic techniques differing in their degree of invasiveness. This presentation will trace some of the developments in the use of x-rays and magnetic resonance techniques for angiography.. In 1939 Robb and Steinberg experimented with an intravenous approach to angiography. Due to the dilution of contrast material which occurs in transit from the venous to the arterial circulation, image quality was not sufficient to justify this less invasive approach.

In the late 1970's investigators from several institutions began to re-explore intravenous angiography. Following the introduction of DSA equipment by three companies at the RSNA in 1980, there was a flurry of enthusiasm for intravenous DSA. By 1983 there were over thirty companies selling apparatus capable of real time image subtraction.. Unfortunately as time passed, it became apparent that the intravenous approach to angiography had significant limitations. Soon it was realized that DSA equipment permitted arterial injections with smaller catheters and smaller amounts of iodine, both of which contributed to less risk. Intra-arterial DSA has become the gold standard angiographic technique for the past decade.

During the mid-1980's magnetic resonance angiographic techniques began to emerge. These relied on inflow-enhancement or phase contrast effects. Although clinically useful methods evolved, the techniques have several limitations including post-stenotic signal loss and saturation of signal. In the early 1990's intravenous MR angiography using gadolinium as a contrast agent became available. The use of gadolinium markedly improves image quality and permits the use of larger fields of view.

One of the main difficulties with intravenous MRA is the need to carefully time the acquisition of the most important central k-space information relative to the contrast passage. Several promising techniques have been used to trigger the acquisition of single high-resolution 3D MR angiograms. These include low dose timing scans, gadolinium signal detection and the use of 2D MR fluoroscopy images to detect the arrival of gadolinium. Another approach is to use time-resolved 3D scans which provide a data set analogous to that of X-ray DSA . Although these images have lower spatial and temporal resolution than X-ray DSA, they provide a 3D data set which provides considerable flexibility for the evaluation of lesions. Presently, reconstruction of the large 3D data sets precludes real- time reconstruction. However, this situation is likely to be temporary. 3D MR-DSA and related contrast-enhanced MRA techniques promise to provide a more reliable and less invasive method than previous attempts at intravenous angiography.

### Educational Objectives

This presentation will provide:

- 1        An historical overview of developments in angiography
- 2        An understanding of the basic properties, advantages and limitations of x-ray angiographic techniques.
- 3        An understanding of the properties of non-enhanced magnetic resonance angiography techniques.

- 4 An understanding of current and emerging techniques for contrast-enhanced magnetic resonance angiography.