Introduction to stroke

What is stroke:
Stroke occurs when an artery leading to/within the brain either bursts or is blocked by a clot [1].

Types of stroke:
1. Ischemic stroke (Figure 1)
   - Caused by blockage within blood vessel
     a. Atherosclerosis → Reduced blood flow
     b. Rupture of plaque → Blood clots → Blood vessel blocked → Permanent damage [1]
2. Hemorrhagic stroke (Figure 2)
   - Caused by rupture of a weakened blood vessel

Diffusion MRI as a diagnostic tool

1. Overall view: the early detection of stroke risk
Traditional MRI can only detect stroke after bleeding happens (Figure 3), but diffusion MRI can sense the changes in the brain before the blood vessel breaks [2] (Figure 4). This is because the high tissue pressure in the risk area causes decrease in diffusion activity, which is reflected on the diffusion weighted image.

2. The principles: a combination of two concepts
   a. The concept of diffusion:
      Diffusion is the random motion of molecules driven by internal thermal energy [2]. For example, the motion of a drop of ink in the water is diffusion (Figure 5).

   b. The concept of nuclear spin:
      Atomic nuclei such as the nuclei of hydrogen atoms rotate at certain speed, this phenomenon is called nuclear spin [8]. When a nucleus rotates, it will produce a magnetic field, which is a detectable signal (Figure 6).

   The combination.
   Diffusion of water molecules causes a loss of the signals produced by nuclear spin, and the magnitude loss is measured. The process is shown in the flow chart (Figure 7).

3. The final step: image construction
In this stage, diffusion coefficients measured are mathematically computed to quantitatively describe the diffusion process. At a certain location, a three dimensional ellipsoid (Figure 8) is drawn with axes representing the diffusion magnitudes in different directions.

Combining ellipsoids at different locations gives an overall view of diffusion in the brain [8] (Figure 9).
Advantages of diffusion MRI

Imaging tissue architecture:
Tissue architectures such as cellular membranes can influence the process of diffusion. Some diffusion weighted images allow us to see the micro-architecture of the tissue imaged [2] (Figure 10).

Examining fibrous tissues:
Diffusion along fibers can be shown on the diffusion MRI image. So fibrous tissues such as white matter of brains and fibers of muscles (Figure 11) can be imaged for diagnosis [6].

Mapping nerve connections:
According to the diffusion intensity, the nerve fibers can be tracked and mapped [6]. Thus, models can be built to reflect the nerve connections (Figure 12).

Limitations & Potential Hazards

1. Metallic Implants (Figure 13)
Diffusion MRI is not suitable for patients with metallic implants.
- Metal does not contain hydrogen
- Causes signal loss
- Distorts magnetic field of surrounding areas
- Ferromagnetic surgical clip
- Experiences a torque and twists
- Hemorrhage

2. Chemical Shift (Figure 14)
It is present at interfaces of tissues which have different molecular organization, e.g., interfaces of fat and other tissues, as the frequency of nuclear spin in fat is lower than in other soft tissues. Fat will be displaced slightly in the image [13].

3. Motion (Figure 15)
It is caused by voluntary, involuntary and microscopic physiological motion, producing “ghosting” or irregular wavelike lines of increased and decreased signal [13].

Future Development

Study of multiple sclerosis (MS):
MS is the hardening of tissue in the brain or spinal cord. Diffusion MRI has the ability to assess in vivo the presence of tissue damage occurring in the normal-appearing white and gray matter. It is sensitive to MS damage and capable of detecting its evolution over relatively short periods of time [15].

Biomarker of response to cancer therapy:
Diffusion-weighted MRI can be used for the characterization of malignancy, including determination of lesion aggressiveness and monitoring response to therapy [16].

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References