Echo Train Length

What is Echo Train Length

Echo train length (ETL), also known as turbo factor, determines the number of additional refocused echoes to be acquired in a spin echo based sequence and is used to decrease scan time. Depending on the sequence, this number can be selected by the user (as in FSE) or is controlled indirectly (as in HASTE) through other parameters such as phase encoding steps. When selecting an echo train length, it is important to remember that the refocused echo is created from an additional refocusing RF pulse. As will be discussed further down, this can have implications for controlling SAR and TR. This page will primarily focus on echo train length as used in the fast spin echo. See HASTE or 3D FSE pages for more explanation of ETL in those sequences.

Consider 1 slice of a T2 weighted spin echo sequence with a phase encoding matrix of 256; to fully acquire the image 256 lines of k-space are needed, and will be acquired 1 line at a time. For an example, if the TR is 3000ms, this will need to be repeated 256 times: 3000msx256 = 768,000ms or ~12.8 minutes. This is quite inefficient, as only 1 echo is acquired with each TR, and the rest of the TR is just spent waiting. To reduce imaging time, let's acquire 16 echoes within that 3000ms TR, the math now looks like this: (3000msx256)/16 = 48,000ms or ~48 seconds. Much faster!

Echo Train Length and Effective TE

When using a fast spin echo, the TE parameter behaves differently than in the traditional spin echo. The selected TE is now one of multiple echoes, and is placed at the center of k-space which allows it to dominate the image contrast; this is known as the 'Effective' TE. Unlike a traditional spin echo where the TE can occur with no echoes before or after it, the fast spin echo will always start with the shortest TE and extend out to the end of the selected ETL. For example, in a fast spin echo where the shortest echo is 10ms and there is a 10ms space between each echo, an ETL of 10 will result in echoes at 10ms, 20ms, 30ms, 40ms, etc until 100ms. Any of those echoes can be selected as the effective TE and placed at the center of k-space. There a few important things to take away from this behavior:

1. There are multiple echoes at varying TE values that will be acquired during a fast spin echo, always
2. The effective TE is the primary echo contributing to image contrast, but not the only echo that can influence it
3. Only the minimum, maximum, and echoes between those end points can be chosen as the effective TE

Selecting an appropriate ETL

When selecting the ETL, it is important to consider the contributions of all the echoes within the ETL to image quality, as there are some special behaviors that occur with trains of RF pulses and echoes. Very long ETL's will result in echoes that may extend out far beyond the desired effective TE. The further out the echo, the more T2 decay will occur and the 'quality' of the echo will degrade and contribute to image blurring. Additionally, a long ETL means that many more refocusing pulses will be required; this will increase SAR and also lead to some degree of tissue saturation and magnetization transfer effects. Long ETL's also take up significantly more space within the TR, so there will be a tipping point where increasing ETL will no long decrease imaging time, as the TR will have to be increased to make room for all the additional echoes. Below is an example of a T2 fast spin echo with different ETLs: 13, 24, 32, 64. Notice how edge details rapidly become blurred as the ETL is increased, and the blurring is preferentially in the phase encoding direction.

Selecting the Effective TE

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