

Towards the Perfect Quantitative MRI Machine

Paul S Tofts, Nicholas G Dowell, Mara Cercignani

Department of Neuroscience, Brighton and Sussex Medical School, Falmer, Brighton BN1 9PX

Summary: There is continued, often intense, activity to improve the performance of quantitative MRI measurement techniques (fig 1). Yet how can we know when our technique is good enough, or even 'perfect' in its used context? The concept of the 'Perfect Quantitative MRI (qMRI) machine' is explored¹; this offers a perspective on efforts to improve quantitative performance².

Proposals: We propose:

A Perfect Quantitative MRI machine is one that, in making a measurement, contributes no significant extra variation to that which already exists from biological variation.

Various grades of performance can be envisaged, depending on the purpose of the measurement. Comparison with normal variation will be the most demanding; comparison with variation within a disease might also be appropriate, depending on the context, and would be less demanding. The grade will depend on the MR parameter being measured. Some might be easy to achieve; others might need a long sustained effort. Here a proposal is made for three levels, each with an appropriate medal³ (see table 1).

Bronze medal: In a group comparison, the Instrumental Standard Deviation (ISD) should be \ll Group SD (see table 1).

Silver medal: in multicentre studies, inter-centre variation has to be controlled. MTR histogram matching using body-coil transmission is probably a perfect silver-medal MTR machine⁴.

Gold medal: in a serial study, instrumental variation can hide subtle within-subject

biological changes. The power of a serial study can be limited by such biological variation; often this is small and unknown, and may be extremely hard to measure. Gold medals will be the hardest to obtain; for some MR parameters the gold medal may be impossible. Exceptions are cerebral blood perfusion (measured by ASL) and lesion load in relapsing-remitting MS, where the natural variation is high and perfect qMRI machines already exist.

Administration of a scheme: Awarding of medals might be determined by a journal reviewer, or by perhaps by the ISMRM. Prizes could be awarded⁵.

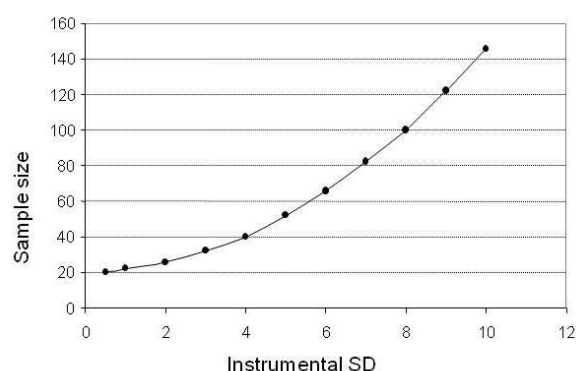


Fig 1: The effect of instrumental precision (ISD) on the statistical power of a study, and the required sample size. By reducing the ISD, the required size can be dramatically reduced, giving a saving in cost and time.

Table 1: proposed medal system

Medal	Target study	Criterion
bronze	Group comparison	ISD < 0.3 GSD
silver	Multicentre study	BCSD < GSD
gold	Serial study	ISD < 0.3 WSSD

Abbreviations: SD = standard deviation; BCSD = between-centre SD; GSD = group SD; ISD = Instrumental SD; WSSD = within-subject SD

¹ The concept of the 'Perfect Machine' originates in the building of the 200 inch Palomar telescope in 1933.

² See PS Tofts *Chapter 1: Concepts: Measurement in MRI* in *Quantitative MRI of the Brain: principles of physical measurement*, eds M Cercignani, NG Dowell and PS Tofts 2018.

³ Medals are proposed, inspired by the ISMRM scheme

⁴ Tofts *Magma* 2006; 19(4):209-22

⁵ a kind of modern day Longitude prize; this might be attractive to a philanthropist