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● *Original Contribution*

III. TRIAL OF MODIFICATIONS TO EUROSPIN MRI TEST OBJECTS

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The original design of the Eurospin test objects (*Magn. Reson. Imaging* 6:195–199; 1988) for the assessment of magnetic resonance imaging (MRI) image quality, was subjected to re-evaluation at several meetings during the subsequent years, culminating in some changes to the designs. Further, an annulus filled with saline was added to the set with the purpose of simulating the loading of the receiver coils normal in clinical use. All of these modified test objects were circulated among 8 European centres in a detailed experimental trial of their utility. The results are presented, indicating increased success and enhanced functionality of this set of test objects.

Keywords: **Performance assessment; Quality control; Protocol; Test objects; Multi-center trial.**

INTRODUCTION

The Eurospin test objects were designed as part of the work of the EC Concerted Research Project "Tissue Characterisation by MRS and MRI" (COMAC BME; project leader, Dr. F. Podo). Their original design was published some years ago[1] and subject to an experimental trial.[2] Since that time, many MRI machines have been examined all over Europe (>200) and the design of the test objects subjected to re-evaluation by the Concerted Research Project. Commercial production was instituted by Diagnostic Sonar Ltd (Baird Road, Kirkton Campus, Livingston, EH54 7BX, UK). This culminated in early 1991 in the construction of a revised set and the inclusion of an annulus (saline filled) to be used for loading of receiver coils to enable, for example, more accurate assessment of signal-to-noise. As with the first designs, an experimental trial was conducted to validate these design changes. Eight European sites (see Appendix) participated in this study.

ORIGINAL DESIGNS OF THE EUROSPIN TEST OBJECT SET

The original Eurospin set consisted of five test objects (TO1-TO5). Table 1 indicates the broad uses of the objects. The test objects are shown in Fig. 1.

General problems with these designs were fairly limited but may be summarised as follows:

1. Signal-to-noise (SNR) values were collected in an unloaded situation since the conductivity of the test object filling fluid (copper sulphate 0.7 g/l, pH = 2) is low. This could lead to problems with signal amplitude being excessive and did not give realistic SNR values appropriate to clinical use (TO1).
2. Slice profiles and thicknesses were difficult to measure in the case of thin slices (e.g., 1 mm) due to the

Table 1. Tested parameters

Parameter	Test object
Signal	
Uniformity	TO1
Image SNR or	TO1
Image SNR with loading	Annulus
Ghosting	TO1
Geometry	
Geometric distortion	TO2
Slice profile	TO2
Slice width	TO2
Slice warp	TO3
Multiple slice position	TO3
Spatial resolution and modulation transfer function	TO4
NMR parameters	
T_1 accuracy	TO5
T_1 precision	TO5
T_2 accuracy	TO5
T_2 precision	TO5
T_1 image contrast	TO5
T_2 image contrast	TO5

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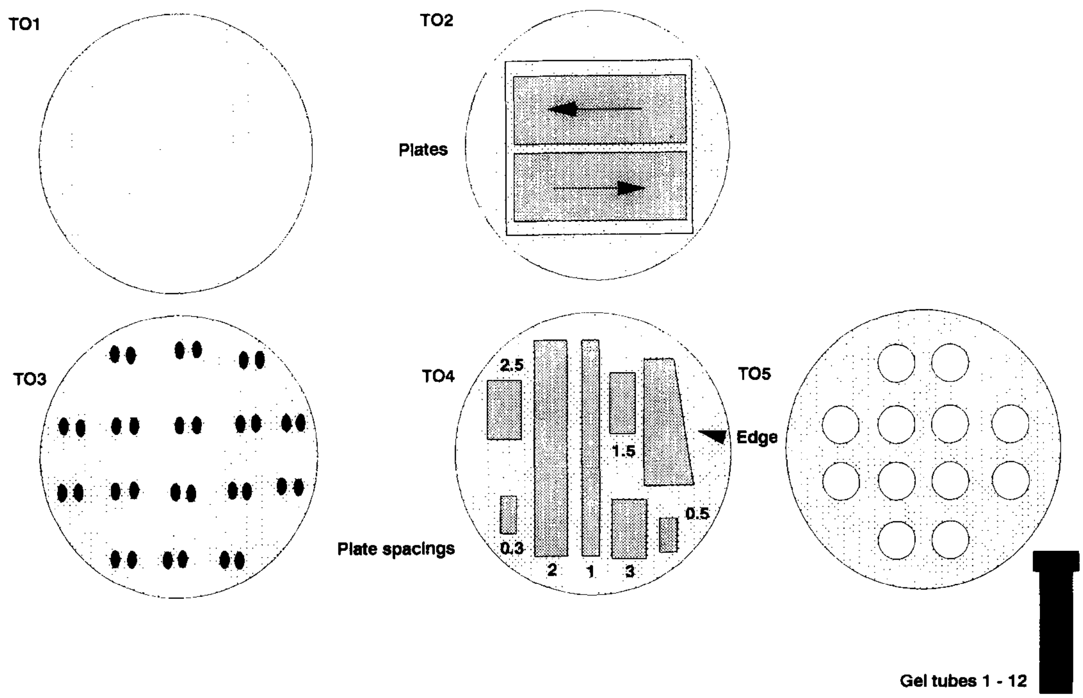

Fig. 1. Eurospin test objects—original designs.

use of an inclined plate technique. A true slice profile must be obtained by deconvolving the plate thickness from the measured profile. More appropriate for such slices—which became more commonly used in the years after the original designs were proposed—are solid wedges. These two methods have been compared by Lerski.[3] Additionally, multislice profiles were difficult to deal with (TO2).

3. The slice position and warp test object (TO3) was difficult to orientate. It was often uncertain whether the test object was correctly aligned along the axis of the scanning machine or whether a true warp was being observed.
4. Some of the resolution test object (TO4) bar patterns, for example, 3 and 2.5 mm were of no value, being easily resolved in all cases. The modulation transfer function (MTF) wedge did not include sufficient "dark space," leading to technical difficulties in accurate computation due to the failure to establish an adequate "zero" level.

NEW DESIGNS OF THE EUROSPIN TEST OBJECT SET

Modified designs of the test objects were arrived at in discussions amongst the participants in the Concerted Action convened to address these problems and were constructed in early 1991. The changes are summarized in Table 2. The loading annulus was filled with physiological saline, but additionally doped with CuS04 to a very short T_1 to ensure it was not imaged during use.

Figure 2 shows the "new" test objects.

EXPERIMENTAL TRIAL

The trial of the new designs was designed to assess whether the changes had successfully overcome the previous problems and whether any new problems had been introduced. The participants covered a range of equipment and manufacturers. In order to structure the

Table 2. Design modifications for the six test objects

Test object	Modification
TO1	No changes
TO2	Both ramps and wedges now included (two sets deep)
TO3	Orientation block added centrally to enable axial misalignment to be identified
TO4	Re-arranged and square blocks added for Modulation Transfer Function measurements
TO5	No changes
Loading annulus	To enable the measurement of image properties under conditions of optimal receiver coil loading

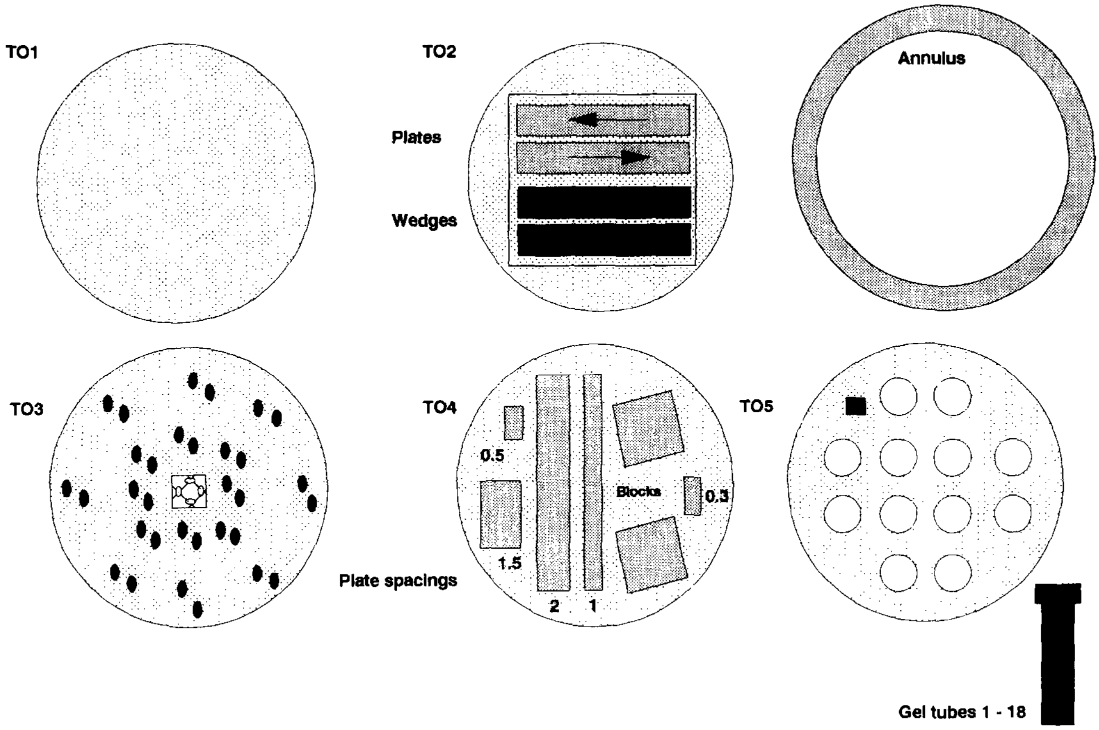

Fig. 2. Eurospin test objects—revised designs.

responses, a questionnaire was sent to all centres and typical images were requested.

Annulus

The loading annulus had been previously examined by Wilkinson et al.[4] The utility of this system in a range of scanners had been established and its success in loading receiver coils was clear. This was confirmed during the trial, one centre noting that the reduction in Q observed was from 400 to 100, whereas a typical head loaded value was around 90.

Some difficulties were experienced with locating the test objects within the annulus. This was essentially a mechanical construction problem due to the difficulties of obtaining perspex tube sizes which exactly matched each others outside diameter (TOs) and inside diameter (annulus). Future production would address this problem via a locating sleeve.

Test Object TO2

The general difficulty with slice measurements [particularly down to 1 mm full width half maximum (FWHM)] in MRI is that appropriate analytical software is often not available on commercial scanning systems. The "new" test object design included solid wedges for thin slice measurements but this requires the averaging of adjacent profile lines and the differentiation of these profiles (see Fig. 3). This is generally impossible without downloading images to a separate image analysis system.

In the experimental trial, only centre 8 was able to carry out full profile measurements on thin slices.

Test Object TO3

The new design incorporated an orientation block in its centre (Fig. 4) with the purpose of detecting a mis-

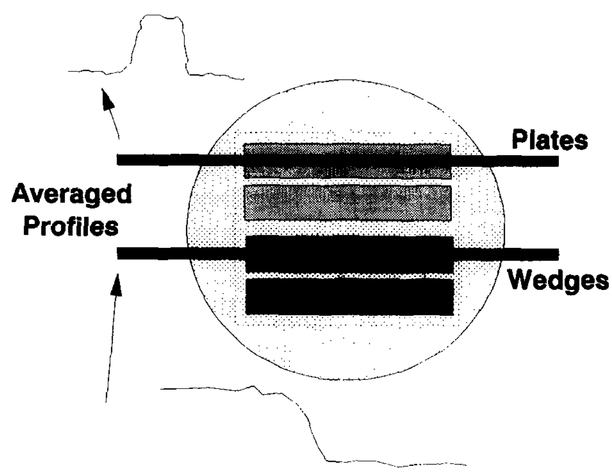

Fig. 3. TO2—slice measurement techniques.

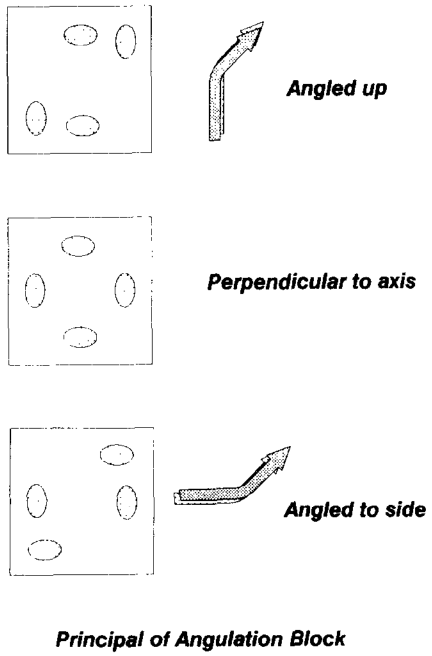

Fig. 4. TO3—principle of orientation block.

alignment with respect to the axis of the machine. This had been felt necessary because apparent slice warp could simply be caused by such misalignment, although a clue to this would be the monotonicity of such "warp." However, some centres commented that although this facility was able to reveal very sensitively axial misalignment, it was very difficult to correct it. In most imaging systems, when the test objects are placed in the head restraint for imaging, they must be wedged with pieces of plastic foam, etc. Making precise and controllable changes to orientation is virtually impossible and while each user might be able to devise his or her own specific clamp and motion system, there is no generalised immediate solution due to the plethora of head restraint or couch systems.

Test Object TO4

The modified design of this object simply involved the reorganisation of the plates of variable spacing and the addition of two sets of angled square blocks for MTF measurements. No difficulties were experienced, but only centre 8 was able to perform the measurement of modulation transfer function (MTF) due to lack of appropriate software based on the technique of Judy.[5] As previously noted by many users, a common difficulty with the use of the bar patterns is the presence of "ringing" artefacts caused by truncation of the Fourier transform (i.e., NMR signals) produced from the sharp edges of the glass plates. This has no easy solution.

CONCLUSIONS

The conclusion of these investigations may be outlined as follows:

1. Difficulties persist in accurate positioning of the test objects. Many users commented that spirit levels and additional markers on the test objects would be helpful and these will be considered in further revisions.
2. The annulus is very effective at providing loaded measurement conditions which, to a large extent, may be applied to a wide range of coil configurations at different NMR frequencies.
3. The lack of suitable measurement software on commercial systems limits the more detailed measurements, for example, slice profile, modulation transfer function. These can therefore only be performed by more technically adept users who are able to download images to their own independent analysis consoles and who have developed their own software. More complex test object designs might partially solve this problem but could not totally be expected to do so.

Acknowledgments—The measurements summarised in this paper were carried out by the centres detailed in the Appendix.

APPENDIX: PARTICIPANTS IN EXPERIMENTAL TRIAL

Centre	Project leader
1. Addenbrookes Hospital Cambridge, UK	Dr. I. Wilkinson
2. Royal Marsden Hospital Sutton, UK	Dr. M.O. Leach
3. University Hospital Utrecht, The Netherlands	Dr. C. Bakker
4. Laboratoire de RMN Medicale Rennes, France	Dr. J.D. de Certaines
5. Institute fur Medizinische Physik Wien, Austria	Dr. E. Moser
6. Deutsche Klinik fur Diagnostik Wiesbaden, Germany	Dr. G. Bielke
7. Magnetic Resonance Laboratory Prague, Czechoslovakia	Dr. M. Hajek
8. Medical Devices Directorate, Department of Health (UK) and Imperial College of Science Technology and Medicine, London	Dr. J.A. Lunt and Ms. J. Bean

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