C. Reducing motion artefacts in foetal MRI: the contribution of the radiographer

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Authors: C. Malamateniou; London/UK
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Learning objectives

1. To understand the challenges and constraints of foetal MRI.
2. To recognise common motion artefacts associated with foetal MRI.
3. To be able to suggest remedial strategies to minimise motion artefacts in foetal MRI scans.
Introduction:

MRI is a safe technique for imaging the foetus due to the lack of ionising radiation. It was initially introduced in 1983 (1) but the use of MRI in this field of diagnosis is steadily increasing following hardware and software advancements as well as clinical needs. It is considered an adjunct to ultrasound for studying the foetal brain in vivo (figure 1) and additionally offers improved soft tissue differentiation and increased field of view compared to ultrasound (2).

The challenge: patient motion and associated artefacts in foetal MRI

In foetal MRI examinations image quality is governed mainly by the signal-to-noise ratio (SNR) and the presence of motion artefacts; the lower the SNR and the more prominent the motion artefact, the lower the quality of MR images. With appropriate modern hardware (including receiver coils) and optimised sequences low SNR should no longer be an issue. Gross patient motion remains the main determinant of image quality of foetal MRI scans.

Motion artefacts may present as ghosting or blurring depending on the imaging sequence but also on the nature (intensity, speed) of movement (figures 2 and 3).

What produces motion artefacts?

Patient motion produces motion artefacts; in the context of foetal MRI motion can either be of maternal or/and foetal origin. More specifically:

1. Maternal motion

Maternal motion may also degrade image quality of fetal brain MRI examinations. Maternal motion may be involuntary or voluntary, ranging from movement of the maternal bowel and diaphragm to body movements because of discomfort, poor communication with the imaging team or maternal stress for the diagnostic outcome of the scan. The commonest source of motion artefacts due to maternal motion is that relating to incomplete or unsuccessful maternal breath-hold (figure 2). Artefacts from bowel movement may be difficult to prevent, particularly if fetal head is adjacent.
2. Foetal motion

Perhaps the most distinguishing characteristics of foetal head motion are that it is three-dimensional and uncontrollable. Recent cine MRI studies confirm that rotations, flexions and extensions in all the main anatomical regions (upper limbs, lower limbs, head and trunk) can be observed during intra-uterine life (figure 4). Less frequent were yawns and other mouthing movements including swallowing. Eye and paradoxical breathing movements could also be observed at all ages, as well as kicking, brief twitches and startles (3).

How can the radiographers help:

Radiographers are strategically placed within the medical imaging team not only to safeguard patient safety and comfort but also to act as the gatekeepers of image quality in foetal MRI and as the first line image optimisation experts.

There are many different ways in which the radiographers can help compensate motion artefacts in foetal MRI:

1. Adequate patient preparation

Adequate advice should be given to the expectant mothers to keep fluids to a minimum and empty their bladder prior to the examination to increase patient comfort and maximise compliance to the scanning instructions. Clear instructions of what is expected from the patients (staying still during the scan, holding their breath etc.) and a brief description of the procedure prior to the examination can improve patient co-operation. Maternal sedation is not generally used (4).

2. Correct use of receiver coils

This is important to maximise signal to noise ratio and for a successful MRI examination, particularly for depicting the minute foetal anatomical features (figure 5).

3. Careful patient positioning

Positioning involves the use of pillows and sandbags to make the mother feel comfortable and a left decubitus position is preferred to prevent inferior vena cava syndrome. Because of accumulation of heat during the RF pulses, the patients are advised to fully change into
examination gowns and lie barefoot in the scanner for effective heat dissipation; a cooling fan in the scanner bore may also be helpful to keep temperature down. Ear protection in the form of head phones should be used at all times. The patients should be monitored throughout the examination and visual contact as well as verbal communication should be maintained to ensure a smooth and safe run of the scan.

4. Correct use of motion resistant imaging sequences

Radiographers may suggest the use of well known motion resistant protocols, including the single-shot fast spin echo (SSh FSE) (5) and echo planar imaging (EPI) (6) techniques, where motion in practically frozen.

Additionally the use of parallel imaging (7) should be employed to decrease total scanning time and minimise the probability of motion occurring and preventing the presence of motion artefacts.

5. Optimisation of commercially available protocols to address clinical needs

Standard preset protocols can be optimised by the MRI multidisciplinary team; the contribution of the radiographer is essential to tailor clinical protocol to specific clinical needs and to each individual patient. Our team at Imperial College has recently developed an optimised robust T1-weighted alternative for foetal brain imaging called Snapshot Inversion Recovery or SNAPIR (8, figure 2).

Conclusion:

Radiographers work in the interface between technological development and applied clinical practice; they are therefore the professionals which ensure that the relevant novel imaging techniques are applied to prevent and minimise motion artefacts and that patient co-operation is maximised through enhanced communication and careful monitoring for a successful diagnostic foetal MRI examination.
**Fig. 1:** Good quality high signal-to-noise ratio free of motion artefacts axial T2-weighted foetal brain MR images acquired using a single-shot Fast Spin Echo technique during early (left) and late gestation (right).

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Fig. 2: Top row: severely motion artefacted axial T1-weighted gradient echo foetal brain images as a result of incomplete maternal breath-hold. All slices are affected by a ghosting type motion artefact (white arrow) Lower row: axial foetal brain scans of the same patient using a motion resistant T1-weighted alternative acquisition called SNAPshot Inversion Recovery or SNAPIR


Fig. 3: Left: mild foetal head motion resulting in mild image blurring; different anatomical structures can be depicted Middle: moderate foetal head motion resulting in increased image blurring; conspicuity of the lower contrast anatomical structures decreases Right: extreme foetal head motion resulting in severely motion artefacted images; very difficult to depict distinct anatomical structures

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Fig. 4: Examples of the foetal movement repertoire. A-C, Time points 0, 4, and 8 seconds of cine data at 22 weeks gestation. D-F, Time points 0, 6, and 10 seconds of cine data at 30 weeks gestation. The younger foetus (A-C) demonstrates a complete flexion at its knees and extension in its trunk, followed by trunk relaxation and knee extension. The older fetus (D-F) also shows general movements consisting of flexion at the knee joint (dashed line) as well as at the elbow (dotted line). Arrows indicate hands, 1 of which is rotating in the older fetus. The overall variability in amplitude of movements that older fetuses perform is significantly reduced and appears associated with uterine restrictions giving a cramped appearance to movements. This is in contrast to younger fetuses, that tend to make full use of their surrounding space.

Fig. 5: A sagittal T2-weighted image of twin pregnancy. The foetus sitting in the lower position (normal foetus) has higher signal to noise ratio compared to the foetus in the higher position (growth restricted foetus). This is because the normal foetus is closer to the MRI signal-receiving imaging coil. Therefore coil positioning is essential to maximise image quality.

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References


**Personal Information**

Dr Christina Malamateniou

Research radiographer

Robert Steiner MRI Unit, Imperial College London

Hammersmith Hospital Campus

W12 0HS

LONDON

United Kingdom

Research Consultant

Fetal/neonatal MRI

Philips Healthcare Hellas

Visiting lecturer

Department of Medical Imaging

Technological Educational Institute of Athens

email: cm1@imperial.ac.uk and c.malamateniou@philips.com