Fetal MRI: 3T or 1.5T?

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Purpose

Fetal MRI has been predominatly performed at 1.5T magnetic field strenght. A few centres have now reported results from imaging at 3T, taking advantage of the increased SNR at higher field, wich is beneficial for the visualisation of fetal anatomy. However, higher field imaging may also produce more artefacts.

The aim of the current study is to offer a more comprehensive and systematic exploration of the gains in anatomical conspicuity across multiple different anatomical structures as well as in different markers of image quality in healthy and complicated pregnancies and to document the challenges and advantages of fetal MRI scans at 3T and 1.5T both from a radiological/diagnostic and a radiographic/image quality perspective. Our study also highlights the practicalities involved in patient safety and care, which are vital for a successful and safe fetal MRI examination.
Methods and materials

We performed a comprehensive evaluation of 20 fetal MRI scans, consisting of 10 fetuses scanned at 1.5T and 10 gestationally age-matched fetuses scanned at 3T, with equal numbers of controls and clinical cases imaged at each field strength (5 each). The age range was 20+3 to 34+5 weeks for the controls and 22 to 35+6 weeks for the clinical cases. Maternal weight was comparable (p=0.7) between the 1.5T (mean 71.4kgs) and 3T (mean 69.1kgs).

Customised patient care and patient safety protocols and optimised imaging techniques were used.

Women were scanned on feet first position to minimise claustrophobia and on mild left lateral tilt to avoid compression of the inferior vena cava by the gravid uterus, supported by MR safe maternity pillow and foam pads.

Maternal temperature was recorded before and after the MRI scan using a tympanic thermometer and vital signs (pulse oxymetry, heart rate) were monitored throughout the scan. Parameters controlling heat deposition and acoustic noise levels were set in advance to the minimum level for all acquisitions.

Fetuses were examined using the following sequences: (a) Single-shot fast spin-echo T2-weighted HASTE images in axial, sagittal and coronal planes. (b) T1-weighted single shot inversion recovery (SNAPIR). (c) Balanced field echo cine acquisitions.

Radiological evaluation: T2-weighted HASTE images at 3 anatomical planes were evaluated for anatomic depiction of 55 different fetal and extra-fetal structures using at 3 point rating scale (1=poor anatomical delineation / un-interpretable images, 2=sub-optimal anatomical delineation but diagnostic images and 3=optimal anatomical delineation). Two independent observers performed the evaluation (KPB, SA).

Radiographic evaluation: a comprehensive detailed evaluation of image quality using a similar 3 point rating system was used (1=low quality, 2=average quality and 3=good quality). Technical aspects were rated such as SNR, field homogeneity and presence of artefacts (including aliasing, susceptibility, banding, but excluding motion artefacts as a random effect, unrelated to field strength) on different fetal imaging acquisitions (T2 HASTE, T1 SNAPIR and cine). The evaluation was performed twice by the same experienced observer (CM).
Observers were blind regarding the field strength for both radiological and radiographic evaluations.

The study has full ethical approval (07/H0707/105), and informed written consent was obtained from all the subjects.

Examinations were performed at a 1.5T system (Ingenia; Philips Medical Systems, Best, the Netherlands, bore diameter 70 cm) and a 3T system (Achieva; Philips Medical Systems, Best, the Netherlands, bore diameter 60 cm).
Results

Anatomical depiction was comparable on both fields.

Overall rating scores for anatomical delineation of all the structures of the fetal brain and head and neck area were comparable between 1.5T and 3T for both control (p = 0.54) and clinical (p = 0.21) cases. In the control group the mean rating scores for all fetal structures were slightly higher at 3T imaging but for extra-fetal structures the scores were lower at 3T. Head and neck fetal structures in all clinical cases were also slightly higher at 3T, but fetal body and extra-fetal structures were significantly lower at 3T. Inter-observer agreement using Cohen's kappa (#) weighted coefficient was substantial, at #=0.84 and intra-observer agreement rate was # =0.93.

Similar to the radiological evaluation, overall mean image quality scores between the 1.5T and 3T were comparable (p=0.72), with an average score for 1.5T and 3T of 2.51 and 2.48, respectively. Signal-to-noise ratios were significantly higher on the 3T images with an average score of 2.83 compared to a much lower score of 1.80 at 1.5T (p=0.0002) whereas signal homogeneity was significantly higher on the 1.5T images (p=0.0005, 2.87 vs. 2.25 at 1.5T and 3T, respectively). Similarly, there were fewer artefacts present at 1.5T, compared to 3T (p=0.06), with the SENSE-type artefact of aliasing occurring more often at 3T (on twelve T2 SINGLE-SHOT acquisitions, compared to only one at 1.5T). (Figures 1, 2 and 3).

Intra-observer agreement for the radiographic evaluation was substantial (#=0.84).
Fig. 1: T2-weighted single shot fast spin echo images of the fetal brain acquired on the transverse plane on two different subjects at 34 weeks gestational age on the 1.5T scanner (left) and at the same gestation on the 3T scanner (right). The image acquired at 1.5T (left) has a lower SNR, as represented by the grainier appearance of brain parenchyma compared to the 3T image; a SENSE artefact is present on the scan acquired at the higher field (arrow), which is due to the overall increased conspicuity of image features at 3T; Signal intensity inhomogeneity is more prominent at 3T (right), here at its mildest form presenting as a local dip of signal intensity (area within the dashed line).

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Fig. 2: T2-weighted single shot fast spin echo axial images of the fetal brain of different control subjects imaged at approximately 27 weeks, at 1.5T (left and middle) and 3T
Low SNR (which presents with more grainy appearance on the images) makes conspicuity of different anatomical structures more challenging and it can therefore impact on diagnosis. Note the marked difference of SNR on the left (low, score=1), in the middle (average, score=2) and on the image on the right (high, score=3), respectively and the impact on the clarity of visualisation of the deep grey matter and cortex in these images. 3T offers markedly increased SNR when imaging the fetus compared to the 1.5T scanners. Images are windowed similarly for a fair comparison.

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**Fig. 3:** T2-weighted single shot fast spin echo images of the fetal brain acquired on the coronal plane on two different subjects at 34 weeks gestational age on the 3T scanner (left) and at the same gestation on the 1.5T scanner (right). The image acquired at 1.5T (right) has a lower SNR, as represented by the grainier appearance of brain parenchyma compared to the 3T image; Signal intensity inhomogeneity is more prominent at 3T (left), presenting as a lower signal intensity in one hemisphere (right-hand side).

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Conclusion

Fetal scans at 1.5T and 3T field strengths are powerful diagnostic tools for detecting different anatomical structures in both normal development and disease, with comparable image quality performance.

Imaging at 3T produces fetal images with a higher SNR, which explains why certain structures can be better visualised at 3T. Albeit the SNR superiority at 3T in the brain, which was the primary anatomical area of interest for this study, high field is troubled by increased signal inhomogeneity and higher prevalence of artefacts, which can degrade image quality and make diagnosis more challenging.

Our conclusion is that fetal MRI at 1.5T is adequate for the demands of a clinical setting and that imaging at 3T currently requires considerable expertise to deal with the complex issues of image artefacts at higher field.
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