Introduction: In recent years diffusion weighted (DW)-MRI has been successfully used for tissue characterization and tumor staging. The apparent diffusion coefficient (ADC) is a potential biomarker that could be used to monitor treatment response or evaluate post-therapeutic changes. While DW-MRI is a potentially powerful tool in diagnostic oncology, the lack of uniform protocols for imaging and data analysis hinder its clinical implementation. Large differences in ADC values are reported in the literature depending on acquisition parameters. The 2009 consensus and recommendation paper highlighted the importance of quality analysis, validation and reproducibility studies. Although there are some emerging reproducibility and repeatability data in the abdomen[4], a recent review by Taouli and Koh highlights the need for further work in this area. Recently, coefficients of variability of around 14% were published for both solid tumors and bone marrow[5]. Other studies seem to indicate that only ADC changes of over 20% or 30% are significant. Substantial variations in ADC values have also been found between different scanners and vendors[6,7], further highlighting the difficulty of setting up multi-centre trials. In preparation for a study on renal cell carcinoma at our centre, we required information on the variability of a free-breathing multi-slice DW-MRI sequence. As these tumors are relatively large and heterogeneous, we were particularly interested in the variability of both large volumes on multiple slices and smaller regions on individual images.

Materials & Methods: Ten healthy volunteers (32.3±4.6 years, 7F) were imaged on 2 separate occasions. DW-MR images were acquired at 1.5T (Philips Achieva) using a free-breathing multi-slice SE-EPI sequence: TR 5.3-5.8 s, TE 62 ms, EPI factor 60, NSA 3, FOV 400-450 mm, rectangular FOV 75 %. matrix 112x256, 28-35 slices to cover the abdomen from the diaphragm to the iliac crest, slice thickness 6 mm, gap 1 mm. Six motion probing gradients with b-values of 0, 100, 200, 500, 750 and 1000 s.mm$^{-2}$ were applied in 3 orthogonal directions and trace images were synthesized for each b-value using the mean of 3 orthogonal directions. ADC maps were calculated on a pixel-by-pixel basis using a mono-exponential fit and, b=0 was excluded from the calculation in order to eliminate perfusion effects. Volume of interest (VOI) analysis was performed for the following organs: spleen, gallbladder, kidney (parenchyma) and liver (segments V and VI). Region of interest analysis (ROI) was also performed using multiple circular ROIs (5 in liver, 3 in each kidney, 3 in spleen, in gall bladder). Paired analysis was carried out on all organs using both ROI and VOI, to determine the coefficient of reproducibility (r=1.606±d.). To facilitate comparison between organs, differences between visits were expressed as a percentage change. Intra and inter-observer variability was also assessed. A flood-field phantom was also imaged at regular intervals over 100 days and 10 times on the same day on 2 occasions.

Results & Discussion: The in-vitro coefficient of variation was 1.3% over 100 days and, 0.5 and 1.0% for the daily experiments. This compares favorably with previous phantom studies[8,9]. As in previous studies[4], a spatial dependency was observed along the z-axis.

In-vivo, there was no statistical difference in the mean ADC value between visits for any organ (both analysed the same day and within a ROI) of less than 23.1%. The mean of the absolute value of the B. Anatomically equivalent slice on the repeat visit. C. ADC values through the spleen, black (visit1) grey (visit 2). Solid line = mean of the entire organ (VOI analysis), dashed lines = mean ADC value for the spleen in this slice, individual points = mean ADC value for the ROI.

Fig 1: Example of ADC measurements through the spleen. A. ADC map of slice 5 through the spleen showing a ROI used for analysis. B. Anatomically equivalent slice on the repeat visit. C. ADC values through the spleen, black (visit1) grey (visit 2). Solid line = mean of the entire organ (VOI analysis), dashed lines = mean ADC value for the spleen in this slice, individual points = mean ADC value for the ROI.

Conclusion: Good in-vitro repeatability of ADC measurements provided a sound basis for in-vivo measurements. In-vivo variability was higher and if considering all organs indiscriminately and single measurements, only changes in ADC value greater than 23.1% would be statistically significant using a 2D ROI. The analysis depends on the size of the region considered and variability is substantially lower (7.9%) for large 3D VOIs.

References
2. Kwee TC et al. JMRI 2008;28:1414-8