Novel methods for assessing the composition of colonic contents in a model of diarrhoea

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Introduction

Objective assessment of colonic content is needed to improve our understanding and the treatment of disorders of gastrointestinal function. We have developed MRI techniques to study the colon noninvasively and have modelled diarrhoeal diseases using a mannitol drink [1]: the ascending colon water content (ACWC) increased after the mannitol compared to glucose control. We initially used a subjective method of assessing the composition of the ascending colon (AC) contents: the images were subjectively scored between 1 (all dark) and 5 (all bright) with 3 having a mixture of dark and bright patches (fig. 1). This abstract developes and compares 2 automated operator-independent methods for the objective assessment of the composition of the ascending colon (AC) contents.

Methods

8 healthy volunteers were imaged on a 1.5 T Philips Achieva scanner with a SENSE 4-element abdominal body coil on two occasions. They were given a drink containing either 5% mannitol or 5% glucose powder in 350 ml of water at time 0 and a large 1000 kcal meal (400 g macaroni cheese, 100 g cheese cake and 250 ml water) at 3 hours. Subjects were scanned at baseline and hourly up to 5 hours (8 hours for two additional pilots). High resolution images of the AC were acquired with a bTFE (TR/TE =3.2/1.58 ms, rec. res. = 0.86 x 0.86 mm^2, 8 slices 5 mm thick, 1 mm gap). ROIs of the AC were manually drawn using Analyze® software and the data were normalized by the mean intensity of the kidney.

First automated method: Bi-Gaussian fit: The histogram of the signal intensity in an ROI over the AC was fitted to the following Gaussian equation using Matlab:

$$y_{fit} = a_1 \cdot e^{\frac{(x-b_1)^2}{2 \cdot c_1^2}} + a_2 \cdot e^{\frac{(x-b_2)^2}{2 \cdot c_2^2}}$$

where c_1 and c_2 were constrained ≥ 0.1 (10 times bigger that one bin) and a_2 was constrained ≥ 0. The ratio a_2/a_1 was used to assess AC content composition.

Second automated method: Gabor texture analysis: The masked colonic contents were analysed using Gabor wavelets [2-4]. In the spatial domain, a 2D Gabor filter is a Gaussian kernel function modulated by a sinusoidal plane wave. A filter bank consisting of Gabor filters with various frequencies and rotations is created. The Gabor feature is obtained by convolving the Gabor filter with the image. A Gabor feature extraction program written in Matlab, was used to compute the texture at different frequencies and orientations. The output is a graph showing the intensities for each frequency (from 0 to 0.3 cycle/pixel) averaged on 9 orientations spanning angles from 0° to 180°, and on all slices in the ROI. The integral between 0.05 and 0.15 was used to assess the AC content composition.

Results

Bi-Gaussian fit: Fig. 2 shows the histograms and fits of the images shown in fig.1 (histogram in grey, 2 gaussians plotted as blue and light blue and the total fit in red). Table 1 summarises the results for the a_2/a_1 ratios calculated on 5 sets for each score from different subjects. The a_2/a_1 values are sensitive to the different grades except for score 1 and 2 that give similar values. Fig. 3 shows the results for one subject for the mannitol case compared to subjective scores, showing a very good accordance and a more smooth transition between dark and bright compared to the scores. However, the current implementation of this method needs the operator to verify the accuracy of the fit and is time consuming.

Gabor texture analysis: Fig.4 gives an example of the texture analysis of different colonic contents for different colonic contents. The Gabor intensity changes with the different patterns particularly in the frequency range 0.05-0.15: for homogeneous contents the intensity is higher compared to a heterogeneous signal. Texture analysis for a whole data set for one subject takes less than 3 minutes and it is fully automated. Fig. 5 plots the value of the integral of the Gabor curve between 0.05 and 0.15 compared to the subjective score values, averaged on the entire set of images on the 8 subjects: for the mannitol case the AC is full of water and the contents are more homogeneous while for baselines and the glucose cases the contents are more heterogeneous and both the subjective scores and the Gabor intensity are lower.

Discussion

The Bi-Gaussian fit and the Gabor texture analysis methods provide an improved objective assessment of the AC contents compared to the subjective scoring. However, the Bi-Gaussian fit method is very time consuming and may not simply be measuring signal heterogeneity whilst the Gabor texture analysis is quick and shows good agreement with other measures of the colonic contents [1]. This could be used in future studies for assessing the effectiveness of a range of agents designed to treat diarrhoeal diseases.

References [1] Placidi et al. ISMRM Proc. 5889 (2010) [2] Gabor. J. Inst. Elect.Engr,(1946) [3] Turner. Biol. Cybernet.(1986) [4] Kämäräinen et al. Pattern Recognition and Image Analysis 17 (2007).
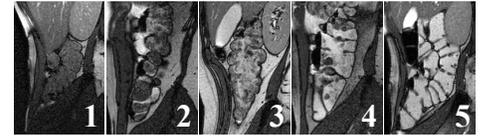
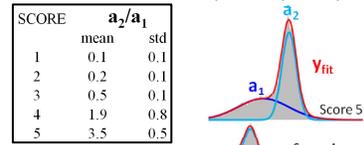**Figure 1** bTFE scans for the subjective heterogeneity measures of the AC: 1 (all dark) to 5 (all bright), [1].
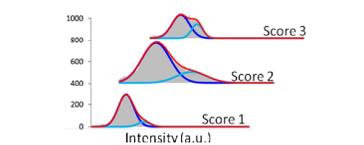

SCORE	a_2/a_1 mean	std
1	0.1	0.1
2	0.2	0.1
3	0.5	0.1
4	1.9	0.8
5	3.5	0.5

Table 1

Figure 2 Histograms for colonic ROIs from the 5 images in fig.1 with the a_2/a_1 values calculated on 5 sets of images for each score.
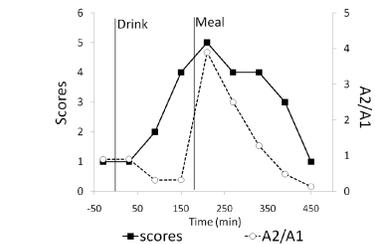

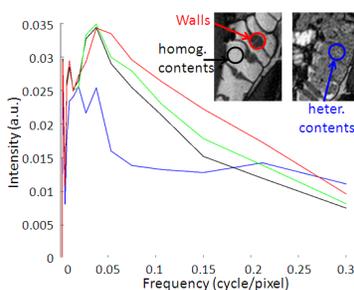**Figure 3** A_2/A_1 vs scores for one subject for the Mannitol case.

Figure 4 Gabor analysis for different AC regions (walls: red, homogeneous contents: black, heterogeneous contents: blue, walls+homogeneous contents:green).
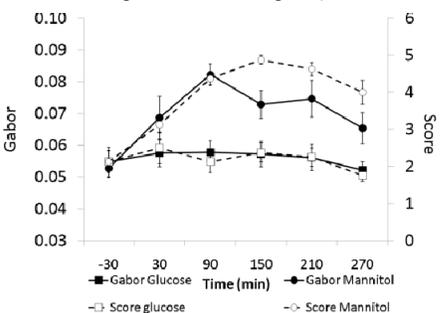

Figure 5 (mean ±SEM) Gabor integral between 0.05 and 0.15 vs scores for the 8 volunteers.