Optimising oral contrast agents for interactive neonatal gut imaging

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Introduction: Imaging the neonatal gut to investigate embryological rotational abnormalities is performed using X-ray fluoroscopy techniques (upper gastrointestinal contrast studies) which carry a significant radiation burden. We are developing an MR equivalent of the X-ray base upper GI contrast study in neonates, using an interactive real-time multi-contrast pulse sequence [1, 2]. The optimal contrast medium for neonatal use or whether this should use a T1w or T2w imaging strategy is unclear [3]. Ideally a contrast medium is required which can be easily visualised on either T1w or T2w sequences, well tolerated by the neonate, but readily distinguishable from the fluid which may already be within small bowel segments (a mixture of milk, water and other contrast media). Currently, there are no gadolinium-based contrast agent licensed or optimised for oral use in children, but several commercial fruit juices have a short T_1 (high in manganese) and may be suitable as oral contrast agents [4]. Concentrated pineapple juice (PJ), for example, has been used as a negative contrast agent for long T_2w imaging in MRCP in children [5]. Our initial evaluation of these fruit juices yielded insufficient signal on interactive T_1w sequences (FSPGR) but relatively high signal on T_2w sequences (SSFSE). However, fruit juices can cause increased neonatal gut transit time, which can be uncomfortable and distressing: this is due to the inability of the immature gut to deal with complex carbohydrate loads of >10%. In this work we investigate the ability of several different dilute contrast media to provide optimal signal. We also investigated use of an inversion prep pulse in-vivo to null any existing bowel fluid whilst retaining the conspicuity of the contrast medium.

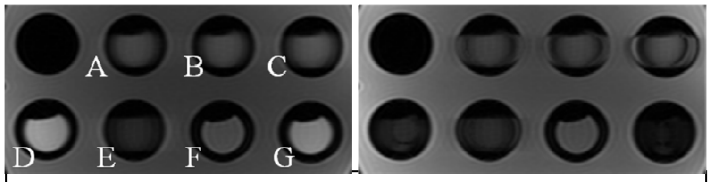

Figure 1:PDw SSFSE imaging of three variations of PJ (A - C), Gastromiro (D), Gadovist (E), Water (F), and Neocate (G). The right panel shows the effect of an inversion preparation pulse with a TI of 1000 msec, which suppresses the signal from Gastromiro (D) and Neocate milk (G)but allowing signal recovery from all PJ (A-C).

Methods: 1. The T_1 of different contrast media was measured and compared using a SSFSE sequence with variable Inversion Recovery time (TI). 7 different contrast media were tested (Figure 1): water, 0.5% dilute gadolinium (Gadovist, Bayer; 0.005mmol/ml), Iopamidol (Gastromiro, Bracco), used for X-ray fluoroscopy procedures), Neocate (Nutricia, Gaithersburg, MD) and pineapple juice diluted to 75% original strength from three UK supermarkets (A-C) to give carbohydrate concentrations of < 10%, following neonatal dietician advice. Many neonates referred have food intolerances and are therefore fed on an amino-acid based milk formula, Neocate.

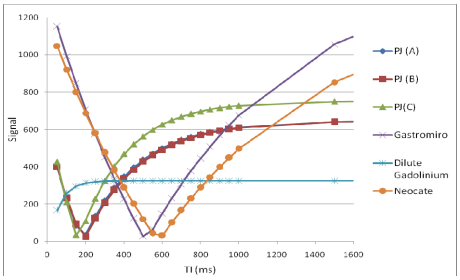

Figure 2. T1 measurement: Signal vs TI time for the 7 different contrast media

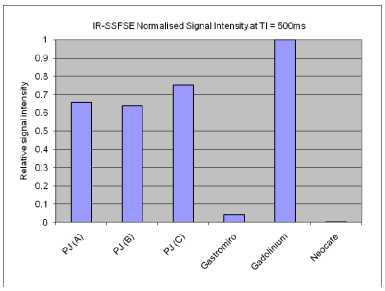

Figure 3. Relative T1 signal, using optimal ex-vivo IR time 500 msec

2. We tested the optimal solution during an upper GI MR study using the interactive IR-SSFSE sequence, as part of an ethically approved study to evaluate using interactive MR as an alternative to X-ray upper GI contrast studies for suspected malrotation [1].

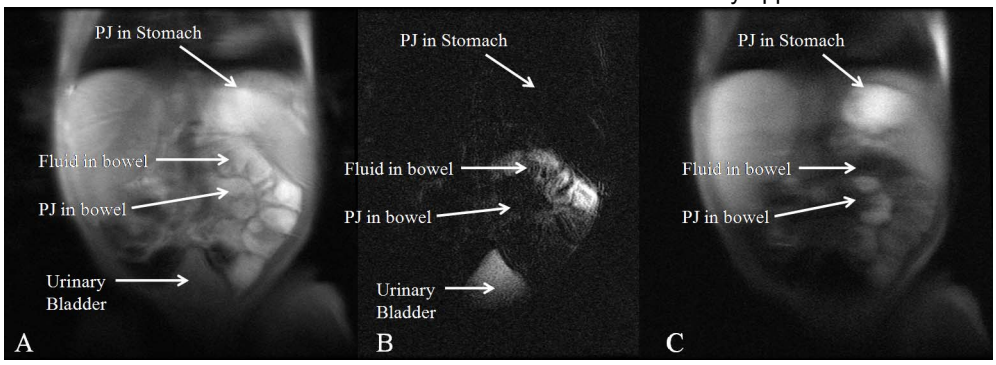

Figure 4. Coronal images from interactive RT SSFSE of neonatal GI tract : 2 week old 3 kg male infant following Pineapple juice-C administration. (A) SSFSE PDw TR 2500ms : unable to differentiate PJ-C from fluid already in the small bowel. (B) T2w hydrographic SSFSE image with TR 4000 ms demonstrating location of bowel fluid (note PJ-C low signal in stomach and bowel), (C) SSFSE PDw + inversion prep pulse, TI = 1000ms nulls the signal from fluid, but shows PJ-C as high signal in stomach and bowel.

Results: 1. The T_1 relaxation times of the different contrast media were: dilute Gadovist 50ms, Gastromiro 810ms, Neocate milk 900ms, PJ-A 290ms, PJ-B 285ms, and PJ-C 240ms (Figure 2). A TI of 500 ms effectively suppressed the signal from Gastromiro and milk whilst the various PJs (A - C) and the dilute gadolinium gave the highest signals (Figure 3). **2.** In vivo, an interactively adjusted TI of 1000ms provided optimal suppression of bowel fluid and high signal for PJ-C in a neonatal male (Figure 4).

Conclusion: In vitro, pineapple juice - C gave the highest signal relative to milk, using a TI of 500ms, whilst in vivo, pre-existing bowel contents were effectively nulled using a TI of 1000ms. The ability to interactively optimise the TI allows relatively long T_1 bowel contents to be suppressed, whilst short T_1 PJ acts as a positive contrast medium to allow accurate delineation of the gut. This strategy may allow the examination to be tailored to the individual, allowing discrimination of an orally administered contrast agent from the background signal generated by pre-existing gut contents.

References : [1] Arthurs OJ et al., Proc ISMRM 2010; 18: 4663 [2] Graves MJ, et al. Proc ISMRM 2007; 15: 1654 [3] Giovagnoni A et al., Abdom Imaging 2002; 27 : 367 - 375 [4] Espinosa MG et al., Magn Reson Imaging 2006; 24 : 195 - 200 [5] Riordan RD et al., BJR 2004 ; 77 : 991 - 999

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