


Visualisation of fetal meconium on post-mortem magnetic resonance imaging scans: a retrospective observational study

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Abstract

Background: Less invasive techniques for fetal post-mortems are increasingly used to correlate with parental wishes. With the use of post-mortem magnetic resonance imaging (MRI), normal appearance of the organs must be established.

Purpose: To investigate the after death appearance of the fetal meconium throughout gestation using the hyperintense appearance of meconium on T1 weighted MRI.

Material and Methods: This was a retrospective study that took place in a tertiary referral centre radiology department. Sixty-two fetal body post-mortem MRI scans (January 2014 to May 2018) between 12 and 41 weeks gestation were reviewed. Signal intensity of meconium at the rectum, sigmoid colon, splenic flexure and hepatic flexure was evaluated and correlated with gestational age. Interrater reliability was calculated.

Results: Meconium did not consistently have high signal intensity on T1 scans and was not always obvious. Rectal meconium had the highest intensity, and the more proximal the bowel the lower the intensity. The meconium had higher intensity at earlier gestations. Interrater reliability for rectal meconium gradings was excellent.

Conclusion: This study provides the first published primary research on the appearance of fetal meconium on post-mortem MRI. Overall, results were variable and suggest an alteration of bowel contents after death, but further investigation is needed to effectively inform practice.

Keywords

Abdomen/gastrointestinal, magnetic resonance imaging, large bowel, paediatrics, fetus

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Introduction

Fetal structural abnormalities are primarily identified by ultrasonography (US) as part of routine antenatal care.¹ Although cost-effective and widely used, US is limited in the amount of information it can provide.² In the last decade, magnetic resonance imaging (MRI) has become more widely available and is used to image a fetus after ultrasound when the results are inconclusive or require further investigation.^{3,4} Specifically for the gastrointestinal (GI) tract, fetal MRI is established as an important addition to US for diagnosis of pathology due to accurate demonstration of the amount and distribution of meconium in the bowel.^{5,6}

The use of fetal MRI at post-mortem is also increasing, as a more acceptable alternative to traditional invasive autopsy to correlate with parental wishes.^{7–9}

Rates of concordance between detection of fetal pathology in traditional autopsy and post-mortem MRI are high,^{10–13} and together with the increased acceptability of PM MRI to parents this shows it is a satisfactory alternative when traditional autopsy is declined.¹⁴ It shows more detailed anatomy than magnetic resonance (MR) scans in utero due to higher

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resolution images taken over a longer time and no movement artefact, for more reliable diagnosis of antenatally detected pathology.⁷ Post-mortem MRI scans are also valuable in determining the developmental stages of the fetus to aid future interpretation of antenatal scans.¹⁵

With the increase in use of post-mortem MRI in fetuses, the normal appearance of the fetal organs must be established. There has thus far been a focus on central nervous system (CNS) and cardiovascular system imaging^{7,15,16} with limited publications on other body systems and no primary research concerning the GI system. The 2015 study for the MRI Autopsy Study (MaRIAS) collaborative group found post-mortem MR imaging has high overall accuracy for abdominal pathology in fetuses, but is relatively poor at detecting intestinal abnormalities.¹⁷

Minimally invasive autopsy is an alternative potential post-mortem approach for parents who decline traditional autopsy,⁸ so the diagnosis of any structural abnormality is dependent on MR image quality and interpretation. Accurate interpretation requires knowledge of normality to detect pathology, and currently radiologists interpreting these scans are relying on their knowledge from fetal and paediatric imaging; however, it is not known if after death appearances are different. The meconium pattern would aid identification of abnormalities such as atresia and malrotation, as in antenatal imaging.⁵ This study aims to describe the normal signal intensity of the fetal meconium at post-mortem MRI.

Material and Methods

Post-mortem MR images of patients were reviewed from January 2014 to May 2018. Post-mortem MR had been performed after the termination, miscarriage, stillbirth or intrapartum death of the baby but with no known abnormality of the bowel. Gestational ages at death were between 12 and 41 weeks. Local ethical and experimental protocol approval was obtained from the University faculty ethics committee, and all methods were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained from all parents to perform the post-mortem MRI as part of routine clinical practice as an alternative to autopsy.

MRI was performed using Siemens Avanto Fit 1.5T (Erlangen, Germany) and Siemens Magnetom Aera 1.5T (Erlangen, Germany) scanners. T2 and T1 sequences were used to obtain post-mortem images in two or more of the axial coronal and sagittal planes. For this study, we reviewed the T1 weighted images as these demonstrate meconium as hyperintense. Acquisition parameters for T1 weighted scans were as follows: time to repeat (TR) 8.2, time to echo (TE) minimum

full, flip angle 12°, matrix 256 × 256, field of view 240 mm, with 120 slices of 1.6 mm thickness.

All images were viewed with IMPAX 6.5.3.3009 (AGFA, Belgium) software using patient archiving and communications systems. On T1 weighted images, the signal intensity of the meconium in the rectum, sigmoid colon and splenic and hepatic flexures was noted on a numerical scale of 1 representing high signal intensity 'white' (Fig. 1), 2 representing medium signal intensity 'light grey' (Fig. 2) and 3 representing low signal intensity 'dark grey' (Fig. 3), based on the visual appearance of meconium. Scans were included regardless of cause of death and no scans were excluded. The final cause of demise was obtained from the pathology report including classification of stillbirth by relevant condition at death (ReCoDe) data¹⁸ for any intrauterine death or stillbirth.

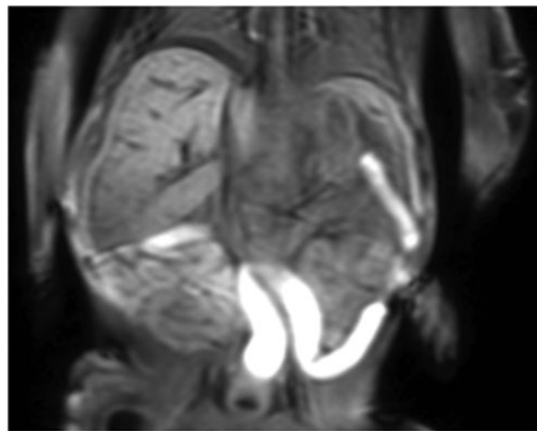


Fig. 1. An example of grade 1 bright white meconium in the fetal rectum, sigmoid colon and splenic flexure.

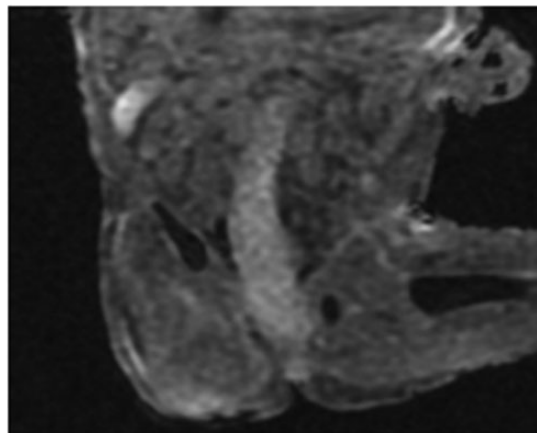


Fig. 2. An example of grade 2 light grey meconium in the fetal rectum.

The signal intensity of the meconium at the rectum, sigmoid colon, and splenic and hepatic flexures was correlated against the number of results at each grade and presented graphically. If the meconium could not

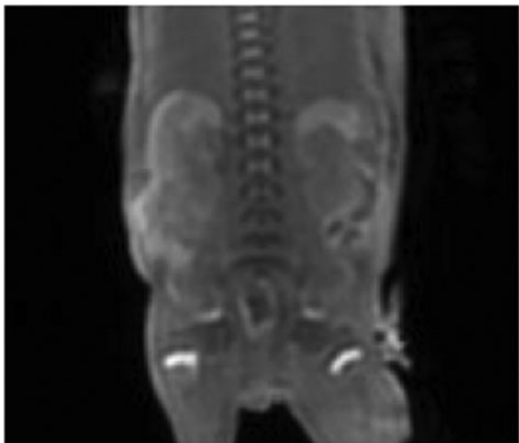


Fig. 3. An example of grade 3 dark grey meconium in the fetal rectum.

be visualised, no signal intensity grading (N/A) was given to that part of the bowel. If only part of the bowel was not visualised, the rest of the bowel was graded as normal. The rectal meconium signal was graded by a second independent observer with over 20 years of experience, to allow assessment of the accuracy and reliability of the grading. The percentage agreement between the original and independent observer measurements was calculated.

Results

A total of 62 cases met the criteria and were analysed. The gestational age at time of demise ranged from 12 to 41 weeks, with a mean \pm 1 standard deviation (SD) of 27.1 ± 8.3 and a mode of 21 weeks ($n = 8$). There were no cases with gestational ages of 13, 15, 23, 24, 29, 30, 32, 34 or 40 weeks. The time between demise to scan ranged from 0 to 14 days, with a mean time of 5 days. The final cause of demise or ReCoDe classification¹⁸ is shown in Table 1.

Table 1. Cause of death for all cases ($n = 62$) using ReCoDe classification for the intrauterine and stillbirth cases.

Type of death		N	Total
Intrauterine death	Umbilical cord, constricting loop (B2)	4	20
	Unclassified, no relevant condition identified (I1)	4	
	Fetus, lethal congenital abnormality (A1)	2	
	Placenta, abruption (C1)	2	
	Placenta, other 'placental insufficiency' (C4)	2	
	Amniotic fluid, chorioamnionitis (D1)	2	
	Fetus, twin-twin transfusion (A6)	1	
	Umbilical cord, other (B4)	1	
	Placenta, other (C5)	1	
	No data	1	
Termination	CNS abnormality	9	15
	CVS abnormality	3	
	Renal abnormality	1	
	Multiple abnormalities	1	
	Social termination	1	
Stillbirth	Placenta, other 'placental insufficiency' (C4)	4	13
	Unclassified, no relevant condition identified (I1)	3	
	Umbilical cord, constricting loop (B2)	2	
	Umbilical cord, other (B4)	1	
	Placenta, other (C5)	1	
	Amniotic fluid, chorioamnionitis (D1)	1	
	No data	1	
Miscarriage	No cause identified	7	10
	CNS abnormality	1	
	Antepartum haemorrhage	1	
	Premature rupture of membranes	1	
Intrapartum death	Chorioamnionitis	1	2
	Shoulder dystocia	1	
Neonatal death	CNS abnormality	1	2
	Lung abnormality	1	

CNS: central nervous system; CVS: cardiovascular system.

Figs 4 to 7 show observations from the images. On 12 of the scans, either the whole bowel or part of it could not be visualised due to maceration of the body or very premature demise, making anatomical identification impossible. For the remainder of the scans ($n = 50$) the entire bowel was visualised.

The rectal meconium had the most grade 1 ratings of high signal intensity (Table 2). The meconium in the sigmoid colon showed similar signal intensity to the rectum, with slightly less scans of a high signal intensity grade 1 but the same amount of mid signal intensity results. The splenic and hepatic flexure results also followed the pattern of decreasing signal intensity as the bowel becomes more proximal. The rectum and the sigmoid colon were the only parts of the bowel where meconium showed a dark signal, with two cases for

each location having low signal intensity, and none in the splenic or hepatic flexures. Overall, the rectal meconium had the brightest signal intensity, and the more proximal the bowel the lower the signal intensity was. Images at later gestations tended to have overall lower signal intensity than those at earlier gestations.

The percentage agreement between the original and independent observer measurements for the rectal signal intensity was 90%, with 56/62 of the measurements being graded the same. In two of the cases that disagreed, the image needed significant manipulation to get a good view of the bowel. In another three of the cases, the bowel appeared to have a bright wall with a grey centre, leading to discrepancies between grade 1 and 2. The last case with a disagreement was a discrepancy between grade 2 and 3.

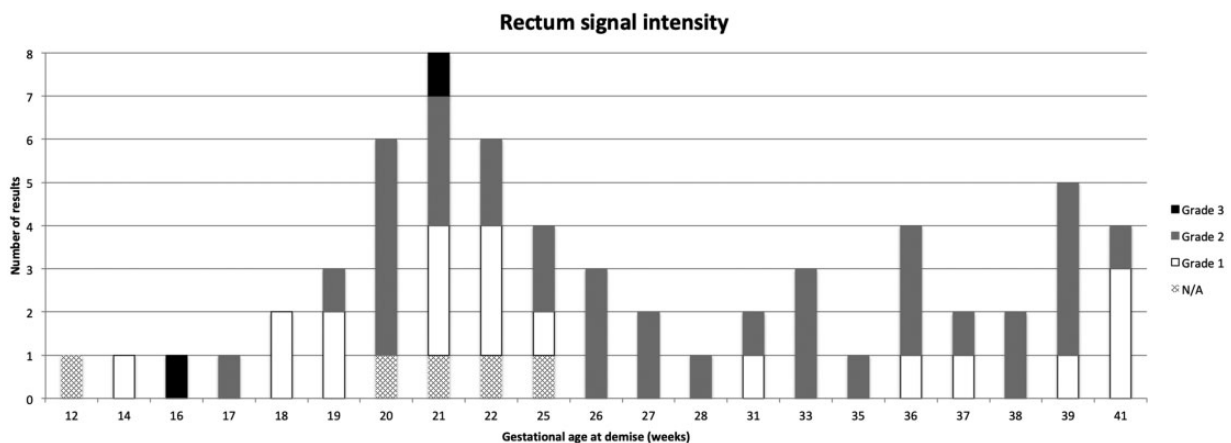


Fig. 4. Signal intensity gradings of meconium in the fetal rectum.

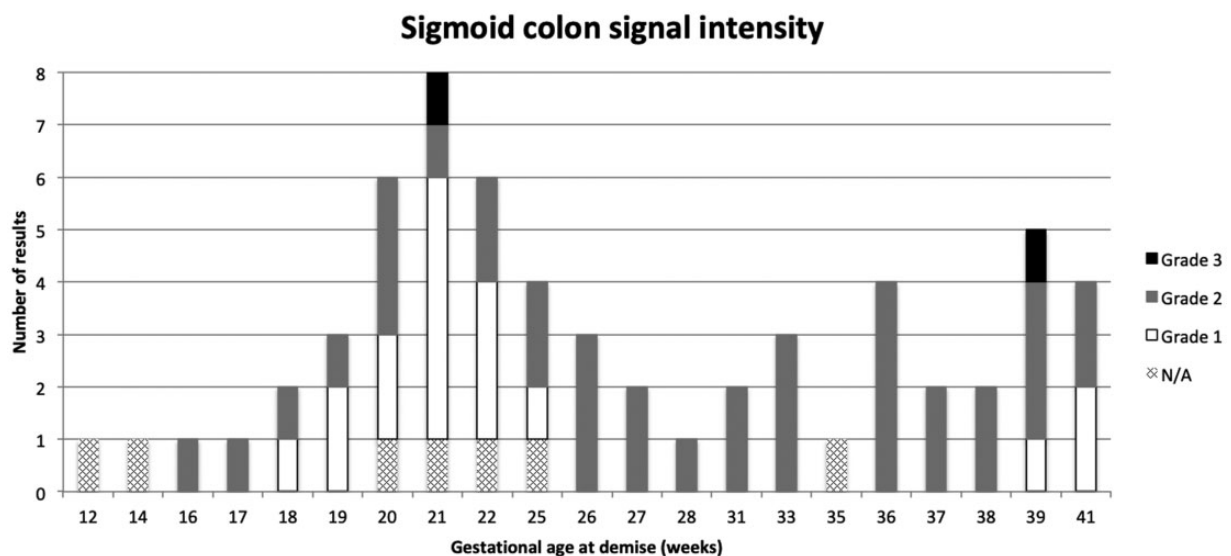


Fig. 5. Signal intensity gradings of meconium in the fetal sigmoid colon.

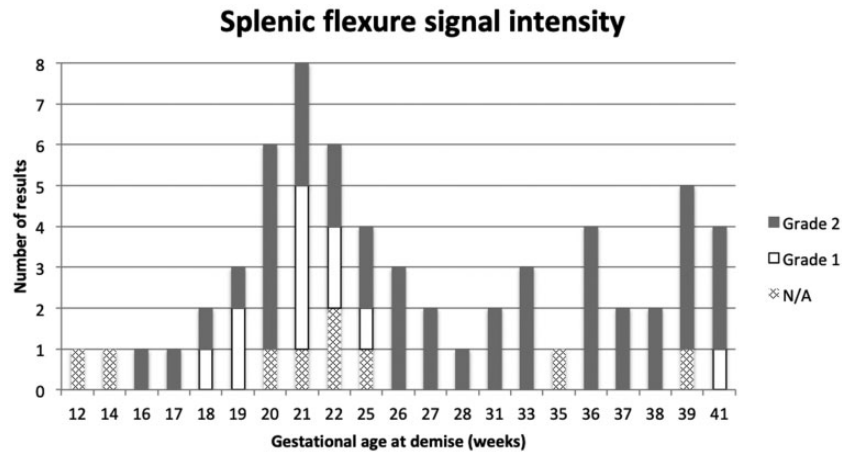


Fig. 6. Signal intensity gradings of meconium in the fetal splenic flexure.

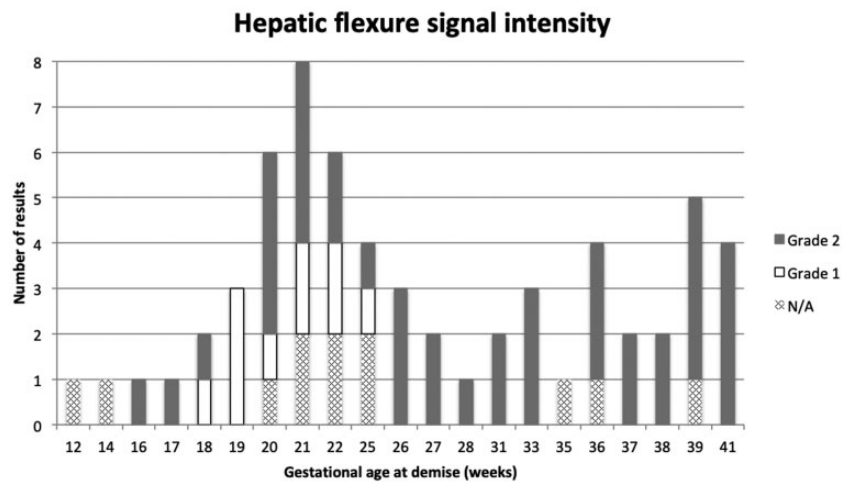


Fig. 7. Signal intensity gradings of meconium in the fetal hepatic flexure.

Discussion

Meconium was visualised in the whole bowel in 50 of the 62 scans, with the highest signal intensity in the rectal meconium and lower signal intensity in more proximal bowel. The meconium also had higher signal intensity at earlier gestations overall. The observed signal intensity of the meconium in different parts of the bowel on T1 post-mortem images was more variable than expected from our knowledge of meconium patterns on fetal MRI scans, where it is seen to accumulate from the distal to proximal large bowel throughout gestation.¹⁹ Meconium was seen in the rectum from as early as 14 weeks, and the rectum was the part of the bowel with the highest signal intensity. The sigmoid colon meconium had slightly lower signal intensity, a trend that continued for the splenic and hepatic flexures. At later gestations each part of the

bowel appeared slightly darker than it did at earlier gestations.

On 12 scans, either the whole of the bowel or part of it could not be visualised. This was due to either very early gestational age or severe maceration of the fetal body making delineation of structures impossible. Despite the difficulty in identifying the bowel in some cases, the percentage agreement of the rectum gradings between the original and independent observer was 90%. Such strong interrater agreement shows the grading method to be reliable and reproducible in clinical practice.

There are no published primary studies concerned with the normal post-mortem bowel. A 2015 review paper mentions normal after death changes of the fetal and neonatal bowel and states gaseous dilatation of bowel loops are a normal post-mortem finding, but it is unspecified in which age group.²⁰ However in the

Table 2. Signal intensity of meconium at each part of the bowel.

	Grade 1	Grade 2	Grade 3	N/A
Rectum	30.65% n = 19	58.06% n = 36	3.23% n = 2	8.06% n = 5
Sigmoid	27.42% n = 17	58.06% n = 36	3.23% n = 2	11.29% n = 7
Splenic flexure	17.74% n = 11	67.74% n = 42	0	14.52% n = 9
Hepatic flexure	16.13% n = 10	64.52% n = 40	0	19.35% n = 12

post-mortem MRI scans observed in this study, there was no gaseous distention in any of the cases.

The difficulty in identifying meconium on post-mortem scans suggests that meconium, or bowel contents, may be altered in some way after fetal demise so would not appear as bright as expected, compared to the normal signal intensity of meconium observed on prenatal fetal MRI images. This may be due to breakdown of the active sodium transport mechanisms in the bowel. Normally, sodium is pumped out of the bowel lumen and water follows due to the change in osmotic gradient.²¹ If this mechanism stops, as it would after death, water would be retained in the bowel and dilute the meconium. If the osmotic gradient reverses, water may also passively enter the bowel augmenting these effects and making the bowel appear darker on T1 images, as has been observed in the results of this study. The observation that the bowel is darker at later gestations on T1 imaging may also be due to this mechanism, as a more mature bowel would have increased active transport of sodium out of the bowel and therefore increased osmosis of water. After death, there may be a greater reversal of this mechanism in older fetuses than younger ones, meaning the meconium in older fetuses becomes more diluted and therefore appears darker on T1 imaging.

It was impractical to also study the appearance of the bowel at conventional autopsy as well as on MRI scans for this study as the cases were referred for PM MRI only as part of a minimally invasive autopsy service. Conventional autopsy would have been useful in order to determine the physical contents of the bowel and conclude if this correlates with previous conclusions from MRI. The centre performing the service had previously undertaken comparison of 500 PM MRI with autopsy (unpublished data). None of the cases used in this study had any indication of bowel pathology prior to demise, and the final cause of demise did not include any cases likely to affect the appearance of the bowel, so it is unlikely that the observations were due to any pathological process. Currently, interpretation of the post-mortem MR

relies either on data from research studies or from the radiologist's experience of fetal and paediatric imaging and the assumption that these are similar.⁵

In conclusion, this study defines the appearance of the meconium on the post-mortem MRI and is different to that reported on fetal MRI. Care must therefore be taken before assuming the appearances are normal. The appearances of the meconium can aid in detection of atresia, malrotation and fistula among other pathologies.⁵ The variation from expected appearances warrants further investigation, and an extensive follow-up analysis of both antenatal and post-mortem scans is required to be able to draw more confident conclusions for clinical practice.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics statement

Local ethical and experimental protocol approval was obtained from the University of Sheffield faculty ethics committee, approval number 007380.

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