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Mechanisms of intradural gas on post mortem magnetic resonance imaging

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ABSTRACT

Objectives: The significance of observing intracranial, intrathoracic and intraabdominal gas on post mortem MRI (PMMR) has been attributed to iatrogenic introduction, fetocide, or body decomposition. Intradural extramedullary gas tracking along the spinal cord on foetal PMMR has not been described, and we hypothesise that it may only occur in suspected neural tube defects (NTD), as open spinal dysraphisms may allow free passage of air into the spinal canal during delivery.
Methods: We reviewed 76 foetal PMMRs performed in our institution. We categorised cases into those who had a NTD confirmed at perinatal autopsy, or had been terminated or stillborn of other causes. We documented the presence of intradural gas and gas elsewhere in the body.
Results: We compared the PMMR findings in 13 foetuses who had NTD confirmed at autopsy (median gestation 20 weeks) against 63 age-matched normal controls (median gestation 20 weeks). All four cases of intradural gas occurred in foetuses with an open NTD (4/13; 31%), with none seen in normal controls (0/63; $p < 0.001$).
Conclusion: Intradural extramedullary gas on foetal PMMR is associated with open neural tube defects.
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1. Introduction

With the recent decline in parental acceptance of invasive autopsy, there has been increasing emphasis on the accurate interpretation of perinatal and paediatric post mortem (PM) imaging as part of a more minimally-invasive approach. Post mortem imaging is becoming widely accepted as part of the examination after death [1], with excellent diagnostic agreement between perinatal and paediatric PMMR and autopsy findings [2]. Part of the challenge of PM imaging is the correct interpretation of imaging findings, including differentiation of pathological diagnoses from artefact or normal post mortem changes.

The significance of observing gas in different body compartments on post mortem imaging has been attributed to a variety of causes, including trauma, resuscitation or body decomposition. The significance of the distribution of intravascular gas in adults has been reported [3–7] and may be seen in the context of normal PM decomposition, iatrogenic introduction or decompression disease. Intrathoracic and intraabdominal gas on PM perinatal imaging has usually been attributed to trauma or putrefaction [8–10]. More specifically in children, intravascular gas has been explained through iatrogenic introduction [11,12].

Intracranial gas has been reported in a neonate at post mortem, although the precise cause and origin was unclear [13,14]. Intradural extramedullary gas tracking along the spinal cord on foetal PMMR has not been described, and we hypothesise that it may be attributed to neural tube defects (NTD), as open spinal dysraphisms may allow free passage of air into the spinal canal during delivery. To test this hypothesis, we retrospectively analysed PMMR in cases of neural tube defects (NTD) were compared to a control population, to determine the presence or absence of intradural gas, with or without gas elsewhere in the body.

2. Materials and methods

This study did not require institutional approval as it was a retrospective audit of our clinical practice, and all parents consented to a clinical pre-autopsy MRI as part of our institution's clinical post mortem assessment. Bodies were stored in a mortuary

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at 4 °C and MRI was performed out of hours, causing least disturbance to clinical services. All scans were performed on 1.5 T (Avanto, Siemens Medical Solutions, Erlangen, Germany) MR scanner using whole body 3D T_2-weighted turbo spin echo (TSE, TR 3500 ms, TE 276 ms, voxel size $0.8 \times 0.8 \times 0.8$ mm^3, 2 averages), 3D T_1-weighted volumetric interpolated breath-hold examination (VIBE; TR 5.9 ms, TE 2.4 ms, flip angle 25°, voxel size $0.8 \times 0.8 \times 0.8$ mm^3, 8 averages) and 3D constructive interference in the steady state (CISS) sequence (TR 9.2 ms, TE 4.6 ms, flip angle 70°, voxel size $0.6 \times 0.6 \times 0.6$ mm^3, 4 averages), as published previously [15].

PMMR images were clinically reported by specialist neuro and body paediatric radiologists, and conventional autopsies were performed by a perinatal pathologist. We retrospectively reviewed our autopsy database to identify NTD cases who had received a pre-autopsy PMMR, and then selected an age and gender matched larger group of controls without NTD at autopsy. PMMR images were reviewed by a radiology resident (NJ) for the presence or absence of NTD, the presence of intradural gas, gas elsewhere in the rest of the body, and scored according to image quality (0 – non diagnostic, 1 – poor, 2 – adequate, 3 – good). We intended to exclude any non-diagnostic scans from our study.

Statistical analysis was performed using Wilcoxon's signed rank test and Fisher's exact test at the 5% level of significance, using SPSS 19.0 for Windows (IBM UK Ltd., Portsmouth, UK).

3. Results

76 cases were reviewed, of which 13 foetuses were confirmed to have a neural tube defect (NTD) at autopsy (mean gestation 20 ± 3.04; median gestation 20 weeks; range 14–24 weeks; Fig. 1). Sixty-three age-matched controls without NTD were included (mean gestation 20 ± 2.48; median gestation 20 weeks; range 15–25 weeks), summarised in Table 1.

From the NTD group, 12/13 scans were deemed adequate or good (score of 2 or 3), and only 1 scored poor (score 1). From the control group, 56/63 scored 2 or above, but imaging was of diagnostic quality in all the other 7 scans which scored 1. No scans were deemed 'non-diagnostic' (score zero) and therefore none were excluded from our study. There was no significant difference in overall image quality between the two groups (NTD group score 2.77 ± 0.60, control group 2.60 ± 0.68).

Four cases of intradural gas were identified, which were all in foetuses with open NTDs (4/13, 31%), with no cases of intradural gas in the control group (0/63, $p < 0.001$). Despite the caudal location of all of the neural tube defects identified, the distribution

Table 1
Comparison of demographics, image quality and gas findings in a cohort of foetuses with neural tube defects and age-matched controls.

	NTD group	Control group	*p*-Value
Number	13	63	–
Median gestation (weeks)	20	20	–
Mean gestation (weeks)	20 ± 3.04	20 ± 2.48	1.00
Gestation range (weeks)	14–24	15–25	–
Male/female ratio	5/8	28/35	–
Image quality (mean score)	2.77 ± 0.60	2.60 ± 0.68	0.37
Presence of intradural gas	4 (30.8%)	0 (0.0%)	< 0.001
Presence of intracardiac gas	2 (15.4%)	6 (9.5%)	0.62
Presence of gas elsewhere	2 (15.4%)	3 (4.8%)	0.20

Image quality was scored 0 – non diagnostic, 1 – poor, 2 – adequate, 3 – good.

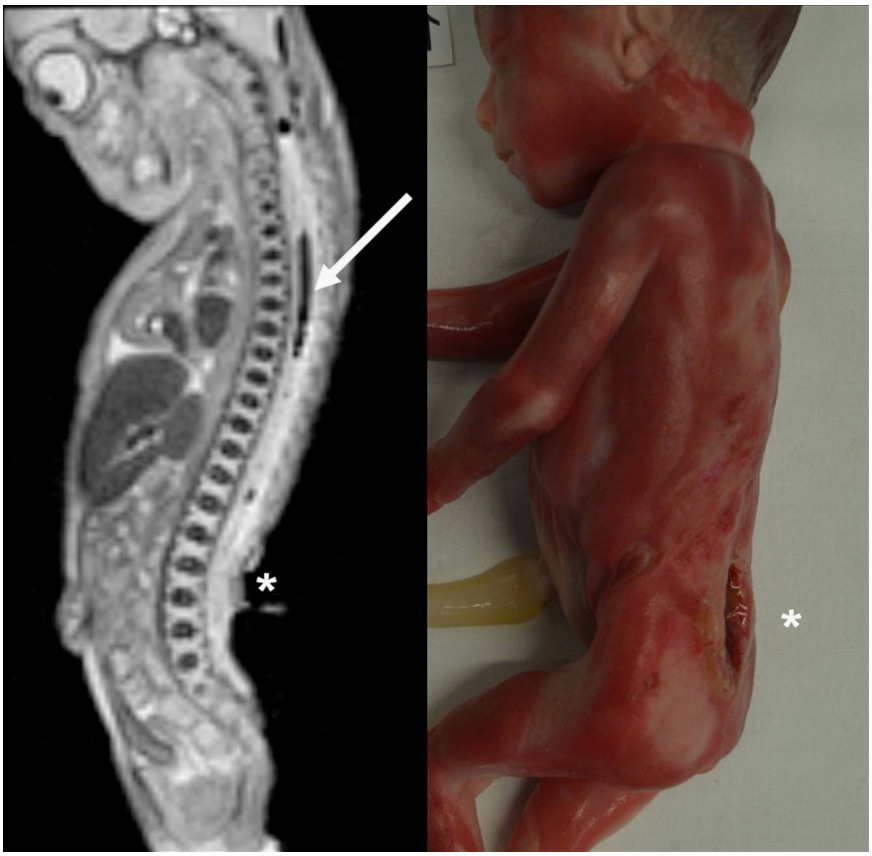

Fig. 1. Intradural gas (white arrow) in the thoracic spine in a T2-weighted PMMR sequence in the (A) sagittal plane. (B) Pathological specimen showing the corresponding open neural tube defect (white asterisk).

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