**Routine abdominal magnetic resonance imaging can determine psoas muscle area in paediatric Crohn’s disease and correlates with bioelectrical impedance spectroscopy measures of lean mass**

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**Abstract**

Background- Paediatric Crohn’s disease (CD) has been associated with undernutrition. Accurate and accessible measures of body composition would provide data to personalise nutritional therapy. We assessed feasibility of MRI-derived measures of psoas cross-sectional area (PCSA) in paediatric CD and correlated with anthropometric and bioelectrical impedance spectroscopy (BIS) measures.

Methods- MRI small bowel/pelvis images of patients with CD, aged <18 years, were retrieved. Patients with concurrent anthropometric and BIS measurements were eligible for inclusion. The PCSA at L3 was calculated by two assessors and combined. To assess reproducibility of measures we calculated the coefficient of variation (CoV). Age, height-Z-scores, weight-Z-scores and BIS measures were correlated with PCSA. Using normal paediatric data from CT-scans we derived psoas area Z-scores for our cohort.

Results- 10 patients were included. Mean age at MRI scan was 14.6 years (11.7 to 16.3). PCSA was calculated for all MRI scans. There was high reproducibility between measurers, mean CoV 0.099. There was a significant positive correlation between PCSA and BIA-derived fat free mass, Pearson correlation coefficient (PCC) 0.831, p=0.003.

Correlation coefficients for PCSA and Height-for-age Z-score, weight-for-age -Z-score and age were PCC 0.343 p=0.33, PCC=0.222 p=0.54, and PCC 0.6034, p=0.065, respectively. The mean PCSA Z-score was -1.81, with 70% of the patients having a Z-score <-2.0

Conclusions- These data demonstrate the feasibility of deriving measures of body composition from routine MRI imagine. There was significant positive correlation between PCSA and BIS-derived lean mass. Further studies are required to confirm applicability of normal ranges prior to routine clinical implementation.

Keywords- MRI; pediatrics; nutritional assessment; body composition; Crohn’s disease; sarcopenia

**Introduction**

Paediatric inflammatory bowel disease (IBD) is a chronic relapsing and remitting condition with long term nutritional sequalae. Paediatric onset Crohn’s disease typically presented with weight loss, growth delay and malnutrition1, however recent data suggests that linear growth has improved although patients continue to present underweight and continue to have nutritional compromise2. Sarcopenia is a reduction of skeletal muscle mass with accompanying loss of strength and function, irrespective of body mass index and can be seen in the context of obesity3. There is emerging adult data indicating that many patients with Crohn’s disease have persistent body composition abnormalities, with sarcopenia associated with poor disease outcomes, including need for surgery and higher rates of complication after surgery4. Whilst there are less data in paediatric Crohn’s disease there are reports of lower muscle mass when compared to the general population5,6.

Body composition assessment in children is challenging, requiring technology that is difficult to implement into routine clinical practice. There are difficulties interpreting values in the context of different ages and the normal childhood growth trajectory. A wide range of methods have been used to estimate muscle mass in paediatric IBD, although these generally employ additional measurements of children performed through dual energy X-ray absorptiometry (DEXA) or computerised tomography (CT) scans7–9. Whilst these data produce meaningful results, the additional radiation exposure makes justification of routine measurements in children difficult. Contemporary data from Israel utilised small bowel magnetic resonance imaging (MRI) in paediatric IBD patients10. The authors found significant correlation with disease severity, and that sarcopenia was a predictor of severe clinical disease course and need for escalation to biologic therapy. MRI scans are routinely used in paediatric IBD to assess small bowel inflammation, alongside assessment of stricturing and fistulating disease11. Utilising these scans for assessment of body composition would be highly desirable.

In the context of Crohn’s disease, nutritional therapy is established as a key element of treatment, including exclusive enteral nutrition and newer exclusion diets12–14. It is increasingly evident that obesity is a problem in IBD patients, resulting in poorer outcomes and increased incidence of additional non-communicable disease15. Whilst simple anthropometry remains a key tool in nutritional assessment we need to be looking towards routine measures of body composition to better characterise patients, identify sarcopenia, in thin and overweight children, providing individualised nutritional interventions to those with body composition abnormalities6.

Within this study we aimed to use MRI scans routinely performed on paediatric patients with Crohn’s disease to establish feasibility of psoas muscle cross-sectional area calculation. We aimed to establish a methodology for assessment of body composition as part of routine follow-up. Additionally, we aimed to relate psoas cross-sectional area to anthropometric and bioelectrical impedance spectroscopy (BIS) measures in children with Crohn’s disease.

**Methods**

Patients were recruited from the paediatric gastroenterology service at Southampton Children’s Hospital. To be included patients had to have a diagnosis of Crohn’s disease in line with the modified Porto criteria16, be aged under 18 years of age and be attending routine appointments at Southampton Children’s Hospital. All patients, or parents, gave informed consent.

MRI scans

Patients who had undergone a routine MRI scan within 4 months of measurement of bioelectrical impedance were included in the analysis. Four months was used as a pragmatic time interval that would not reflect significant changes in muscle mass in clinically stable patients. The MRI must have included the L3 segment of the psoas muscle and therefore was restricted to small bowel and pelvic MRIs.

Bioelectrical impedance spectroscopy measurements

At the time of recruitment all patients had bioelectrical impedance spectroscopy (BIS) measurements performed. BIS is methodology for measuring body composition based on electrical resistance as a current travels through the body. We utilised the derived estimate of total lean mass (in kg), alongside the lean mass index (lean mass (kg)/height in metres squared), as a proxy for sarcopenia17. These measures have previously been utilised in paediatric IBD to determine body composition18.

BIS measurements were made using ImpediMedSFB7 (Pinkenba, QLD 4008 Australia), a single-channel tetra-polar device able to measure resistance and reactance across 256 frequencies. Calibration occurred before each use with a known circuit of impedance provided by the manufacturer. All measures were done in triplicate, with the mean included in the final analysis. Measurements were conducted using a standard tetrapolar electrodes distribution (on the hands and feed). Measurements of BIS were completed in unfasted subjects. All BIS data files were processed using specialist software (Bioimp, ImpediMed), with data points rejected if they met any of the following criteria; i) positive X centre (Xc) values, ii) negative resistance values.

Patients were clinically stable over the duration of the study with no changes in medication between MRI and BIS measures.

MRI Psoas muscle mass calculation

Muscle area was measured independently by two radiologists (DP and MG). The cross-sectional area of the left and right psoas muscles was calculated using SyngoVia software19, with the measurement taken outlining the psoas muscle using the freehand ROI tool and nudge tool for adjustment of the margin at the level of the mid L3 vertebral body. SyngoVia has been previously validated to measure psoas muscle area20. These measures were then combined to give an overall ‘combined’ psoas cross-sectional area (PCSA). These data are reported as PCSA in cm2.

Anthropometric measurements

Anthropological measurements of height and weight were performed and recorded in accordance with local Standardised Operating Procedures and World Health Organisation (WHO) guidelines. These were converted into height Z-score, weight Z-score and BMI Z-scores using the WHO reference data21.

Data and statistical analysis

For each left psoas measurement and each right psoas measurement we calculated the coefficient of variation from the two radiological measurements to determine the reproducibility. We used Pearson correlation to determine the relationship between individual anthropometric and BIS derived variables and the psoas muscle cross sectional area. In order to assess if our patients had lower lean muscle mass compared to ‘normal’ children we utilised reference values of combined psoas area measures derived from computerised tomography (CT) of well children undergoing trauma scans through an online tool (<https://ahrc-apps.shinyapps.io/sarcopenia/>)22. This provided psoas area Z-scores based on a patient sex, age and PCSA. We utilised these data to determine the feasibility of interpretation of MRI derived psoas cross sectional area to determine sarcopenia in our IBD population.

Ethical approval

Ethical approval was granted by the London (Westminster) research ethics committee (18/LO/1457).

**Results**

Ten patients were eligible for inclusion. All had a diagnosis of Crohn’s disease. Mean age at MRI scan was 14.6 years (range 11.7 to 16.3 years) and 9/10 patients were male.

Feasibility of measures

Free-hand annotation at the level of mid L3 vertebral body was performed as an addition to routine reporting of MRI scans. All scans retrieved for analysis were annotated. It was possible to calculate PCSA in 100% of scans, table 1.

Coefficient of variation

We assessed the reproducibility of measurements between measurers using the coefficient of variation. Multiple measures were available for 8 patients, table 2. The mean coefficient of variation was equivalent to 9.9% (range 1.4-29.4%). The mean individual PCSA for all ages, was 7.83cm2 (range 4.98-13.9cm2).

Psoas cross sectional area correlates with BIS-derived lean mass

Pearson correlation identified a significant positive correlation between combined PCSA and BIS-derived lean mass, Pearson correlation coefficient (PCC) 0.831, p=0.003, figure 1A. There was also a positive correlation between age and BIA-derived lean mass, PCC 0.759, p=0.011, figure 1B.

Lean mass index calculation

The mean lean mass index in this patient group was 15.55kg/m2 (range 8.53-19.01kg/m2). There was a positive correlation between combined L3 PCSA, PCC 0.682, p=0.03.

Relationship of psoas area with age, height and weight

We assessed the relationship between height-for-age Z-score and weight Z-score with the mean combined L3 PCSA. Height-for-age Z-score and PCSA, PCC=0.343, p=0.33, figure 2A. Similarly, weight Z-score and PCSA, PCC=0.222, p=0.54, figure 2B.

Age at the time of MRI scan was correlated with mean combined L3 PCSA, PCC 0.6034, p=0.065, figure 2C.

Application of CT-derived normal psoas area to MRI data

Psoas area Z-scores for our 10 patients were calculated based on CT-derived normal data. The mean Psoas area Z-score was -1.81, with 70% of the patients having a Z-score <-2.0, table 1.

**Discussion**

These data demonstrate that routine MRI scans, performed on patients with Crohn’s disease, can be used to derive measures of psoas cross-sectional area. These measures significantly correlate with BIS-derived estimates of lean mass. This indicates that PCSA reflects derived lean mass when normalised for a patient’s height. Reproducibility of psoas area measures was relatively high with around 10% variability in measures across all patients. Overall, these measures are highly feasible as part of routine MRI reporting and would enable assessment of body composition during these routine scans. Assuming comparable measures are derived from CT and MRI images, application of normal paediatric data would indicate that 70% of our Crohn’s disease patients had a PCSA >2 standard deviations below average. These data enable assessment of body composition in children with IBD to be performed as part of routine scanning and may enable identification of children with sarcopenia through integration of normal reference ranges.

There is increasing interest in personalised nutritional therapy for Crohn’s disease6. In addition, obesity has presented novel challenges in a disease previously typified by undernutrition15. The role of dietary management for induction of remission in paediatric Crohn’s disease is well established, however the place of routine supplemental nutrition is less certain, particularly with increasing numbers of children with IBD being overweight or obese12,23,24. In adult IBD, sarcopenia is associated with increased morbidity and mortality, and worse outcomes including the need for surgery4,25. However, obesity is also associated with worse long-term outcomes in IBD and increased risk of additional non-communicable disease15. The balance of ensuring patients are nutritionally replete including micronutrient status, without promoting adiposity, requires a personalised approach to nutrition. More recent body composition data indicates that up to 25% of children with IBD have excess adiposity, which may be missed by routine anthropometric screening using height-for-age and BMI alone 26. Beyond this, exclusive enteral nutrition has been shown to increase lean mass, but not fat mass, at induction in newly diagnosed Crohn’s disease patients18. Clearly, a practical and easy measure of body composition is required to tailor nutritional therapy to patients. The ability to utilise normal data, derived from CT scans, demonstrated a psoas muscle deficit in 70% of our patients. Whilst these results should be interpreted with some caution, they do hint at a significant level of sarcopenia in patients with Crohn’s disease. We have detailed studies of PCSA and abdominal skeletal muscle area in the context of IBD, table 3.

MRI scans for small bowel assessment should be routinely performed at diagnosis in all children with Crohn’s disease and are routinely used to monitor disease and as part of the work of for surgery, particularly for structuring disease11. This provides an opportunity to utilise measures of body composition derived from these data to personalise ongoing nutritional intervention. The originality of these data centres on the use of routine MRI scans in paediatric patients. There is an opportunity to intervene during pubertal growth in these patients, with long-term health impacts if patients have ongoing lean muscle deficits.

In this study we demonstrate the feasibility of gathering MRI derived psoas cross-sectional area, alongside the strong correlation with age and BIA-estimated lean mass. Whilst this is currently a manual process a neural network has been trained on CT to identify the L3 level and calculate psoas volumes and this would be a technique to automate the calculation on MRI imaging27. Future studies compared manual to automated psoas muscle area are important and should be performed in paediatric age groups.

An additional measurement from routine clinical MRI scans would be a measurement of intra-muscular adiposity. This could be calculated within the area of the psoas muscle using a Dixon sequence which provides measurement to visualise water content and fat content separately28. This can be utilised to calculate the fat fraction within the muscle, a calculation performed following segmentation within SyngioVia software tools. The additional Dixon sequence requires no contrast administration and takes less than a minute to acquire in the scanner. This would allow further estimation of adiposity as part of routine MRI imaging.

We acknowledge that there are several limitations of these data. We were able to perform the analysis on only 10 patients due to time differences between BIS measures and MRI imaging. The role of sex and puberty was not able to be examined due to the relatively low patient number and preponderance of male patients. There are also recognised limitation of BIS-derived measures of body composition, with the variable accuracy of these measures and the variable fasting state of the patients, although it is a recognised methodology for estimation of body composition. A further limitation is that the majority of studies reporting accuracy of BIS or CT-estimated PCSA are cross validations of two imperfect methods against each other, rather than validations against a gold standard such as deuterium dilution29. We acknowledge that total skeletal muscle area at L3 may prove to be a better proxy of total lean body mass, however this is limited in a paediatric population by lack of reference data to place measurement values in context30.

Conclusion

These data provide a strong indication that routine MRI imaging are useful in the assessment of lean mass in children with Crohn’s disease, with strong correlation between psoas area and BIS-derived estimates of lean mass. This raises the possibility of being able to offer tailored nutritional support to impact on outcome. Further studies are required to confirm normal measures derived from CT scans are applicable and to determine the prevalence of sarcopenia. Implementation of additional MRI sequences to assess adiposity, prior to routine clinical implementation, to aid personalisation of nutritional therapy is an important next step.

**Tables and Figures**

**Table 1-** Combined psoas cross sectional area Z-scores derived from ‘normal’ paediatric CT images22.

**Table 2-** Coefficient of variation for eight patients with multiple measures of psoas cross-sectional area.

**Figure 1A**- Positive relationship between combined mean psoas cross-sectional area and bioelectrical impedance (BIA) derived whole body lean mass (Kg), Pearson correlation coefficient, 0.831, p=0.003, **1B-** Positive relationship between combined mean psoas cross-sectional area and age at MRI scan (years), Pearson correlation coefficient 0.759, p=0.011.

**Figure 2A-** Correlation of combined mean psoas cross-sectional area and height Z-score Pearson correlation coefficient, 0.343, p=0.33, **2B-** Correlation of combined mean psoas cross-sectional area and weight Z-score, Pearson correlation coefficient, 0.222, p=0.54, **2C-** Correlation of combined mean psoas cross-sectional area and age at MRI scan (years), Pearson correlation coefficient, 0.6034, p=0.065,

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**Conflicts of interest**

The authors declare no conflicts of interest.

**Contributorship**

JJA and RMB conceived the study. DP and MG performed the MRI measurements. JJA analysed the data with help from LM and MJJ. JJA wrote the manuscript with help from all authors. All authors approved the manuscript prior to submission

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