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CONTENTS

RADIOLOGY

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Editorial

Corresponding author
Anthony Todd Dotson, MSRT, RT(R), (CT)
Assistant Professor
Department of Kinesiology, Health and Imaging Sciences
Morehead University
Morehead, Kentucky 40351, USA
Tel. 606-783-5175
E-mail: a.dotson@moreheadstate.edu

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License *versus* Non-License States

Anthony Todd Dotson, MSRT, RT(R), (CT)*

Department of Kinesiology, Health and Imaging Sciences, Morehead University, Morehead, Kentucky 40351, USA

Technologists in the imaging modalities (radiology, computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, nuclear medicine, etc.), mostly are required to obtain a certification and state license for whichever state they may work. There are, however, some states that have passed litigation that allow for workers in the imaging sciences to administer ionizing radiation without any formal education or training. There are currently eleven state that do not require any form of qualification to administer ionizing radiation.[1] In those states organizations can hire anyone to administer ionizing radiation to the public, as oppose to licensure states that require a minimum of two years of education and certification of a national board exam to do the same. This writing will compare the pros and cons of requiring a license and not requiring one.

State licensure is a common requirement for employment in the field of imaging. Seventy-five percent of the United States require technologists in an imaging department to obtain both a state license and a certification *via* the American Registry of Radiologic Technologists (ARRT).[2] American Society of Radiologic Technologists (ASRT) Vice President of Government Relations and Public Policy, Christine Lung states, "*Licensure is a state government's way of ensuring that personnel meet minimum professional standards before engaging in radiologic technology… prohibit unqualified individuals from performing examinations*."[1]

The Joint Commission, which is responsible for the accreditation of health care facilities such as hospitals, has a strong stance for licensure and certification of imaging professionals. After introducing the new standard for patient and workplace safety regarding ionizing radiation, particularly in CT, the Joint Commission is hopeful to mitigate the risk at hand and bring a standard across the board regarding licensure.[3] The reasoning behind the push from accrediting agencies and professional organizations is to ensure and promote patient safety by requiring technologists be educated so that they are subject matter experts. To sit for the board exam technologists are required to study topics including patient care, radiation safety, image production, and imaging procedures.[4] According to a survey by the ASRT, technologists who are not certified are more likely than their peers to rely on managers and other technologists to keep them informed on the latest advancements.[5] The lack of current information concerns, in that their peers may fail to inform them of advancements, or could even spread misinformation. Conversely, technologists that are certified are much more likely to cite reputable sources such as professional journals and workshops, and continuing education credits, as their way of staying up-to-date.[5]

There are also economic reasons that technologists would want to make sure licensure is required to their field. The simple principle of supply and demand dictates that if licensure is required, then the supply of qualified technologists is decreased and the demand will increase. This will cause an increase in compensation to the limited number of qualified technologists.

The reasoning behind non-licensure is that the cost of technologists will decrease for the healthcare organization because they do not have the qualifications that licensure requires. This is less expense for the organization. Going back to the principle of supply and demand, this will increase the supply of technologists and decrease the demand. If that happens, the compensation to the technologists will stagnate or decrease. Of the states that choose not to require license radiation workers, the average pay for a radiologic technologist is lower than

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the national mean.[6] With only 49.4% of technologists nationwide reporting that they are satisfied/very satisfied with their pay, this is an important consideration.[6]

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Research

*Corresponding author
Suk-Hwan Jang, MD
Department of Orthopedic Surgery
Inje University Seoul Paik Hospital
Mareunnae-ro 9, Jung-gu
Seoul, South Korea
Tel. +82-10-2252-0730
E-mail: orthopodjang@gmail.com

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Relative Ratio of Coracohumeral Distance is Greater in Patients with Subcoracoid Impingement (SCI)

Jae-Chan Shim, MD[1]; Suk-Hwan Jang, MD[2*]

[1]Department of Radiology, Inje University, Seoul Paik Hospital, Seoul, South Korea
[2]Department of Orthopedic Surgery, Inje University, Seoul Paik Hospital, Seoul, South Korea

ABSTRACT

Purpose: No standard imaging diagnostic criteria have yet been established for subcoracoid impingement (SCI) of the shoulder. The purpose of this study was to evaluate coracohumeral distance (CHD) in patients with or without SCI with the hypothesis that patients with SCI would have narrower CHD.
Materials and Methods: One hundred fifty patients with subacromial impingement (SAI) were evaluated. The subjects with subcoracoid impingement which was affirmed clinically and confirmed by ultrasound guided subcoracoid injection (n=39) was compared with patients with SAI only (n=111). Patients with stiffness and rotator cuff tear were excluded. Absolute CHD was measured on magnetic resonance imaging (MRI) axial images and on ultrasound with the humerus in neutral position and internal rotation. Also relative ratio of distance difference (RRDD) defined as the difference of CHD in neutral position and internal rotation compared with absolute CHD in neutral on ultrasound was also measured.
Results: The distance measured in neutral position was similar between ultrasound (US) imaging and MRI ($p>0.05$) and both measurements did not have significant difference between the two groups ($p>0.05$). On ultrasound, there was no significant difference in CHD in neutral and the internal rotation position between the two groups. However, RRDD value was significantly greater in SCI group ($p<0.05$).
Conclusion: Although, the SCI group and the SAI group were not matched for age, sex, or BMI, no significant difference in CHD was seen between the SCI and SAI groups. RRDD value was greater in SCI group suggesting that individualized CHD in internal rotation should be taken into account when assessing patients with subcoracoid impingement.

KEY WORDS: Shoulder; Subcoracoid impingement (SCI); Ultrasound; Coracohumeral distance.

ABBREVIATIONS: CHD: Coracohumeral distance; MRI: Magnetic Resonance Imaging; CT: Computed Tomography; RRDD: Relative Ratio of Distance Difference; SCI: Subcoracoid impingement; SAI: Subacromial impingement; VAS: Visual Analogue Scale.

INTRODUCTION

Subcoracoid impingement (SCI) is known to be caused by the narrow space between the coracoid and the lesser tuberosity which in turn causes impingement of the subscapularis and the biceps tendon with movements requiring forward flexion, internal rotation, and horizontal adduction.[1-3] It has been recognized as an etiology of anterior shoulder pain for over a century. Many studies addressed the topic and have emphasized SCI to be relatively common, yet often unrecognized and underreported.[4-6] An accurate diagnosis is critical for selecting an effective treatment among a wide range of options starting from conservative management to open and arthroscopic coracoplasty.[7] Despite numerous studies on the topic, no standard imaging diagnostic criteria have yet been established.

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Plain radiography, computed tomography (CT), and magnetic resonance imaging (MRI) have been used to evaluate coracohumeral distance (CHD).[8-11] However, standard CT and MRI allow only static evaluation of the subcoracoid space and are not practical for bilateral evaluation. Diagnostic ultrasound is a well-established tool for the evaluation of rotator cuff condition and guiding therapeutic injections. We report the use of ultrasound (US) and MRI to measure CHD in patients with SCI with the hypothesis that patients with SCI will have narrower CHD.

MATERIALS AND METHODS

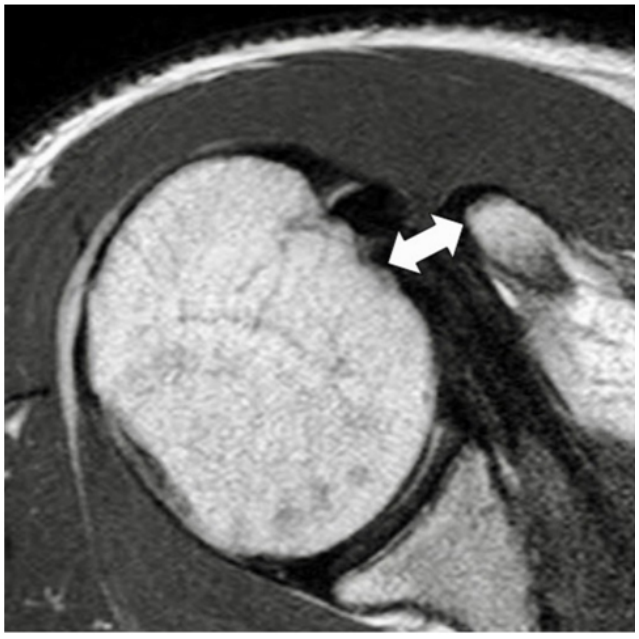
A total of 373 patients who were diagnosed with impingement syndrome clinically and radiographically at an outpatient clinic at a single institute between May 2014 and Feburary 2015 were identified. The inclusion criteria were the symptom duration of more than 3 months, no abnormalities on plain radiography, no rotator cuff tear on MRI, normal contralateral shoulder, and compliance and willingness to undergo all required sonography and tests. The exclusion criteria were stiffness or instability of the shoulder, previous surgery, and inflammatory condition of shoulder including infection or calcific tendinitis.

Finally, 150 patients in total were found to meet the inclusion criteria. All patients had visual analogue scale (VAS) score checked at initial presentation and underwent a physical examination, MRI, and bilateral sonography. Depending on their clinical findings, the subjects were divided into two groups: SCI with subacromial impingement (SAI) group (SCI group) and SAI only group (SAI group).

SCI group had clinical features of SAI and positive clinical findings suggesting the diagnosis of SCI, which consisted of the typical history of anterior shoulder pain, tenderness at the coracoid process, and a positive coracoid impingement sign, and positive coracoid impingement test. Coracoid impingement sign was considered positive when a patient reported anterior shoulder pain when the arm was in forward elevation, internal rotation, and adduction.[12] The coracoid impingement test was performed by a diagnostic injection of lidocaine 2 mL (2%) and triamcinolone 1 mL (40 mg/ml) in to the subcoracoid recess with ultrasound guidance. The test was considered positive if the pain was reduced by more than 30% at VAS and the physical examination was negative after two weeks.

CHD was measured on MRI (1.5-T cylinder shaped, Inter Achieva; Philips, The Netherlands), which was taken with the subject's arm in neutral position. CHD was defined by the greatest subcoracoid narrowing from coracoid cortical margin to the humeral cortical margin as suggested by Giaoli et al[8] (Figure 1). CHD was also measured on screen during the bilateral shoulder sonography with the arm adducted and in a neutral position. CHD was measured coronally using a multifrequency linear array ultrasound transducer with a peak frequency of 13 MHz (Toshiba Medical Systems, Tochigi, Japan) twice the symptomatic shoulder and once on the asymptomatic shoulder in each subject. The same sequence of measurements was taken with the arm adducted and internally rotated to a point when the cortical margin of the lesser tuberosity was closest to the coracoid tip (Figure 1). After the measurements with sonography, the relative ratio of distance difference (RRDD), defined as the percentage of the distance difference in the neutral position and internal rotation compared with the distance in the neutral position, was

Figure 1: Coracohumeral Distance (CHD) which was defined as the Greatest Subcoracoid Narrowing from Coracoid Cortical Margin to the Humeral Cortical Margin was measured on MRI Axial View.



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also calculated. This method was used to standardize the relative distance difference in internal rotation to the individually different CHD (Figure 2).

SPSS software (version 18.0 for Windows; SPSS Chicago, IL, USA) was used for statistical analyses. Student's *t*-test was used to compare the CHD between SCI and SAI groups and other variables. The nonparametric data were evaluated with χ^2 test. The significance was defined as $p<0.05$.

RESULTS

In total 39 (26%) subjects showed all the clinical features of SCI, including positive coracoid impingement test (SCI group) and 111 (74%) had only SAI symptoms (SAI group). There was no significant difference among the side of involvement, mean age, sex distribution, VAS score at initial presentation, and the duration of symptoms (Table 1). The intraclass correlation coefficients for the intraobserver reliability of sonographic CHD measurements in the neutral position and internal rotation were in the excellent rage with 0.84 and 0.82, respectively. In all subjects, there was no significant difference in the mean CHD between the involved and uninvolved shoulder in neutral (p=0.58) or internal rotation (p=0.50). No significant difference in the mean CHD in neutral position was seen between the measurements on MRI and ultrasound (p=0.87) (Table 2).

The difference in the mean CHD in internal rotation between the SCI (0.48±0.15) and SAI groups (0.51±0.22) on ultrasound did not show significant difference (p=0.11). There was no significant difference between the two groups regarding the measurement difference in neutral position and internal rotation (p=0.90). However, the RRDD, which was used to standardize the amount of CHD difference in neutral position and internal rotation to the different CHD's among individuals, was 50.3%±9.3% in SCI group and 35.7%±9.9% in SAI group and differed significantly (p=0.01) (Table 3).

DISCUSSION

This study hypothesized that patients with SCI will have narrower CHD. We used dynamic ultrasonography, measuring CHD in two positions, and showed that although there was a significant difference in RRDD between the two groups, the absolute CHD in the neutral position or in the internal rotation did not differ significantly between the two groups. This implies that the individualized difference in coracohumeral interval during the internal rotation, which is one of the key motions to elicit SCI,

Figure 2: (A) CHD was measured Coronally with the Arm Adducted and in Neutral Position from the Cortical Margin of the Lesser Tuberosity to the Cortical Margin of the Coracoid Tip.(B) The Same Measurements was taken with the Arm Adducted and Internally Rotated to a Point when the Lesser Tuberosity was Closest to the Coracoid tip. Relative Ratio of Distance Difference (RRDD) is defined as the Percentage of the Distance Difference in Neutral and in Internal Rotation Compared with Distance in Neutral. (RRDD=(A-B)/A 100).

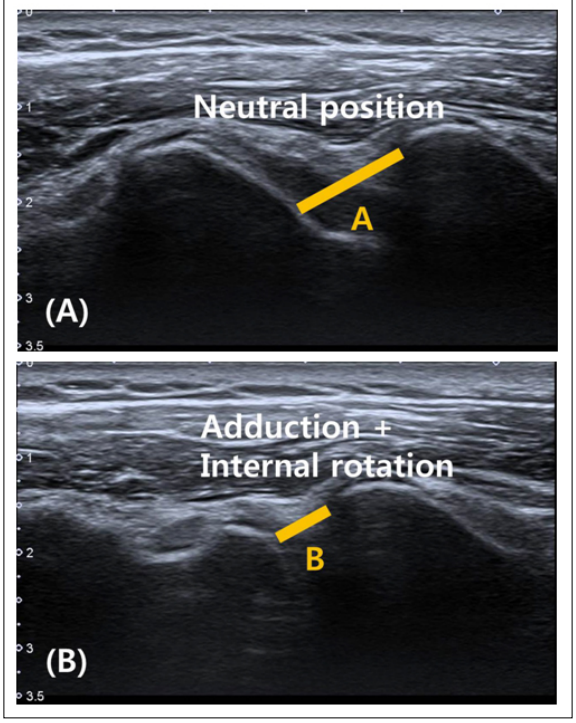

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Table 1: Demographic Data and Comparison of Clinical Presentation between SCI and SAI Group.

	SCI group	SAI group	*p*-value
Number (total 124)	39 (26%)	111 (74%)	-
Affected side			0.52
Dominant	28	75	
Non-dominant	11	36	
Age (years)			0.99
Range	32-70	26-71	
Mean	54.1	51.9	
Sex distribution			0.40
Male	20	60	
Female	19	51	
Symptom duration (months)*	8.1± 6.0	7.7 ± 6.5	0.42
VAS (at rest)*	1.7 ± 1.8	1.6 ± 1.1	0.57
VAS (at ROM)*	6.0 ± 1.0	6.3 ± 0.9	0.82

*Mean±SD

Table 2: Comparison of CHD in Neutral Position between MRI and Ultrasonogrphy (US).

	MRI.	US	*p*-value	95% confidence interval
CHD*	0.93±0.19	0.94±0.21	0.87	-0.15, 0.17

*Mean±SD

Table 3: Comparison of CHD between SCI and SAI Group.

	SCI group (n=28)	SAI group (n=96)	*p*-value
CHD on MRI (cm)	0.91±0.16	0.92±0.19	0.85
CHD on ultrasonography			
Neutral	0.92±0.25	0.94±0.37	0.49
Internal rotation (IR)	0.48±0.15	0.51±0.22	0.11
Neutral-IR difference	0.44±0.21	0.43±0.29	0.90
RRDD (%)*	50.31±9.30	35.72±9.91	0.01†

Mean±SD
*Relative ratio of distance difference
†$p<0.05$

may be associated with the symptoms. The relation between the coracoid and the humerus has been studied extensively over the past two decades.

Most authors agree that the diagnosis of SCI is mainly clinical. Gerber et al[2] described SCI as a dull anterior shoulder pain aggravated by forward flexion and internal rotation. A physical examination of affected patients shows tenderness at the coracoid tip and reproduction of pain with the arm internally rotated at 90° abduction or adducted with 90° of shoulder flexion. Many studies have reported subcoracoid stenosis to be relatively common, but often unrecognized and underreported.[4,5] Isolated SCI is very uncommon and its incidence has been reported to be 2.8-19%.[3,13,14] In order to overcome the low number of subjects, we enrolled patients with SAI without rotator cuff tear or stiffness and divided them into two groups depending on whether they had SCI. In our study, the incidence of SCI was found to be 26% in the patients with SAI.

Many studies have reported promising results for the treatment of SCI with the advent of arthroscopic coracoplasty[7,15]; however, determining proper candidates for such surgery has become crucial. Although, there are many studies investigating the relation between the coracoid and the humerus, the role of imaging in the diagnosis of SCI is still controversial. Standard radiographs may show far laterally projecting coracoid process in the anteroposterior view or in the supraspinatus outlet view. Kragh et al[16] identified a chevron-shaped coracoacromial outlet in the patients with primary SCI. There may also be sex-based differences in the average coracohumeral interval, with females having a space measuring 3 mm or smaller than that in males.[8] Bonutti et al[17] described abnormal CHD to be less than 11 mm on MRIs in the patient with shoulder pain. Richards et al[18] reported narrowed CHD in patients having tears of the subscap-

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ularis. They found an average CHD of 10 mm in the patients without rotator cuff pathology and a decreased distance of 5 mm in the patients with subscapularis tears. MRI examination was found to be 5.3% sensitive but 97% specific for SCI.[8]

Several studies have shown that coracohumeral interval decreases with shoulder position. Gerber et al[10] used CT to evaluate coracohumeral interval in healthy patients. They found that the average value of 8.7 mm decreases to 6.8 mm with forward flexion. Friedman et al[11] used dynamic MRI to evaluate coracohumeral interval, and asymptomatic volunteers showed coracohumeral interval of 11 mm in maximum internal rotation, whereas symptomatic patients showed 5.5 mm. However, these techniques are not widely available and cumbersome and also are not a cost-effective diagnostic option.

Ultrasonography is an easily available, dependable method to evaluate the relation between the coracoid and humerus and diagnose SCI. In addition, the dynamic real-time evaluation of the subcoracoid recess thereby overcoming static evaluation obtained by CT or MRI as well as concomitant usage of the treatment by delivering injections to the affected sites makes sonography more beneficial.

Ultrasonography for the diagnosis of SCI has been reported only in one study in the literature, showing a narrowed CHD in patients with clinically diagnosed SCI (n = 8).[19] However, the sonographic measurements were done statically in a single position on a small number of patients without comparison with MRI.

To the best of our knowledge, no study has examined so far SCI dynamically with ultrasonography. We ruled out other possible shoulder pathologies with MRI and also compared CHD in the neutral position.

However, this study had several limitations. The SCI and SAI groups were not matched for age, sex, or BMI. We have not taken into account of the soft tissue thickening on the anteroinferior aspect of the coracoid tip representing the fibrous falx as demonstrated by Dumontier et al,[3] which can be a potential source of impingement. We grouped patients according to their findings during clinical examination. However, the clinical examination is subjective by nature, and the validity of subcoracoid physical tests has not yet been reported. Although, the effectiveness of the steroid mixed with local anesthetic injection confirmed the accuracy of our clinical diagnosis of SCI, but it may as well alleviate the symptoms related to other shoulder pathologies and confuse the diagnosis. Future studies are warranted to prove the reliability and validity of our procedure.

CONCLUSION

Although, the SCI group and the SAI group were not matched for age, sex, or BMI, no significant difference in CHD was seen between the SCI and SAI groups. RRDD value was greater in SCI group suggesting that individualized CHD in flexion and the internal rotation should be taken into account when assessing patients with SCI.

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CONFLICTS OF INTEREST

All authors declare no conflicts of interest.

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Opinion

*Corresponding author
Habib Mohamed Bin Ismail, MBBS
Buckinghamshire Health Trust
Amersham HP7 0JD, UK
Tel. 07510306339
E-mail: habib.mohamed91@gmail.com

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Will Plain Abdominal Radiographs become Obsolete?

Habib Mohamed Bin Ismail, MBBS*; Akif Malik, MBBS

[1]Buckinghamshire Healthcare NHS Trust, Amersham HP7 0JD, UK
[2]Oxford University Hospital, Headington, Oxford OX3 7HE, UK

ABSTRACT

Plain abdominal radiographs are often used as the first line investigation in diagnosing abdominal pathologies such as bowel obstruction and gastrointestinal perforation. However, their interpretation can often be non-specific. Given the reduction in radiation doses in recent years, This article reviews the role of plain abdominal radiographs and other imaging modalities in bowel obstruction and gastrointestinal perforation.

KEY WORDS: Abdomen; X-rays; Obstruction; Perforation; Radiation; Dose.

ABBREVIATIONS: RCR: Royal College of Radiologists; CTDI: Computed Tomography Dose Index; LBO: Large Bowel Obstruction; DLP: Dose length product; SBO: Small Bowel Obstruction; NHS: National Health Service; Gy: Grays; Sv: Sieverts.

INTRODUCTION

The Royal College of Radiologists (RCR) recommend plain abdominal radiographs in the evaluation of suspected bowel obstruction or perforation, inflammatory bowel disease flare ups, acute and chronic pancreatitis, foreign bodies and blunt or penetrating abdominal injuries.[1] Other possible indications include suspected ureteric colic, constipation and palpable abdominal masses.

Plain abdominal radiographs are the initial radiological investigation performed in most patients who present to hospital with abdominal pain. These can be performed supine and erect, with the addition of an erect chest radiograph if perforation is suspected. Plain abdominal radiographs can be categorised as normal, abnormal or non-specific. Kellow et al[2] conducted a large retrospective analysis of interpretation of plain abdominal radiographs in 874 non-trauma patients. Forty-six percent of abdominal radiographs were interpreted as non-specific whilst 72% of patients with normal abdominal radiographs, who went on to have further imaging, had subsequent abnormalities. Other studies have replicated similar results outlining interpretation of plain abdominal radiographs as inaccurate and non-specific.[3-5] Computed tomography (CT), as expected, has been shown to be more sensitive (96%) compared to plain abdominal radiographs (30%).[6] Despite this, plain abdominal radiographs are sensitive in selected patients - those with bowel obstruction, viscus perforation, foreign bodies and ureteric calculi.[6-8] Thus, one might argue that CT should be used first line, in certain instances if available, given its greater sensitivity in picking up pathology; however, one must remember that theradiation dose of CT should be considered as it is approximately ten times that of a plain abdominal film.

THE PROBLEM WITH IONISING RADIATION

While we rely heavily on ionising radiation for both diagnosis and intervention, it is not without risk. It can damage tissues and promote carcinogenesis. Stochastic and deterministic effects are two effects of ionising radiation. Stochastic effect quantifies the probability of carcinogenesis occurrence and is proportional to the dose. Deterministic effects are effects that could potential-

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ly cause functional impairment of the organ or tissue. However, this only occurs above a certain threshold. Some examples of deterministic effects include skin erythema or necrosis, infertility and cataract formation.[9]

CT scanning was first used on a patient in 1971 when a CT of the Head was performed for a suspected frontal lobe tumour; the first CT scan of the body was performed in 1974.[10]

CT requires a large dose of radiation and patient dose quantification is important. CT Dose Index (CTDI) is the radiation output of a CT scanner. This allows the comparison of safety and effectiveness of different CT scanners. Dose length product (DLP) is the dose of a complete CT examination (i.e., all series in a scan) and this is related to the stochastic risk. DLP is derived from CTDI Volume which quantifies helical scanning.[9,11-13]

Radiation dose is quantified by effective dose or absorbed dose. Effective dose is an estimate of the overall harm to the patient by radiation. It is difficult to quantify accurately as the dose for each radiosensitive organ will need to be estimated. It reflects the relative risk from exposure to ionising radiation and is therefore not individual-dependent but provides an estimate for all individuals. It is measured in Sieverts (Sv) or rem (roentgen equivalent man). Absorbed dose is energy absorbed per unit mass/ organ. It quantifies risk of organ damage from radiation. It is measured in Grays (Gy).[12,14] Reducing effective dose is challenging as it is dependent on patient size.[15]

Putting things into perspective, the UK average annual radiation dose is about 3 millisieverts (mSv) a year, most of it occurring from natural radioactivity.[16] Abdominal and pelvis radiographs require approximately 0.7 mSv each.[17] The average dose for CT Abdomen/ Pelvis is between 10 and 24 mSV.[18,19] However, a recent study showed that the median effective dose for CT scan of a multiphase abdomen and pelvis is 31 mSV.[20]

ABDOMINAL RADIOGRAPHS IN THE EVALUATION OF SMALL BOWEL OBSTRUCTION

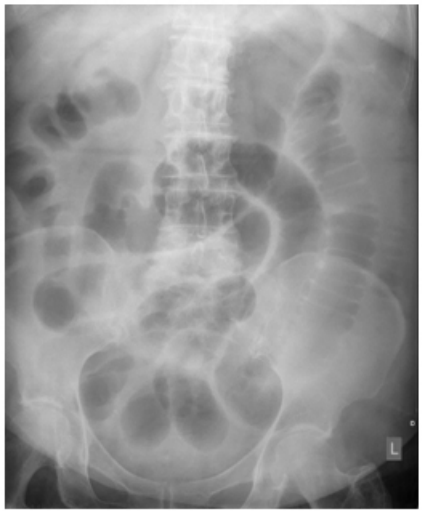
Abdominal radiographs are generally over-requested.[2] The commonest reasons for request are for the investigation of obstruction, perforation and foreign body ingestion.[21,22]

The most common cause of small bowel obstruction (SBO) is postoperative adhesions. Other causes include incarceration secondary to hernias, neoplasm and Crohn's disease.[23,24] The sensitivity and specificity of abdominal radiographs in the evaluation of mechanical small-bowel obstruction is poor, with failure to confirm diagnosis in a third of cases.[25-28] Thus, in these patients, further imaging is inevitably required.[25] These often include ultrasound or CT with contrast. CT has been shown to be superior in specificity and sensitivity compared to plain abdominal radiograph in determining the presence and cause of obstruction.[26,28] If abdominal radiography is suggestive of SBO, it is frequently followed-up with a CT scan.[27,29] Dilatation of small bowel is a common finding on plain abdominal radiograph which could suggest small bowel obstruction, paralytic ileus or intra-abdominal disorder.[30] Such patients will eventually require a CT scan to identify the cause of the blockage. Thus, if a strong clinical suspicion of small bowel obstruction exists, is it necessary to perform a plain abdominal radiograph first? Plain abdominal radiographs can either be false negative, non-specific or positive. Most of the above scenarios will result in the request of a CT scan, thus resulting in even more radiation than if a CT scan were to be performed as the first radiological investigation on its own.

Having said this, in adhesional SBO, the cause is not always readily identified by a CT scan.[31] In such patients, small bowel obstruction is conservatively managed (and, indeed, in most patients with SBO). Thus, plain abdominal radiographs may have a specific role in managing these patients out-of-hours where the availability of CT scans is limited.

Figure 1 demonstrates small bowel obstruction on an abdominal X-ray.

Figure 1: Small Bowel Obstruction on a Plain Abdominal Radiograph.[49]



ABDOMINAL RADIOGRAPHS IN THE EVALUATION OF SIGNIFICANT BOWEL OBSTRUCTION

Large bowel obstruction (LBO) is a surgical emergency with the commonest cause being colorectal cancer.[32] Other causes include caecal volvulus, sigmoid volvulus, diverticulitis, hernias, foreign bodies, medications (including opiod-based illicit drugs), inflammatory bowel disease, external compression, adhesions and intussusception.[33] Radiological findings of LBO include dilatation of the large bowel proximal to the occlusion in the colon. Air-fluid levels can be seen on supine abdominal radiographs which suggests acute obstruction.[33] Common sites of obstruction include the caecum, the hepatic and splenic flexures, and the recto-sigmoid colon. Similar to patients with SBO, ab-

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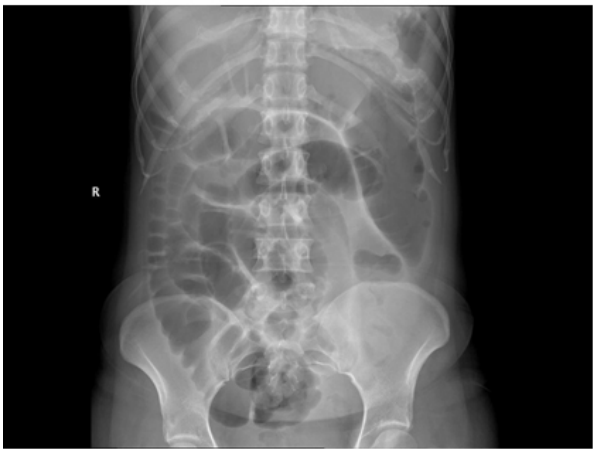
dominal radiograph is the first imaging modality used in patients suspected of having LBO, with the sensitivity and specificity of abdominal radiographs in LBO being 84% and 72% respectively.[33] Abdominal ultrasound can also aid in the diagnosis of LBO.[34] Patients with suggestion of LBO on the abdominal radiograph will go on to have an urgent CT scan to identify the cause of LBO - intraluminal, mural and extraluminal. Furthermore, CT can also aid in the detection of metastases in LBO secondary to malignancy. The sensitivity and specificity of CT scans in LBO is 96% and 93% respectively.[35,36] As with SBO, should patients with suspected LBO have an initial plain abdominal radiograph if they will ultimately require a CT scan, especially when the commonest cause (colorectal cancer) is unlikely to be managed "conservatively"?

Figure 2 demonstrates large bowel obstruction on an abdominal X-ray.

Figure 2: Large Bowel Obstruction on a Plain Abdominal Radiograph.[50]

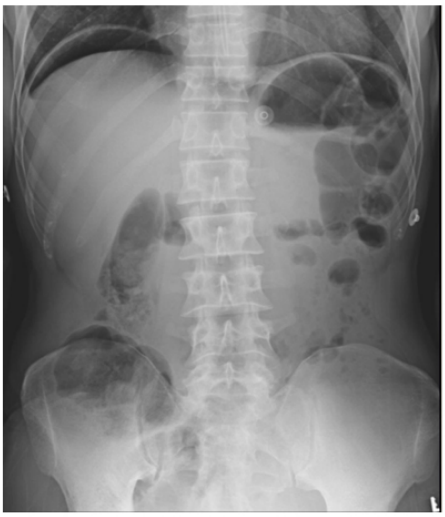


GASTROINTESTINAL PERFORATION

Gastrointestinal perforation is also a surgical emergency, with peptic ulcer disease being reported as the most common cause of perforation.[37] It is usually identified as pneumoperitonem on an erect chest and/or abdominal radiograph.[38] Specific signs include Rigler sign, football sign and triangle sign.[31,39] Plain abdominal radiography is not accurate for pneumoperitoneum with studies on specificity ranging from 53% to 89.2%.39-42 False positive results can result in unnecessary laparotomy and needless exposure to general anaesthesia.[6,39] Undoubtedly, patients with pneumoperitoneum should urgently be taken to theatre. However, given advances in imaging and the availability of CT scanners, most patients with pneumoperitoneum on abdominal radiograph will have further imaging. CT scans are extremely sensitive (92%) and specific (94%) for GI perforation.[43,44] The signs suggestive of gastrointestinal perforation on CT include the ligamentum teres sign and falciform ligament sign (indicating free gas).[45] Other symptoms include the presence of free intraperitoneal fluid and leaking of contrast agent through the bowel wall.[46] Furthermore, CT is also sensitive for identifying the site of perforation (90%).[47]

Solis et al[38] showed in a small retrospective study that CT delays surgery in patients with pneumoperitoneum on abdominal radiograph. Thus, given the risk of unnecessary laparotomy and unnecessary delays in surgery where it is required, patients with strong clinical suspicion of GI perforation should ideally have a CT instead of Abdominal X-ray (AXR) as first line investigation (Figure 3).

Figure 3: Gastrointestinal Perforation on a Plain Abdominal Radiograph.[51]



LIMITATIONS

There are various restrictions proposed to replacing plain abdominal radiographs with CT-scans, as a first line modality. Firstly, CT scans are less readily available compared to plain film imaging, given that they require increased resources in terms of time and overall expense. Secondly, many of the previous studies may well be limited by limited by recall bias in which the overall outcome of the CT scan or AXR may not always include the initial clinical suspicion. Finally, if CT examinations replaced plain abdominal radiographs as an initial modality in certain instances, it would significantly impact on the workload of Radiologists. The National Health Service (NHS) produced its annual report on NHS imaging and radiodiagnostic activity and reported that the average growth per year in the last 10 years for CT requests has been 10.3%.[48] The RCR state that the UK has 48 radiologists per million population, with most Western countries having double this number. The suggestion that we move CT imaging to a first-line modality before abdominal radiographs may not be pragmatic.

CONCLUSION

AXR are known to have a low sensitivity and specificity compared to CT scans in the assessment of patients presenting with

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acute abdominal pain. Despite this, it is the view of the authors that the role of AXRs will not become obsolete given aforementioned pragmatic difficulties in getting a CT scan CT scan as a first-line image and the risk of the much greater radiation dose that CT carries. However, if it is almost certain that a patient will go on to have a CT scan based on clinical findings alone, there is scope for bringing this into practice to avoid the combined radiation dose of AXR and CT together *versus* CT alone. Otherwise, the iRefer guidelines developed by the RCR should be adhered to, where an abdominal X-ray may be useful under certain circumstances.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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Retrospective Study

*Corresponding author
Faraz Hosseini-Ardehali, BSc, MBBS
Department of Radiology
Lister Hospital, Coreys Mill Lane
Stevenage, SG1 4AB, UK
Tel. 01438314333
E-mail: faraz.hosseini-ardehali@nhs.net

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A Crohn's Conundrum: Can the Faecal Calprotectin Level Act as a Sensitive Cut-off to Prevent Unnecessary MRI Small Bowel Scans?

Faraz Hosseini-Ardehali, BSc, MBBS*; Kapila Jain, MBBS, MD, FRCR; Rob Mead, BPharm, MBBS, MRCP, MD

Lister Hospital, Coreys Mill Lane, Stevenage, SG1 4AB, UK

ABSTRACT

Background: Current gastroenterology practice in evaluating those with diarrhoeal symptoms and a positive faecal calprotectin (CP) is to perform colonoscopy. Colonoscopy however is limited, in that it cannot exclude disease proximal to the terminal ileum. Therefore, for many patients not known to have Crohn's disease, gastroenterologists are often concerned about the possibility of more proximal small bowel Crohn's and request an magnetic resonance imaging (MRI) small bowel scan.
Aims: This is the first study to investigate whether patients with a clinical suspicion of Crohn's but with a normal colonoscopy will benefit from MRI in terms of diagnostic evaluation if they have a CP below the cut-off.
Method: MRI small bowel reports, CP levels and colonoscopy reports were analysed (where obtainable) from 422 scans at a district general hospital in Stevenage, between 02/04/2015 and 21/07/2017. Eighty-five patients had features suggestive of Crohn's but had normal colonoscopy findings. These were divided into those who had a CP above or below 600.
Results: Within 55 patients who had a calprotectin below 600, we report that none (0%) of these patients were found to have significantly positive findings for Crohn's on subsequent MRI. Amongst 30 patients with a positive CP, 8 (26.6%) were found to have active disease on MRI. The sensitivity of calprotectin was therefore identified to be 100% (95% CI 63.06% to 100%) and the specificity of the test was 71.43 % (95% CI 60% to 81.15%). Negative predictive value (NPV) was 1.00 and positive predictive value (PPV) was 0.27.
Conclusion: Our study is the first to suggest that in patients with features of Crohn's who have a normal colonoscopy, calprotectin performs impressively as a sensitive marker of the presence of small bowel inflammation on subsequent MRI. Further prospective studies would be needed to validate a potential approach of using the biomarker as a cut-off to reduce unnecessary MRI small bowel scans.

KEY WORDS: Crohn's disease; Magnetic resonance imaging (MRI); Faecal calprotectin.

ABBREVIATIONS: CP: Faecal Calprotectin; MRI: Magnetic Resonance Imaging; CRP: C-Reactive Protein; ESR: Erythrocyte Sedimentation Rate; CDAI: Crohn's Disease Activity Index; DBE: Double-Balloon Enteroscopy; IBD: Inflammatory Bowel Disease; IBS: Irritable Bowel Syndrome; CTE: Computed Tomography Enterography; CDEIS: Crohn's Disease Endoscopic Index of Severity; RCR: Royal College of Radiologists; NPV: Negative Predictive Value; PPV: Positive Predictive Value; CI: Confidence Interval.

INTRODUCTION

Crohn's Disease is an autoimmune chronic inflammatory bowel disease associated with both environmental and genetic factors with onset usually in early adulthood.[1-3] The standard approach to clinical evaluation of the disease involves combining endoscopy findings with radi-

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ological and biochemical investigations. For most patients, the disease follows a relapsing and remitting course and thus there is the need for regular follow-up and evaluation of the degree of response to conventional medical therapies, and if this is not the case, for consideration of novel biologic therapies or surgical intervention.[4] The disease often manifests within the small bowel although can be distributed throughout any location along the gastrointestinal tract.[3] Therefore, the absence of visible disease during a colonoscopy cannot exclude small bowel involvement. A previous endoscopic study of the small bowel revealed that disease is indeed present there amongst 65% of Crohn's patients.[5] Therefore, information from faecal biomarkers and radiological investigations taken into consideration in conjunction with colonoscopy findings when assessing the comprehensive pattern of disease amongst individual patients.[6]

Previously other markers of disease activity have been investigated, such as C-reactive protein (CRP). CRP is a traditional and well-recognised sensitive marker of the degree of inflammatory activity within the bowel. However, as has been described to also be the case for erythrocyte sedimentation rate (ESR) and platelet count, CRP is not specific for Crohn's.[1,6]

Faecal Calprotectin as a Biomarker of Inflammation

Calprotectin is a 36-kilodalton protein that is present in plasma but also understood to be concentrated in stool samples. In physiology, the protein is not normally found in gut mucosa.[7] However, in pathophysiological states such as within the inflammatory lesions of Crohn's disease, neutrophils migrate through the bowel wall and reach the mucosa. This protein is then released from the cytoplasm of granulocytes. As the protein remains intact in stool samples for up to 7 days, calprotectin is an investigation that has become widely used in a range of clinic or general practice settings as a surrogate marker of inflammation in inflammatory bowel diseases.[8,9] It is understood, however, that increased levels of faecal calprotectin may represent the presence of inflammatory processes within the intestine from a broad range of aetiologies.[1] Defining the presence *versus* absence of inflammation has been of particular clinical value in one group of patients; differentiating between patients with inflammatory bowel disease (IBD) and those with non-IBD diagnoses, such as irritable bowel syndrome (IBS). A 2007 quantitative meta-analysis of 35 studies evaluated the role of faecal calprotectin in this diagnostic dilemma and found the test to be effective in discerning patients with Crohn's disease from those with IBS.[10] Further studies have supported calprotectin as a more reliable marker of inflammation than ESR and CRP. Tibble et al[6] included a comparison of CP, ESR and CRP for differentiating between Crohn's and IBS. CP was found to have a 100% sensitivity and a 97% specificity when a cut-off point of 30 mg/l was used, and that the diagnostic accuracy of calprotectin was superior to ESR and CRP.[6] Early studies such as these utilised 111 indium marked white cells as a gold standard, related to its validated ability to represent intestinal inflammation.[11]

A 2010 meta-analysis sought out to answer a similar clinical question to that posed by ourselves: whether the faecal calprotectin levels could be used to improve patient selection for colonoscopy following presentation with clinical features suggestive of Crohn's. The aim was to determine whether colonoscopy could be safely omitted in the diagnostic evaluation of low risk patients assessed as such based on the presence of this biomarker at lower-levels. Six prospective studies in adults were included in the analysis. The study found a sensitivity of 93% (95% CI, 0.85 to 0.97) for calprotectin in detecting inflammatory disease later confirmed by colonoscopy. The specificity was found to be 93% (95% CI, 0.79 to 0.99). The authors concluded that by using calprotectin levels in patient selection, there could potentially be a 67% reduction in colonoscopy procedures.[8]

The Crohn's disease activity index (CDAI) is measure of disease activity through clinical assessment. This index, together with serological and faecal inflammatory markers, is taken into consideration by the clinician when holistically assessing disease activity and response to treatment during follow-up.[2] Costa et al who found significantly higher-levels of calprotectin amongst patients with higher clinical disease activity scores.[12] An increasingly adopted therapeutic target is the attainment of 'mucosal healing'. This can be assessed through both endoscopy and radiological investigations.[13]

Findings from a recent study using double-balloon enteroscopy (DBE) to compare the accuracy of inflammatory markers in the detection of disease activity and mucosal healing have further supported the role of calprotectin as a sensitive marker of disease activity.[7] Calprotectin demonstrated a stronger correlation ($r=0.77$; $p=0.001$) with disease activity when compared to CRP ($r=0.65$; $p<0.001$) or to platelets ($r=0.49$; $p<0.001$) and serum albumin ($r=-0.47$; $p=0.001$).[7] Notably, the authors concluded that calprotectin was a particularly useful marker of disease regression in those patients with Crohn's who had involvement of the ileum. It could be argued that the outcome of this study backs up a potential role for calprotectin to be used as a cut-off for reducing the burden of unnecessary MRI small bowel scans. This study also demonstrated that despite its widespread clinical use, CRP did not perform as well as calprotectin and was only increased in Crohn's patients with more moderate to severe disease activity.[7]

Limitations of Colonoscopy in Crohn's

Colonoscopy has the advantage of providing a direct visualisation of the colonic mucosa and facilitating biopsy of lesions. It is therefore very useful in investigating patients presenting with symptoms suggestive of an inflammatory process within the bowel. However, colonoscopy can only visualise the colon up to the terminal ileum and therefore is limited in evaluating the pattern of disease involvement in Crohn's.[14] In addition, there are rare but significant potential complications associated with the procedure such as bowel perforation. Colonoscopy is also associated with considerable procedural discomfort for patients.

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Attempts at use of ultrasound for this scenario are limited by the presence of intervening bowel gas.[15]

Computed tomography enterography (CTE) is another cross-sectional imaging modality to investigate Crohn's disease. A 2012 study using this modality amongst 153 patients undergoing colonoscopy with intubation of the terminal ileum found that up to 54% of patients with small bowel or with upper gastrointestinal involvement were found to have a normal terminal ileum on endoscopy. The authors also suggested that in some cases disease evident on cross-sectional imaging may evade visualisation under colonoscopy because of a pattern of intramural or mesenteric involvement. In many other cases, the absence of disease was attributable to the more widely recognised explanation of the disease skipping the terminal ileum. This study bolsters the application of cross-sectional imaging in investigating patients with clinical features of Crohn's disease but with a negative colonoscopy.[16]

Capsule endoscopy has a significant role in the evaluation of small bowel lesions beyond the reach of the endoscope; however, is also limited in that it cannot be used with the presence of structuring disease in the small bowel, which is common in Crohn's.[14]

Double-balloon enteroscopy (DBE) has been demonstrated to have a role in identifying inflammatory lesions in the ileum and other parts of the small bowel beyond the reach of conventional colonoscopy; however, the use of this method is confined to small-scale use in specialist centres and is not routinely used in clinical practice due to the risks involved and duration of procedure.[3,7]

Role of MRI in Assessment of Small Bowel Disease

Over the last few years there has been an increasingly widespread adoption of cross-sectional imaging modalities such as MRI in the evaluation of Crohn's disease. CTE is utilised to a lesser extent due to the considerable level of exposure to ionising radiation involved. MRI also has the advantage of superior soft tissue contrast resolution when compared to computed tomography (CT) and multiplanar capability[3]; however, CT has better spatial resolution.[14,15] MRI necessitates the use of adequate oral contrast for the purposes of distending the bowel in order to better visualise areas of enhancement.[15] Furthermore, whilst endoscopy has the ability to assess mucosal surface disease, MR has the ability to evaluate the extent of involvement of active inflammation through the thickness of intestinal wall, and investigate both intramural and extramural disease.[3,4] In addition, MRI has the ability to evaluate the structural complications of Crohn's such as fistulas and abscesses.[2] MRI is also able to detect lymphadenopathy.[3] A key factor behind the burgeoning demand for MRI is its ability to both visualise bowel segments proximal to strictures which may be beyond the reach of colonoscopy.[3] Thus better spatial resolution and the improvements in techniques to reduce artefact secondary to bowel peristalsis have led to a more widespread adoption of MRI in assessment of small bowel pathology.[13]

Radiological findings suggestive of active inflammation include mural signal intensity, degree of enhancement with gadolinium contrast and mural thickness. Mural thickening has been found to correlate with CDAI, a disease score based on clinical and laboratory data.[14]

MRI has been validated in the assessment of Crohn's through a number of studies such as Rimola et al, which correlated MRI lesion marker of severity with their corresponding visualised lesions on endoscopy.[15] In this study, the two investigations were performed during the same day. Endoscopic assessment of severity of inflammatory lesions was undertaken with the Crohn's disease endoscopic index of severity (CDEIS). This scoring system takes into account features such as the presence of deep or superficial ulcers and the presence of luminal bowel stenosis along the length of the colon through to the terminal ileum. The study looked at patients with an established diagnosis of Crohn's and found that there was a close relationship between the severity of endoscopic lesions and MRI findings associated with severity. The most suggestive MRI finding was oedema of the wall, which was found in 77.5% of ulcerated segments on endoscopy, and this was not present in any regions of the colon identified as normal on endoscopy.[15] The sensitivity of MRI was increased when multiple radiological findings such as relative contrast enhancement were considered together with wall thickening. Such MRI findings had a high diagnostic accuracy. The study suggested specifically that in patients with known Crohn's, MR could be used as an alternative to colonoscopy to provide a complete assessment of the colon for disease.[15] In addition, it has been observed that there is a decrease in MRI findings such as contrast enhancement of the bowel wall in patients who progress from active disease to disease in remission, and that MRI is useful for the follow-up of patients with Crohn's.[2]

Del Vescovo et al identified that with the use of dynamic contrast enhanced MR of the terminal ileum, MRI findings correlated well with histological confirmation ($r=0.8$; $p<0.001$, Spearman test). It was found that this more modern imaging technique was associated with an increased accuracy in differentiating inactive from active disease.[4]

Whilst MRI is widely used in excluding inflammatory bowel disease in patients who present with enteric symptoms, the method is limited in its ability to detect early stages of Crohn's, such as mucosal nodularity and superficial aphthous ulceration.[3]

METHODS

A total of 422 MRI small bowel study scans carried out at a large district general hospital, Stevenage from between the dates of 02/04/2015 and 21/07/2017 were analysed. One hundred nineteen of these were excluded as there was no information regarding scan reports and/or faecal calprotectin levels for these

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patients. Of the remaining 301 scans, 21 (6.9%) scans were excluded as they were for indications other than the investigation of Crohn's disease. One hundred seventy-four (57.8%) scans were carried out to investigate the extent of disease activity or the degree of remission in patients with known Crohn's disease. Only 78 scans were included as they had a recent calprotectin taken prior to scan (<4 months).

One hundred six (35.2%) scans had been undertaken to investigate the presence of small bowel involvement within patients who had presented with symptoms suggestive of Crohn's disease. From this cohort 85 patients who underwent MRI small bowel study and had a normal colonoscopy prior to scan were included.

In the statistical analysis applied to the cohort of patients who presented with symptoms suggestive of Crohn's but did not have a prior diagnosis, we define a 'true positive' test result as an MRI demonstrating the presence of disease in a patient who had a calprotectin level of greater than 600. Similarly, a 'true negative' test result refers to an MRI scan which did not demonstrate any significant evidence of disease in a patient who had a calprotectin level below 600. The 'sensitivity' of calprotectin therefore reflects the performance of this biomarker in correctly identifying all those patients who are found to have evidence of small bowel disease on MRI. Similarly, the 'specificity' of calprotectin relates to the performance of this test in identifying patients in whom small bowel involvement is found to be absent on subsequent MRI.[17]

Furthermore, the positive predictive value (PPV) of the test reflects the likelihood that the patient has an MRI scan demonstrative of significant disease, given the calprotectin level is above 600. The negative predictive value (NPV) of the test refers to the likelihood that the patient has an MRI scan reporting the absence of any significant disease if the calprotectin level is below 600.

The statistical analysis was similar in the cohort of patients with an established diagnosis of Crohn's, however, in this group of patients, sensitivity and specificity relate to the performance of this test in identifying the presence or absence of active disease respectively.

RESULTS

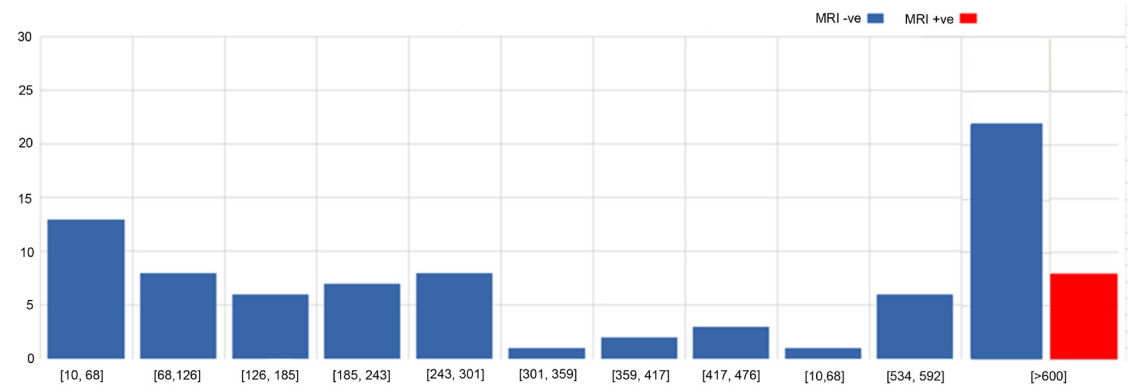
Calprotectin Level as a Cut-off for MRI Investigation of Patients with Symptoms of Crohn's Disease

Eighty-five patients who presented with symptoms suggestive of Crohn's disease and then had a normal colonoscopy were studied (Figure 1). When looking at the 55 of these patients who had a calprotectin below the cut-off value of >600, we found that none (0%) of these patients were found to have significant evidence of Crohn's disease on the subsequent MRI scan. Of the 30 patients who did have a positive calprotectin, 8 (26.6%) of these were found to have significant disease on MRI. The sensitivity of calprotectin was therefore identified to be 100% (95% CI, 63.06% to 100%) and the specificity of the test was found to be 71.43 % (95% CI, 60% to 81.15%). The NPV was calculated to be 1.00. The PPV was found to be 0.27.

Calprotectin as a Cut-off for Investigating State of Disease Activity/Remission in Patients with known Crohn's Disease

Of the 40 patients with known Crohn's disease who have a recent (<4 months) calprotectin that was positive and then underwent MRI to investigate disease activity, 25 (62.5%) of these had a scan demonstrative of active disease. Of the 38 patients with known Crohn's disease who have a negative recent (<4 months) calprotectin who underwent MRI to investigate disease activity/extent of remission, 16 (42.1%) of these had a scan demonstrative of active disease. The sensitivity of a positive calprotectin for the presence of active disease amongst patients with known Crohn's was found to be 60.9% (95% CI, 44.5% to 75.8%) and

Figure 1: Histogram to Show Distribution of Calprotectin Levels in MRI +ve and MRI -ve Groups.



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the specificity 59.5% (95% CI, 42.1% to 75.3%) (PPV 0.63, NPV 0.58).

DISCUSSION

The Royal College of Radiologists (RCR) reports that there are ever increasing workload demands on radiology services as a result of a low radiologist to population ratio, and an increasing burden of reporting lists on that limited number. Overall, the number of radiological investigations has increased by 42% in the last 10 years. Of particular note is the fact that the largest area of growth in radiological investigations carried out is likely to be in MRI, which is projected to amount to a number of 7.8 million in 2022.[18] There is therefore need for studies evaluating novel approaches to reduce the burden of inappropriate examinations.

To the best of our knowledge, we are the first authors to investigate the performance of a calprotectin cut-off level within the specific role of selecting patients (who have had a normal colonoscopy) for MRI with the intention of reducing the burden of unnecessary scans carried out in the radiology department of a district general hospital. Our data has demonstrated that within the 55 patients who had a normal prior colonoscopy with a calprotectin of less than 600, none of these were found to have significant evidence of small bowel involvement on the subsequent MRI scan. This in theory suggests a 100% sensitivity of the biomarker at this level. We believe that if our findings are corroborated with further prospective studies on the use of calprotectin in patient selection for MRI, use of this marker may be a viable approach to reduce such unnecessary MRI examinations. Evidence from prior studies, some of which described above, suggests calprotectin is a sensitive but non-specific investigation for the presence of inflammatory bowel disease. As corroborated by the previous data, our data suggests by comparison a lower specificity for the investigation identifying the presence of disease, at 71.43 % (95% CI, 60% to 81.15%).

In our study we have additionally attempted to investigate the use of calprotectin levels in patient selection for MRI small bowel scans that were requested for investigating active disease in patients with known Crohn's. This is a likely source of increased demand on MRI over the coming years given the expansive use of biological therapies such as ustekinumab and adalimumab. There is the need to characterise the extent of small bowel involvement whilst selecting patients for these therapies and monitoring the degree of radiographic response once therapy has been initiated.[19] It may be that further studies validating the use of calprotectin as a cut-off may have considerable economic benefits in reducing the need for MRI and perhaps itself having a direct role in patient selection for biological therapies. This study found similarly that calprotectin was less sensitive 60.9% (95% CI, 44.5% to 75.8%) in this context of identifying patients with known Crohn's who would demonstrate the presence of active disease on MRI. In addition, the test was less specific for this outcome, at 59.5% (95% CI, 42.1% to 75.3%). It should be noted that this aspect of the study was limited by the use of calprotectin data within a broad time period of 4 months prior to the scan. During the intervening time period in between the positive calprotectin and the scan, changes to a medical therapy regimen would have resulted in reduced active disease on the subsequent MRI scan. Further prospective studies investigating such a role of calprotectin may include calprotectin levels obtained immediately prior to scan.

CONCLUSION

Our study is the first to suggest that in patients with clinical features of Crohn's disease who have a normal colonoscopy, calprotectin performs impressively as a sensitive marker of the presence of small bowel inflammation on subsequent MRI. There could therefore be significant clinical utility for this biomarker in deciding whether such patients need to undergo further small bowel imaging following a colonoscopy. Further higher-powered prospective studies would be merited to investigate this potential use in the clinical setting and therefore if suitable its application in reducing the growing burden of MRI requests to the radiology department and sparing patients of unnecessary investigations.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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