

The association between guideline adherent radiographic imaging by chiropractic students and the diagnostic yield of clinically significant findings

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Background: Radiographic guidelines aim to increase the diagnostic yield of clinically relevant imaging findings whilst minimising risk. This study assessed the appropriateness of radiographic referrals made by student chiropractors and explored the association between guideline appropriate imaging and clinically significant radiographic findings.

Methods: Radiographic referral and report findings (n=437) from 2018 were extracted from Macquarie University chiropractic clinics. Appropriateness of radiographic referrals was assessed according to current radiographic guidelines. Radiographic findings were assessed for clinical significance. The association between guideline appropriate radiographic referral and

Lien entre les demandes d'examen radiographiques conformes aux lignes directrices provenant d'étudiants en chiropratique et le rendement diagnostique des examens cliniquement pertinents

Contexte : Les lignes directrices relatives aux demandes d'examens radiographiques visent à accroître le rendement diagnostique des résultats des examens d'imagerie cliniquement pertinents tout en minimisant le risque. La présente étude a consisté à évaluer la pertinence des examens radiographiques demandés par des étudiants en chiropratique et à examiner le lien entre la pertinence des demandes d'examens d'imagerie et les résultats des examens radiographiques cliniquement pertinents.

Méthodologie : Des demandes d'examens radiographiques et des rapports d'examens (n = 437) en 2018 ont été extraits de dossiers de la clinique de chiropratique de la Macquarie University. La pertinence

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clinically significant radiographic findings was assessed using logistic regression analysis and odds ratios were estimated.

Results: The proportion of guideline appropriate imaging was 55.8% (95%CI: 51.2-60.4). An association between guideline appropriate radiographs and clinically significant findings was found (OR: 2.2; 95%CI: 1.3-4.1).

Conclusions: Approximately half of all radiographic referrals made by chiropractic students were guideline concordant. Guideline appropriate imaging was associated with an increase in clinically significant radiographic findings.

(JCCA. 2021;65(1):66-75)

KEY WORDS: chiropractic; radiographs; guidelines; diagnostic yield; appropriate use

Introduction

Radiographic imaging is used within chiropractic practice to diagnose serious pathology or trauma, determine appropriate treatment options, and detect contraindications to care.¹ Historically chiropractors also used radiographs to perform biomechanical analysis of the spine and inform technique selection and application.¹ In the last two decades however, radiographic guidelines for the chiropractic profession have discouraged routine radiographs for these reasons, due to the associated risks and lack of evidence of clinical benefit.²⁻⁴ In particular, radiographs commonly demonstrate pathoanatomical changes of limited clinical significance, such as isolated anatomical anomalies or degenerative findings.^{1,5,6} These radiographic findings may lead to overdiagnosis, increased down-

des demandes d'examens radiographiques a été évaluée en fonction des lignes directrices relatives aux demandes d'examens radiographiques en vigueur. La pertinence des résultats des examens radiographiques a été évaluée. On a examiné le lien entre les demandes d'examen radiographique conformes aux lignes directrices et les résultats d'examens radiographiques cliniquement importants à l'aide d'une méthode d'analyse par régression logistique et on a estimé les risques relatifs.

Résultats : La proportion de demandes d'examen d'imagerie qui étaient conformes aux lignes directrices s'est élevée à 55,8 % (IC à 95 % : 51,2-60,4). On a établi un lien entre les demandes d'examens radiographiques conformes aux lignes directrices et les résultats cliniquement pertinents (RR : 2,2; IC à 95 % : 1,3-4,1).

Conclusions : Environ la moitié de toutes les demandes d'examens radiographiques provenant d'étudiants en chiropratique étaient conformes aux lignes directrices. Les demandes d'examens d'imagerie conformes aux lignes ont été associées à une hausse de résultats d'examens cliniquement pertinents.

(JACC. 2021;65(1):66-75)

MOTS CLÉS : chiropratique, examens radiographiques; lignes directrices; rendement diagnostique; utilisation appropriée

stream healthcare utilisation, and create unnecessary patient concern.^{1,7,8} Amongst chiropractors, a high variance in radiographic imaging utilisation rates of between 8% to 84%¹ has been observed. A lack of knowledge and a lack of adherence to current radiographic guidelines has been noted amongst chiropractors, within both clinical and teaching environments⁹⁻¹¹, potentially driving higher imaging rates. Resistance to current radiographic guidelines amongst chiropractors is largely due to concerns that current guidelines do not account for the use of joint manipulative therapy, and that injury or sub-optimal treatment may result if radiographs are not used to screen patients for underlying pathology or anatomical variation prior to joint manipulative therapy.¹²⁻¹⁴

The purpose of radiographic guidelines are to inform

the appropriate use of imaging in clinical practice; that is to increase the diagnostic yield of clinically significant radiographic findings, whilst minimising associated risks.^{1,15} A clinically significant radiographic finding is one that will result in a change to the management of the patient, such as those that either indicate underlying pathology requiring medical referral or increase the likelihood of adverse events following joint manipulation.¹⁶ Clinically significant findings include those indicating underlying cancer, infection, fracture, inflammatory arthritis, joint instability, or osteopenia.^{1,16} Many other radiographic findings, including degenerative changes and isolated anatomical anomalies such as transitional segments and lumbar spondylolisthesis, have not shown clear association with patient symptoms or change to clinical management, making them of unlikely clinical significance.^{1,17,18} Although pathoanatomical changes are common on radiographs performed in chiropractic populations, the majority of changes are of uncertain clinical significance.^{5,6,19} Radiographic findings of known clinical significance are uncommon, with a diagnostic yield ranging from 0.1% to 6.6%.^{5,6,19} If radiographic guidelines are fit for purpose, radiographs taken in accordance with guidelines should be more likely to demonstrate clinically significant radiographic findings than those taken outside of guidelines. Although guideline appropriate imaging has been shown to have a low likelihood of missing pathology²⁰, to our knowledge, the association between guideline appropriate imaging and the diagnostic yield of clinically significant radiographic findings in a chiropractic population has not been assessed.

It is particularly important to ensure that student chiropractors are practicing within an evidence-based paradigm to the standards expected for chiropractic clinicians. Additional drivers of poor adherence to radiographic guidelines that may exist amongst student chiropractors include higher diagnostic uncertainty compared to clinicians and accreditation requirements to demonstrate competence in performing a minimum number of radiographs. There has only been one study that has investigated appropriate radiographic imaging use in the chiropractic student setting. Ammendolia *et al.*⁹, concluded that whilst only 10% of presenting patients were inappropriately referred for radiographs, this accounted for nearly half of all radiographic imaging referrals made; diagnostic yield and association with guideline adherence were not assessed.⁹

Therefore, the aims of this study are to determine (i) the proportion of guideline appropriate imaging performed by chiropractic students in their clinical internship year; (ii) the proportion of imaging performed that identified clinically significant pathology; and (iii) whether the use of guideline appropriate imaging referral is associated with an increased diagnostic yield of clinically significant findings on imaging.

Methods

Design and setting

A retrospective clinical record audit was conducted of all radiographic imaging referrals and reports from January to December 2018 at the Macquarie University chiropractic clinics. Macquarie University operates three chiropractic teaching clinics to provide supervised clinical placements for final year Master of Chiropractic students. The student clinicians are supervised by registered chiropractors to provide diagnosis (including radiographic imaging where indicated) and management for public patients. Ethical approval was provided by the Macquarie University Human Research Ethics Committee (Approval No.: 5201954218658) for this study.

Participants

All patients who were referred for radiographic imaging through the Macquarie University chiropractic clinics from January to December 2018 were included in this study. Patients were excluded if their imaging referral was from another health provider, the imaging was performed at an outside radiology centre, or they did not sign consent for their clinical data to be used for research purposes.

Data extraction

Radiographic referral forms and reports were downloaded from the OPAL-RAD PACs system and de-identified prior to data extraction, with unique identifying numbers allocated. Two researchers independently extracted data from the de-identified radiographic referral forms and reports into Microsoft excel. Referral form data extracted included: chiropractic teaching clinic where the radiographic imaging was performed, date of referral, date of birth, clinical reasons for the radiographic referral, and the radiographic series requested. Radiographic report data extracted included: date of the radiographic study, radio-

graphic series performed, and the radiographic findings. Extracted data were checked for consistency between the two data extractors and any discrepancies were corrected against the original record.

Data synthesis

Appropriateness of the radiographic imaging referral

Two researchers independently categorised the clinical information provided on the referral form as either appropriate or inappropriate compared to current radiographic guidelines for the chiropractic profession.²⁻⁴ Guideline appropriate reasons for radiographic imaging referral included suspicion of underlying serious pathology, history of trauma, suspicion of contraindications to spinal manipulative therapy, or non-response to care.²⁻⁴ Any discrepancies between the researchers were discussed to reach a consensus. If consensus could not be reached a third researcher was consulted. The strength of initial agreement in categorising the appropriateness of imaging between the two researchers was assessed using kappa statistics, and was categorised as slight (0-0.2), fair (0.21-0.4), moderate (0.41-0.6), substantial (0.61-0.8), and almost perfect (0.81-1.0).²¹

Clinically significant radiographic findings

Two researchers independently categorised the reported radiographic findings as clinically significant, possibly significant or clinically insignificant. Clinically significant findings were defined as those likely to change clinical practice or contraindicate the use of joint manipulation, including underlying serious pathology (e.g., osteoporosis, cancer, infection, inflammatory arthritis), fracture, or instability.¹⁶ Instability was assessed on radiograph when flexion and extension radiographs were performed. Possibly significant findings were defined as those that would not contraindicate joint manipulation, but have been reported by chiropractors to potentially inform clinician decisions related to the application of manual therapy.^{1,12,13} These included pathoanatomical changes such as degenerative joint disease, lumbar spondylolisthesis, transitional segments, and scoliosis. Radiographic findings of possible changes that needed clinical correlation or further investigation were also categorised as possibly significant (e.g. possible hypermobility, possible intervertebral foramen narrowing).

All other findings were categorised as clinically insignificant, this included isolated anatomical variances such as spina bifida occulta which are unlikely to have any clinical impact.¹⁹ Any discrepancies between the researchers were discussed to reach a consensus. If consensus could not be reached a third researcher was consulted. Initial agreement in categorising radiographic findings between the two researchers was assessed using kappa statistics.

Data analysis

Appropriateness of the radiographic imaging referral

The appropriateness of the radiographic imaging referral was analysed descriptively as the proportion of radiographic referrals determined as appropriate or inappropriate divided by the total number of radiographic referrals. Proportions of appropriate imaging were stratified by the clinic where the imaging referral was made, the anatomical region of imaging referral (e.g. lumbar, cervical etc.), and the age of patient (in decades) to observe for any trends across these categories.

Clinically relevant imaging

The proportion of clinically relevant imaging was analysed descriptively as the number of radiographs with clinically significant findings, possibly significant findings, or clinically insignificant findings divided by the total number of radiographs. The proportions of clinically relevant imaging were stratified by the clinic where the imaging referral was made, the anatomical region of imaging referral (e.g., lumbar, cervical etc.), and the age of patient (in decades).

Association between guideline appropriate imaging and clinically relevant imaging

Two models were created to assess the association between guideline appropriate imaging and clinically relevant imaging. In model one, the original criteria were applied and only imaging with clinically significant findings was considered clinically relevant. Any radiographic imaging with possibly significant or clinically insignificant findings were considered not clinically relevant. In model 2, adapted criteria were applied to reflect the uncertainty in clinical relevance of some radiographic findings. In

Table 1.

Age of patients, number of radiographic imaging series, and the number of radiographic imaging series per anatomical region, performed at each Macquarie University chiropractic clinic.

	Total	Clinic 1	Clinic 2	Clinic 3
Age range (yrs)	11 - 89	17 - 81	12 - 86	11 - 89
Mean age (SD)	41.8 (20.7)	40.5 (19.4)	44.0 (21.8)	41.8 (21.3)
Radiographic series (N)	437	150	83	157
Radiographic series per anatomical region (N)				
Cervical	98	32	19	34
Thoracic	81	26	13	35
Lumbar	145	46	33	50
Upper limb	48	22	6	17
Lower limb	65	24	12	21

model 2 the clinically significant findings and possibly significant findings were combined and considered as clinically relevant. For each model, two by two tables and logistic regression analysis (adjusted for patient age) were used to assess the association between guideline appropriate imaging and clinically relevant imaging. Odds ratios with 95% confidence intervals were calculated in SPSS (IBM SPSS Statistics v25).

Results

In the 2018 calendar year there were a total of 25,831 patient visits across the three Macquarie University chiropractic clinics. Of these, 4,500 patient visits were either new patients or a new presentation of an existing patient. In the same time period, 437 radiographic imaging referrals were requested. Therefore, radiographic referral proportions were 1.7% of all patient visits and 9.7% of new patients or presentations. The age range of the patients, mean age, number of radiographs performed in each clinic and the number of radiographic series performed per anatomical region are presented in Table 1. The clinic of referral was not recorded on 47 of the referral forms.

Appropriateness of the radiographic imaging referral

Guideline appropriate imaging referrals were made in

244/437 (55.8%; 95%CI: 51.2-60.4) of cases. The appropriateness of radiographic imaging referral stratified by clinic, anatomical region, and age is presented in Table 2. No clear trend in the proportion of guideline appropriate referrals is seen when stratified by clinic or age. An increase in guideline appropriate referrals is evident in the extremities (upper and lower limb) compared to the spine, with the lowest proportion of guideline appropriate referrals in the lumbar spine. Of the guideline appropriate reasons for radiographic imaging referral, the most common reasons were: no improvement after a course of treatment (38.1%, 93/244); history of trauma (37.7%, 92/244); suspicion of underlying pathology, including suspected contraindications to manipulation (13.1%, 32/244); assessment of neurological symptoms (6.6%, 16/244); and adolescent scoliosis (3.3%, 8/244). There was fair agreement²¹ in the initial categorisation of the appropriateness of radiographic imaging referral (kappa, 95%CI: 0.3, 0.2-0.4).

Clinically significant radiographic findings

The proportion of radiographs with clinically significant findings was 65/437 (14.9%; 95%CI: 11.8-18.5), and those with possibly significant findings was 190/437 (43.5%; 95%CI: 38.9-48.2). The proportion of clinically significant findings stratified by clinic, anatomical region,

and age is presented in Table 2. No clear trends in the proportion of clinically significant findings is seen when stratified by clinic or anatomical region. An increase in clinically significant findings is seen in patients over 60 years. Of the clinically significant radiographic findings, the most common findings were: fracture or trauma (30.8%, 20/65); underlying pathology, including inflammatory arthritis or DISH (27.7%, 18/65); osteopenia (24.6%, 16/65); instability (9.2%, 6/65); and congenital findings that would contraindicate manipulation (7.7%, 5/65). Findings that were categorised as possibly significant included: degenerative changes (54.7%, 104/190);

clinical correlation required or need for further investigation (19.5%, 37/190); congenital anomalies of possible significance (12.1%, 23/190); lumbar spondylolisthesis (10.5%, 20/190); intervertebral foramen or canal stenosis without neurological symptoms (2.1%, 4/190); and old fracture (1.1%, 2/190). There was moderate agreement²¹ in the initial categorisation of the clinically significant findings (kappa, 95%CI: 0.6, 0.5-0.6).

Association between guideline appropriate imaging and clinically relevant imaging

For model 1, the proportion of radiographs with clinic-

Table 2.
The proportions of appropriate radiographic imaging referrals and clinically significant findings, stratified by Macquarie University chiropractic clinic, anatomical region, and by age.

	Appropriate n (%; 95% CI)	Not appropriate n (%; 95% CI)	Clinically significant n (%; 95% CI)	Possibly significant n (%; 95% CI)	Clinically insignificant n (%; 95% CI)
Total (N=437)	244 (55.8; 51.2, 60.4)	193 (44.2; 39.6, 48.9)	65 (14.9; 11.8, 18.5)	190 (43.5; 38.9, 48.2)	182 (41.7; 37.1, 46.3)
Clinic					
1 (N=150)	83 (55.3; 47.3, 63.1)	67 (44.7; 36.9, 52.7)	19 (12.7; 8.3, 18.9)	55 (36.7; 29.4, 44.6)	76 (50.7; 42.8, 58.6)
2 (N=83)	52 (62.7; 51.9, 72.3)	31 (37.4; 27.7, 48.1)	15 (18.1; 11.3, 27.7)	41 (49.4; 38.9, 59.9)	27 (32.5; 23.4, 43.2)
3 (N=157)	80 (51.0; 43.2, 58.7)	77 (49.0; 41.3, 56.8)	23 (14.7; 10.0, 21.0)	71 (45.2; 37.6, 53.0)	63 (40.1; 32.8, 47.9)
Anatomical region					
Cervical (N=98)	58 (59.2; 49.3, 68.4)	40 (40.8; 31.6, 50.7)	13 (13.3; 7.9, 21.4)	52 (53.1; 43.3, 62.6)	33 (33.7; 25.1, 43.5)
Thoracic (N=81)	40 (49.4; 38.8, 60.1)	41 (50.6; 40.0, 61.2)	14 (17.3; 10.6, 27.0)	19 (23.5; 15.6, 33.8)	48 (59.3; 48.4, 69.3)
Lumbar (N=145)	62 (42.8; 35.0, 50.9)	83 (57.2; 49.1, 65.0)	19 (13.1; 8.6, 19.6)	82 (56.6; 48.4, 64.4)	44 (30.3; 23.5, 38.3)
Lower extremity (N=65)	44 (67.7; 55.6, 77.8)	21 (32.3; 22.2, 44.4)	9 (13.9; 7.5, 24.3)	23 (35.4; 24.9, 47.5)	33 (50.8; 38.9, 62.5)
Upper extremity (N=48)	40 (83.3; 70.4, 91.3)	8 (16.7; 8.7, 29.6)	10 (20.8; 11.7, 34.3)	14 (29.2; 18.2, 43.2)	24 (50.0; 36.4, 63.6)
Age range					
11-20 (N=33)	13 (39.4; 24.7, 56.3)	20 (60.6; 43.7, 75.3)	1 (3.0; 0.5, 15.3)	6 (18.2; 8.6, 34.4)	26 (78.8; 62.3, 89.3)
21-30 (N=140)	89 (63.6; 55.3, 71.1)	51 (36.4; 28.9, 44.7)	16 (11.4; 7.2, 17.8)	34 (24.3; 17.9, 32.0)	90 (64.3; 56.1, 71.7)
31-40 (N=46)	25 (54.4; 40.2, 67.9)	21 (45.7; 32.2, 59.8)	6 (13.0; 6.1, 25.7)	15 (32.6; 20.8, 47.0)	25 (54.4; 40.2, 67.9)
41-50 (N=14)	9 (64.3; 38.8, 83.7)	5 (35.7; 16.3, 61.2)	0.0 (0.0; 0.0, 2.2)	10 (71.4; 43.4, 88.3)	4 (28.6; 11.7, 54.7)
51-60 (N=54)	36 (66.7; 53.4, 77.8)	18 (33.3; 22.2, 46.6)	1 (1.9; 0.3, 9.8)	42 (77.8; 65.1, 86.8)	11 (20.4; 11.8, 32.9)
61-70 (N=44)	20 (45.5; 31.7, 59.9)	24 (54.6; 40.1, 68.3)	9 (20.5; 11.2, 34.5)	30 (68.2; 53.4, 80.0)	5 (11.4; 5.0, 24.0)
71-80 (N=45)	21 (46.7; 32.9, 60.9)	24 (53.3; 39.1, 67.1)	17 (37.8; 25.1, 52.4)	23 (51.1; 37.0, 65.0)	5 (11.1; 4.8, 23.5)
81-90 (N=10)	6 (60.0; 31.3, 83.2)	4 (40.0; 16.8, 68.7)	6 (60.0; 31.3, 83.2)	3 (30.0; 10.8, 60.3)	1 (10.0; 1.9, 67.8)

Table 3.

Association between guideline appropriate referrals and clinically relevant imaging.

Model 1: Original criteria for clinically relevant imaging*				
		Clinically relevant imaging		
		Yes	No	Total
Guideline appropriate referral	Yes	46	198	244
	No	19	174	193
	Total	65	372	437
Logistic regression analysis (OR, 95% CI): 2.2 (1.3, 4.1)				
Model 2: Adapted criteria for clinically relevant imaging#				
		Clinically relevant imaging		
		Yes	No	Total
Guideline appropriate referral	Yes	146	98	244
	No	109	84	193
	Total	255	182	437
Logistic regression analysis (OR, 95% CI): 1.2 (0.8, 1.9)				

*The original criteria only included clinically significant findings as clinically relevant imaging.

#The adapted criteria used the combination of clinically significant findings *and* possibly significant findings, as clinically relevant imaging

ally significant findings was 65/437 (14.9%; 95%CI: 11.8-18.5), and of these, the proportion that was guideline appropriate was 46/65 (70.8%; 95%CI: 58.8, 80.4), as presented in Table 3. Logistic regression analysis resulted in an odds ratio of 2.2 (95%CI: 1.3, 4.1), indicating that there is 95% confidence that odds of a clinically significant finding being present are between 1.3 to 4.1 times greater when the radiographic referral is guideline appropriate.

In model 2, the proportion of either clinically significant or possibly significant findings was 255/437 (58.4%; 95%CI: 53.7-62.9), and of these, the proportion that was guideline appropriate was 146/255 (57.83%; 95%CI: 51.1, 63.2) as presented in Table 3. Logistic regression analysis demonstrated that there was no statistically significant association between guideline appropriate referrals and the presence of either clinically significant or possibly significant radiographic findings. (OR; 95%CI: 1.2; 0.8, 1.9).

Discussion

This study demonstrated that although just over half of the radiographs performed by chiropractic students within the teaching clinics were considered guideline appropriate (55.8%; 95%CI: 50.2, 60.4), only 14.9% (95%CI: 11.8, 18.5) of radiographs demonstrated clinically significant findings. Of the remaining radiographs, 43.5% (95%CI: 38.9, 48.2) demonstrated possibly significant radiographic findings, of uncertain clinical relevance. The odds of finding a clinically significant radiographic finding on radiographic imaging are between 1.3 and 4.1 times greater when the imaging referral is guideline appropriate. A statistically significant association was not demonstrated between guideline appropriate imaging and the detection of either clinically significant or possibly significant radiographic findings (OR 1.2, 95%CI: 0.8, 1.9).

The diagnostic yield of clinically significant radiographic findings in this study was 14.9%, and included

reports of fracture, inflammatory arthritis, instability and osteopenia. This is similar to previously reported proportions of underlying pathology of approximately 12% in both medical²⁰ and chiropractic⁶ populations. In contrast to a previous study performed in a chiropractic teaching clinic, the proportion of possibly significant radiographic findings in our study was lower at 43.5% compared to approximately 55%.⁶ However, the previous study included some radiographic findings (such as anatomical variances like spina bifida occulta) that we considered of unlikely clinical significance.⁶ The proportion of clinically significant findings increased in patients greater than 60 years of age, which is consistent with research identifying age above 65 in females and 75 in males as possible risk factors for pathology.²⁵ Older guidelines suggest that age above 50 may be considered a risk factor of pathology.^{2,4} However, this was not identified in this study, with few patients in the 51-to-60-year age group having clinically significant radiographic findings.

To our knowledge, no other study has specifically looked at the association between guideline appropriate imaging and diagnostic yield. Here, an association between guideline appropriate imaging and imaging findings was present when clinically significant findings were considered alone, but was no longer apparent when possibly significant findings were added to the clinically significant group. This is consistent with current guidelines being designed to detect pathologies that will definitively impact clinical practice rather than those of less certain significance.^{1,15,22} Although an association between guideline appropriate imaging referral and clinically significant radiographic findings was observed, still nearly 30% of clinically significant radiographic findings were present on radiographs categorised as guideline inappropriate. This is in contrast to a Canadian study, where no serious pathology was identified in patients who were not indicated for imaging.²⁰ In the Canadian study, however, patients determined not to need imaging did not receive any, so the presence or absence of clinically significant imaging findings could not be performed. Instead, these patients were followed up at one-year for any subsequent diagnosis of pathology.²⁰ False positive imaging findings are common²³, and some of the clinically significant radiographic findings in the current study may in fact be determined as benign changes on further investigation. It is however, of clinical importance to acknowledge that referral for

radiographs in strict alignment with current radiographic guidelines, may not detect all clinically significant radiographic findings.

Just under half of all radiographic referrals by chiropractic students were considered guideline inappropriate. Depending on the anatomical region, the proportion of inappropriate imaging varied from 15.7% in the upper limb to 57.2% in the lumbar spine. This variation may reflect higher diagnostic uncertainty in the low back²⁴ and a lack of indicators for imaging with high diagnostic certainty²⁵. Certainly, low back pain is strongly associated with imaging overuse²⁶ and inconsistency between imaging referral and guideline recommendations²⁷. The proportion of inappropriate imaging in the lumbar spine in this study is similar to the small amount of available evidence from chiropractic teaching clinics, where, in Canada, up to 47.3% of radiographs did not conform to guidelines.⁹ These proportions of inappropriate imaging in student clinics are higher than the approximately one third of inappropriate imaging of the lumbar spine seen in clinical practice.²⁷ Higher proportions of non-indicated imaging amongst students may be due to a lack of knowledge, less certainty in their clinical decision-making process, or the need to meet radiographic imaging academic requirements. Concern has been raised over the diagnostic accuracy of many of the red flags that current radiographic guidelines are based on²⁵, potentially decreasing both clinician and student confidence in current guidelines. Strategies to increase clinical decision-making confidence, such as the development clinical decision-making frameworks^{28,29}, within both teaching and clinical environments need to be considered.

Strengths and limitations

The strengths of this study include the systematic approach to data collection and categorisation. All radiographic imaging referrals from a single calendar year across the three Macquarie University chiropractic clinics were collected. Categorisation of the data was performed by two independent researchers to a pre-determined rubric informed by current literature. All disagreements in categorisation were discussed between the research team to ensure final consistency between decisions and with published guidelines.

Limitations include the retrospective nature of the data collection and the level of agreement in categorisation

decisions. Data collection was limited to the information provided on the referral forms, which may not have included all relevant clinical details, and potentially may have impacted decisions regarding the appropriateness of the radiographic imaging referral. However, it is very likely that the strongest reasons for referring for imaging were listed on the forms, as students have to provide their clinical supervisors with appropriate justification for the radiographic imaging referral. Some reasons for referral, such as 'no improvement after a course of treatment' had limited clinical information but were categorised as concordant with guidelines for two reasons: 1) the phrasing is consistent with that used in the reference guidelines²⁻⁴; and 2) clinical supervisors would have been aware of the additional clinical information when approving the radiographic referral. Only fair agreement²¹ between the researchers was seen for the initial decisions regarding the appropriateness of imaging. Many of the radiographic referral forms reported reasons for referral that did not definitively align with radiographic guidelines, and a judgement call had to be made by the researchers. Further discussion between the research team was held to come to final and consistent decisions on the categorisation. Finally, it is possible that the proportion of appropriate imaging may be overestimated in this study due to the uncertainty around the diagnostic accuracy of red flag indicators of potential pathology²⁵ that were used to indicate appropriate imaging in this study.

Conclusion

Approximately half of all radiographic referrals made by Macquarie University student chiropractors were guideline appropriate. While guideline appropriate radiographic imaging was associated with an increase in clinically significant radiographic findings, demonstrating the utility of current guidelines, not all clinically significant findings were detected by guideline appropriate imaging. Radiographic guidelines are a useful tool to aid clinical decision-making regarding the need for radiographic imaging to detect clinically significant findings; however, clinician judgement is needed as some clinical scenarios indicating radiographic imaging referral may fall outside current guidelines.

References

1. Jenkins HJ, Downie AS, Moore CS, et al. Current evidence

- for spinal X-ray use in the chiropractic profession: a narrative review. *Chiropr Manual Ther.* 2018;26:48.
2. Bussieres A, Taylor J, Peterson C. Diagnostic imaging practice guidelines for musculoskeletal complaints in adults - an evidenced-based approach - part 3: spinal disorders. *J Manip Physiol Ther.* 2008;31: 33-88.
 3. Bussieres AE, Peterson C, Taylor JA. Diagnostic imaging guideline for musculoskeletal complaints in adults: an evidence-based approach -part 2: upper extremity disorders. *J Manip Physiol Ther.* 2008;31: 2-32.
 4. Bussieres AE, Peterson C, Taylor JA. Diagnostic imaging practice guidelines for musculoskeletal complaints in adults: an evidence-based approach - part 1: lower extremity disorders. *J Manip Physiol Ther.* 2007;30: 684-717.
 5. Vining RD, Potocki E, McLean I, et al. Prevalence of radiographic findings in individuals with chronic low back pain screened for a randomized controlled trial: secondary analysis and clinical implications. *J Manip Physiol Ther.* 2014;37:678-687.
 6. Beck RW, Holt KR, Fox MA, et al. Radiographic anomalies that may alter chiropractic intervention strategies found in a New Zealand population. *J Manip Physiol Ther.* 2004;27:554-559.
 7. Graves JM, Fulton-Kehoe D, Jarvik JG, et al. Health care utilization and costs associated with adherence to clinical practice guidelines for early magnetic resonance imaging among workers with acute occupational low back pain. *Health Serv Res.* 2014;49:645-665.
 8. Traeger A, Sharma S, Buchbinder R, et al. 34 Overdiagnosis of low back pain. *BMJ Evid Based Med.* 2018;23:A15.
 9. Ammendolia C, Côté P, Hogg-Johnson S, et al. Do chiropractors adhere to guidelines for back radiographs?: A study of chiropractic teaching clinics in Canada. *Spine.* 2007;32: 2509-2514.
 10. Jenkins HJ. Awareness of radiographic guidelines for low back pain: a survey of Australian chiropractors. *Chiropr Man Ther.* 2016;24:39.
 11. Ammendolia C, Taylor J, Pennick V, et al. Adherence to radiography guidelines for low back pain: a survey of chiropractic schools worldwide. *J Manip Physiol Ther.* 2008;31: 412-418.
 12. Bussieres AE, Patey AM, Francis JJ, et al. Identifying factors likely to influence compliance with diagnostic imaging guideline recommendations for spine disorders among chiropractors in North America: a focus group study using the Theoretical Domains Framework. *Implement Sci.* 2012;7:82.
 13. Ammendolia C, Bombardier C, Hogg-Johnson S, et al. Views on radiography use for patients with acute low back pain among chiropractors in an Ontario community. *J Manip Physiol Ther.* 2002;25: 511-520.
 14. Oakley PA, Cuttler JM, Harrison DE. X-Ray imaging

- is essential for contemporary chiropractic and manual therapy spinal rehabilitation: Radiography increases benefits and reduces risks. *Dose Resp.* 2018;16:1559325818781437.
15. Bussi eres AE, Peterson C, Taylor JA. Diagnostic imaging practice guidelines for musculoskeletal complaints in adults—an evidence-based approach: introduction. *J Manip Physiol Ther.* 2007;30:617-683.
 16. World Health Organisation. WHO guidelines on basic training and safety in chiropractic. Geneva: World Health Organisation, 2005.
 17. van Tulder M, Assendelft W, Koes B, et al. Spinal radiographic findings and nonspecific low back pain: a systematic review of observational studies. *Spine.* 1997;22:427-434.
 18. Rudy IS, Poulos A, Owen L, et al. The correlation of radiographic findings and patient symptomatology in cervical degenerative joint disease: a cross-sectional study. *Chiropr Man Ther.* 2015;23:1.
 19. Jenkins H, Zheng X, Bull P. Prevalence of congenital anomalies contraindicating spinal manipulative therapy within a chiropractic patient population. *Chiropr J Austral.* 2010;40:69.
 20. Ferrari R. Imaging studies in patients with spinal pain Practice audit evaluation of Choosing Wisely Canada recommendations. *Can Fam Phys.* 2016;62: e129-e137.
 21. Landis, JR and Koch GG. The measurement of observer agreement for categorical data. *Biometrics.* 1977;33(1):159-174.
 22. Chou R, Qaseem A, Owens D, et al. Diagnostic imaging for low back pain: advice for high-value health care from the American College of Physicians. *Ann Intern Med.* 2011;154:181-189.
 23. Wnuk NM, Alkasab TK, Rosenthal DI. Magnetic resonance imaging of the lumbar spine: determining clinical impact and potential harm from overuse. *Spine J.* 2018;18:1653-1658.
 24. Maher C, Underwood M, Buchbinder R. Non-specific low back pain. *Lancet* 2017;389: 736-747.
 25. Downie A, Williams C, Henschke N, et al. Red flags to screen for malignancy and fracture in patients with low back pain: systematic review. *BMJ.* 2013;11:347.
 26. Downie A, Hancock M, Jenkins H, et al. How common is imaging for low back pain in primary and emergency care? Systematic review and meta-analysis of over 4 million imaging requests across 21 years. *Br J Sports Med.* 2020;54(11):642-651.
 27. Jenkins HJ, Downie AS, Maher CG, et al. Imaging for low back pain: is clinical use consistent with guidelines? A systematic review and meta-analysis. *Spine J.* 2018;18:2266-2277.
 28. Finucane LM, Downie A, Mercer C, et al. International framework for red flags for potential serious spinal pathologies. *J Orthopaed Spor Phys Ther.* 2020;50(7):350-372.
 29. Hobbs M, Crafford D, MacRae K, et al. The usefulness of a novel patient management decision aid to improve clinical decision-making skills in final year chiropractic students. *Chiropr Man Ther.* 2019;27:5.