

HOW FREQUENTLY DO LATERAL CERVICAL SPINE RADIOGRAPHS ALTER TREATMENT OPTIONS IN CHIROPRACTIC PRACTICE?

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ABSTRACT

Introduction: Neck pain is a common health complaint in the UK and the second most common complaint seen by chiropractors worldwide. Spinal manipulative therapy (SMT) is an effective treatment intervention for patients with neck pain. The risks of SMT of the cervical spine (cSMT) are well documented in the literature; however, investigations into patient risk factors are lacking. Debate exists within the profession regarding the appropriate use of x-rays for spinal complaints with screening for contraindications to cSMT seen by some as inappropriate. This retrospective review of records and service evaluation examines how frequently lateral cervical spine x-rays alter treatment options in 1 chiropractic practice.

Methods: Data from 626 patient records were retrospectively reviewed from a private chiropractic clinic in the UK. Of the 626 new patients, 293 (47%) had x-rays of their cervical spine before commencing treatment. Patient x-rays and x-ray reports were reviewed for contraindications to cSMT.

Results: Of the 293 cervical spine x-rays, 177 (60%) revealed contraindications to cSMT over the 4 years of data collection. Thus, 28% of the 626 new patients who attended the clinic during that time period had their treatment option altered due to findings of contraindications on lateral cervical spine x-rays. Data analysis found that of those x-rays with contraindications, 46% had more than 1 contraindication present in the same patient. Extrapolating these data to the entire new patient population who attended the clinic, 15% of patients per annum had their treatment options altered as a direct result of x-rays findings.

Conclusion: The study found that 60% of cervical spine x-rays revealed contraindications to cSMT over the entire study period. Approximately 30% of lateral cervical spine x-rays revealed contraindications to cSMT, subsequently altering the treatment options of patients. This study adds supporting evidence to the validity of

x-rays in chiropractic clinical practice in reducing risks of adverse events from cSMT and increasing patient safety. (*J Contemporary Chiropr* 2022;5:57-75)

Key Indexing Terms: Chiropractic; Cervical Spine; Radiology

INTRODUCTION

Neck pain is a common global issue that has a significant impact on the UK's national health perception. It adds considerable economic costs to the national health service. (1,2) Safiri *et al* found that the largest percentage increased change in age, incidence and years lived with neck pain per 100,000 were in the UK, recorded at 14.6%, 9.1%, and 14.2% respectively. (2) They also found that the point prevalence globally was highest in females between 45 and 49 years of age (2) Neck pain is the second most common complaint seen by chiropractors worldwide, responsible for 22.5% of all chiropractic patients. (3) The General Chiropractic Council (GCC) stated in their counterfactual report that 1,005,000 patients saw a chiropractor in 2009. (4)= Patient numbers were projected to increase to 1,043,000 over the next decade, meaning approximately 234,675 patients are currently visiting chiropractors in the UK for neck pain per annum.

Spinal manipulative therapy (SMT) has been shown to be an effective treatment intervention for patients with neck pain. (5,6) The risks of cSMT however, are not fully understood. (7,8) with adverse events following cSMT being well documented in the literature (7,9-17) Adverse events from cSMT are defined as mild, with short-term, non-serious, transient/reversible effects; moderate, that can be medium to long-term and described as distressing; and major events are described as long-term, serious events that require further treatment. (18)

Adverse events from cSMT are described in the literature as common (7) and include increased pain, stiffness, dizziness, tiredness, headache, nausea, neurovascular compromise, vertebral artery dissection, stroke, and death. (7,15,19-27) Cagnie *et al* investigated the frequency of side effects following SMT using lifestyle factors such as sex, smoking status, and existing medical conditions. (28) They concluded it is theoretically possible to reduce

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the frequency of side effects following SMT if the patients at risk can be correctly identified. Cagnie *et al* did not use any form of pre-treatment diagnostic imaging to assess their participants of underlying risk factors. (28) Jenkins *et al* found that 30% of cervical spine x-rays obtained in chiropractic clinical practice will find anomalies that may alter the application of spinal manipulation. (29) Cagnie *et al* only assessed side effects following the first treatment, and the authors fail to provide data on how to identify those patients at risk of side effects. (28)

Some researchers have concluded that cSMT should be abandoned due to the risk of potentially catastrophic events such as neurovascular compromise (30) Wand *et al* reference a systematic literature review of adverse effects of cSMT by Ernst (11) The Ernst review paper was reviewed during the literature review process for this current study but was excluded for being conducted by a single researcher, failure to provide details on the appraisal criteria, and high level of bias as per the Joanna Briggs critical appraisal checklist. (31,32)

There is disagreement within the chiropractic profession regarding the appropriate use of x-rays in clinical practice for both diagnostic and screening purposes. (33-37) One side of the debate are authors advocating the use of diagnostic imaging for "Red Flag" evaluations only. (38-40)

The basis of the "Red Flags" only stance for spinal x-rays hinges on 2 premises that are specifically for the use of x-rays for cases of acute low back pain (39) The first premise is that 90% of acute episodes of low back pain will spontaneously resolve within 4-6 weeks. (41-45) The claim of 90% of low back pain cases resolve within 2 months originates from Fry. Fry conducted a retrospective review of records of 125 patients who presented to a general practice surgery with low back pain and concluded that 82% made a complete recovery within four weeks. (45-46) However, Fry included patients who failed to return to the clinic for a follow-up appointment in the recovered group. (45) Similarly, Coste *et al* reported 90% of 92 patients with low back pain experienced spontaneous resolution of their symptoms within 2 weeks. (47) Several flaws exist within the Coste *et al* study, notably a lack of detail regarding if the participants sought the treatment of another healthcare professional, or any self-directed treatment the participants may have employed, such as the application of ice, or exercise.

The second premise states that serious pathologies of the spine are rare and collectively represent approximately 6% of all causes of low back pain. (48) The assumption, therefore, is that x-rays are not required unless serious pathology is suspected, such as infection, fracture, dislocation, cancer, or an inflammatory disease process. (39)

Contrary to the first premise, Kiri *et al* in a prospective longitudinal study of 902 participants with follow-ups at 5, 10, and 28-years concluded that 88% remained symptomatic 28-years later. (49) Several authors have concluded that the greatest predictor of low back pain in adolescence and adulthood is low back pain during childhood. (50-56)

Signs and symptoms of patients who present to any health care professional can vary depending on the stage of the disease/pathological process (57) In cases of musculoskeletal disorders, such as cervical spondylosis, many patients are asymptomatic. (58) However, once the condition progresses to affect neural or vascular structures, it has 3 symptom complexes: neck pain, radiculopathy, and myelopathy. (57-59) Beck *et al* discuss spondylosis, concluding that chiropractors must be aware of the discrepancy between clinical signs and symptoms of some musculoskeletal disorders and their radiographic appearance, thus relying on symptoms alone may not be appropriate. (60) Cases can seem advanced in symptomatology and disability yet appear mild or moderate on radiograph. The pathological process of spondylosis can lead to segmental instabilities and kyphosis (57,58), which are listed in the literature as contraindicated to cSMT. (61)

One reason for limiting the use of x-rays in the chiropractic profession is the accusation of inappropriate or overuse of x-rays by the profession and thus unnecessarily exposing patients to ionising radiation. (62) This perspective has already influenced the chiropractic profession, with a ban on chiropractors having x-ray facilities within their clinics in The Netherlands. (63) Notwithstanding, until 2010 the GCC and its Professional Conduct Committee found 26 instances of unjustified exposure to ionising radiation spanning 8 years. (4) The GCC then extrapolated these data to show this equated to a total of 3.25 instances per annum or approximately 0.000323% of the total population of patients under chiropractic care in the UK. (4) The GCC annual report a decade later found a total of 6 complaints of "lack of clinical justification for investigations/x-rays." (64) The risk of cancer from chiropractic x-rays of the lumbar spine has been estimated to be 2.75%, which equates to quality-adjusted life years lost through cancer from chiropractic x-rays to be 0.0011. (4) However, this is specifically for lumbar spine exposures, which the UNSCEAR 2000 report states delivers an effective dose to the patient is 1.8 milli Sieverts (mSv), whereas cervical spine examinations are recorded at 0.27 mSv. (65) Thus, cervical spine x-rays have a smaller impact on patient lifetime cancer risk. Along with a plethora of literature questioning if low dose and low dose rate ionising radiation carries any risk to the patient. (66,68) Vaiserman *et al* state there is no increased cancer risk from diagnostic examinations using <100 mSv (68) Schultz *et al* concluded from their

systematic literature review that doses from as many as 20 CT scans are unlikely to result in cancer. (69)

Several attempts have been made to determine the appropriateness of SMT using x-rays. (33,78–80) Beck *et al* reviewed 847 full spine patient x-rays spanning from 1997 to 2001, concluding that 68.1% of the x-rays they reviewed revealed anomalies that may alter the application of SMT. (60) Pryor and McCoy reviewed 500 patient files at a chiropractic teaching clinic, of whom 423 received x-rays of their spines. Pryor and McCoy found 91% of the cervical spine radiographs revealed pathologies, abnormalities, or anomalies that might alter patient management using manual therapy intervention. (79) However, Pryor and McCoy also discuss the lack of evidence that some conditions they included in their study are true contraindications for cSMT. Ammendolia uses this lack of evidence to question if there is a need to alter patient management and sites a lack of improved patient outcomes as their main critiques of the use of x-rays to screen patients for contraindications to SMT. (62) Jenkins *et al* found 30% of the cervical spine x-rays reviewed in their study revealed contraindications to cSMT. (80) However, Jenkins *et al* questioned the validity of the posterior ponticle as a true contraindication to cSMT and stated that upon removal of this finding from their data, the prevalence of cervical spine contraindications dropped to 2.1%. (80) To support the removal of posterior ponticles from their contraindications, Jenkins *et al* reference 2 chiropractic textbooks (81,82) by Gatterman (82) and Yochum and Rowe. (81) Of interest, Jenkins *et al* do not reference the most recent edition of the Yochum and Rowe textbook from 2005, in which they stress that whilst vertebrobasilar insufficiency from a posterior ponticle is controversial, the importance of taking appropriate precautions and conducting a thorough examination when this finding is discovered on x-ray. (81) Gatterman discusses the posterior ponticle as a relative contraindication, but state that extension and rotational manipulations should be avoided. (82)

If the argument can be made that these findings do not alter treatment options due to insufficient evidence of compromised patient safety. (62), then the literature must support this claim. However, the literature is controversial (81); thus, there is insufficient evidence that they do not require alterations in treatment options from cSMT. If patient safety is the absolute objective, then these findings should be treated with caution a priori until evidence can be provided that cSMT is safe in the presence of such findings.

Oakley *et al* state that x-ray evaluation is the only way to assess cervical spine parameters associated with patient symptoms, “red flags” and both relative and absolute contraindications to cSMT. (83) Alternatives

including pre-manipulation tests have been found to lack sensitivity, specificity, and validity, thus are unhelpful to the clinician assessing a patient suspected as vulnerable to neurovascular compromise following cSMT. (84,85) Also, pre-manipulation tests are supposed to assess for vertebral artery insufficiency (84,85) Therefore, these tests are only useful when examining those patients at risk of the most severe adverse events and fail to provide anything meaningful when assessing those patients at risk of mild or moderate adverse events following cSMT. (84)

McAviney *et al* used lateral cervical spine x-rays to demonstrate a relationship between a loss of cervical lordosis and sagittal balance are associated with the development of neck pain. (86) These authors found that a cervical lordosis $<20^\circ$ and cervical kyphosis are associated with the development of neck pain and cervicogenic symptoms, positing a normal range of lordosis between 31° and 40° . (87) These data are similar to previous literature that has shown hypolordosis of the cervical spinal is associated with neck pain. (88) Kyphotic deformity of the cervical spine increases compressive loading of the vertebral bodies, and intervertebral discs, which accelerates degenerative changes, leading to discoligamentous injury and neck pain. (57,89-91) Restoring the cervical spine to a lordotic configuration following surgical intervention is seen as an optimal outcome as it reduces the likelihood of adjacent segmental disease. (92,93) Alteration of the instantaneous axis of rotation of the cervical vertebrae strongly correlates to neck pain indicating abnormal movement patterns of the cervical spine are common in neck pain patients. (94,95) Capsular ligament laxity is a known sequela to abnormal movement patterns, leading to joint instability and neck pain. (96)

Loss of cervical lordosis has been shown to alter vertebral artery hemodynamics. (97,98) Bulut *et al* matched 30 patients with confirmed loss of cervical lordosis to 30 controls with a normal cervical lordosis measured on lateral cervical spine x-rays. Doppler ultrasound evaluations of the participants' vertebral arteries discovered a reduction in lumen diameter, flow volume, and peak systolic velocity of those with loss of cervical lordosis compared to those with normal cervical lordosis. (97) Whilst the patients in this study were young (between 18 and 49 years) it has been shown that patients at risk of vertebral artery dissection are younger than those who suffer a thromboembolic stroke. (9,99-101)

Katz *et al* assessed the cervical lordosis of 7 participants (5 female, 2 male) between 28 and 58 years of age using lateral cervical spine x-rays. The geometric shape of the participants' cervical spines ranged from 19° kyphotic to 20° lordotic. X-rays were repeated in the supine position with the addition of a spinal orthotic, which altered the

participants' cervical spines to lordosis ranging from 22.1° to 44.7°. The participants then underwent a cerebral magnetic resonance angiogram (MRA) to evaluate the arterial blood flow of the circle of Willis and cerebral artery blood flow when lying in a neutral position. The MRA's were then repeated with the addition of the same spinal orthotic as the repeated x-rays. Katz *et al* found improvement in blood flow ranging from 23% to 225.9%. (98) Whilst the sample size of seven participants is poor, Katz *et al* demonstrated limited evidence that hypolordosis and kyphosis of the cervical spine result in vertebrobasilar insufficiency in some patients with neck pain. The findings from Katz *et al* echo previous findings from Olszewski *et al* who concluded that cervical spondylosis is associated with altered vertebrobasilar blood flow velocity leading to the development of vertigo. (102)

As a clinician who uses x-rays in chiropractic clinical practice, the data and findings discussed above lead me to ask the question; how frequently do lateral cervical spine x-rays alter treatment options in chiropractic practice?

METHOD

The method selected to conduct this study was a service evaluation using a retrospective review of patient records from a private chiropractic clinic in the South of England, UK. The records of all the patients who attended the clinic

Table 1. British Chiropractic Association X-ray Justification List. (103)

British Chiropractic Association X-ray Justification List
Patient is aged >50 years
History of trauma
Neurological deficit/symptoms
Unexplained weight loss
Inflammatory arthropathy
Drug or alcohol abuse
Malignancy
Pyrexia
Investigations of scoliosis
History of surgery in the area of interest
Failure to improve following conservative treatment
Equivocal biomechanical findings
Investigations of extreme postural anomaly
Clinical examination limited by pain

Table 2. PCCRP For Biomechanical Assessment of Spinal Subluxation in Chiropractic Clinical Practice. (34)

PCCRP For Biomechanical Assessment of Spinal Subluxation in Chiropractic Clinical Practice
Abnormal Posture
Spinal Subluxation (defined by the PCCRP document)
Spinal Deformity (e.g., scoliosis, hyper kyphosis, hypokyphosis)
Trauma, especially trauma to the spine
Birth Trauma
Restricted or Abnormal motion
Abnormal Gait
Axial Pain
Radiating Pain (e.g., upper extremity, intercostal, or lower extremity)
Headache
Suspected Short Leg
Suspected Spinal Instability
Follow-up for previous deformity, previous abnormal posture, previous spinal subluxation/displacement, previous spinal instability)
Suspected Osteoporosis
Facial Pain
Systematic health problems (e.g., skin disease, asthma, auto immune diseases, organ dysfunction)
Neurological Conditions
Delayed developmental conditions
Eye and vision problems other than corrective lenses
Hearing disorders, vertigo, and tinnitus
Spasm, inflammation, or tenderness
Suspected abnormal pelvic morphology
Post-surgical evaluation
Suspected spinal degeneration/arthritis
Suspected congenital anomaly
Pain upon spinal movement
Any "Red Flag" covered in previous guidelines

between the 1st March 2017 and 1st March 2021 were first identified. Ethics approval was granted by the ethics board of Sheffield Hallam University, and no ethical

Table 3. PEO model.

P (Patient)	Patients attending the clinic between 1st March 2017 to 1st March 2021
E (Exposure)	Patients who required x-ray evaluation of their cervical spine prior to commencing cSMT
O (Outcome)	cSMT was subsequently found to be inappropriate by x-ray analysis

approval was required from the local National Health Service (NHS) due to the research method. The lists of x-ray justifications used are from the British Chiropractic Association (BCA) and the Practising Chiropractors' Committee on Radiology Protocols (PCCRP) For Biomechanical Assessment of Spinal Subluxation in Chiropractic Clinical Practice (34,103) are shown in Tables 1 and 2. The PCCRP document is published in the US National Clearinghouse in July 2009 and is the accepted radiological guideline book of the International Chiropractor Association (ICA) The BCA justification lists the clinical findings that require x-ray evaluation of the patients presenting to British chiropractors. Patient records were then analysed to show who required x-ray examination of their cervical spine prior to commencing cSMT.

The data collected for the current study were obtained from patient records, therefore not all patients who attended the clinic required x-rays of their cervical spine. Patients were only x-rayed if they exhibited 3 or more of the justifications listed in Tables 1 and 2.

For the current study, the lateral cervical spine projections were reviewed. These projections alone were reviewed because:

- It provides a strict data pool for analysis.
- Lateral cervical spine projections are predominantly used for biomechanical analysis and segmental stability of the cervical spine thus is essential for some contraindications to cSMT. (105-111)
- Flexion and extension evaluations of the cervical spine are performed in the sagittal plane to assess segmental motion and stability. (105-111) Thus, these were included in the study.

All lateral cervical spine projections obtained between the 1st March 2017 to 1st March 2021 were reviewed providing 4 consecutive years of patient data. The PEO model of Patients, Exposure, and Outcomes is applied in this study as demonstrated in Table 3.

Inclusion criteria for the patient's x-rays include all lateral cervical spine x-rays obtained in the clinic during the period stated that contain all relevant anatomy. (C1 to C7) X-rays were excluded if the images were of poor quality due to motion artefact, inadequate exposure (too high or low) or if not all the relevant anatomy was visible. These criteria allow for maximum data collection and negate the possibility of any sexual, racial, or gender discrimination against any patients.

The study aims to identify the number of lateral cervical spine x-rays taken in a UK chiropractic clinic that directly influence the application of cSMT. This will include pathological/disease processes, segmental stability,

Table 4. Radiographic Criteria for the Diagnosis of Segmental Instability of the Cervical Spine. (112)

Radiographic Criteria for the Diagnosis of Segmental Instability of the Cervical Spine from Panjabi	
Anterior elements destroyed or unable to function (2 pts)	
Posterior elements destroyed or unable to function (2 pts)	
Neutral X-ray Findings	Sagittal Plane Displacement >3.5 mm or 20% (2 pts)
	Relative Segmental Sagittal Plane Angulation >11° (2 pts)
	Abnormal Disc Narrowing (1 pt)
Developmentally Narrow Spinal Canal (1 pt)	Sagittal Diameter <13 mm or Pavlov's Ratio <0.8
Flexion/Extension X-ray Findings	Sagittal Plane Displacement >3.5 mm or 20% (2 pts)
	Sagittal Plane Rotation >20° (2 pts)
Physical Examination Findings	Positive stretch test (2 pts)
	Spinal cord damage (2 pts)
	Nerve root damage (1 pt)
	Dangerous loading anticipated (1 pt)
(5 or more points = unstable)	

Table 5. List of absolute contraindications (61)

Absolute Contraindications of the Cervical Spine
Anomalies such as Dens Hypoplasia, Unstable Os Odontoideum, etc.
Acute Fracture
Spinal Cord Tumour
Acute Infection such as Osteomyelitis, Septic Discitis, and Spinal TB
Meningeal Tumour
Hematomas whether spinal cord or intracanalicular
Malignancy of the Cervical Spine
Frank Disc Herniation
Basilar Invagination of the Upper Cervical Spine
Arnold-Chiari Malformation
Dislocation of the Cervical Vertebrae
Aggressive types of Benign Tumours such as Aneurysmal Bone Cysts, Giant Cell Tumour, Osteoblastoma, and Osteoid Osteoma
Harrington Rods or Surgical Clamps/Screws

segmental alignment, and biomechanical dysfunction as it impacts the integrity of the functional spinal units. White and Panjabi described a systematic approach to the biomechanical assessment of the cervical spine using x-rays (Table 4). (112)

Data Collection

Firstly, the total number of new patients who attended the clinic between 1st March 2017 and 1st March 2021 was determined by searching the clinic's electronic patient database, PracticeHub. These data were then divided into the year that the patients' x-ray examination took place, providing a total of four years of consecutive data. These twelve-month intervals were determined to start from:

Year 1: 1st March 2017 until 28th February 2018

Year 2: 1st March 2018 until 28th February 2019

Year 3: 1st March 2019 until 29th February 2020

Year 4: 1st March 2020 until 28th February 2021

Next, a review of the clinics' x-ray log was performed to find those patients who received x-ray evaluations of their cervical spine. Of these, only those patients whose x-rays had been electronically analysed using PostureRay® were included. PostureRay® software allows the operator

to biomechanically assess the patients lateral cervical spine x-rays for relative rotation angles (RRA's), absolute rotation angles (ARA's), Cobb angles, Risser-Ferguson angles, sagittal balance, rotational angles of excursion, excursion distances, and the posterior tangent method. (108,111,113–118) The DICOM x-ray images are imported into PostureRay® from the Carestream Vita Version 4 x-ray processing software. Biomechanical x-ray analysis using PostureRay® consists of mapping all four vertebral body corners of C2 through to C7 (88) These biomechanical measurements, alongside findings of specific disease/pathological processes, degenerative changes, anomalies, and congenital normal variants listed as relative and absolute contraindications to cSMT were used to decide if cSMT was appropriate in each patient's case.

These lists of contraindications are included from Haynes-Mazion in Table 5, Jenkins, Zheng, and Bull in Table 6 and Puentedura *et al* Rushton *et al* and Scholten-Peeters *et al* in Table 7 (8,13,15,29,61)

The author is also the examining physician of all patients within the clinic.

- All x-ray analysis was performed by the author, using the same computer system and software (PostureRay®)
- All patient records were created by the author, thus accessing these data for analysis did not require any additional permissions from third parties.

Table 6. Contraindications and Clinically Significant Findings Regarding SMT (80)

Contraindications and Clinically Significant Findings Regarding SMT	
Contraindications	Clinically Significant Findings
Occipitalisation	Clasp-knife Deformity
Os Odontoidium	Facet Tropism
Hypoplasia/agenesis of Dens	Cervical Rib
Epitransverse Process	Hemivertebra
Platybasia/Basilar Impression	Transitional Vertebrae
Agenesis of Atlas Posterior Arch	
Complete or Incomplete Posterior Ponticle	
Block Vertebra	
Atlantoaxial Instability	

Table 7. List of absolute contraindications and relative contraindications/precautions for cSMT. (8,13,15)

Absolute Contraindications to cSMT	Precautions/Relative Indications to cSMT
(Acute) Fracture	Inflammatory Disease
Relevant Recent Trauma	Rheumatoid Arthritis
Dislocation	Ankylosing Spondylitis
Ligamentous Rupture	History of Cancer
Instability	Long-term Steroid Use
Active Cancer	Osteoporosis
Acute Myelopathy	Systemically Unwell
Spinal Cord Damage	Hypermobility Syndromes
Upper Motor Neuron Lesions	Connective Tissue Disease
Multi-level Nerve Root Pathology	A first Sudden Episode before age 18 and after age 55
Worsening Neurological Function	Cervical Anomalies
Recent Surgery	Local Infection
Acute Soft Tissue Injury	Throat Infection
Unremitting, Severe, Non-mechanical Pain	Recent Manipulation by another health Professional
Unremitting Night Pain	Vascular Disease
Vertebral/Carotid Artery Abnormalities	Blood Clotting Disorders/Alterations in Blood Properties
Vertebrobasilar Insufficiency	Anticoagulation Therapy
	Absence of a Plausible Mechanical Explanation for the Patient's Symptoms
	Immediate Post-Partum

All data pertaining to the patient's identities were removed prior to analysis and for the write up of this project. This included names, dates of birth, patient numbers, and any specific dates of when the examinations took place. Data collection included data found only within the patients' x-ray reports, meaning that no data collected will be traceable to any individual patient should a breach

Table 8. Yearly data of new patients and the percentage of whom received x-rays.

	New Patients	X-rays Required	Patients X-rayed (%)
Year 1	115	62	54%
Year 2	132	74	56%
Year 3	182	83	46%
Year 4	197	74	38%
Total	626	293	46%

in data security occur. All data were stored on a password-protected external hard drive, which was housed in a locked, fireproof safe, to which only the researcher had access within the clinic premises.

Data Analysis

The safety to proceed with cSMT was determined by the biomechanical measurements of ARA and RRA's were all compared to the predetermined normal values found in the literature. Segmental stability/instability was determined by comparing each patient's intersegmental values of RRA, ARA, sagittal balance, rotational angles of excursion and excursion distances and compared to normal values found in the literature. (88,108,112-115)

The RRA and ARA values, along with the conditions listed in Tables 5, 6, and 7 were used to determine if the application of cSMT was appropriate for each patient x-rayed. Jenkins *et al* define contraindications as "a problem identified before a procedure is applied that would make application of the treatment (SMT) inadvisable to that area because of its potential harm or delay appropriate treatment." (80) Jenkins *et al* define clinically significant findings as "something that involves a change to treatment approach for best treatment outcomes." (80)

Results

A total of 626 new patients attended the clinic between 1st March 2017 and 1st March 2021. Of these, 319 (51%)

Table 9. Percentage of patients who received

Year	Males	Females	% Males	% Females
Year 1	37	25	60%	40%
Year 2	28	46	38%	62%
Year 3	43	40	52%	48%
Year 4	33	41	45%	55%
Total	141	152	48%	52%

Table 10. Age demographic of all new patients per year.

Year	Range	Average	Median	SD
Year 1	15 to 88	44	44	16
Year 2	5 to 90	45	44	18
Year 3	15 to 76	44	41	15
Year 4	14 to 83	43	40	16
Total Average		44	42	16

were female and 307 (49%) were male. A total of 293 met the clinical justification criteria warranting x-ray examination of their cervical spine prior to commencing cSMT (46% of total new patients) Of these, 152 (52%) were female and 141 (48%) were male. These data show that of the 319 female new patients, 48% required x-ray examination, and 47% of the 307 male new patients required x-rays of their cervical spine. A breakdown of the number of new patients and the number of whom required x-ray examination per annum are displayed in Table 8.

The gender distribution across these years shows most new patients who attended the clinic were female (51%) However, this finding is not consistent across all years, as years one and three show most new patients were males (51% and 53% respectively) Of those who required x-rays, 52% of the total x-rays were female, however, years one and three show mostly males were x-rayed (60% and 52% respectively) This is logical as both years one and three had the greatest number of male patients. Table 9 demonstrates the full analysis of the patient gender profile of those who received x-rays.

Patient ages range from two to 90 years of age throughout the years included in this study (Table 10) The average age of patients was 43 years, and the median age across all four years data was 42 years with a standard deviation of 17 years.

Patients' age demographics from those who required x-ray examination shows year 1 having the greatest median age of 44 years, whereas year 2 shows the greatest average age

Table 11. Age demographics of patients who required x-rays.

Year	Range	Average	Median	SD
Year 1	13 to 88	44	42	17
Year 2	5 to 90	45	44	18
Year 3	13 to 84	43	40	15
Year 4	2 to 84	42	40	17
Average Total		43	42	17

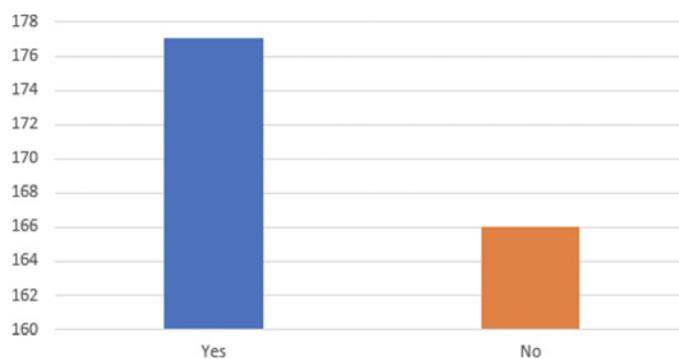


Figure 3. Total X-rays that Altered the Application of cSMT 2017-

of 45 years. The data from year 2 also revealed the greatest age range of patients who required x-ray examination from five to 90 years of age. The total average age of those patients who required x-ray examination was 44 years, with a median age of 42 years and a standard deviation of 16 (Table 11)

Of the 293 lateral cervical spine x-rays reviewed in this study, 177 (60%) altered the treatment options deeming cSMT inappropriate (Figures 3 and 4) This equates to 28% of all new patients who presented to the clinic subsequently had their treatment options altered as a direct result of contraindications found on x-ray (Tables 13 and 14) Zero x-ray images or reports were excluded from the study.

Per annum data shows that year one was the only year where most x-rays (56%) did not alter treatment options (Figure 5) There is no obvious explanation for this outlying data, as data surround patient demographics do now show any outlying factors for year one. However, clinical factors regarding the necessity for x-rays are a likely explanation and were not investigated by the current study.

The data gathered regarding the x-rays that revealed contraindications were analysed to assess how many x-rays revealed a single contraindication to cSMT and how many found >1 contraindication present in the same patient. Of the 177 x-rays that revealed contraindications,

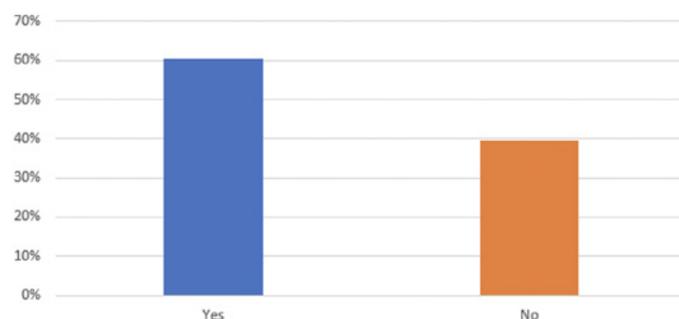


Figure 4. Percentage Total of X-rays that Altered cSMT

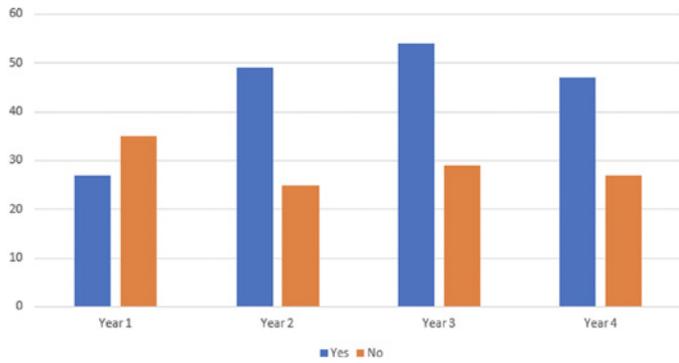


Figure 5. Total Number of X-rays that Altered the Application of cSMT per

95 (54%) contained a single contraindication to cSMT and 82 (46%) revealed >1 contraindication (Tables 12 and 13) On average of 15% of new patients had a single contraindication to cSMT, 14% showed multiple contraindications per annum. Finally, 32% of lateral cervical spine x-rays revealed a single contraindication to cSMT and 29% revealed multiple contraindications.

Data from year two shows the highest percentage of patients x-rayed (56%), however year two also received the larger population of older patients with the highest median age of patients (44 years) This is in comparison to the data from year four, which revealed 56% fewer x-rays (33% of total new patients) of patients but more than twice as many new patients attended the clinic in year four (223) than in year 1. (105) One explanation of this high frequency of cervical spine x-rays in year one and such a low frequency in year 4 could be due to the median ages of the patients within these year groups. The patient median age in year 1 was the highest at 44.5 years (SD 16), whereas year 4 had the lower median age of 40 years (SD 16) of each patient this cannot be established is not the purpose of this study.

Further analysis of the data is required to gain more specific detail into how many of the findings occur in isolation or combination. Initial analysis of the x-ray findings showed multiple findings (e.g., cervical

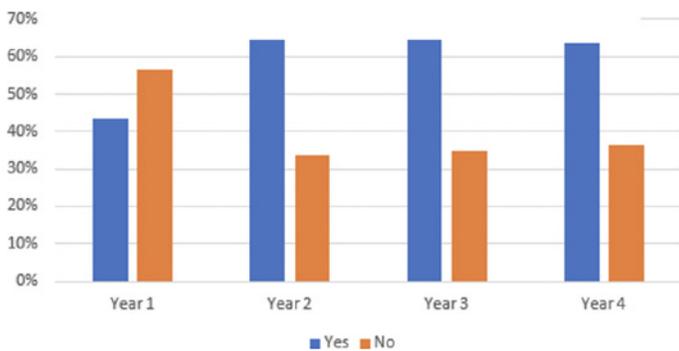


Figure 6. Percentage of X-rays that Altered the Application of cSMT

kyphosis and segmental instability) were found in the same patient however this data was not reported due to overlap of some findings. For example, advanced degenerative changes, adjacent segmental disease, and segmental instability are associated with one another and therefore frequently found simultaneously 57. As a result, attempting to differentiate between them provides no benefit, and combining them as a single finding renders each meaningless. Also, these findings contribute vastly more data points from the same patient group making it difficult to gleaming meaningful conclusions from so much data compared to so few patients. The decision was made to simply report the data as either a single contraindication or >one contraindication found simultaneously as this is relevant to clinicians and does not create more data points than necessary to answer the research question.

DISCUSSION

The current study was designed to evaluate how frequently x-rays of the cervical spine altered the application of cSMT. It was hypothesised that using a deductive approach, it is possible to explore the research question of how frequently lateral cervical spine x-rays alter treatment options in chiropractic practice.

The current study revealed 46% of patients required x-rays evaluation of their cervical spine prior to commencing cSMT. Of which, 60% altered the application of cSMT as a direct result of their findings. This equated to approximately 30% of new patients presenting to the clinic required alterations in treatment options per annum. These data are comparable to other data published in the literature (29,60,78,79) This study also found that 46% of these x-rays found more than one finding contraindicating cSMT present in the same patient.

Beck *et al* found 68.1% of the x-rays they reviewed revealed anomalies that alter the application of spinal manipulation. These authors also found that 11.6% of the reviewed x-rays were of asymptomatic patients, of which 69.4% showed an anomaly that altered the application of SMT. However, Beck *et al* (2004) did not limit their study to any one spinal region, reviewing full spine projections (60) Jenkins *et al* (2010) found 30% of the cervical spine x-rays reviewed in their study revealed contraindications to cSMT. (29)

A total of 626 patients attended the clinic between March 2017 and March 2021. Of which, 293 received x-rays and were reviewed in the current study. Of the 293 patients who received x-rays, 152 (52%) were female, thus of the 319 female patients who attended the clinic during the four years data collected, 47% received x-rays of their cervical spine. This finding is comparable to the male

Table 12. Demonstrating the number of x-rays that revealed only a single contraindication.

Year	One Finding Only	Total of one Finding per Year (%)	Total new Patients per Year (%)	Total of x-rays per Year (%)
Year 1	13	48%	11%	21%
Year 2	20	41%	15%	27%
Year 3	37	68%	20%	45%
Year 4	25	47%	13%	34%
Total	95	51%		
Average of Total (177)	54%			
	Average per Year	51%	15%	32%

Table 13. Demonstrating the number of x-rays that revealed more than one contraindication.

Year	> one finding	>one finding per year	Total new Patients per Year (%)	Total Of X-rays per Year (%)
Year 1	14	52%	12.2%	22%
Year 2	29	59%	22%	39%
Year 3	17	31%	9%	20%
Year 4	22	53%	11%	34%
Total	82	49%		
Average of Total (177)	46%			
	Average per Year	49%	14%	29%

patient population, where of the 307 male patients, 141 (47%) received x-rays of their cervical spine. The median age of the patients throughout the four years of data collection was 41.6 years, whilst the average of those who received x-rays of their cervical spine was slightly older with a median age of 42.5. These data are consistent with the findings of Beliveau *et al* from their scoping review of chiropractic patient profiles determined chiropractic patients are predominantly female (57%) with a median age of 43.4 years.(3)

Data in the literature report the most severe adverse events associated with cSMT occur in patients <45 years of age (7,9,119–122) Rothwell *et al* stated that patients' vertebral artery dissections were five times more likely to occur in patients <45 years of age. (121) Others have reported risks of carotid or vertebral artery dissections are between three and twelve times more likely to occur in patients receiving cSMT in the <45 age bracket (7,9,99–101,123) However, spontaneous vertebral or carotid artery dissections account for up to 25% of strokes in patients <45 years of age (124–126) It, therefore, follows, that the data from these authors show that not only are the patients in this age category more likely to

suffer spontaneous arterial dissections, but they are also statistically more likely to be seeking chiropractic care. (3) The patient data in the current study revealed similar patient demographics regarding age and sex shown in the literature. (3)

Cassidy *et al* also found no increased risk of vertebral or carotid artery dissection from cSMT from their population-based case-control and case-crossover studies. (9,123) This led the authors to conclude that the symptoms of headache and neck pain that prompted the patients to seek chiropractic care were likely caused by the vertebral or carotid artery dissection. However, Cassidy *et al* fail to rigorously define “chiropractic care” or “neck-related chiropractic care” in their studies, thus the relevance to their findings and the current study is questionable. Non-vascular complications from cSMT have been reported in the literature. (127) Oppenheim *et al* discuss cases of pathologic fracture, cervical disc herniation, myelopathy, and radiculopathy following cSMT. Oppenheim *et al* describe complications of cSMT as “under-recognised” and “likely grossly under-reported” calling for pre-manipulation diagnostic imaging to identify those at risk of such complications.

(128) One criticism of Oppenheim is from Haldeman who pointed out that Oppenheim *et al* (2005) report 18 cases of various complications spanning six years, thus the incidence of these complications are exceedingly rare, a rate of which would be the envy of any other treatment interventions. (128) Notwithstanding, if complications from cSMT are indeed under-reported as Oppenheim *et al* state, then the criticism from Haldeman is moot, as the actual number is unknown. Also, without additional evidence to support the gross under-reporting claim made by Oppenheim *et al* is conjecture.

Dvorak report a frequency of transient complications following cSMT using high-velocity/low amplitude thrust techniques of 1:16,716. (129) Other authors have stated risks of serious adverse events following cSMT vary between 1 in 50,000 to <1 in 5,000,000. (130,132,133,141) However, there is a great difference between safety risks following cSMT and the appropriateness of cSMT to a given patient. The current paper was not designed to explore adverse events following cSMT but rather to assess the frequency at which x-rays influence the application of cSMT.

Benign adverse events from SMT have been reported to occur in 23-83% of patients. (7,17,22,23,28,134-137) Rubinstein *et al* reported 56% of chiropractic patients reported experiencing adverse events following SMT, 13% of which were reported as severe. (136) Rajendran *et al* reported the highest incidence of adverse events following SMT (83%), 74% of which were increased pain, and 58% experienced stiffness. (135) Neither Rubinstein *et al* nor Rajendran *et al* included any form of diagnostic imaging findings to aid in exploring predictors of adverse events following cSMT nor did they report if the patients who experienced adverse events were assessed for the appropriateness of cSMT.

Hurwitz *et al* reported from their randomised clinical trial that adverse events from cSMT occur in 30% of patients. (138) These authors, therefore, recommend altering treatment interventions from manipulation to mobilisation, especially to those with severe neck pain. (138) The current study found 32% of patient x-rays revealed at least one contraindication to cSMT, altering treatment options to alternatives, such as mobilisation.

It is our opinion that x-rays are necessary to determine the appropriateness of cSMT and accurately select those patients who are more likely to benefit from cSMT and reduce the risk of adverse events.

Study Limitations

The current study suffers from several limitations including only analysing lateral cervical spine radiographs whilst excluding other cervical spine projections. Any contraindications visible on anterior-

posterior projections, such as advanced atherosclerosis of the carotid arteries may have been missed in the data collection.

Limitations with the study design and method mean the study results are not generalisable or meaningful to all professionals who use cSMT. As a service evaluation, the results cannot be generalisable across all UK chiropractic clinics, therefore the meaning of these results to the profession at large is low. As stated in the method section, not all chiropractors use cSMT in their practice, which further diminishes the findings of the current study are only relevant to those who practice cSMT as defined in the method section.

As the researcher, examining clinician and author of this study are one and the same, the issue of bias towards the findings of this study must be acknowledged. The issue of bias using a retrospective review of records was discussed in the method section. The researcher tackled the research question from a manual therapist's perspective, using a post-positivists approach. Therefore, the introduction of bias cannot be avoided as a clinician who uses x-rays with their clinical practice, objectivity is in question. The inclusion of collaborators for this study may have reduced the risk of bias but was not possible for this MSc thesis.

Notwithstanding, however, the researcher simply applies the findings of other researchers discussed in this study. The practical application of x-rays prior to commencing cSMT provides the researcher with the experience of these data in the real world of clinical practice. The researcher then approached the research question using a deductive methodology from scenarios with patients who experienced adverse events following cSMT only to subsequently discover contraindications on x-ray when re-examining the patient. This can be viewed as either bias towards the study from personal experiences, or providing the researcher with hands-on, clinical experience of both adverse events and utilising x-rays in practice on patients with neck pain. Since ideas are generated from our sense experiences (139) it is reasonable for a clinician to tackle the research question.

The inclusion of posterior ponticles as a contraindication to cSMT may bias the results. The lack of knowledge and investigations into mild and moderate adverse events in those patients with a posterior ponticle makes it challenging to include or exclude them as a true relative or absolute contraindication.

Clinical factors surround the necessity for x-rays were not investigated by the current study. For example, the clinical justifications from Tables 1 and 2 most frequently used were not collected for this study. This was not the purpose of the study, thus outside its scope. However, these data may help with data analysis regarding why some years

show significantly more patients were x-rayed than others. Due to the unpredictability of clinical practice, the types of patients who may present to the clinic and why will influence the necessity for x-ray examination.

CONCLUSION

The current study found 60% of lateral cervical spine x-rays obtained in a UK chiropractic clinic alter the treatment options for patients. To the authors' knowledge, this is the first study that analysed the findings of lateral cervical spine projections only to assess for alterations in treatment options. Whilst Jenkins *et al* included all spinal regions in their data analysis, the results from the cervical spine data were similar to the current study findings. (80)

Future studies into adverse events following cSMT may benefit from including data from pre- and/or post-manipulation x-ray findings of those patients who suffer even benign adverse events. Much of the literature exploring adverse events following cSMT focuses on severe and therefore rare adverse events whereas the more commonly experienced mild and moderate adverse events are largely ignored. Quantifying rare events is challenging by the nature of rare events, so focussing attention on more commonly seen mild and moderate adverse events may yield more applicable data on contraindications to cSMT. (7)

Whilst it is important to identify those at the greatest risk of severe adverse events, the ability to identify those patients for whom cSMT is not appropriate and those who are more likely to experience mild and moderate adverse events should be investigated. This study has shown that pre-treatment x-rays frequently alter the treatment options in chiropractic clinical practice. However, due to the nature of clinical practice, in the current study, not all patients presenting with neck pain received x-rays of their cervical spines.

Ultimately, the debate surrounding the appropriateness of x-rays in chiropractic clinical practice should be based within the patients' values and preferences regarding that person's healthcare. (140) Clinicians and academics on either side of this debate are simply trying to reduce unnecessary risks to the patient. The current study adds evidence that x-rays frequently alter treatment options for patients seeking chiropractic treatment in the UK. The current study also adds evidence that x-rays are a valuable tool for identifying appropriate treatment interventions for patients with neck pain and reduce the risk of adverse events in chiropractic clinical practice by removing cSMT as a treatment option for those patients.

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