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Does Overall Cervical Spine Pathology Relate to the Clinical Heterogeneity of Chronic Whiplash?★

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Abstract

Background and purpose—There remains limited evidence for the clinical importance of most imaging findings in whiplash. However, it is possible the type and number of findings on Computed Tomography (CT) may contribute to prognostic recovery models. The purpose is to interpret cervical spine pathologies in the context of known factors influencing recovery.

Materials and methods—This is a secondary analysis from a database of 97 acutely injured participants enrolled in a prospective inception cohort study. Thirty-eight participants underwent standard of care cervical spine CT in the emergency medicine department. All 38 participants were assessed at <1-week, 2-weeks, and 3-months post-injury and classified using percentage scores on the Neck Disability Index (recovered/mild (NDI of 0–28%) or moderate/severe (NDI ≥ 30%)). Between-group comparison of categorical variables (gender (male/female), presence of at least one CT finding (yes/no), and presence of ≥ 3 pathologies on CT (yes/no)) was conducted using 2-tailed Fisher's exact test.

Results—Participants from both groups demonstrated at least one observable pathology. The group with persistent moderate/severe symptoms presented with significantly more pathology at baseline than those who later reported recovery or milder symptoms at 3-months post injury ($p = 0.02$).

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Conclusions—This preliminary study, which needs replication in a larger cohort, provides foundation that the number of degenerative pathologies seen on initial post MVC CT may be associated with the subsequent clinical course of whiplash.

1. Introduction

The pathomechanics of whiplash injury from a typical motor vehicle collision (MVC) have evolved from an injury model of rapid angular displacements [1], to a more contemporary model of injurious mechanisms involving the occupants of a vehicle struck from rear-, frontal-, or side-impacts [2–4]. Therefore, we included not only patients involved in a rear-end collision, but also those with neck pain and a description of front- and side-impacts as well. The resultant development of a nonphysiological “S-shaped” cervical curve could potentially impact and injure any number of anatomical tissues (e.g., intervertebral discs, ligaments, facet joint capsules, muscles and nerves) [4–6].

However, despite this mechanistic knowledge, there is no universally accepted injury tolerance applicable to the entire population of occupants involved in a typical rear-end vector impact [7]. Furthermore, for any of the candidate lesions, no structural cause of whiplash and its associated disorders (WAD) following a MVC has been consistently found with routine imaging applications, supporting the acknowledged position that the clinical course is driven by complex interactions of biological, psychological, and social factors [8]. The preponderance of such evidence appears to be driving a shift in clinical behaviours in which potential structural pathology is not adequately investigated [9,10].

In the course of routine acute care of the patient with potential MVC-related suspected spine trauma, medical practitioners make individual judgments for diagnostic tests on a patient-by-patient basis. The American College of Radiology Appropriateness Criteria (ACR-AC) is the principal guideline in the United States for clinical decisions regarding the use of diagnostic imaging. Similar societal guidelines supported by the same body of evidence and informed by the criteria set forth in the Canadian Cervical Spine Rule and/or the National Emergency X-Radiography Utilization Study (NEXUS) [11] are available worldwide [12].

While the ACR-AC clinical condition of *Suspected Spine Trauma* provides some guidance as to who should get imaging to detect acute injury, it does not suggest how front-line providers should or could correlate non-emergency imaging findings with the subsequent clinical course. It is known that pre-injury neck pain, older age, high baseline pain intensity, higher self-reports of neck related disability, pre-collision medical diagnoses [13], and signs of peritraumatic distress are associated with poor recovery [7,14], and delayed return to work [15]. It is, however, not clear if indeterminate imaging findings, beyond fracture and ligamentous instability, may be associated with the subsequent clinical course of whiplash.

The state of knowledge in the field of cervical trauma is complicated due to a number of imaging-based studies that reveal pathological findings are common across a wide age range of people with, and without, spinal pain [16–26]. Such discrepancies question the prognostic and diagnostic value of pathological findings on spinal imaging studies in and beyond the whiplash condition. However, in considering that the risk of future low back pain increases

with the number of pathologic abnormalities (3 or more) [27,28], it is plausible that the presence and number of pathologic abnormalities in the cervical spine are also potentially important factors related to WAD recovery.

The aim of this investigation was to interpret the type and number of cervical spine pathologies in the context of other known risk factors for poor recovery following WAD in an inception cohort presenting to an emergency care setting where computed tomography (CT) scans of the head and neck were performed as part of usual care.

2. Materials and methods

This is a secondary analysis of data drawn from an existing database of 97 acutely injured participants enrolled in a prospective study investigating the neuromuscular mechanisms underlying poor recovery following whiplash injury from an MVC ([ClinicalTrials.gov Identifier:NCT02157038](https://clinicaltrials.gov/ct2/show/study/NCT02157038)).

Participants were recruited via an urban academic emergency medicine department with level 1 trauma designation and were eligible provided they reported neck pain resulting from a MVC and were within the Quebec Task Force Classification category of WAD Grade II (movement restriction with no radicular symptoms) [29]. Exclusion criteria were younger than 18 or older than 65 years of age, one or more previous MVC's in their lifetime, treatment for neck pain disorders in the past ten years, any nervous system disorder (e.g. stroke, Parkinson's), metabolic system disorder (e.g. diabetes), or those who, by standard Emergency Medical Services' protocols were deemed to be at risk for multisystem trauma. The CT study of the cervical spine was performed at the Emergency Medicine Department as part of standard care for their acute visit; provided the treating clinicians felt the patient had sufficient probability of injury as predicted by either the Canadian Cervical Spine Rule (CCR) or NEXUS [11] criteria to warrant imaging.

All participants were followed and assessed at <1-week (T1), 2-weeks (T2), and 3-months (T3) post injury as part of the parent prospective study. A research assistant administered questionnaires to all participants at each assessment. Age, sex, and BMI were captured using a standardized self-report form. The local Institutional Review Board granted ethical approval and all participants provided informed written consent prior to data collection.

2.1. CT study

Clinically indicated CT (based on the CCR or NEXUS) without contrast of the cervical spine was performed in all participants. 2.5 mm helical images were obtained through the entire cervical spine. Bone, soft-tissues and the 2D coronal and sagittal reformatted images were reviewed and approved by board-certified attending diagnostic neuroradiologists with specific training in head, neck, and spine imaging. An orthopaedic resident in training (a physical therapist) who was blind to the status of the patient in terms of questionnaire responses, organized all radiology reports, counting and aggregating all reports of pathology on each participant. Based on previous work investigating the number of different lumbar spine MRI findings [28], the primary outcome for this study was the total number of different pathological findings from the CT exam. An a priori decision was made to select

abnormalities related to bony and soft-tissue pathology amenable to CT identification (e.g. central or foraminal stenosis, disc-osteophyte, disc-degeneration, disc-height loss, disc-protrusion, antero- or retrolisthesis, facet arthropathy, uncovertebral joint degeneration).

2.2. Self-reported neck-related disability

Self-reported neck-related disability was measured using the Neck Disability Index (NDI), which has been used extensively to quantify neck disability [30]. Percentage scores $\geq 30\%$ have been reported to indicate moderate/severe neck-related disability [31].

2.3. Measure of psychological distress

The **Posttraumatic Stress Diagnostic Scale (PDS)** was used to collect data related to symptom severity around post-traumatic stress [32]. Based on the results from a recently derived [33] and externally validated [14] clinical prediction rule (CPR), we chose to only use the hyperarousal subscale score as a measure for self-reported emotional distress [14,31].

2.4. Statistical analysis

Participants were classified based on NDI percentage scores at 3-months post-injury as either recovered/mild (NDI of 0–28%) or moderate/severe (NDI $\geq 30\%$). These classifications have been used previously [14,31,33,34]. Standardized mean difference (SMD, $[\bar{X} \text{ Group 2} - \bar{X} \text{ Group 1}] / \text{pooled standard deviation}$) was calculated for the PDS at each time point to further describe the two groups. Comparison of continuous measures between groups (Age (y), Body Mass Index (BMI, kg/m^2), signs of distress (PDS), and number of CT-defined pathologies (total count) was done using the independent sample *t*-test. Between-group comparison of categorical variables (gender (male/female), presence of at least one CT finding (yes/no), and presence of ≥ 3 pathologies on CT (yes/no)) was conducted using 2-tailed Fisher's exact test, which is recommended when anticipated cell sizes are small (<5) [35]. Statistical significance was set at $p < 0.05$.

3. Results

Consistent with institutional standard of care, 38 of the 97 participants (39%) underwent CT of the cervical spine at the discretion of the treating clinicians who felt the patient had sufficient probability of injury as predicted by either the Canadian Cervical Spine Rule or NEXUS criteria to warrant imaging [11]. The remaining 59 (61%) did not undergo acute CT scan as imaging **was not indicated** by CCR or NEXUS clinical criteria and thus, were not included in this analysis.

The age, gender, BMI and classification demographics on all participants across all three time points are shown in Table 1 with 8/38 (21%) participants classified as moderate/severely disabled by virtue of their 3-month NDI scores. Over 80% of participants were female, though there were no observable differences in gender distribution between the two groups. Participants who were classified as recovered/mild 3-months post injury were younger (mean of 33.6 years), but not significantly, than those classed moderate/severe (mean of 41.0 years) ($p = 0.11$). There was a significant difference in BMI (Kg/m^2) between

the two groups with those classed as moderate/severe having a larger BMI (28.2 Kg/m²) compared to those nominating recovery (24.2 Kg/m²) ($p = 0.05$).

3.1. Groups described by psychological distress

Results for the measures of psychological distress are presented in Table 1. At T1 (<1-week post injury) participants in the moderate/severe group reported higher NDI ($p = 0.01$) and PDS ($p = 0.04$) scores. The SMD of the PDS remained fairly stable but increased from baseline to 3-months post MVC (Baseline SMD = 0.79, 2 weeks = 0.67, 3 months = 0.86), confirming the moderate/severe group reported persistent feelings of neck-related disability and trauma-related distress.

3.2. CT findings

Pathological findings for the two groups are presented in Table 2. Overall 33% of participants in the recovered/mild group had at least 1 observable pathology, compared to 63% in the moderate/severe group ($p = 0.15$). When the more conservative threshold of three or more pathological CT findings at baseline (T1) was used, 63% (5/8) of those with persistent signs and symptoms at T3 were positive, contrasted to only 16.6% (5/30) of those nominating recovery or milder symptoms ($p = 0.02$).

4. Discussion

These preliminary results appear to indicate that these patients who have degenerative non-acute findings at the time of evaluation after a whiplash mechanism MVC may be more likely to progress to a worse WAD outcome relative to those with more fully 'normal' findings on CT. Consistent with the wider whiplash literature, the high-risk group comprised 21% of the exposed population who demonstrated a more complex peritraumatic and subsequent chronic clinical presentation compared to nearly 80% who later report feeling recovered or having milder symptoms.

The validated clinical prediction rule of recovery pathways after whiplash injury previously identified the following prognostic factors for ongoing moderate/severe pain and disability: 1) being 35 years of age or older, 2) having an initial NDI score of 40% or more, and 3) the presence of hyperarousal symptoms at baseline [14]. Of the 8 participants in this study who continued to rate higher neck-related disability (higher NDI %) and hyperarousal at 3-month follow-up, six were over the age of 35 with higher initial NDI scores (>40%) and symptoms of hyperarousal at inception. Those participants with lower scores (<28%) on the NDI at 3-months, indicating recovery or milder symptoms, were on average younger, and all started with both lower NDI scores and hyperarousal at inception, in accordance with the previously described CPR [14]. It is however noteworthy that the CPR was not perfect; 8 of the 30 nominating recovery or milder symptoms were over the age of 35 years, and 11 of the 30 scored >40% on the NDI at enrolment.

Albeit preliminary, this study may reveal a potentially important piece of new knowledge in this field. While it is acknowledged that previous cross-sectional and prospective imaging work has failed to consistently reveal pathological findings that are strongly related to whiplash symptoms and outcomes [21,36–41], this work is a primary example where the

number of degenerative pathological findings were considered and appear to be in parallel with known clinical risk factors.

We acknowledge the prognostic value of radiological observations in patients with acute and chronic whiplash remains highly controversial, particularly considering evidence to suggest some pathoanatomical findings from traditional imaging applications of the cervical region are common in asymptomatic participants ranging from 20 to 70 years of age [16]. However, emerging evidence suggests that MRI findings of pathology are more common in those with low back pain than those without [27,42,43], and the number of findings are associated with worse outcomes [28]. Whether the same holds true for findings on clinically indicated CT or MRI of the cervical region is unknown, yet this study offers some preliminary evidence that multiple, not isolated, findings of pathology may contribute to, if not enhance, existing prognostic models of recovery, especially in the presence of other known risk factors [9,44].

Importantly, we acknowledge and interpret that these CT findings are likely pre-existent and associated with chronic degenerative changes. Whether the number of pre-existing pathologies (e.g. central stenosis, uncovertebral joint degeneration) somehow represents a risk-factor for poor-recovery where the potentially injurious [45,46] and the distressing event triggered existing vulnerabilities [47,48] is unknown. However, this is similar to recent evidence suggesting precollision pain and medically unexplained symptoms predict chronic whiplash related pain [13], and such findings warrant inclusion in future prospective modelling studies.

We also cannot ignore the possibility that the patient's knowledge of pathological findings from the CT imaging report could influence their clinical course, or expectations for recovery [49,50]. Patients at the emergency medicine department where this study was completed, including all of those enrolled in this research study, are informed of the scan results, but such communication does not typically include specific findings. Rather, ***there are no acute abnormalities on your CT***, or ***there is no acute injury on your CT to be concerned about***. This fits with the 0% yield for fracture in all scans that were clinically indicated by the highly sensitive CCR and NEXUS rules.

While a radiology report is made available to some, but not all, as part of this institutional setting, it is not possible to state whether each patient that receives their imaging report reads it, nor can comment be made on their interpretation thereof. However, it would be misguided to suggest knowledge of pathology alone would directly influence recovery. Readers may recognize that whiplash recovery is multifactorial, driven by both medical and non-medical factors [8,48,51]. Therefore, the clinical course of WAD recovery should not hang on any single factor.

Future work should, based on current knowledge around the heterogeneity of the WAD condition, aim to prioritize *who needs diagnostic imaging, when they need it, what type of imaging would be optimal, how should the results be delivered, what is/are the potential consequence/s of the patient knowing the results, and how would these findings, in tandem with other known risk factors, inform a plan of care*; such as the recent findings that a

conservative, non-surgical, intervention of stress inoculation training and exercise offers an informed and effective management option for some, but not all [52].

The diagnostic and prognostic value of traditional imaging in whiplash injury remains unclear at least in part due to the variability in the approaches used in assessment, analysis of imaging findings [17–21,31,34,36–41,53,54], and a lack of recognition for current knowledge regarding the known risk factors for poor recovery following whiplash [7,14,15,33,55,56]. Furthermore, unlike other common clinical diagnostic tests with well-established values of normative ranges (e.g. standard blood tests), there is a lack of easily accessible normative radiologic reference values to understand the presence and significance of soft-tissue pathologic findings for a relatively asymptomatic, but ageing, spine. As a result, it is not surprising that interpretation of the importance of imaging findings is subjective, somewhat controversial, and often referred to as incidental. Although, it is likely that reported imaging findings of uncovertebral joint osteophytosis with central stenosis and facet arthropathy in a 20-year-old woman (or man) would have very different clinical implications than if they were observed and reported in a 70-year-old woman (or man) following whiplash. There is currently no normative sex- or age-dependent data to guide clinicians on the clinical importance of these findings, much less for interpreting them in light of potentially important demographic and clinical data. Larger scaled prospective studies examining the prevalence, and meaningfulness of pathology (CT or MRI), and potential rate of change over time, in participants with varying levels of neck-related disability and distress across a wider-age range are warranted; particularly to further investigate any relationship between senescence and pathology.

While preliminary, the study also provides foundation that the number of degenerative pathological findings from warranted CT studies may contribute to current prognostic models of WAD recovery. In particular, where 3 or more pathologies are identified and this may align with recent evidence suggesting pre-collision pain and medically unexplained symptoms help to understand recovery on a patient-by-patient basis [13].

5. Limitations

The study is not without limitations. The small sample size could be interpreted as not generalizable to other samples or the larger population exposed to and injured from a whiplash. However, consistent with the wider-literature, we have identified 21% participants (n of 8) of this cohort who went on to experience a more complex clinical picture. This group of individuals ‘fits’ the clinical profile of those patients at risk of poor recovery and this further supports the heterogeneity of whiplash recovery. In particular, they are slightly older (though not significantly), report higher levels of neck-related disability and arousal when compared to the nearly 80% of this population that went on to either fully recover or report milder symptoms.

The degenerative pathology findings cannot be considered to be causative, which also means that conservative (rehabilitation) or more invasive (surgical or otherwise) treatments of the identified pathologies may not necessarily relate to lowering the risk of poor recovery in the long-term. This needs to be further investigated in larger prospective studies.

6. Conclusion

The intention of this work is not to suggest ‘we need more imaging’. Quite the opposite. The intent is to elevate the importance of recognizing the multiple biopsychosocial factors that can/do influence recovery from whiplash. In purest terms, imaging findings (when warranted per standard guidelines) in tandem with other known risk factors may increase confidence of the primary, secondary, tertiary drivers of an individual patient’s recovery trajectory, which should ultimately inform a plan of care. It is noteworthy that 61% (59/97) of those acutely injured (and enrolled in our parent study), were not referred for imaging, which befits best practice management of traumatic neck pain and suggests judicious use of clinically indicated imaging through available guidelines and clinical experience [12].

The current work offers new directions for research in the field to consider multivariate and multisystem pre- and post-collision factors in establishing prognostic phenotypes [51], and may lead to new intervention targets to prevent chronicity in the future.

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Table 1

The age, gender, and classification demographics of subject groups across all 3 time points.

	Recovered/mild (n = 30)	Moderate/severe (n = 8)	p-Value
Age, years (SD)	33.6 (10.8)	41.0 (12.8)	0.11
Gender (n, % female)	26 (86.7%)	6 (75%)	0.64
BMI (Kg/m ²)	24.2 (4.5)	28.2 (6.9)	0.05
Within 1 week of MVC (t1)			
NDI (% , SD)	36.1 (15.6)	50.3 (6.9)	0.01
PDS (arousal)	4.7 (4.0)	8.1 (4.4)	0.04
MVC to t1, days (SD)	5.5 (1.4)	5.5 (1.5)	0.95
2 weeks after MVC (t2)			
NDI (%)	30.8 (15.3)	49.5 (9.4)	0.002
PDS (arousal)	5.1 (3.6)	7.6 (3.6)	0.09
MVC to t2	17.2 (7.9)	15.0 (2.6)	0.43
3 months after MVC (t3)			
NDI (%)	11.6 (8.3)	44.5 (12.8)	<0.001
PDS (arousal)	3.6 (3.6)	7.0 (4.5)	0.02
MVC to t3	108.1 (18.)	105.5 (16.9)	0.72

Abbreviations: BMI, body mass index; NDI, Neck Disability Index; PDS, Posttraumatic Stress Diagnostic Scale; MVC, motor vehicle collision; t1, time point 1 (within 1 week of MVC); t2, time point 2 (2 weeks after MVC); t3, time point 3 (3 months after MVC). Values are mean (SD), except for gender.

Table 2

CT findings of pathology across the groups (%).

	Recovered/mild (n = 30)	Moderate/severe (n = 8)	p-Value
Central stenosis	10%	63%	0.005
Disc osteophyte	20%	50%	0.11
Disc protrusion	16.6%	37.5%	0.21
Uncovertebral degeneration	6.7%	50%	0.01
Foraminal stenosis	16.6%	36.3%	0.21
Anterolisthesis	6.7%	25%	0.19
Facet arthropathy	6.7%	25%	0.19
Intervertebral disc height loss	13.3%	25%	0.37
Retrolisthesis	3.3%	12.5%	0.38
3 or more pathological findings	16.6%	63%	0.02
Bony fracture	0%	0%	–
Total pathology	33.3% had at least 1 pathology	63% had at least 1 pathology	0.15