Retrospective Study

Missed Emergency Department Diagnosis of Mild Traumatic Brain Injury in Patients with Chronic Pain After Motor Vehicle Collision

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Background: Mild traumatic brain injury (mTBI), or concussion, is the most common presentation of TBI in the emergency department (ED), but a diagnosis of mTBI may be missed in patients presenting with other acute injuries after a motor vehicle collision (MVC).

Objective: To estimate the frequency of missed diagnoses of mTBI in patients seen in the ED after MVC who later developed chronic pain syndromes.

Study Design: Retrospective cohort study.

Setting: An interventional pain management clinic.

Methods: Data were drawn from information collected during standardized intake assessments completed by 33 patients involved in an MVC referred to a community-based clinic for chronic pain management. The prevalence of missed mTBI and postconcussion syndrome (PCS) were estimated based on the clinical diagnosis, which included reviewing acute care medical records, the Rivermead Post-Concussion Symptoms Questionnaire (RPQ) scores, and patient-reported injury history.

Results: There was a high prevalence of presumed mTBI in this sample (69.7%) of patients involved in an MVC, but an acute care diagnosis was made in only 39.1% of cases. Patients diagnosed with mTBI at acute care had significantly lower PCS symptom scores than patients whose diagnosis was missed ($P < 0.05$). Diagnostic brain imaging (magnetic resonance imaging [MRI] or computed tomography [CT]) was more frequently ordered ($P < 0.05$) in patients diagnosed with mTBI. Using a modified RPQ developed for use with chronic pain patients, 54.5% of the sample met criteria for PCS. Loss of consciousness, meeting established criteria for mTBI, postinjury headache, and meeting criteria for posttraumatic stress disorder were significantly correlated with the development of PCS.

Limitations: Data may be subject to recall and selection bias. Additional research with a larger study sample is needed to investigate correlations between individual symptoms and the development of PCS following an MVC.

Conclusion: Patients presenting to the ED following an MVC have a high prevalence of mTBI. Patients whose diagnosis of mTBI is missed end up with significantly more severe postconcussion symptoms. While all patients included in this study were either referred or being treated for chronic pain after an MVC, they all also went on to develop PCS and disability following their accident, suggesting that better screening for mTBI after an MVC might identify those who may require more follow-up or rehabilitation therapy. In particular, those presenting with loss of consciousness, an altered mental state, posttraumatic amnesia, or postinjury headache are at increased risk of PCS.

Key words: Motor vehicle collision, postconcussion syndrome, chronic pain, posttraumatic stress disorder, concussion, mild traumatic brain injury, emergency department

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Each year, an estimated 69 million cases of traumatic brain injury are seen worldwide (1-3). The majority of these injuries are classified as mild traumatic brain injuries (mTBI), also called concussions. Concussions are the most common reason for emergency department (ED) visits (4); motor vehicle collisions (MVC) are a leading cause of concussions. MVCs account for 14% of all annual TBI-related ED visits in the United States (5) and approximately one-quarter (24%) of adults with MVC injuries sustained a concussion (6). Therefore, with EDs commonly being the first point of care for patients who suffer an MVC, it is important for the ED physician to make an accurate concussion diagnosis.

Sharma et al (7) reported that 42.9% of acute care mTBI diagnoses were missed in patients who had been in an MVC. Accordingly, the reported prevalence of mTBI after MVC may be underestimated by missed or delayed diagnoses, suggesting the need for better acute care protocols to facilitate early diagnosis of mTBI (7). It is critical that mTBI is documented and diagnosed as early as possible because a missed diagnosis may worsen clinical outcomes by increasing the risk of postconcussion syndrome (PCS). Patients whose diagnosis is missed will typically not receive guideline-based treatment, self-care advice (8), or adequate follow-up care, potentially delaying recovery (9,10) and worsening disability (11-13).

There are a number of reasons why a physician may miss a concussion diagnosis. Diagnostic errors in primary and acute care settings have been linked to inadequate clinical assessment, failure to order or correctly interpret diagnostic tests, and failure to seek specialist consultation (14-17). Moreover, concussion diagnoses, especially after an MVC, are often confounded by other health issues. For instance: the symptoms of mTBI can be transient, and in an MVC may be overshadowed by whiplash-associated disorder or other injuries (7,9); not to mention the emotional symptoms related to the collision or the potential threat to life (e.g., posttraumatic stress disorder [PTSD]). Our previous research has demonstrated how PTSD and chronic pain are often comorbid with concussion following an MVC in long-term care, and that these conditions will commonly present with similar symptoms, (18) making a potential concussion less obvious. Other factors include posttraumatic amnesia, which can impair patient recall of MVC-related symptoms and signs (19,20), and the subtle nature of the neuropathology of mTBI itself, for which neuroimaging (computed tomography [CT] scan or conventional magnetic resonance imaging [MRI]) is not sensitive or specific (7,9).

An accurate mTBI diagnosis following an MVC is critical in the ED in order to provide necessary early intervention(s) and patient education aimed at reducing complications after a head injury. Specifically, ED physicians should be providing appropriate written discharge instructions, including recommendations for physical and cognitive rest, symptomatic treatments, avoidance of head impact (or deceleration exposure), and instructions for following up with primary care or providing a referral to a specialist (21-23). However, according to Seabury et al (24), fewer than half of the patients presenting to the ED with an accurate mTBI diagnosis receive educational materials on discharge or follow-up care, suggesting that postconcussion education and protocols are underutilized in the emergency setting, and that this may be even more prevalent among patients whose diagnosis is missed. Overall, it appears that an accurate concussion diagnosis helps to promote the provision of appropriate patient education and discharge instructions, and thus improve outcomes, whereas a missed concussion diagnosis would be expected to worsen outcomes.

Previous research suggests that 20%-50% of patients may experience prolonged symptoms after mTBI, including headaches, sleep disturbances, fatigue, tiredness, dizziness, impaired memory, and problems with vision and hearing (25,26). One population-based study (n = 1,716) reported a 75% prevalence of at least 3 mTBI-related symptoms 6 weeks after an MVC (27), with 30% of these patients also reporting clinically relevant pain. PCS denotes symptoms that persist for longer than 3 months after the injury (28,29). While one study found that the median time to recovery from mTBI after an MVC was 100 days, 23% of those patients still met criteria for PCS one year after their injury (6). Reported predictors of prolonged mTBI recovery include postinjury headache; loss of consciousness; retrograde or posttraumatic amnesia; altered mental state (feeling dazed, confused or disoriented); dizziness or nausea; impaired concentration; and prior head injury (26,30-32).

While many patients spontaneously recover after a TBI, it is estimated that about 5.3 million Americans and more than 500,000 Canadians are living with TBI-related disabilities, including many that persist after mTBI (i.e., PCS) (33). Many patients with PCS also suffer from chronic pain, a very debilitating condition affecting an estimated 20% of adults worldwide, including 6 million

people in Canada and 25 million in the United States (34-36). Moreover, Nampiaparampil (37) conducted a systemic review of 23 studies involving 4,206 patients and found that the comorbidity of chronic pain and mTBI approached 75%. Additionally, incidence rates of chronic pain following mTBI can be as high as 58% (38). Moreover, pain from other injuries related to an MVC may be another contributing factor to missing an mTBI diagnosis at the ED.

The present study is a retrospective cohort analysis that addresses the importance of accurately diagnosing an mTBI during the initial ED evaluation of any injury. The primary aim of this study was to investigate the frequency of missed mTBI diagnoses among patients suffering from chronic pain and PCS following an MVC. Additionally, in line with our previous research (18), we report on outcomes related to posttraumatic stress disorder in relation to missed concussion diagnoses. Missed diagnoses of mTBI were identified by reviewing medical records, patient-reported clinical history, and Rivermead Post-concussion Symptoms Questionnaire (RPQ) scores. Validated screening tools were used to estimate the prevalence of PCS and PTSD in our sample. Based on previous reports of the high prevalence of PCS symptoms in patients with chronic pain (37-40) and PTSD (41-43), a modified Rivermead score was used (18). This has been previously described (18), and is limited to vestibular and visual symptoms which are not seen in chronic pain syndromes.

Methods

Study Design, Setting, and Patients

From March 2016 through January 2017, a total of 71 patients were referred to our clinic (Seekers Centre, Ottawa, ON, Canada) for chronic pain management after an MVC. All of these patients' data were routinely collected at our clinic during medical intake assessments which included screening for PCS and PTSD using validated questionnaires. Of these 71 patients, 54 were taken directly to the ED for acute post-MVC care. As part of routine clinic care, ED medical records were requested for these patients (if not already provided by the referring health care provider, and if the patient was attached to a primary care provider). Complete records were provided or available for 33 patients, which comprised the final study sample (Fig. 1).

Data were collected using the OCEAN mobile data platform (CognisantMD). Information was entered on a tablet PC (Samsung) and imported to the existing electronic medical records software (OSCAR, McMaster University). Each assessment lasted approximately one hour and was conducted in person at the clinic. Patients completed their forms with assistance from an experienced clinical associate. All patients were screened uniformly, and answered all questions in full. An experienced pain physician (Richard Nahas, MD) reviewed the clinical history and questionnaires with each patient to establish a diagnosis of PCS, with the clinical associate present to ensure the accuracy of the data.

Ethics

This study was approved by the Bruyère Research Ethics Board. All patients provided written informed consent prior to data collection.

Study Measures

Demographic and MVC-related Data

Basic demographic information was collected during the intake. Patients were asked about loss of consciousness and symptoms after an MVC, including headache; altered mental state (dazed, disoriented, or confused); dizziness; nausea; tinnitus; amnesia; blurred vision; or diplopia.

Emergency Department Medical Care

We reviewed ED medical records during the patient interview to support clinical decision-making. They were later reviewed to confirm if a discharge diagnosis of TBI was made.

mTBI Diagnostic Criteria

Diagnostic criteria for mTBI (at the point of ED visit) used in this study were adapted from the Mild Traumatic Brain Injury Committee of the American Congress of Rehabilitation Medicine (44) and previously described by Marshall et al (45). Patients typically meet criteria for mTBI if they have one or more of the following symptoms: any loss of consciousness; any loss of memory of events immediately before or after the accident; and any alteration of mental state at the time of the accident (e.g., feeling confused, dazed, or disoriented) (45). We used more strict criteria, including only those who had at least 2 of these symptoms post-MVC.

Post-Concussion Syndrome

We used a modified Rivermead Post-Concussion Symptoms Questionnaire (RPQ-6) that included the 6 visual and vestibular symptoms that are most specific to

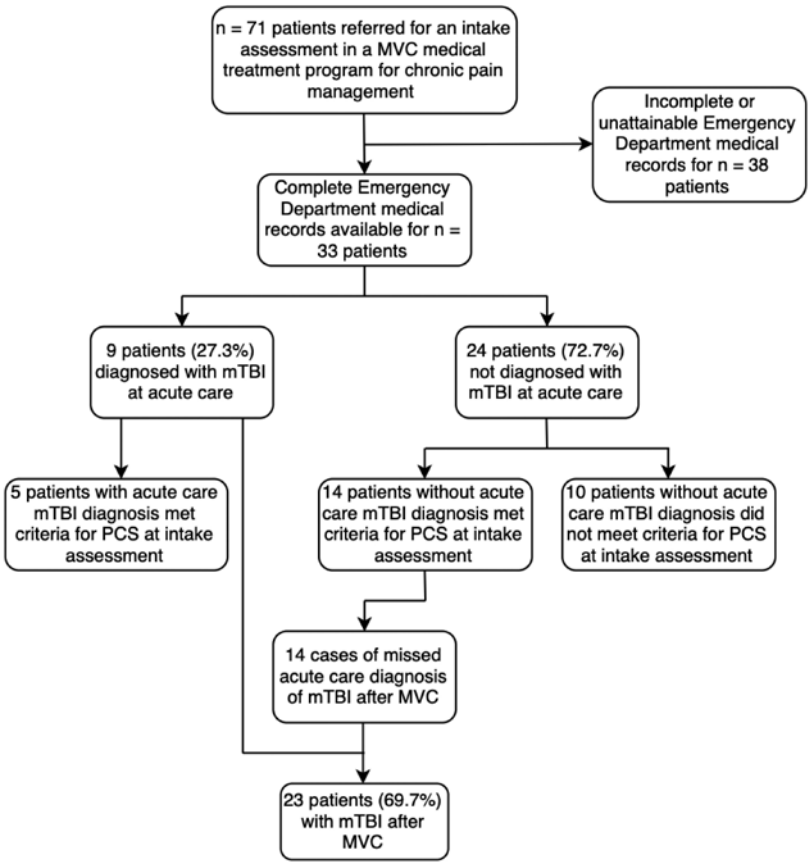

Fig. 1. *Mild traumatic brain injury (mTBI) prevalence and the frequency of missed acute care diagnoses of mTBI in patients with chronic pain after a motor vehicle collision (MVC).*

mTBI (18,46) to estimate the prevalence of PCS in our sample. The standard RPQ is a 16-item questionnaire, with each item comparing a patient's pre- and post-injury state. It is scored on a 5-point Likert scale ranging from 0 ("Not experienced at all") to 4 ("A severe problem"), where higher total scores signify greater symptom severity.

We modified the RPQ for this study to address the fact that many of the symptoms of PCS are also reported by patients with chronic pain syndromes. This overlap in symptoms is commonly seen in clinical practice, and has been identified as a confounder in previous reports (39,40). Confounding symptoms include headaches, constitutional symptoms (sleep disturbance, fatigue, restlessness), psychological symptoms (irritability, depression, frustration), and cognitive symptoms (poor memory, poor concentration, taking longer to think). Our modified RPQ-6 was based on the questions in the RPQ that rate 6 TBI-specific symptoms related to vision (blurred vision, light sensitivity, double vision) and vestibular function (dizziness, nausea, noise sensitivity). These symptoms have been reported to occur rarely in isolated chronic pain syndromes (39,40). The RPQ-6 has values ranging from 0 to 24; PCS was defined as a score of 12 or greater, as previously described (18) (Table 1).

Posttraumatic Stress Disorder

The Posttraumatic Stress Disorder Checklist (PCL-5) is a validated screening tool for PTSD, and is the official checklist of the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) (47). It is a 20-item questionnaire, with each item being scored on a 5-point Likert scale ranging from 0 ("Not at all") to 4 ("Extremely"). A total score of $\geq$ 44 suggests a high likelihood of a PTSD diagnosis (48), and was used to identify PTSD in this study.

Data Analysis

Our data were exported from the OCEAN database platform to Microsoft Excel for Mac 2011 Version 14.0.0 (Microsoft Corporation), and analyzed using SPSS Statistics Version 20.0 (IBM Corporation). Shapiro-Wilks tests were performed to test data for normality. Mann-Whitney U tests, χ^2 tests of independence and ϕ coefficient calculations were performed at a statistical significance threshold of $\alpha = 0.05$.

Results

As shown in Table 2, our sample consisted of 33 patients with chronic pain following an MVC. Seventeen (51.5%) were women, with a mean age of 43.6 (SD = 14.8). The average time between the MVC and screening for the present study was 830.0 days (SD = 765.4), with 63.6% taking place more than 12 months after the MVC. Brain imaging (CT or MRI) was performed as part of the ED evaluation in 24.2% of the total study population. Additionally, an altered

Table 1. *Results of the Rivermead Postconcussion Symptoms Questionnaire (n = 33)*

	Item Score Frequency						
Measures	**0**	**1**	**2**	**3**	**4**	**Mean Item Score**	**Problem (%)[a]**
Headaches	1	0	2	7	23	3.545	97.0
Cognitive Disturbances						3.050	
Forgetfulness	2	1	5	11	14	3.030	90.9
Poor concentration	0	2	1	18	12	3.212	93.9
Thought processing	0	3	4	19	7	2.909	90.9
Mood Disturbances						3.081	
Irritability	1	2	6	12	12	2.970	90.9
Depressed mood	1	0	5	13	14	3.182	97.0
Frustration	1	0	5	16	11	3.091	97.0
Constitutional Symptoms						3.121	
Fatigue	0	0	1	11	21	3.606	100.0
Sleep quality	1	0	3	11	18	3.364	97.0
Restlessness	2	4	10	13	4	2.394	81.8
Visual Disturbances						1.707	
Blurred vision	12	1	7	10	3	1.727	60.6
Light sensitivity	4	1	10	11	7	2.485	84.8
Double vision	21	3	1	7	1	0.909	27.3
Vestibular Disturbances						2.354	
Dizziness	7	0	7	15	4	2.273	78.8
Nausea	12	2	6	9	4	1.727	57.6
Noise sensitivity	2	1	5	10	15	3.061	90.9

[a] Defined by an item score of 2 ("a mild problem"), 3 ("a moderate problem"), or 4 ("a severe problem").

Table 2. *Descriptive statistics of the sample (n = 33).*

	Study Sample (n = 33)	
	n	**%**
Age	Mean = 43.6 (SD = 14.8)	
Gender		
Women	17	51.5
Men	16	48.5
Duration from motor vehicle collision to intake assessment		
Less than 12 months	12	36.4
Greater than 12 months	21	63.6
Immediate to motor vehicle collision		
Loss of consciousness	9	27.3
Alteration of consciousness[a]	25	75.8
Postinjury headache	20	60.6
Met diagnostic criteria for mild traumatic brain injury[b]	20	60.6
Post motor vehicle collision emergency department medical care		
Imaging of head ordered[c]	8	24.2
Concussion diagnosis	9	27.3
Whiplash-associated disorder diagnosis	15	45.5

[a] Includes experiencing symptoms of confusion, dizziness, nausea, tinnitus, blurry/double vision, amnesia, or difficulty concentrating immediately following MVC. [b] Diagnostic criteria adapted by Marshal et al (42). At least 2 of the following symptoms: any loss of consciousness for up to 30 minutes, a loss of consciousness exceeding 30 minutes, any loss of memory of events immediately before or after the accident for as long as 24 hours, posttraumatic amnesia for longer than 24 hours, and any alteration of mental state at the time of the accident (e.g., feeling confused, dazed, or disoriented). [c] Images of head include either computed tomography scan or magnetic resonance imaging.

mental state after the MVC was experienced by 75.8% of patients, but only 27.3% experienced loss of consciousness.

When we reviewed the medical records from each patient, we found that 60.6% of the study sample met the diagnostic criteria for mTBI at the time of the ED visit. Acute care diagnoses of mTBI and whiplash-associated disorder were made in 27.3% and 45.5% of study patients, respectively, and n = 6 (18.2)% received a diagnosis of both. Of the 9 patients diagnosed with mTBI at their acute care ED visit, only 5 presented with PCS at the time of our study, suggesting a potential resolution of symptoms among 4 patients (Fig. 1). Therefore, at the time of the ED visit, 24 patients were sent home with no diagnosis of mTBI.

Among the 24 patients with no ED diagnosis of an mTBI, we found that 14 met our PCS criteria. The implication of this is that 14 of 23 (60.9%) mTBI diagnoses were missed during the ED visit, with a total prevalence of 69.7% mTBI diagnosis in our sample. Lastly, 72.7% of the study sample also met the PCL-5 screening criteria for PTSD.

Mann-Whitney U tests were conducted to compare RPQ and RPQ-6 scores between patients diagnosed with mTBI at their acute care ED visit and patients whose mTBI diagnosis was missed (Table 3). Patients diagnosed with mTBI at the ED visit (n = 9) had significantly lower RPQ-6 scores (U = 34, Z = 1.795, $P = 0.036$, d = 0.796) than patients whose diagnosis was missed

(n = 14). This indicates a greater severity of PCS among patients whose diagnosis was missed in the ED. Those diagnosed with mTBI/PCS at the ED visit also had lower RPQ (i.e., the standard RPQ, not RPQ-6) scores (U = 42, Z = 1.291, *P* = 0.099, d = 0.402), but the results were not significant.

Chi-squared (χ^2) tests of independence identified a significant correlation between an mTBI diagnosis in the ED record and brain imaging being ordered (χ^2 [1, n = 33] = 6.607, *P* = 0.010, Φ = 0.447) (Table 4). Similarly, a PCS diagnosis using stricter RPQ-6 criteria was significantly correlated with a reported loss of consciousness (χ^2 [1, n = 33] = 5.887, *P* = 0.015, Φ = 0.422), headache after an MVC (χ^2 [1, n = 33] = 4.891, *P* = 0.027, Φ = 0.385), meeting diagnostic criteria for mTBI (χ^2 [1, n = 33] = 7.530, *P* = 0.038, Φ = 0.385)] and the presence of PTSD (χ^2 [1, n = 33] = 5.215, *P* = 0.022, Φ = 0.398). Overall there was a negative, yet nonsignificant correlation between an ED diagnosis of mTBI and PCS in our sample (χ^2 [1, n = 33] = 0.697, *P* = 0.372, Φ = -0.124).

Table 3. *Mann-Whitney U test comparisons of RPQ and RPQ-6 scores between patients injured in an MVC with missed acute care diagnoses of mTBI and patients diagnosed with mTBI at acute care.*

	Missed Acute Care mTBI Diagnosis (n = 14)[a]		Diagnosed with mTBI at Acute Care (n = 9)		*P* value	Effect Size (Cohen's d)
	Mean	SD	Mean	SD		
RPQ Score	50.00	4.72	46.22	12.43	0.0985	0.4016
RPQ-6 Score	16.00	2.39	11.89	6.90	**0.0359***	0.7963

RPQ, Rivermead Postconcussion Symptoms Questionnaire
[a]defined by patients who were not diagnosed with mTBI at acute care but met RPQ-6 screening criteria for PCS.
*statistically significant

Table 4. *Association of motor vehicle collision (MVC)-related factors with acute care diagnosis of mTBI and PCS development.*

	Prevalence of the factor in study sample (n = 33)		Acute care mTBI diagnosis		PCS	
	n	%	Φ	*P* value	Φ	*P* value
Gender						
Men	16	48.5	0.186	0.286	0.089	0.611
Women	17	51.5	0.186	0.286	0.089	0.611
Symptoms at Acute Care Assessment						
Loss of consciousness	9	27.3	0.069	0.690	0.422	0.015
Alteration of consciousness[a]	25	75.8	0.029	0.868	0.052	0.767
Postinjury headache	20	60.6	0.076	0.663	0.385	0.027
Met diagnostic criteria for mTBI[b]	20	60.6	0.321	0.107	0.385	0.038
Acute Care Assessment Factors						
Medical care within 24 hours of MVC	23	69.7	0.108	0.536	0.043	0.805
Imaging of head ordered[c]	8	24.2	0.447	0.010	N.A.	N.A.
Whiplash-associated Disorder Diagnosis	15	45.5	0.261	0.134	0.100	0.566
mTBI	9	27.3	N.A.	N.A.	-0.124	0.372
Posttraumatic Stress Disorder[d]	24	72.7	N.A.	N.A.	0.398	0.022

Φ, phi coefficient; N.A., non-applicable; a Symptoms include confusion, dizziness, nausea, tinnitus, blurry/double vision, amnesia, or difficulty concentrating immediately following an MVC.; b Diagnostic criteria adapted by Marshal et al (41). At least 2 of the following symptoms: any loss of consciousness for up to 30 minutes, a loss of consciousness exceeding 30 minutes, any loss of memory of events immediately before or after the accident for as long as 24 hours, posttraumatic amnesia for longer than 24 hours, and any alteration of mental state at the time of the accident (e.g., feeling confused, dazed, or disoriented); c Images of head include either computed tomography scan or magnetic resonance imaging; d Defined by patients meeting screening criteria for PTSD: a total score of ≥ 44 on the Posttraumatic Stress Disorder checklist (43).

Discussion

The present study identified a high prevalence of mTBI following an MVC with 23 of 33 (69.7%) patients meeting criteria for mTBI. Moreover, based on our clinical assessment and review of ED records, we found an overall frequency of missed mTBI diagnoses in the ED in 14 of 23 patients (60.9%) following an MVC (Fig. 1).

The frequency of missed mTBI diagnoses after an MVC reported in the current study (60.9%) is considerably higher than the 42.9% previously reported by Sharma et al (7) specific to an MVC (7), but reasonably close to the overall prevalence of 58.5% reported by them (including slips/falls/assaults, etc). Nonetheless, our study suggests that current ED protocols for diagnosing mTBI should be revised, and better tools are needed to more accurately diagnose brain injury.

A clinical decision rule based on the RPQ-6 might help physicians distinguish pain-related symptoms from those of concussion. Accordingly, use of the RPQ-6 is one advantage of our study. Had we used the PCS criteria established by Thompson et al (49), a cut-off score of ≥ 16 on the standard RPQ, PCS criteria would have been met by 100% of patients in our sample. Clinical prediction rules are increasingly popular tools that have the potential to improve diagnostic accuracy and direct treatment decisions (50). While a clinical risk score for PCS after mTBI has been developed for children (51), such a tool is lacking for adults. Our findings support the potential for the RPQ-6 to fulfil such a role, as it is useful in identifying PCS in patients with or without chronic pain; however, further research is needed to validate and better define its use.

Our reported correlation between postinjury headache and eventual PCS is consistent with previous reports (26,30,32). Our data also correlate with other established diagnostic criteria for mTBI, including loss of consciousness, posttraumatic amnesia, and altered mental state, with poor outcomes after an MVC. All patients who present to an ED after an MVC should be screened for mTBI and considered at increased risk of PCS and worse long-term outcomes. Lastly, consistent with the existing literature, we found no significant association between gender and risk of PCS (30,32).

Approximately two-thirds of our study population suffered an mTBI, which is consistent with the known high risk of mTBI after an MVC (6,7,52,53). Our long-term retrospective data also found a correlation between an early diagnosis of mTBI and less severe PCS symptoms as reported by patients several years after their injury. This is supported by the fact that patients who were diagnosed with mTBI in the ED had significantly milder PCS-related symptoms (based on their RPQ-6 scores) than patients whose mTBI diagnoses were missed. Given these findings, it is possible that compared to patients in this study whose diagnoses were missed, those diagnosed with mTBI were more often provided education and discharge instructions aimed at managing symptoms and reducing complications after head injury. This can include providing patients with recommendations for physical and cognitive rest; symptomatic treatments; and avoidance of head impact (or deceleration exposure) (23). However, we cannot confirm or deny this hypothesis due to the lack of available data.

It is also possible that patients diagnosed with mTBI at the ED were given instructions to seek a follow-up with their primary care physician or a specialist. To that end, it may be prudent for ED physicians to always recommend patients who have had an MVC to follow up with their primary care physician as soon as possible after their visit to the ED. This would allow the patient to receive a more thorough evaluation in an environment that is more suitable to addressing their unique individual needs. That being said, this still puts the onus on the ED physician to acknowledge the possibility of an mTBI in any case of an MVC, regardless of obvious head impact or visible head injury, and to make the recommendation for a follow-up with the patient's primary care physician.

Regardless of where the diagnosis is made, in order to promote a faster resolution of symptoms among patients and prevent the development of PCS, there is a need for greater vigilance and better clinical prediction tools to accurately identify an mTBI after an MVC, especially among patients with risk factors for prolonged recovery, such as loss of consciousness, posttraumatic amnesia/memory loss, altered mental state, and postinjury headache.

Interestingly, our study also found a statistically significant correlation between an mTBI diagnosis and diagnostic brain imaging being ordered in the ED. However, it is difficult to predict whether the results of these diagnostic scans led to an ED diagnosis of mTBI for patients in this study, since the literature suggests neuroimaging like CT and MRI is not sensitive or specific enough to detect the subtle neuropathology of mTBI (7,9). It is more likely that diagnostic brain imaging was ordered for patients with a more noticeable indication(s) of potential brain injury, such as those presenting with a head wound, or presenting with

multiple and/or more severe concussion-related symptoms, such as impaired memory, nausea, dizziness, or postinjury headache.

Our study sample also had a high prevalence of PTSD (72.7%). This may be attributed to comorbidity between PCS, chronic pain, and PTSD, which was found among 48.5% of patients (n = 16) in our sample. Previous studies have correlated mTBI with PTSD (41); these patients may be at greater risk of poorer outcomes (42). Our data also point to a correlation between PTSD and PCS (Table 3), and may suggest that PTSD symptoms can exacerbate PCS symptoms and act as a barrier to recovery. The presentation of comorbid chronic pain, PTSD, and PCS has been termed the polytrauma clinical triad, first described in combat-injured veterans (54), and later in patients injured in an MVC (18). More broadly, it may be appropriate to consider the constellation of symptoms reported in chronic pain, PCS, and PTSD as a functional brain syndrome in which central sensitization (55,56) and hyperarousal (57,58) may inhibit repair of the diffuse axonal injury that occurs during mTBI (53,59,60).

This is the first study to evaluate PCS and missed mTBI diagnoses among patients with chronic pain after an MVC. This is important because of the complex interaction of biomechanical, pathophysiological, and psychosocial factors affecting outcomes in these patients. Moreover, it is possible that this complex presentation of overlapping symptoms may contribute to a missed mTBI diagnosis in the ED, as some physicians may have been more focused on pain, particularly neck pain, and the risk for cervical spine injury. Our patients all had PCS after an MVC, making them a homogeneous study population that may better estimate PCS risk, prevalence, and outcomes after an MVC.

Limitations

Our study was not without limitations. This is a preliminary report based on retrospective data and relies on self-reported information from patients with potential impaired memory due to head injury and trauma, making it subject to significant recall bias (61) and the accuracy of reported information may have declined over time. Patients may have felt a need to overreport symptoms for several reasons, including secondary gain, perceived injustice, anxiety about unresolved symptoms, and ongoing medicolegal disputes. Nonetheless, neither recall bias nor other factors are limited to PCS-specific symptoms, and these factors are unlikely to explain the correlations we report here.

Our data are also subject to selection bias, as our study population had an established diagnosis of chronic pain secondary to an MVC (62). This likely represents a high-risk population that was referred for more significant perceived impairment and morbidity and this selection bias may have increased the prevalence of PCS and PTSD in our sample. Our sample size is also small which hinders the generalizability of our findings. That being said, while our sample may not be representative of the general patient population injured in an MVC, the high prevalence of both mTBI after MVC and postconcussion syndrome reported in this study is noteworthy, as is the potential role of a modified RPQ-6 as a more specific screening tool for PCS.

Future studies should seek to identify correlations between specific symptoms, such as posttraumatic amnesia and future development of PCS. A clinical decision rule might help identify those at increased risk of poor recovery. Previous reports suggest a link between vestibular function and injury to temporomandibular structures (51) and between cervico-ocular coordination and whiplash-associated disorders (63). These factors should also be further investigated in future research.

Conclusion

To conclude, our study adds to a body of research suggesting that many patients who present to the ED after an MVC will have suffered a concussion injury. These are commonly missed during their initial ED evaluation and this is correlated with significantly worse outcomes. Patients with an ED presentation that suggests an mTBI should receive early education and treatment for their symptoms (9,21,24). Finally, we suggest that it may be more appropriate to consider these patients at risk of chronic pain, PCS, and PTSD, which are diagnoses with overlapping symptoms, as having a functional disorder now known as the polytrauma clinical triad. There is a high risk of this disorder after an MVC, and the ED physician should assess patients injured in an MVC with the goal of identifying those at greatest risk of poor brain outcomes.

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