

Healthcare pathways for mild traumatic brain injury patients in New Zealand, determined from Accident Compensation Corporation data

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ABSTRACT

AIMS: To describe healthcare pathways for mild traumatic brain injury (mTBI) patients in New Zealand and identify areas for improvement.

METHODS: A data science methodology was applied to mTBI ACC claims (children and adults) between 1 September 2016 and 1 September 2018, and payment and purchase order data until 1 September 2020. Frequency, median and interquartile ranges were used to describe the pathway.

RESULTS: Of the 55,494 claims and 63,642 referrals, >99% were accepted by ACC. Claim processing took more than a week for 7% (3,647) of claims and referral processing took more than three days for 33% (21,139) of referrals. One in four (25%) cases referred to a concussion clinic took >2 months to receive the service due to administrative delays. Of all patients, 36% (20,413) received more than the initial appointment, and their median time in the pathway was 49 days (IQR, 12–185). TBI diagnostic codes were not added at initial appointment in 6% (3,382) of cases.

CONCLUSIONS: Administrative claim and referral processes resulted in minimal delays in the pathway for most patients. However, the volume of claims meant delays affected thousands of New Zealanders every year. Pathways could be improved by facilitating mTBI diagnosis, improving follow-up rates and reducing unnecessary administrative processes.

Mild traumatic brain injuries (mTBI) affect 35,000 people every year in New Zealand.¹ When a person sustains a mTBI in New Zealand and seeks medical treatment from an Accident Compensation Corporation (ACC) registered health professional, the treatment provider lodges an ACC 45 injury claim form. An accepted claim covers compensation for a range of services that include approved medical treatment, income replacement, social and vocational rehabilitation and ancillary services (transportation and accommodation) as part of the patient's healthcare pathway.²

Whilst classified as being mild in severity, people affected by mTBI can go on to experience significant and enduring consequences that can last for months or years if left untreated.³ A routine follow-up 7–10 days after injury is recommended to determine if the person has recovered or requires further treatment.^{4,5} Multidisciplinary rehabilitation services often referred to as concussion clinics do improve recovery for those experiencing persistent difficulties after mTBI.⁶ Early access to concussion clinics is associated with faster recovery and improved social, emotional and functional outcomes.^{7,8} Conversely, delays in access to concussion clinics have been associated with worse symptoms and lower wellbeing.⁹ In New Zealand,

anyone can receive a referral to a concussion clinic if they have an accepted ACC claim for a medically diagnosed mild or moderate TBI or persisting concussion symptoms from an injury in the previous year.¹⁰ However, there has been concern from patients and clinicians that the patient journey through ACC healthcare pathways are complex with delays in access to treatment.^{11–13} Therefore, understanding of ACC mTBI healthcare pathway characteristics from a patient-centric perspective was needed to identify areas for improvement.

Methods

Ethical approval

The project was approved by ACC Ethics Committee (#426) and Auckland University of Technology Ethics Committee (AUTEK #20/21).

Methodology

The Cross-Industry Process for Data Mining (CRISP-DM) is a process model widely used in data science.^{14,15} The first three phases of the CRISP-DM methodology were applied to ACC data to reliably map out the patient journey, provide a description of ACC mTBI healthcare pathways in New Zealand and identify areas for improvement. The first

phase (business understanding) involved understanding the application domain (ACC processes and mTBI care) and converting this knowledge into the study objectives. The second phase (data understanding) involved becoming familiar with the data, understanding how it relates to the processes outlined in the business understanding, identifying data quality problems and discovering initial insights. This information is used to direct the third data preparation phase to construct a data set (e.g., deriving new variables) that can be used to meet the study objectives. The remaining phases involve creating a data mining model, evaluating the model and reporting findings.¹⁴ Following this systematic process allows reliable and representative analyses of real-world large data and produces novel, useful and understandable insights related to study objectives.¹⁶

Business and data understanding

To enable a comprehensive understanding of ACC processes, meetings with ACC, mTBI service providers and academics were held. Service schedules and operational guidelines of mTBI service contracts were used to understand the data within the wider clinical context and healthcare processes. Business Process Model Notation, a graphical notation that depicts the key players and their actions in a business process, was used to present the ACC mTBI healthcare pathway process.¹⁷ Business and data understanding revealed that ACC's mTBI data definition did not capture all mTBIs. Therefore, a list of International Classification of Diseases Version 10 codes (ICD 10 codes) and readcodes were used to define TBI and mTBI in this study (see Appendix 1). Data quality reports were created to direct the data preparation phase.

ACC data stored in three data sets (claims, payments and purchase orders) were retrieved. The mTBI patient ACC claims data for all ages for 1 September 2016 and 1 September 2018, and corresponding payment and purchase order data until 1 September 2020, were selected. The claims data set included information on the patient, their injury diagnoses, claim processing times and lodgement claim provider (first treatment of the pathway). The purchase order data set contained items created by ACC which represent the referrals (to another provider or requests for more patient treatments) by treatment providers. A description of the referral, requesting provider and referral processing times are included. The payments data set contained payments generated for all services the patient received, retrieved from invoices sent to ACC. The service item (the service provided to the patient at the most detailed level), the provider,

service date and cost were included.

Data preparation

The three data sets were merged, exclusion criterion applied (data outside study period, moderate and severe TBI, non-residents of New Zealand and declined claims), data cleaned and new variables derived. Service items were labelled with a type (treatment, administration for treatment, income maintenance, provider travel, patient travel, lump sum or other) based on item explanations found in ACC service schedules and operational guidelines. New variables were derived to answer research questions (e.g., time from injury to pathway exit). The final data set contained 55,494 unique claims, 696,800 unique payments and 63,642 unique referrals. Service dates, service types, date of mTBI code being added to the claim and treatment provider were used to determine common providers, follow-up rates, missed mTBI diagnoses and length of pathways. Injury, first treatment day and claim and referral processing dates were used to determine pathway delays. Data were combined to describe the healthcare pathway for each claim. Study definitions and details of data exclusion criterion are in Appendix 2 and Appendix 3.

Statistical analyses

All data in CSV files were analysed with Python (version 3.9.2). Data were highly skewed; therefore, results are reported as medians (Mdn), interquartile ranges (IQR), Fisher–Pearson coefficient of skewness (g_1) and Fisher's coefficient of kurtosis (g_2) with bias correction, frequencies and percentages. Some mean (M) and standard deviation (SD) values are reported for comparison with literature.

Results

Process model

Figure 1 outlines the process model for the ACC mTBI healthcare pathway (details in Appendix 4). Key events were patient injury, treatments with a treatment provider on the first day of treatment (where ACC 45 injury claim form was completed), claim lodgement to ACC, ACC claim registration, ACC claim acceptance or decline and second treatment day if claim was accepted, with treatment provider referral if needed. A referral required ACC approval: registration of referral (creation of purchase order) and ACC referral decision. ACC paid treatment providers for treatments invoiced and patients/employers for other expenses or income maintenance. The patient remained in the ACC mTBI healthcare pathway until no further services were required or approved by ACC.

Figure 1: Process model of ACC mTBI healthcare pathway showing patient first and second(+) treatments with treatment provider(s) and ACC interactions for claims and referrals for the patient.

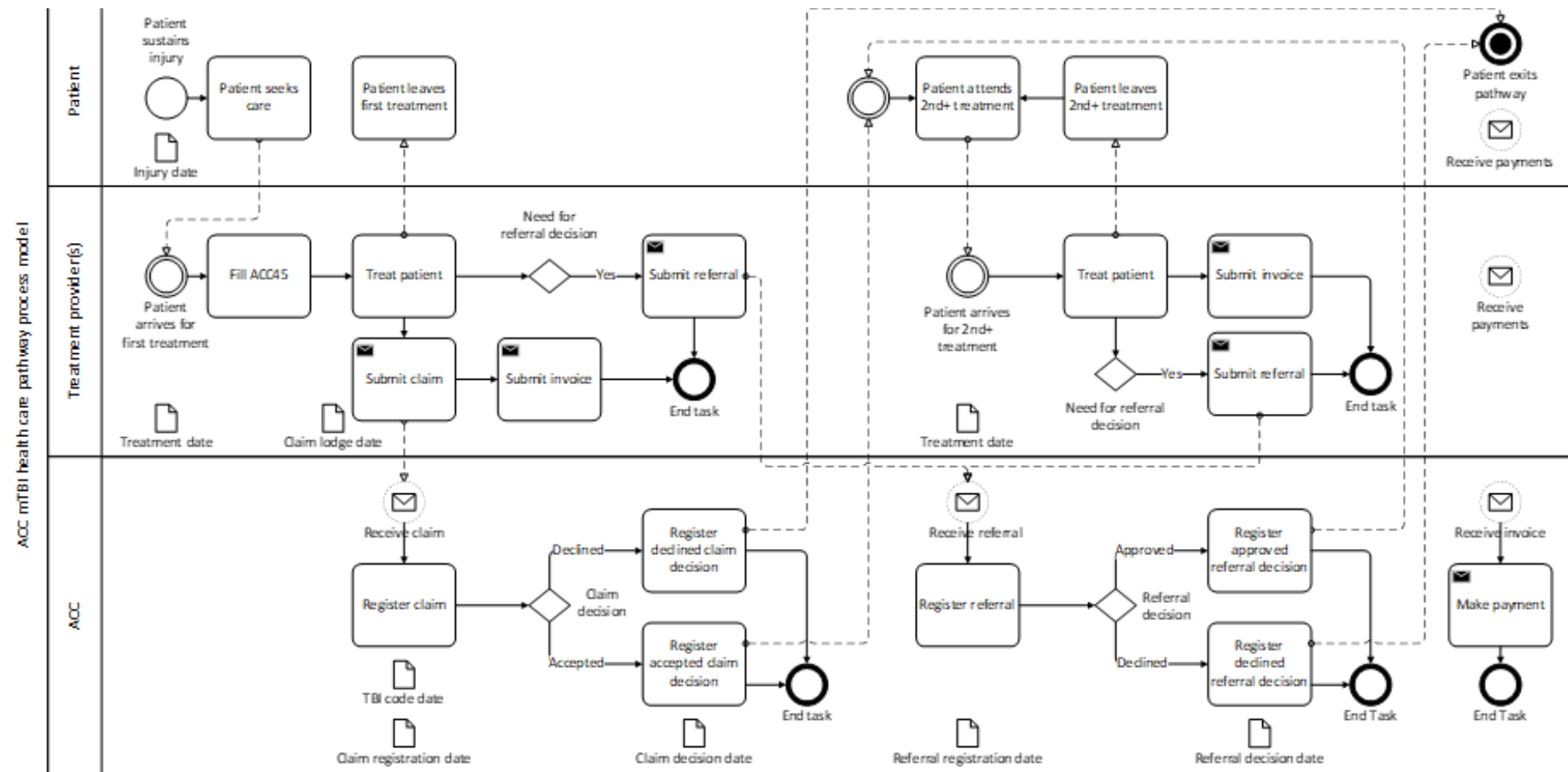


Table 1: Population characteristics of mTBI claims over the two years (September 2016 to September 2018) by sex and total patients.

		Female frequency (% of total 55,494)	Male frequency (% of total 55,494)	Total frequency (% of total 55,494)
Sex		22,707 (41)	32,787 (59)	55,494 (100)
Age at injury (mid-decade age bands)¹				
	00–04	1,642 (7)	2,375 (7)	4,017 (7)
	05–14	3,412 (15)	7,895 (24)	11,307 (20)
	15–34	8,538 (38)	14,363 (44)	22,901 (41)
	35–64	5,942 (26)	6,006 (18)	11,948 (22)
	≥65	3,173 (14)	2,148 (7)	5,321 (10)
Ethnicity				
	NZ European	15,511 (68)	20,529 (63)	36,040 (65)
	Māori	3,314 (15)	6,042 (18)	9,356 (17)
	Pacific Peoples	1,165 (5)	2,775 (8)	3,940 (7)
	Asian	1,483 (7)	1,730 (5)	3,213 (6)
	Other ethnicity	882 (4)	1,247 (4)	2,129 (4)
	Residual categories	352 (2)	464 (1)	816 (1)
Urban-rural residency profile				
	Urban	19,763 (87)	28,256 (86)	48,019 (87)
	Rural	2,901 (13)	4,474 (14)	7,375 (13)
	Unknown	43 (<1)	57 (<1)	100 (<1)
Residential region				
	Auckland	7,709 (34)	11,067 (34)	18,776 (34)
	Canterbury	3,106 (14)	4,510 (14)	7,616 (14)
	Waikato	2,431 (11)	3,574 (11)	6,005 (11)
	Wellington	2,083 (9)	2,813 (9)	4,896 (9)
	Otago	1,741 (8)	2,289 (7)	4,030 (7)
	Bay of Plenty	1,116 (5)	1,599 (5)	2,715 (5)
	Manawatū-Wanganui	958 (4)	1,419 (4)	2,377 (4)
	Northland	863 (4)	1,255 (4)	2,118 (4)
	Taranaki	730 (3)	1,201 (4)	1,931 (3)
	Hawkes Bay	601 (3)	891 (3)	1,492 (3)
	Southland	369 (2)	608 (2)	977 (2)

Table 1 (continued): Population characteristics of mTBI claims over the two years (September 2016 to September 2018) by sex and total patients.

		Female frequency (% of total 55,494)	Male frequency (% of total 55,494)	Total frequency (% of total 55,494)
Residential region				
	Gisborne	199 (1)	329 (1)	528 (1)
	Marlborough	206 (1)	310 (1)	516 (1)
	Tasman	193 (1)	293 (1)	486 (1)
	West Coast	177 (1)	288 (1)	465 (1)
	Nelson	180 (1)	276 (1)	456 (1)
	Unknown	43 (<1)	57 (<1)	100 (<1)
	Other	2 (<1)	8 (<1)	10 (<1)
Place of injury				
	Home	10,161 (45)	9,656 (29)	19,817 (36)
	Place of recreation or sports	3,873 (17)	9,544 (29)	13,417 (24)
	Road or street	3,161 (14)	4,434 (14)	7,595 (14)
	School	1,492 (7)	3,222 (10)	4,714 (8)
	Commercial/service location	1,120 (5)	1,519 (5)	2,639 (5)
	Industrial place	149 (1)	424 (1)	573 (1)
	Farm	227 (1)	271 (1)	498 (1)
	Place of medical treatment	131 (1)	109 (<1)	240 (<1)
	Other	2,359 (10)	3,547 (11)	5,906 (11)
	Not obtainable	34 (<1)	61 (<1)	95 (<1)
Mechanism of injury				
	Fall injury	12,654 (56)	14,614 (45)	27,268 (49)
	Sport injury	4,758 (21)	12,261 (37)	17,019 (31)
	Motor vehicle injury	1,993 (9)	2,507 (8)	4,500 (8)
	Assault injury	1,275 (6)	3,112 (9)	4,387 (8)
Employment status				
	Non-earners	13,869 (61)	19,756 (60)	33,625 (61)
	Employed	8,177 (36)	11,839 (36)	20,016 (36)
	Self-employed worker	661 (3)	1,192 (4)	1,853 (3)

Table 1 (continued): Population characteristics of mTBI claims over the two years (September 2016 to September 2018) by sex and total patients.

		Female frequency (% of total 55,494)	Male frequency (% of total 55,494)	Total frequency (% of total 55,494)
Work intensity				
	Sedentary work	14,525 (64)	19,773 (60)	34,298 (62)
	Light work	2,608 (11)	1,753 (5)	4,361 (8)
	Medium work	3,529 (16)	4,381 (13)	7,910 (14)
	Heavy work	1,080 (5)	4,059 (12)	5,139 (9)
	Very heavy work	197 (1)	1,676 (5)	1,873 (3)
	Not stated	768 (3)	1,145 (3)	1,913 (3)

* Mechanism of injury percentages represent the proportion of claims where mechanism of injury type is true, not percentage of total.

Table 2: Frequency and percentage of claims for the top 10 treatment providers for first-day treatments, no follow-up, and missed mTBI diagnosis.

Treatment providers	Number of first-day treatments (% of total 65,827)	Number of first-day treatments that did not result in a second treatment day (% of first provider treatments 40,144)	Number of first-day treatments where a TBI code was added after claim registration (% of first provider treatments 4,609)
General practitioners	40,385 (61)	24,815 (61)	2,160 (5)
Emergency departments	20,517 (31)	13,810 (67)	1,489 (7)
Radiologists	2,099 (3)	809 (39)	339 (16)
Dentists	767 (1)	115 (15)	183 (24)
Physiotherapists	588 (1)	89 (15)	78 (13)
Emergency transport	572 (1)	177 (31)	222 (39)
Nurses	382 (1)	267 (70)	28 (7)
Sports concussion clinic	81 (<1)	N/A**	1 (1)
Osteopaths	75 (<1)	12 (16)	11 (15)
Medical specialists	60 (<1)	16 (27)	17 (28)
Other	301 (<1)	10 (N/A)	81 (N/A)

*More than one treatment was provided on the first treatment day for some claims, therefore, the number of first day treatments was greater than the number of claims.

**Treatments for the sports concussion clinic were in bulk, therefore, number of treatment days could not be calculated.

Table 3: Frequency and percentage of claims (with clear pathway exit) for time from injury to pathway exit for the entire data set and for claims with more than one treatment day.

Time bands	Frequency for time to pathway exit for entire data set (% of total 54,881)	Frequency for time to pathway exit for claims with more than one treatment day (% of total 19,800)
0-7 days	33,814 (62)	3,113 (16)
1-2 weeks	4,221 (8)	2,280 (12)
2-4 weeks	4,215 (8)	2,855 (14)
1-2 months	2,970 (5)	2,336 (12)
2-6 months	4,502 (8)	4,212 (21)
6-12 months	2,729 (5)	2,627 (13)
12+ months	2,430 (4)	2,377 (12)

Figure 2: Distribution of time from injury to pathway exit for the entire data set and for claims with more than one treatment day. A broken y-axis has been used for the entire data set.

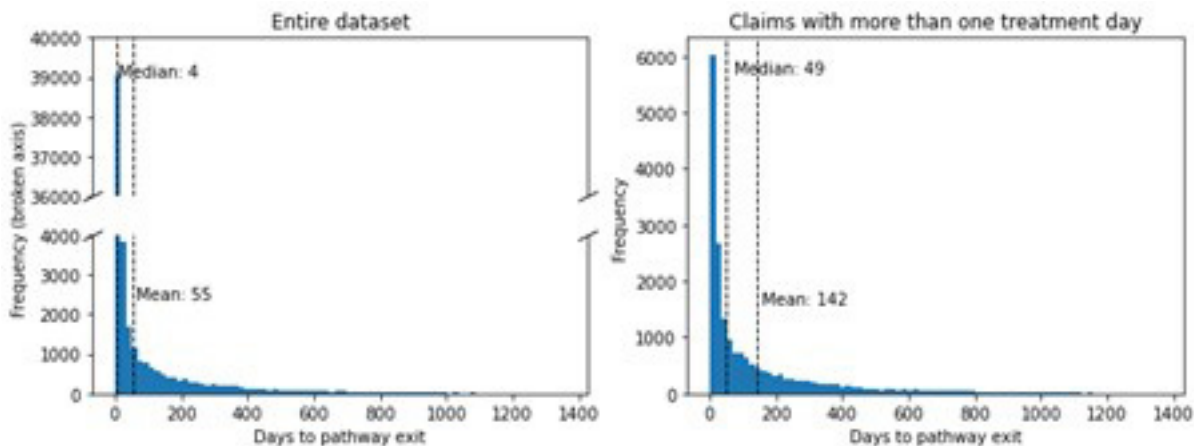
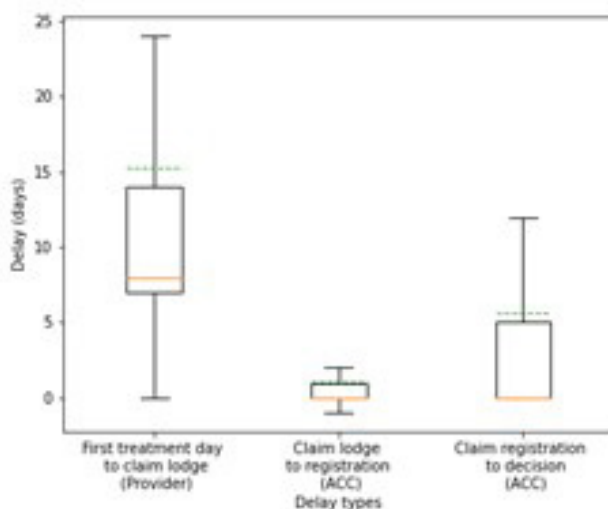


Figure 3: Individual delays for claims with total claim processing time of seven days or more (first treatment to claim decision).



Outliers have been excluded from the figure to improve clarity. Dashed green line represents the mean.

Table 4: Time from injury to first treatment and referral registration to decision for all claims and individual claim processing delays for patients with seven days or more of total claim processing delay represented as frequency and percentages.

	Claim processing delays for claims with seven or more days from first treatment to claim decision				
	Patient to provider	Provider to ACC	ACC		ACC
Delay	Injury to first treatment day (% of total 55,485*)	First treatment day to claim lodgement (% of total 3,233**)	Claim lodgement to registration (% of total 3,647)	Claim registration to decision (% of total 3,647)	Referral registration to decision (% of total 63,642)
0 days	15,907 (29)	83 (3)	2,648 (73)	2,519 (69)	41,274 (65)
1 day	12,379 (22)	154 (5)	583 (16)	65 (2)	586 (1)
2 days	8,202 (15)	91 (3)	149 (4)	30 (1)	230 (<1)
3 days	5,131 (9)	95 (3)	143 (4)	41 (1)	250 (<1)
4-7 days	7,243 (13)	905 (28)	64 (2)	284 (8)	998 (2)
1-2 weeks	3,058 (6)	1,129 (35)	0 (0)	385 (11)	2,033 (3)
2-4 weeks	2,024 (4)	493 (15)	2 (<1)	220 (6)	4,150 (7)
1-2 months	899 (2)	156 (5)	0 (0)	68 (2)	4,031 (6)
2-6 months	476 (1)	97 (3)	0 (0)	27 (1)	75,23 (12)
6-12 months	135 (<1)	18 (1)	0 (0)	0 (0)	1,874 (3)
12+ months	31 (<1)	2 (<1)	4 (<1)	8 (<1)	530 (1)
Negative days			54 (1)***		163 (<1)****

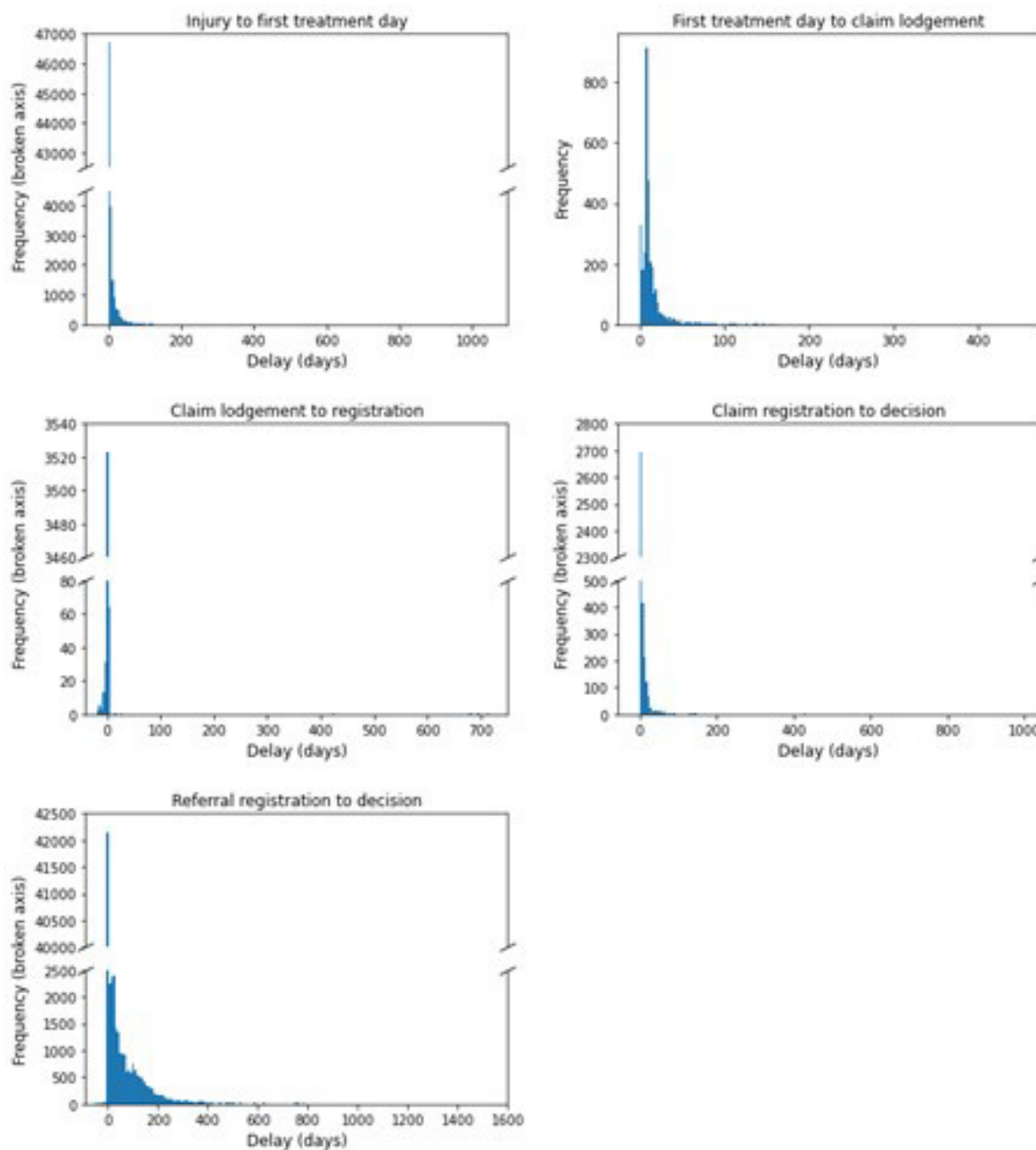
*Nine injuries occurred at place of medical treatment and did not have any following treatment days. These were excluded for the calculation for time from injury to first treatment day.

**24,421 first treatment days were missing from the payments data set. These were identified from the claims data set when data sets were merged. The date of claim lodgement was used as a proxy for date of first treatment day for these claims. Therefore, they were excluded for the calculation for time from first treatment day to claim lodgement.

***Negative claim lodgement to registration days could be due to the injury being registered without a claim via another form of communication and a claim was later lodged, or an incorrect input of lodge date from ACC.

****Negative referral registration to decision days were presumed to be indicative of an automatically approved service being provided with a referral retrospectively created later. Most negative referrals were for emergency transport.

Figure 4: Distribution of individual delay times in the pathway: injury to first treatment day; claim processing delays, for claims with more than one week from first treatment day to claim decision; referral registration to decision. Broken y-axes have been used for all delays apart from first treatment day to claim lodgement.



Claims characteristics

For the two years there were 55,494 (>99%) accepted mTBI claims; 41% were for patients aged 15–34, 59% were males, and half of all mTBI were caused by a fall (Table 1).

Pathway characteristics

General practitioners provided 61% of all 65,827 first-day treatments (Table 2). Only 36% of patients (19,800) had another treatment day (follow-up) after initial medical presentation (40% for sport-related mTBIs). General practitioners, emergency departments and nurses had the highest percentage of first-day treatments with no follow-up. A TBI code was added after claim registration (i.e., indicative of missed mTBI diagnosis) in 6% (3,382) of claims. For half of these claims (1,620) it took longer than two weeks for a TBI code to be added. Emergency transport had the highest percentage of missed mTBIs (Table 2).

Time to pathway exit

For 54,881 claims (99%) where the patient pathway exit could be clearly determined (i.e., no further services received for 90 days prior to study end), median and average times in the healthcare pathway ranged between four and 55 days (IQR, 1–25; g_1 , 4.0; g_2 , 18.9; SD, 141.1). For claims with more than one treatment day, median and average number of days until patient pathway exit ranged between 49 and 142 days (IQR, 12–185; g_1 , 2.3; g_2 , 5.6; SD, 204.4). Table 3 shows times to exit pathway for both cohorts, and Figure 2 shows the distribution of the data.

Pathway delay times

The median days from injury to first treatment (medical presentation) was one day (IQR, 0–3; g_1 , 15.4; g_2 , 358.0). Total claim processing time (first treatment day to claim decision) was seven days or longer for 7% (3,647) of claims. In this cohort, the median days from first treatment to claim lodgement was eight days (IQR, 7–14; g_1 , 6.9; g_2 , 65.7), zero days from lodgement to registration (IQR, 0–1; g_1 , 31.3; g_2 , 996.6), and zero days from registration to decision (IQR, 0–5; g_1 , 20.4; g_2 , 532.0) (Figure 3). Time from injury to first treatment day for all claims and individual claim processing delays for patients with seven days or more of total claim processing delay are presented in Table 4. All except 327 (<1%) of 63,642 referrals were approved by ACC. Median time for referral registration to decision was zero days (IQR, 0–22; g_1 , 5.1; g_2 , 43.5). However, 33% of referral deci-

sions took more than three days (21,139) (Table 4). There were 53,207 (24%) treatments delivered by a provider prior to referral approval and 78% of claims with a declined referral exited the pathway after the referral was declined. The distributions of delay times are presented in Figure 4.

Concussion clinics

Concussion clinics provided treatment to 10% (5,485) of claims. Of 5,498 concussion clinic referrals, only 13 (<1%) were declined. ACC took a median of 31 days (IQR, 3–99; g_1 , 2.7; g_2 , 14.3) from registration date to reach a decision for a concussion clinic referral. Median and average number of days from injury to first concussion clinic treatment were 32 and 55 days (IQR, 20–60; g_1 , 4.2; g_2 , 33.6; SD, 65.4). Of all claims, 25% (1,356) took more than two months to be seen by a concussion clinic.

Discussion

Streamlining patient care is crucial to patient satisfaction and optimised recovery, yet this study showed the ACC mTBI healthcare pathway in New Zealand can be difficult to navigate. Most patients' claims and referrals were accepted by ACC and administrative claim and referral processes resulted in minimal delays. However, while percentages of the overall sample were small, delays in receiving a mTBI code and time to approval of their claims or referrals affected thousands of people. Some mTBI diagnoses were delayed, only 36% of claims received a follow-up appointment and one in four needing specialist services had delayed access to service of >2 months. Pathways could be improved by reducing unnecessary administrative processes, facilitating mTBI diagnosis on initial presentation of injury, improving rates of follow-up and routine collection of patient outcome data.

To enable patients to seek medical advice promptly, good public awareness of mTBI signs and symptoms is needed, alongside confidence in the healthcare system. While studies have shown good awareness of signs and symptoms in sports athletes (although some misconceptions such as how a brain injury occurs remain),^{18,19} little is known about general public knowledge to inform patient awareness campaigns. This is relevant given findings showed that most injuries occurred outside of the sports context. Most patients (75%) presenting for medical treatment were seen in the first three days after injury. However, 6,623 claims (12%) took over one week to be seen after injury.

Given the importance of appropriate and early management of mTBI,⁴ analyses of characteristics of these patients (such as residential region and ethnicity) may locate subgroups for interventions to increase motivation for and access to medical treatment after mTBI. Additionally, data on when the patient makes an appointment and when they receive treatment could reveal issues with access to care due to availability of the providers who require appointments to be booked, such as general practitioners.

Previous estimates from incidence studies in New Zealand have suggested that 70,000 mTBIs occur over two years,¹ which is more than the 55,494 accepted claims identified in this data set. This suggests that >10,000 New Zealanders did not have an ACC claim following mTBI. While some participants experience ongoing difficulties after mTBI,^{3,11-13} many recover naturally. It may be that the >10,000 cases with no claim did not feel the need to seek medical treatment as their symptoms were minor and/or they recovered well. However, it may also be that some mTBIs may have been missed. Indeed, one New Zealand study revealed 19% of people with mTBI did not have a TBI code on their ACC claim.²⁰ A standardised screening process for people at risk of mTBI following a traumatic accident such as assault, vehicle accident or fall from a height may help to pick up missed mTBI cases early.²¹ Additionally, 6% of cases had a delay in a mTBI code being added to their claim. This is likely due to patients presenting to allied health professionals such as physiotherapists who are not able to use TBI diagnostic codes, or the need for medical doctors to focus on more acute injuries. Without a relevant diagnostic code, questions may be raised about the appropriateness and acceptance of claims or referrals for treatment and lead to significant pathway delays. Permitted use of a “suspected mTBI” code may be useful in these circumstances to highlight the need for medical review and diagnosis.

Ontario Neurotrauma Foundation guidelines for mTBI⁴ recommend timely telephone and/or in-person follow-up after initial medical presentation to check for recovery and to ensure the person can access further advice and treatment services. However, our study revealed that two-thirds of patients did not receive a follow-up appointment. While medical clearance before a return to sport is recommended, only 40% of those who sustained a sport-related mTBI received a follow-up appointment. Patients can find it hard to ask for help and need someone else to drive the

process and to navigate the healthcare system.¹² Consequently, processes are needed to prompt the booking of a follow-up appointment after initial medical presentation to ensure this process is proactively led by services.

ACC does not routinely collect or integrate patient outcome data within its core database. Therefore, it was difficult to determine whether patients exited the pathway because they had recovered from injury or whether pathway exit was due to lack of follow-up from the treatment provider, the patient deciding to not continue to seek care, the patient seeking treatment from providers not covered by ACC or ACC declining or terminating cover for services. Similarly, it was not clear if the 64% of claims that had one treatment day did not need further follow-up, did not know to seek further support, or had the means to access further support. To account for this, analysis only looked at claims with more than one treatment day which had significant implications on the results. In this reduced cohort, the percentage of claims that exited the pathway within seven days dropped from 62% to 16%, the median day from injury to pathway exit increased from four to 49 days and time to exit pathway became more distributed. Processes to routinely monitor and record patient outcomes are needed to ensure full patient recovery before pathway exit and to allow further evaluation of the healthcare pathway.

Time from injury to receipt of concussion clinic services was longer (mean 55 days) in comparison to a New Zealand sports concussion clinic study where people could self-refer (mean 9 days).²² For those who attended the self-referral clinic 45% of participants showed clinical recovery within 14 days of injury, 77% by four weeks after injury, and 96% by eight weeks after injury.²² In our study, only 28% of claims exited the pathway within 14 days of injury (as an indicator of recovery), 42% by four weeks after injury, 54% by eight weeks after injury, with 12% of claims (2,377) still in the pathway after 12 months after injury. Evidence has shown that delays to concussion services can lead to deterioration of symptoms.⁹ Earlier referral to specialist concussion clinics for patients who need it could significantly improve patient outcomes.

Less than 1% of mTBI claims were declined over the two years, suggesting that claims were appropriate in most cases. Given the low rates of declined claims, the requirement of an ACC decision for claim cover could be removed from the pathway. To receive a recommended follow-up

covered by ACC within 7–10 days of injury,⁵ the claim needs to be accepted in under a week from the date of first treatment. This was not the case for 3,647 claims where the delay in providers lodging the claim after treatment was the main contributor to not meeting this target. This may be because a follow-up appointment was not a requirement in the ACC mild TBI strategy and treatment providers may not be aware of the importance of follow-up. Given that general practitioners and emergency departments together provide 92% of first-day treatments but have low rates of arranging follow-up (60–67%), practitioner education on the importance of follow-ups is needed to facilitate referrals. Patient costs for a follow-up appointment are likely to be prohibitive.²³ Funding of follow-up appointments following a mild TBI may increase the likelihood of keeping the patient in the system until they have recovered.

Referrals require ACC approval prior to treatment. If a referral decision is reached within three days, it allows time for delays in treatment provider availability for a patient to receive further treatment within 1–2 weeks of the last treatment. One in three referral decisions took more than three days to process. To counter this key delay in the healthcare pathway to provide timely care, some treatment providers delivered treatment prior to referrals being approved. In such cases, if the referral was declined, the treatment provider was left to cover costs. Therefore, this delay affected both patient care and treatment providers. The <1% declined referrals suggest that treatment providers were making valid referrals. In most cases, a declined referral resulted in the patient leaving the pathway. This means that the patient did not receive any further treatment, despite the treatment provider's opinion of more treatment being necessary. Given the effect that referral processing times and decisions have on patient and treatment providers, the pathway could be improved by removing the need for referral approval. A standardised screening assessment and referral criteria such as the Brain Injury Screening Tool²¹ may facilitate mTBI

healthcare pathway navigation, provide outcome monitoring and reduce time in service.

The structure and quality of ACC data and complexity of ACC processes meant that reliable healthcare pathway analysis would not have been possible without use of the systematic approach CRISP-DM methodology. From domain and data understanding gained, key players, their roles and potential delays in healthcare provision were identified and data mapped onto this pathway. Construction of meaningful variables that could be clearly defined enabled mapping of the real-world journey from the perspective of patients. Findings of this study would have varied significantly if different data definitions and a service perspective were used. Our study likely captured more mTBIs than other ACC reported findings because TBI codes from the literature were used that are not part of the ACC mTBI definition. The more inclusive definition used is recommended for future studies utilising ACC data.

There were limitations to our analysis. Data relied on accurate use of diagnostic codes to identify mTBIs, yet it is acknowledged mTBIs may have been missed or coded inaccurately due to an inability of allied health professionals to use a mTBI code. Patients who sought care from non-ACC funded services at onset or during the pathway were not captured in this analysis. The lack of outcome data was a key limitation in analyses and use of cessation of services as recovery may have prevented identification of some issues with the mTBI pathway. Treatment delays due to lack of availability of providers may have existed but were not captured or stored in the ACC database. The ACC relational databases used to store data limited our ability to extract useful insights on relationships between variables useful for healthcare pathways. More complex and flexible data representation and querying would provide better patient journey insights to improve the ACC mTBI healthcare pathway. Future research should analyse how pathway characteristics differ based on different sub populations such as children and adults, residential region, ethnicity and sex.

COMPETING INTERESTS

Nil.

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Data availability statement: Due to restrictions on use of data stated in the data sharing agreement, the research team are not able to share the data used for these analyses. However, data sets generated and analysed during the current study may be requested via ACC.

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Appendices

Appendix 1: TBI and mTBI definition.

Drawing from International Classification of Diseases Version 10 codes (ICD 10 codes) used to identify administrative TBI data in the literature²⁴⁻²⁹ and research team expertise, a list of ICD 10 codes and Readcodes were used to define mTBI and moderate to severe TBI in this study and are listed in the appended Excel sheet (converted for these purposes into a Word table: https://uploads-ssl.webflow.com/5e332a62c703f6340a2faf44/633cb73f8edd88cf64ec34f3_5821%20-%20Appendix%201%20Table.pdf.)

Appendix 2: Definitions used in the study.

Service item	The service provided to the patient at the most detailed level, the entity that represents a row in the payments data set.	
Service types (service items grouped into categories)	Treatments	Health-related service items i.e., service items that involved an assessment or treatment of the patient by health-related professionals. Health-related professionals that were identifiable in service items included: acupuncturists; allied health practitioner; audiologists; chiropractors; general practitioners; neurologists; neuropsychologists nurses; occupational therapists; optometrists; osteopaths; physiotherapists; psychiatrists; urgent care practitioners; and vocational rehabilitation practitioners.
	Administration for treatment	Service items that a treatment provider undertakes related to a treatment e.g., report writing.
	Patient travel	Service items related to patient travel.
	Provider travel	Service items related to treatment provider travel to provide a treatment.
	Income maintenance	Service items for payments to the patient or to the employer to cover the patient's income until full return to work is established.
	Lump sum	Service items for compensation for permanent impairments.
	Other	Service items that do not meet other category definitions e.g., non-attendance fees, equipment, vehicle repairs, public holiday supplement and medication.
Services	Any of the service types	
Treatment providers	Categories of health professionals based on the ACC service contract they delivered the treatment under e.g., a medical doctor delivering treatment at a concussion clinic would be categorised as concussion clinic.	
Treatment day	Ranked dates of the healthcare pathway that contain treatments for a claim.	
First treatment day	The first date where treatments are delivered for a claim.	
Known pathway exit claims	Claims that have at least 90 days between last service date and the end of study time period (1 September 2020).	
Pathway exit	Date of last service.	
Services	Any of the service types	
ACC mTBI healthcare pathway	The experiences and journey of the mTBI patient related to the ACC claim and provision of ACC funded services from date of injury to date of pathway exit.	
Urban-rural residency profile	ACC records the residential area unit of the patient based on the 2006 New Zealand area unit definition. The urban-rural profile for the 2006 New Zealand area unit was obtained from Statistics New Zealand and used to label residential area units of patients in this study as urban or rural. Where residential address information was unavailable, the variable was labelled as "Unknown".	

Appendix 3: Data exclusion criterion.

All available data from the three data sets (claims, purchase orders and payments) for all TBI and possible TBI diagnostic codes where the injury occurred in the period of 1 September 2016 to 1 September 2020, including any other claims that were lodged by the TBI patient 14 months prior to and after the TBI claim were requested from ACC. Claims were included if they had at least one mTBI diagnostic code (readcode or ICD 10 code) in any of the readcode or ICD 10 code positions on the ACC 45 form. Claims that also contained moderate or severe TBI codes were excluded. mTBI claims for injuries occurring between 1 September 2016 and 1 September 2018 were included, along with their corresponding payment and purchase order data until 1 September 2020. The cohort of pre- and post-mTBI claims was removed for this study. ACC covers injuries sustained in New Zealand regardless of residency status. Therefore, claims for patients that had a residential and occupational address outside of New Zealand (where applicable) were excluded to mitigate the chance of pathway exits being due to non-New Zealand residents leaving New Zealand. Declined claims were counted then excluded from the analysis.

Appendix 4: Description of the process model for the ACC mTBI healthcare pathway.

Figure 1 outlines the process model for the ACC mTBI healthcare pathway. When a patient sustains an injury (injury date) and reports to a treatment provider for care (treatment date), e.g., general practitioner, the treatment provider assesses and treats the injury and fills out an ACC 45 injury claim form. This form contains the information about the patient, the injury, the injury diagnosis and the provider. The patient then leaves the first treatment. The treatment provider lodges a claim by submitting the ACC 45 form to ACC (claim lodge date). A delay between the treatment date and the lodge date exists if the ACC 45 form is submitted after the day of the treatment. If the claim is submitted in electronic format, the claim is automatically registered in the ACC system. In this case, the date the claim is registered (claim registration date) is the same as the claim lodge date. If the claim is submitted in paper form via email, the ACC 45 form needs to be manually registered into the ACC system by a member of the ACC registration team. This can cause a delay between claim lodge date and claim registration date. The injury diagnostic codes on the form are input into the system at the same time the claim is registered. Therefore, if a TBI has been diagnosed by the provider who delivered the first treatment, the TBI code date will be equal to the claim registration date. A missed TBI diagnosis can be identified when a TBI code is added after the claim is registered, meaning that it was later diagnosed by the same or different provider. Once the claim is registered, ACC decides whether to accept or decline the claim (claim decision date). The decision is made based on the information on the ACC 45 form, additional requested information from the patient or provider, and a medical opinion from ACC medical staff. If the claim is declined, the patient can initiate a review process that can result in the claim decision remaining or the claim being accepted. Due to this decision process, a delay between claim registration date and claim decision date can exist. If the claim is declined or further care is not required, the patient leaves the ACC mTBI healthcare pathway. If the claim is accepted and requires further services, the patient can continue to seek care from the same or a different treatment provider. The treatment provider may make a referral to another treatment provider or request more treatments for the patient. Certain treatments are covered by ACC for mTBIs without needing ACC approval. If required treatments need to be approved by ACC (e.g., referral to concussion clinic), the treatment provider submits a referral request to ACC. When the request is received by ACC, purchase order (PO) lines are created (referral registration date) and ACC decides whether to approve or decline the referral (referral decision date). The time it takes ACC to make the decision can cause a delay between referral registration date and referral decision date. If the referral is declined, the patient is not covered to receive the corresponding treatments and if other available treatments are not suitable, the patient may leave the ACC mTBI healthcare pathway. If the referral is approved, the patient can continue to receive treatment. In some instances, a provider will deliver a treatment that requires ACC approval prior to the decision being reached. In this case, the treatment date for a referral will be prior to its decision date. If the referral is declined, the treatment provider usually funds the treatment that was provided. Treatment providers invoice ACC for services delivered after the treatments. ACC pays the treatment providers, and treatment details and costs on the invoice are stored in the ACC database. ACC may also pay patients for income maintenance, lump sums, treatment costs paid by the patient and other expenses that are also recorded. The patient remains in the ACC mTBI healthcare pathway until no further services are required or approved by ACC.