Identifying cases of chronic pain using health administrative data: A validation study

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Abstract

Background: Chronic pain is a pervasive and challenging public health issue. Prevalence estimates vary widely, both globally (2-54%) and in Canada (6.5-44%). Most estimates are derived from surveys, which are expensive and labour intensive. Health administrative data is a potential easily-accessed, low-cost method to obtain epidemiological and cost estimates of chronic pain, but its validity as a source to ascertain cases of this complex and multi-faceted condition is unknown. The purpose of this study was to derive and validate an algorithm to identify cases of chronic pain using health administrative data.

Methods: A reference standard was developed and applied to the electronic medical records data of a general population sample participating in the Canadian Primary Care Sentinel Surveillance Network. Preliminary chronic pain algorithms were then created and refined through health administrative data analysis of four populations with known chronic pain diagnoses. Classification performance of the chronic pain administrative data algorithms was compared to that of the reference standard, and statistical tests of selection accuracy (sensitivity, specificity, positive predictive value, negative predictive value, likelihood ratio positive, likelihood ratio negative, diagnostic odds ratio, Kappa agreement, and area under the Receiver Operating Characteristic curve) were calculated.

Results: The optimal algorithm to ascertain cases of chronic pain from health administrative data was a combination of one chronic pain clinic procedure code OR five physician claims with a pain-related diagnostic code in five years with more than 183 days separating at least two claims. The sensitivity was 0.703 (0.684-0.721 95% confidence interval), the specificity was 0.668 (0.657-0.679 95% confidence interval), and the positive predictive value was 0.408(0.398-0.418 95% confidence interval). The Chronic Pain Algorithm identified 37.6% of a Newfoundland and Labrador provincial cohort.

Conclusions: Health administrative data is a valid source for information on chronic pain in Canada. The optimal chronic pain algorithm can be used to determine epidemiology and health care utilization statistics on people seeking physician care for chronic pain, and to evaluate cost effectiveness of any change to policy or health service delivery.

Background

Chronic pain is a pervasive and challenging public health issue [1-5]. Globally, prevalence estimates range drastically from 2 to 54% [2,4,6-11], with similar variability reported in Canada (6.5-44%) [3,12-21]. Such variability in prevalence creates uncertainty when planning for present and future health care needs. Annual costs related to chronic pain in Canada are expected to exceed over $10 billion by 2025 [19,22,23]. In Canada, chronic pain prevalence estimates were derived from national or regional surveys [3,12,15-20]. Although surveys provide descriptive information, they are expensive and labour intensive [24]. Another easily-accessible and low-cost method to obtain prevalence estimates is to use algorithms applied to health administrative data that is collected by provinces in Canada [25]. Whether cases of chronic pain, a complex and multi-faceted condition, could be extracted from administrative data is not known. If accurate and valid, this technique will enable a rapid and efficient method to obtain important epidemiological, health planning, and policy data for this important chronic condition.

Each province and territory in Canada administers universal health plans that cover most hospital and physician services to nearly all of their residents [26]. Despite only capturing information obtained through physician and hospital encounters, the health administrative data generated is used to extract annual population-based estimates on distribution, trends, and direct health care costs of various medical conditions in Canada through validated algorithms [27]. Previous studies on chronic pain that used administrative data ascertained cases through convenience samples [28], surveys [29], code sets not previously validated [4,30], or validated algorithms for specific pain conditions [31-34], such as low back pain [35]. One study successfully derived a chronic pain case definition for electronic medical record data [11], but the clinical information utilized (in an American health care setting) is not universally collected and is not available in Canadian administrative data [36,37].

The growing dependence on administrative data for chronic disease surveillance emphasizes the importance of using valid algorithms for case ascertainment [25]. The challenge of using health administrative datasets is that its record level data is not collected for research purposes and is often plagued with poor quality and significant variation [25,38]. This is exacerbated by chronic pain often being considered a symptom of another trauma or disease process with no objective diagnostic “gold standard” to use for validation [1,4,11,39,40], unlike other chronic diseases with standard objective diagnostic tests such as Diabetes [41,42], Multiple Sclerosis [38], and Rheumatoid Arthritis [43]. Applying standardized methodology to create, validate, and report administrative data algorithms that identify cases of chronic pain as “a single disease entity” [44] advances the utility of the information obtained and examined by researchers, clinicians, and health policy makers [25].

An administrative data algorithm is a combination of diagnostic and procedural code patterns (known as spatial frequency) together with encounter frequency patterns (known as temporal frequency) [25,45]. It operates similar to diagnostic testing in medical practice [25,45]. A chronic pain algorithm must include spatial and temporal frequency criteria that align with accepted practice in the diagnosis of chronic pain [25]. A standardized set of diagnostic and/or procedural codes is required to identify chronic pain-related conditions and treatments in administrative data [25]. Pain extending beyond three months post onset, or six months for the purposes of research, as defined by The International Association for the Study of Pain is the required temporal benchmark for chronic pain case ascertainment [46]. A review of eleven studies in the field revealed eleven different chronic pain definitions and/or code sets used in research [2-4,7-10,15,20,30,47]. Currently, there is no consistency in chronic pain research regarding appropriate spatial and temporal frequency.

The aim of the present study was to determine whether Canadian health administrative data would provide valid information on cases of chronic pain. The study sought to achieve this by using administrative data collected in one Canadian province, Newfoundland and Labrador (NL), to develop an algorithm with the appropriate spatial and temporal criteria. Validity and reliability were examined against an electronic medical record database audit. This study marks the first step in addressing the long-term goal of compiling detailed statistics on the chronic pain condition in the Canadian context, which can be used to inform policy around health service provision for this high needs population.

Methods

Setting

The Canadian Primary Care Sentinel Surveillance Network (CPCSSN)-NL data was used for algorithm validation. The CPCSSN is a clinical data source comprised of information retrieved directly from the electronic medical records of consenting patients attending participating primary care practices across Canada [48]. In February 2013, the CPCSSN-NL was receiving de-identified data on just over 35 000 patients of all ages (approximately 7% of the NL population) [49] annually from 45 physicians (approximately 9% of the NL registered primary care physicians) [50] practicing in 8 primary care clinics in mainly urban NL [51].

The CPCSSN data elements include diagnostic codes, medical record text, health conditions problem list, medical procedures table, and medications prescribed by the attending primary care physician [52]. The World Health Organization maintains and updates a standardized system of numeric or alphanumeric codes to classify medical diagnoses called the International Classification of Disease (ICD), and the CPCSSN utilizes three- to five-digit codes from the 9th revision of the ICD (ICD-9) [52, 53]. Clinical data is organized via the patient's unique health insurance number and is de-identified prior to data transfer to CPCSSN [48]. The CPCSSN data undergoes rigorous quality control procedures and was previously determined to be a valid data source to study eight chronic diseases [54], and a valid proxy (77.5–97.2% sensitivity and 93.1–99.4% specificity) to manual review of electronic chart raw data for validation studies [55].

Reference Standard Cohort and reference standard

The Reference Standard Cohort was comprised of primary care patients of all ages who met the inclusion criteria of consent to participate in the CPCSSN-NL since December 31, 2009 or earlier and had a minimum of two years of electronic medical record data for analysis. Since the CPCSSN-NL data has only been collected since 2005 [48], the data range from January 1, 2006 to December 31, 2011 was extracted for this cohort.

Using both spatial and temporal benchmarks that align with a chronic pain definition, the CPCSSN-NL reference standard for chronic pain was developed by combining ICD-9 diagnostic codes, Anatomical Therapeutic Chemical Classification Codes, textual data, and encounter frequency from the CPCSSN data. The reference standard was based on published literature [4, 11, 30, 31, 33–35, 39, 56–62], consultation with chronic pain experts (HF, ET, and JF) and a pharmacy expert (CD), and codes/text utilized in the CPCSSN-NL data. Patients in the Reference Standard Cohort were classified as having chronic pain if any one of the following CPCSSN-NL data criteria was met: 1) a single encounter date with (the ICD-9 diagnostic codes 338.0, 338.2[1], or 338.4) OR (text with "chronic" and "pain" in the same text entry not necessarily following each other); OR 2) receipt of at least 90 days of opioid medication used almost exclusively for pain (Supplementary Table 1, Additional file 1) in the CPCSSN-NL study period; OR 3) four or more encounter dates with (an ICD-9 pain-related diagnostic code (Supplementary Table 2, Additional file 1)) OR (text with "pain") within a 2-year period with more than 183 days separating at least two pain-related encounter dates.

Administrative data sources

Two administrative data sources were used for the chronic pain algorithms: 1) the Provincial Discharge Abstract Database (NL Discharge Abstract Data), which is the NL component of the Canadian Institute of Health Information national Discharge Abstracts Database, containing information on all separations from acute health care facilities in NL, including admission date and up to 16 diagnostic codes, and 2) Medical Care Plan (MCP) Fee-for-Service Physicians Claims File (MCP Claims File) containing information, including one diagnostic code and one provincial billing code, on all claims for health services provided by fee-for-service physicians in NL. All data is organized by each NL resident's unique health insurance number [36, 63].

All NL Discharge Abstract and MCP Claims File data is used for research and surveillance of multiple injuries and disease states [27]. Rigorous quality control procedures are applied to the NL Discharge Abstract data on an annual basis, and MCP Claims File data is considered complete due to its collection for service remuneration [51, 64, 65]. The MCP Beneficiary File was used to obtain demographic and benefits eligibility information, including age, sex, rural/urban location of residence, and health authority region of residence. All required record-level data from January 1, 1999 to March 31, 2010 were obtained from these datasets.

The NL Discharge Abstract Data used five-digit ICD-9 codes up to March 31, 2001, and six-digit ICD-10(Canadian) codes from April 1, 2001 onwards. The MCP Claims File data used three-digit ICD-9 codes throughout the data study period. Although the eleventh revision of the ICD contains specific classifications of chronic pain conditions [40], the ICD-9 and ICD-10(Canadian) do not [53]. To account for the many proxies used by clinicians and researchers for pain-related diagnoses [4, 11, 30, 39], previous studies [4, 11, 30, 31, 33–35, 39, 56–61] and consultation with pain experts (HF, ET, and JF) were used to select the pain-related ICD-9 and ICD-10(Canadian) diagnostic codes (Supplementary Table 3, Additional file 1) searched in the NL administrative data. Chronic pain-related provincial procedure codes (Supplementary Table 4, Additional file 1) searched in the MCP Claims File were reserved for medical assessment and treatment of people with chronic pain carried out by anesthesiologists in "organized hospital pain clinics" [66].

Administrative data algorithms

Convenience samples of known chronic pain cases were obtained to develop and sensitivity-test preliminary chronic pain algorithms. Inclusion criteria for the pain populations were: 1) attending an interdisciplinary chronic pain rehabilitation program from 2006–2011, 2) attending an interdisciplinary chronic pain rehabilitation program from 1999–2005, 3) being on the waitlist to attend an interdisciplinary chronic pain rehabilitation program on September 1, 2012, or 4) being prescribed and dispensed any opioid medication used almost exclusively for pain (Supplementary Table 1, Additional file 1) during the period from 1999–2011 as a subsidized patient of the NL Prescription Drug Program. The interdisciplinary chronic pain rehabilitation program is located in St. John's, NL,

and is known as the Centre for Pain and Disability Management [67]. The NL Prescription Drug Program provides financial assistance for eligible prescription medications to qualified seniors and low-income individuals/families [68].

For the algorithm development step, MCP Claims File and NL Discharge Abstract Data for the pain population attending the interdisciplinary chronic pain rehabilitation program from 2006–2011 was searched for the presence of pain-related diagnostic and procedure codes (spatial benchmarks). Encounter and hospitalization dates associated with pain-related diagnostic codes were searched for the presence of the six-month temporal benchmark. Preliminary algorithms were created by combining the presence of: 1) chronic pain-related procedure codes (Supplementary Table 4, Additional file 1) in the MCP Claims File, 2) one or more entries by a medical specialist recording a pain-related diagnostic code (Supplementary Table 3, Additional file 1) in either the MCP Claims File or NL Discharge Abstract Data, and 3) required number of entries by any physician recording a pain-related diagnostic code (2–5 claims and/or hospitalizations) and more than 183 days separating at least two entry dates in the MCP Claims File or the NL Discharge Abstract Data. Initially, the algorithms were observed for all available years of the data (1999–2010). The algorithms were then observed for specified time windows to maximize potential chronic disease surveillance utility. A previous study identified up to seven years as the optimal clearance period for recurrent low back pain [69]; therefore, the time windows of between one and seven years was chosen to observe required algorithm spatial and temporal benchmarks.

For the preliminary algorithm sensitivity-testing step, the algorithms were tested for sensitivity on the administrative data of the four pain population groups.

For the algorithm validation and selection step, a refined list of algorithms was selected, applied to the Reference Standard Cohort administrative data, and rigorously tested for validity via multiple statistical tests of selection accuracy comparing administrative data case ascertainment to that of the reference standard. Figure 1 summarizes the methodology and associated dataflow.

Algorithm application to a provincial cohort

Once an optimal algorithm to identify chronic pain cases from administrative data was selected, it was applied to the administrative data of a provincial cohort of NL residents. All residents identified as eligible for MCP benefits (approximately 98% of the total NL population) in the MCP Beneficiary File for any fiscal year between 2003 and 2010 were included in the provincial cohort, of which 99.6% had linkages to the MCP Claims File (fee-for-service physician visits) and 65.3% had linkages to the NL Discharge Abstract Data (acute-care hospitalizations).

Data linkage

The CPCSSN-NL data, the NL Discharge Abstract Data, and the MCP Claims File data were obtained from the NL Center for Health Information [63]. The CPCSSN-NL data was linked to the Reference Standard Cohort via the unique provincial health insurance (MCP) numbers. Record-level data from the MCP Claims File and NL Discharge Abstract Data were linked to the Reference Standard Cohort, the interdisciplinary chronic pain rehabilitation program patient populations, the NL Prescription Drug Plan patient population, and the provincial cohort via the MCP numbers. Analysts at the NL Centre for Health Information performed all data extraction, linkage, cleaning, and de-identification prior to the provision of the linked datasets to the research team for analysis.

Statistical analysis

Distribution of chronic pain cases in the Reference Standard Cohort were described and compared to those not identified as having chronic pain through a t-test for mean age and Chi-squared tests for proportions (statistical significance defined by the 95% confidence interval for the difference in proportions not including the null (0) value (i.e. $p < 0.05$)). Preliminary algorithm sensitivity was calculated in each pain population by dividing algorithm-selected cases by the total corresponding pain population. For algorithm validation and selection, the chronic pain algorithms were applied to the administrative data of the Reference Standard Cohort, and algorithm classification performance was compared to that of the reference standard. To adequately account for the complexities inherent to chronic disease administrative data algorithms during validation [25, 70], a broad range of statistical tests for accuracy and their 95% confidence intervals (CI) were calculated for each proposed administrative data algorithm using the classic 2 × 2 table. Sensitivity and specificity assessed case ascertainment utility, and positive predictive value, negative predictive value, likelihood ratio positive, likelihood ratio negative, and diagnostic odds ratio assessed selection accuracy [25, 45, 71, 72]. The Kappa agreements between each administrative data algorithm and the CPCSSN reference standard were calculated using the classic 2 × 2 table [72–74]. The area under the Receiver Operating Characteristic curve, also a case ascertainment accuracy test, for each proposed algorithm was obtained.

To optimize algorithm functionality in assessing the disease burden of chronic pain, the research team sought to maximize case selection while minimizing false positives. The optimal algorithm was chosen based on the balance between sensitivity and specificity while maximizing positive predictive value [41, 45, 75], with the goal of each being greater than 0.70 [21]. A plot of calculated sensitivity and specificity values for each algorithm was made and the intersection of the plot lines assisted in choosing the optimal algorithm. Once the selected optimal Chronic Pain Algorithm was applied to the Reference Standard Cohort administrative data, identified false positive and false negative cases were reviewed in further detail. SPSS version 24 and Excel 2013 were used for statistical analysis. MedCalc^{R} was used to calculate confidence intervals for sensitivity, specificity, positive predictive value, negative predictive value, likelihood ratio positive, and likelihood ratio negative [76]. GraphPad Software was used to calculate confidence intervals for Kappa agreement [77].

Results

Reference standard

Compared to the Statistics Canada 2011 census-reported NL general population (Figure 2) [78-82], the 2011 demographics of the Reference Standard Cohort had similar sex distribution but a higher median age (48.0 years vs. 44.0 years). The Reference Standard Cohort had an overrepresentation of people aged 65 and over and underrepresentation of people aged 14 and under. There was also a higher percentage of people in the Reference Standard Cohort residing in the Eastern Regional Health Authority (mostly urban) catchment area. The Eastern Regional Health Authority is one of four located in NL.

Table 1 details the distribution of chronic pain cases in the Reference Standard Cohort. Chronic pain prevalence as defined by the reference standard was 24.6%, of which 58.8% were identified as female and 54.2% were aged 55 or older. Mean age was significantly higher at 55.5 years (19.1 years standard deviation) in the Chronic Pain Group versus 44.1 years (22.9 years standard deviation) in the No Chronic Pain Group.

Administrative data algorithm development and preliminary sensitivity testing

The 2006-2011 interdisciplinary chronic pain rehabilitation patient group consisted of 266 patients. The mean age was 48.0 years and 57.9% were identified as female. After linkages, 256 (97.0%) had at least one physician claim with a pain-related diagnostic code in the MCP Claims File and 172 (64.7%) had at least one hospitalization recording at least one pain-related diagnostic code in the NL Discharge Abstract Data. Twelve people (4.5%) had an entry with the ICD-10(Canadian) code for the diagnosis of acute or chronic pain (R52) in the NL Discharge Abstract Data. After linkages, 96.7% of the 1999-2005 interdisciplinary chronic pain rehabilitation program patient group (N=361, mean age 52.4, 50.1% female), 93.8% of the interdisciplinary chronic pain rehabilitation program waitlist patient group (N=130, mean age 45.6, 64.6% female), and 93.7% the NL Prescription Drug Plan pain patient group (N=38,532, mean age 61.0, 57.6% female) had at least one entry of a pain-related diagnostic code in either the MCP Claims File or the NL Discharge Abstract Data.

Supplementary Table 5, Additional file 2 provides a complete list of possible algorithm combinations considered, the number of each pain patient group identified by each algorithm, and the calculated sensitivities. The algorithm sensitivities were widely variable, ranging from 0.029 to 0.959, depending on the pain patient group and the algorithm restrictiveness. Including encounter dates from the NL Discharge Abstract Data had minimal effect on the sensitivity of the algorithms except when considering medical specialist treatment dates. In the interest of being parsimonious, the NL Discharge Abstract Data was only used when including medical specialist treatment dates for algorithm validation.

Algorithm validation and optimal selection

A total of 56 administrative data chronic pain algorithms were tested against the reference standard in the Reference Standard Cohort. Supplementary Table 6, Additional file 3 provides the full list of tested algorithms and their validation statistics.

The highest sensitivity (0.917, 0.906-0.928 95% CI) resulted from the least restrictive algorithm requiring the lowest required number of claim dates recording a pain-related diagnostic code (>/=2) in the longest observation time window (7 years). Algorithm sensitivity decreased as the number of required claims increased, the observation time window decreased, or the medical specialist encounter criterion was added. The algorithm with the highest sensitivity had the lowest specificity (0.332, 0.322-0.343 95% CI) and the highest false positive rate (0.668). The negative predictive value (ranging from 0.783 to 0.925) and the likelihood ratio negative (ranging from 0.853 to 0.250) followed the same trend as the sensitivity.

The highest specificity (0.938, 0.932-0.944 95% CI) resulted from the most restrictive algorithm requiring the highest number of claim dates for a pain-related diagnostic code (>/= 5) in the shortest observation time window (1 year) and requiring an encounter with a medical specialist recording a pain-related diagnostic code. Algorithm specificity decreased as the number of required claims decreased, the observation time window increased, or the specialist encounter criterion was removed. The algorithm with the highest specificity had the lowest sensitivity (0.200, 0.184-0.216 95% CI) and the lowest false positive rate (0.062). The positive predictive value (ranging from 0.309 to 0.513) and the likelihood ratio positive (ranging from 1.373 to 3.234) followed the same trend as the specificity. The intersection of sensitivity and specificity plot lines was observed at approximately 0.67.

The area under the Receiver Operating Characteristic curve ranged from poor (0.569, 0.555-0.583 95% CI) to acceptable (0.690, 0.678-0.702 95% CI) selection accuracy of the chronic pain algorithms [83]. The Kappa agreement between the administrative data algorithms and the CPCSSN reference standard ranged from slight (0.150, 0.139-0.160 95% CI) to fair (0.303, 0.283-0.323 95% CI) [84].

Considering the study's goal and the validation test results, the optimal Chronic Pain Algorithm was determined to be: 1) a single encounter date recording a chronic pain-related provincial MCP procedure code in the MCP Claims File; OR 2) five or more encounter dates recording a pain-related diagnostic code in a five-year period with more than 183 days separating at least two pain-related encounter dates in the MCP Claims File. This algorithm identified 42.3% of the Reference Standard Cohort and 37.6% of the 584 875 people in the provincial cohort.

The Chronic Pain Algorithm had 0.703(0.684-0.721 95% CI) sensitivity, 0.668(0.657-0.679 95% CI) specificity, 0.408(0.398-0.418 95% CI) positive predictive value, 0.874(0.866-0.880 95% CI) negative predictive value, 2.115(2.030-2.207 95% CI) likelihood ratio positive, 0.445(0.474-0.417 95% CI) likelihood ratio negative, 4.754(4.300-5.256 95% CI) diagnostic odds ratio, 0.685(0.673-0.698 95% CI) area under the Receiver Operating Characteristic curve (or adequate indicator of selection accuracy) [83], and 0.298(0.280-0.316 95% CI) Kappa agreement (or fair) [84].

Of the 2435 false positive cases, 1828 (75.1%) had at least one treatment with a specialist for a pain-related condition or attended treatment for chronic pain at an organized pain clinic. As well, 758 (31.1%) false positive cases were identified by the Chronic Pain Algorithm in administrative data prior to (but not within) the date range of the CPCSSN-NL data. Of the 709 false negative cases, only 66 (9.3%) did not have at least one claim in the MCP Claims Data recording a pain-related diagnostic code, and 166 (23.4%) did not meet the benchmark of more than six months between at least two claims dates involving treatment for a pain-related condition. As well, 651 (62.9%) false negative cases would be selected if fewer treatments were required and/or the observation time window was longer (i.e. a less restrictive algorithm).

The Chronic Pain Algorithm was tested further for selection accuracy in the age and sex strata of the Reference Standard Cohort (Table 2). In summary, there was an indication of varying selection bias of the Chronic Pain Algorithm towards people aged 65 and over, and against people aged 34 and younger.

Discussion

There is a critical need to determine the societal burden of chronic pain [1, 5, 6, 19, 22]. A validated administrative data algorithm to estimate the epidemiology of chronic pain not only enables financial estimates to be determined [85], it also enables assessment of the effects of change to health care and population health policy [75]. This study was undertaken to develop and test an algorithm to identify cases of chronic pain as a single chronic disease using Canadian health administrative data. By linking data from patient groups with a known chronic pain diagnosis and general population groups over an 11-year study period, a new and valid chronic pain algorithm was created that performed at 0.703 sensitivity and 0.668 specificity. The optimal recommended algorithm to ascertain cases of chronic pain from health administrative data for future study was; 1) a single encounter date recording a chronic pain-related provincial MCP procedure code in the MCP Claims File; OR 2) five or more encounter dates recording a pain-related diagnostic code in a five-year period with more than 183 days separating at least two pain-related encounter dates in the MCP Claims File. This algorithm satisfied both spatial and temporal benchmarks consistent with the diagnosis of chronic pain [11, 25, 30, 45, 46]. The algorithm identified 37.6% of a NL population cohort from health administrative data.

Achieving optimal case ascertainment

The Chronic Pain Algorithm performance was comparable to other validation studies assessing health administrative data algorithms for specific chronic pain conditions with respect to the ascertainment measures of sensitivity and specificity. Algorithms identifying cases of neck and back disorders had the best and most consistent performance on tests of selection accuracy (up to 0.71 sensitivity, 0.89 specificity, and 0.83 positive predictive value) [39]. That study's population included only people with known chronic pain diagnoses, unlike our study. A validation study examining administrative data of survey respondents found very good specificity (> 0.90) but poor sensitivity (0.20–0.55) for arthritis case definitions [75]. Algorithms for other specific and less common chronic pain conditions performed less consistently on validation testing. These included Fibromyalgia (0.32–0.42 sensitivity, 0.94–0.97 specificity) [39], painful neuropathy (0.22–0.39 sensitivity, 0.58–0.80 specificity) [33, 39], Chronic Regional Pain Syndrome (0.04–0.07 sensitivity, 0.93–0.98 specificity) [39], and Irritable Bowel Syndrome (0.112–0.989 sensitivity) [56, 86, 87]. Choice of codes, frequency criteria, and the chosen validation cohort contributed to variability in the validation results of these studies. Since no other study reported validation of administrative data algorithms for chronic pain as a single disease, the present study will form the benchmark against which future studies validating chronic pain algorithms will be compared.

Ascertainment versus accuracy

The present study overcame significant challenges to create a valid administrative data algorithm for chronic pain that included all necessary spatial and temporal benchmarks. There being no measurable objective diagnostic test [1] and no consistent agreement of experts on the diagnostic criteria for chronic pain [40] made for a less explicit reference standard against which to compare the chronic pain administrative data algorithms. Algorithm development was further complicated by the discord among physicians regarding best treatment practices for chronic pain conditions [1, 40], as evidenced by the high number of unique three-digit ICD-9 (67 in total) and ICD-10(Canadian) (83 in total) codes used to identify pain-related conditions in the NL administrative data. The Chronic Pain Algorithm, as a result, identified a high number of false positive and false negative cases, which negatively impacted the selection accuracy tests of positive predictive value, likelihood ratio, and area under the Receiving Operator Characteristic curve. Since the goal of this study was to create an administrative data algorithm to eventually measure the disease burden of chronic pain in the general population, more weight was placed on ascertainment measures (i.e. sensitivity and specificity) than on selection accuracy measures [41, 45, 75].

Algorithm validity to study chronic pain distribution

The Chronic Pain Algorithm identified 42.3% of the Reference Standard Cohort, which was higher than the 24.6% identified by the reference standard. The high number of false positives identified by the Algorithm influenced this discrepancy. When considering the overrepresentation of people 65 years and older in the Reference Standard Cohort, it is possible that the reference standard under-ascertained cases of chronic pain. The identification of 37.6% in the NL provincial cohort by the Chronic Pain Algorithm was comparable to the 36% chronic pain prevalence in Atlantic Canada (which includes NL) reported by a survey in 2007 [16] but higher than the 21.5% Atlantic Canada prevalence reported in 2011 by another survey [12]. Poor Kappa agreement between survey data and administrative data for identifying cases of a pain condition was previously reported and may influence this observation [86]. Although disagreement between administrative data and medical record or survey data exists, the Chronic Pain Algorithm applied to population-based, widespread administrative data will provide an accurate reflection of geographical variation of chronic pain distribution [85].

Strengths and limitations

The main strength of this study lies in its methodology that followed established guidelines [25]. First, the spatial and temporal patterns in the administrative data of patient groups known to have chronic pain were studied to develop the preliminary chronic pain algorithms. The algorithms were then validated by calculating multiple tests of selection accuracy in a general population cohort whose demographics closely approximated that of the NL general population [25, 52]. Finally, using the CPCSSN electronic medical record data to apply the reference standard allowed for sufficient sample size to test sensitivity and specificity of multiple algorithms with 0.02 precision and 0.05 alpha at a fraction of the effort of a paper chart audit.

There were several limitations to this study. The MCP Claims File does not capture pain-related treatments delivered by allied health professionals, salaried physicians, or those funded by a third party (such as Workers Compensation) affecting case ascertainment. As with other jurisdictions in Canada, the MCP Claims File allowed only one diagnostic code entry per episode of care per practitioner. A non-pain-related diagnosis might have been the chosen code entry for a particular visit even if a pain condition was assessed/treated affecting case ascertainment [39]. Lower sensitivity of the Chronic Pain Algorithm in age groups 34 years and under may impact its generalizability in studying chronic pain distribution in this age range. The known lower chronic pain prevalence in this age range [3, 88] combined with the age demographics of the pain populations used to develop the preliminary algorithms factor into these sensitivity findings [25]. Using MCP provincial procedure codes in the Chronic Pain Algorithm affects its generalizability outside the NL jurisdiction. However, similar procedure codes are used in other provincial jurisdictions [89, 90] and can be substituted for the NL chronic pain intervention procedure codes. A chronic

limitation for all validation studies involving administrative and medical records data is the dependence of its quality on the accuracy of data entry at source [25, 38, 55].

Conclusions

Provincial administrative data in Canada was determined to be a valid source of information on chronic pain. The Chronic Pain Algorithm satisfied both spatial and temporal frequency benchmarks of the chronic pain definition and was deemed a valid method to ascertain cases of chronic pain. Cohorts of chronic pain patients seeking physician care can now be identified from health administrative data to study epidemiology, health care utilization, and longer term health outcomes. Creation of such cohorts using the Chronic Pain Algorithm can also be utilized to assess the effectiveness of any change to policy or health service delivery for this population.

List Of Abbreviations

NL, Newfoundland and Labrador; CPCSSN, Canadian Primary Care Sentinel Surveillance Network; MCP, Medical Care Plan; ICD-9, *International Classification of Disease-9th Revision*; ICD-10(Canadian), *International Classification of Disease-10th Revision (Canadian)*; CI, confidence interval; HREB, Health Research Ethics Board.

Declarations

Ethics approval and consent to participate

The Health Research Ethics Board (HREB) (Office for Human Research Protections identification number IRB00011348) of the Health Research Ethics Authority of Newfoundland and Labrador provided full approval of the study protocol (HREB Reference #13.157). The Secondary Uses Committee of the NL Centre for Health Information and the Research Proposals Approval Committee of the Eastern Regional Health Authority also reviewed and approved the study protocol following HREB approval. Since the health administrative data analyzed was part of routine data collection and normal operations of the NL Centre for Health Information, NL Prescription Drug Plan, and the Eastern Regional Health Authority, and the data was then de-identified, individual patient and/or NL resident consent was not required. The primary care physicians participating in the CPCSSN database provided written consent on behalf of their patients to have their patient electronic medical record data regularly transferred to the CPCSSN, which follows strict and secure privacy protocols when using the de-identified data from the patients' electronic medical records. Data sharing and confidentiality agreements were also put in place. The participating primary care physicians provided written information (posters and pamphlets in their offices) to patients about the CPCSSN, how their data will be used, and that they had the option to opt out of data collection at any time. The ethics approval obtained for the CPCSSN project in Newfoundland and Labrador included a waiver of explicit patient consent because of the infeasibility of obtaining individual consent for the large geographical population involved in the project, and because only secondary data analysis of pre-existing de-identified data was performed. Patients' consent to participate in the CPCSSN database and for their de-identified information in the electronic medical record to be used for research purposes, including data linkages, was thus implied [52,91].

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are securely held at the NL Centre for Health Information and the Eastern Regional Health Authority but restrictions apply to the availability of these data, which were used under data-sharing agreements for the current study, and so are not publicly available. Data are however available from the NL Centre of Health Information if pre-specified criteria are met following its information request procedures. The study author (HF) may be contacted for the dataset creation plan.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors read and approved the submitted version of this manuscript. All authors agreed to be personally responsible for their own contribution and ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature. HF drafted the work and substantively revised it, and made substantial contributions towards the study design, data acquisition, analysis, and interpretation. JK substantively revised the work, and made substantial contributions towards study design, data acquisition, analysis, and interpretation. MP substantively revised the work, and made substantial contributions towards study conception and design and data acquisition and interpretation. SA made substantial contributions towards study design, and data acquisition, analysis, and interpretation,

and writing of the manuscript. RA substantively revised the work, and made substantial contributions to the study design, and data acquisition and interpretation.

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Additional Files

Additional file 1 **Supplementary Tables 1-4:** Medication codes, diagnostic codes, and provincial procedure codes used in the Canadian Primary Care Sentinel Surveillance Network-Newfoundland and Labrador data, the Newfoundland and Labrador Prescription Drug Plan data, the Newfoundland and Labrador Medical Care Plan Fee-for-Service Physicians Claims File data, and/or the Newfoundland and Labrador Provincial Discharge Abstract hospital data, .docx, 42 kb

Additional file 2 **Supplementary Table 5** Preliminary chronic pain administrative data algorithms and sensitivity testing in pain patient populations, .docx, 53 kb

Additional file 3 **Supplementary Table 6** Selection accuracy of chronic pain algorithms in Reference Standard Cohort, .docx, 56 kb

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Tables

Table 1 2011 Demographics of Chronic Pain Group vs. No Chronic Pain Group in Reference Standard Cohort

	Chronic Pain Group[a] N=2386	No Chronic Pain Group[a] N=7329
	n(% of group)	n(% of group)
Age Group		
0-14	32(1.3)	755(10.3)
15-24	133(5.6)	1005(13.7)
25-34	206(8.6)	1039(14.2)
35-44	288(12.1)	1019(13.9)
45-54	435(18.2)	1081(14.7)
55-64	521(21.8)	934(12.7)
65-79	500(21.0)	892(12.2)
80+	271(11.4)	604(8.2)
Sex		
Male	984(41.2)	3744(51.1)
Female	1402(58.8)	3585(48.9)
Regional Health Authority		
Eastern	2262(94.8)	6548(89.3)
Central	34(1.4)	321(4.4)
Western	84(3.5)	390(5.3)
Labrador-Grenfell	6(0.3)	67(0.9)
Pain Conditions[b]		
Neuropathic Pain	766(32.1)	531(7.2)
Musculoskeletal Conditions & Arthritis	1715(71.9)	1853(25.3)
Musculoskeletal Trauma	864(36.2)	883(12.0)
Neck & Back Pain	1546(64.8)	1412(19.3)
Bone Disorders	427(17.9)	353(4.8)
Headaches	700(29.3)	631(8.6)
Other Conditions Associated with Chronic Pain	1567(65.7)	1729(23.6)
Central Pain Syndrome, Chronic Pain, or Chronic Pain Syndrome	98(4.1)	0

Notes: a. Chi square tests were used to determine significance of difference between group proportions. Statistical significance was defined as the 95% confidence intervals of strata proportion differences not containing the null (0) value (i.e. $p < 0.05$). Difference between the proportions of the Chronic Pain Group and the No Chronic Pain Group in all strata were considered significant; b. Inclusion in the pain condition group was defined as an individual having >/= 1 encounter for a condition in the Pain Condition diagnostic group (Supplementary Table 2, Additional file 2) in the Canadian Primary Care Sentinel Surveillance Network-Newfoundland and Labrador electronic medical record data

Abbreviations: N, total population of group

Table 2 Selection accuracy of the Chronic Pain Algorithm[a] in Reference Standard Cohort age and sex strata

	Prevalence Defined by Reference Standard	Prevalence Defined by Chronic Pain Algorithm	Sensitivity	Specificity	PPV	NPV	LR+	LR-	DOR	Kappa
Reference Standard Cohort	24.6%	42.3%	0.703	0.668	0.408	0.874	2.12	0.44	4.76	0.30
Age Group										
14&U	4.1%	7.6%	0.250	0.931	0.133	0.967	3.63	0.81	4.51	0.13
15-24	11.7%	21.2%	0.346	0.805	0.190	0.903	1.77	0.81	2.18	0.11
25-34	16.5%	34.2%	0.576	0.705	0.279	0.894	1.95	0.60	3.26	0.20
35-44	22.0%	38.3%	0.635	0.689	0.366	0.870	2.04	0.53	3.86	0.25
45-54	28.7%	48.6%	0.747	0.619	0.441	0.859	1.96	0.41	4.80	0.30
55-64	35.8%	52.2%	0.738	0.600	0.507	0.805	1.85	0.44	4.24	0.31
65-79	35.9%	59.0%	0.780	0.516	0.475	0.807	1.61	0.43	3.79	0.26
80+	31.0%	64.8%	0.815	0.427	0.390	0.838	1.42	0.43	3.29	0.19
Sex										
Male	20.8%	36.6%	0.652	0.709	0.371	0.886	2.24	0.49	4.58	0.28
Female	28.1%	47.7%	0.738	0.625	0.435	0.859	1.97	0.42	4.69	0.30

Note: a. The optimal Chronic Pain Algorithm was defined as: 1) a single encounter date recording a chronic pain-related provincial Medical Care Plan procedure code in the Medical Care Plan Fee-for-Service Physicians Claims File; OR 2) five or more encounter dates recording a pain-related diagnostic code in a five-year period with more than 183 days separating at least two pain-related encounter dates in the Medical Care Plan Fee-for-Service Physicians Claims File.

Abbreviations: PPV, positive predictive value; NPV, negative predictive value; LR+, likelihood ratio positive; LR-, likelihood ratio negative; DOR, diagnostic odds ratio.

Figures

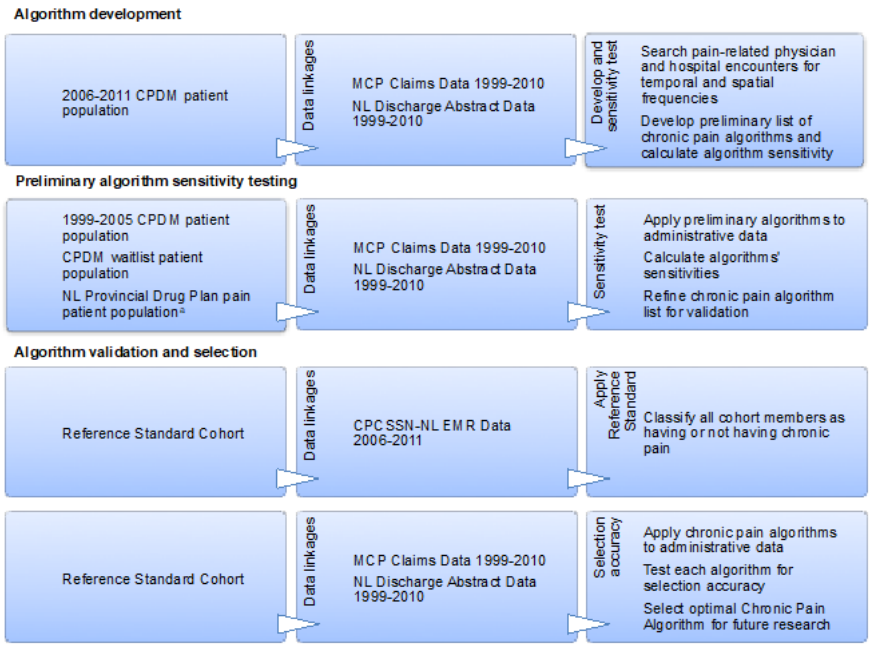

Figure 1

Summary of study methodology and associated data flow. Note: a. NL Prescription Drug Plan is a financial assistance program covering eligible prescription medications to qualified seniors and low-income individuals/families, patients selected were prescribed and dispensed opioid medication used almost exclusively for pain (Supplementary Table 1, Additional file 1) during the period from 1999-2011 as a subsidized patient of the NL Prescription Drug Program. Abbreviations: CPDM, Centre for Pain and Disability Management (an interdisciplinary chronic pain rehabilitation program); MCP, Medical Care Plan; NL, Newfoundland and Labrador; CPCSSN, Canadian Primary Care Sentinel Surveillance Network; EMR, Electronic Medical Records

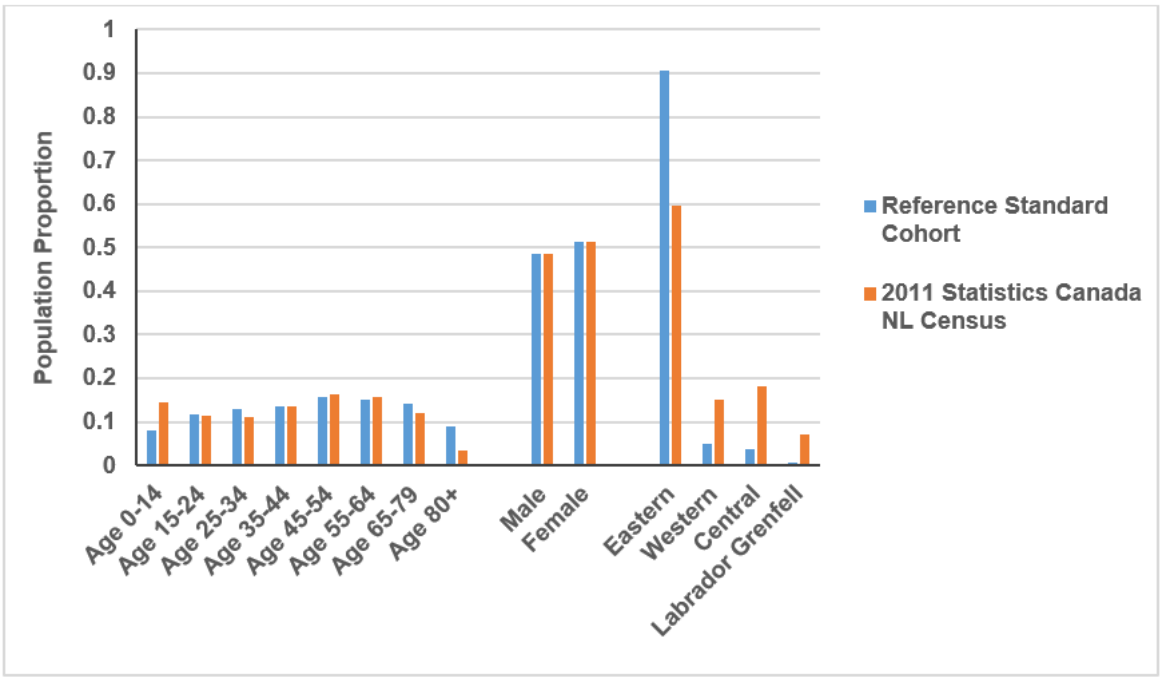

Figure 2

2011 Demographics of the Reference Standard Cohort versus the Newfoundland and Labrador general population. Notes: Proportions of the Reference Standard Cohort and the Statistics Canada 2011 census-reported Newfoundland and Labrador population in each age, sex, and regional health authority stratum are compared. Eastern, Western, Central, and Labrador Grenfell are the four Regional Health Authorities in Newfoundland and Labrador. Abbreviations: NL, Newfoundland and Labrador

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile2.docx
- Additionalfile1.docx
- Additionalfile3.docx