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Use of SNOMED CT[®] and LOINC[®] to Standardize Terminology for

Primary Care Asthma Electronic Health Records

M. Diane Lougheed MD, M.Sc., FRCP^{1,2,4,*}, Nicola J. Thomas RN, BN, M.Sc., CAE³,

Nastasia V. Wasilewski B.Sc, M.Sc.^{1,2}, Alison H. Morra², Janice P. Minard RN, M.Sc.^{1,2}

¹Department of Medicine, Queen's University, 102 Stuart Street, Kingston, Ontario, K7L 2V6, Canada

²Asthma Research Unit, Clinical Research Centre, Kingston General Hospital, 76 Stuart St. Kingston, Ontario, K7L 2V7, Canada

³Health Sciences Faculty, St. Lawrence College, 100 Portsmouth Ave. Kingston, Ontario, K7L 5A6, Canada

⁴Department of Public Health Sciences, Queen's University, Kingston, Ontario, K7L3N6, Canada

*Corresponding author: M. Diane Lougheed MD, M.Sc., FRCP(C) Professor, Departments of Medicine, (Respirology) Biomedical and Molecular Sciences and Public Health Sciences, Queen's University, 102 Stuart Street, Kingston, Ontario K7L 2V6 Tel. 613-548-2348 Fax. 613-549-1459 mdl@queensu.ca

Abstract

Objectives: The burden of asthma ranks among the highest for chronic diseases. Interoperable EHRs can improve the management of chronic diseases such as asthma by facilitating sharing of

data between health care settings along the continuum of care. Terminology such as SNOMED CT[®] (Systematized Nomenclature of Medicine-Clinical Terms) and LOINC[®] (Logical Observation Identifier Names and Codes) are prerequisites for interoperability of electronic health records (EHRs). We sought to determine the extent to which data elements in a validated asthma care map (ACM) are congruent with these terminologies.

Methods: A certified asthma educator entered all 169 elements in the ACM into the SNOMED CT[®] browser. Matched elements were assigned a concept name, an identification number and classified into a hierarchy. LOINC[®] terminology was reviewed for asthma-related pulmonary function tests (PFT).

Results: Forty-two % of the ACM elements were complete matches to existing SNOMED CT[®] concepts, 24% partial matches and 34% unmatched. Specific asthma control parameters were either complete (n = 3) or partial (n = 4) matches, but overall ‘asthma control’ was unmatched. There were 92% complete or partial matches for PFT elements to SNOMED CT[®] and 83% to LOINC[®].

Conclusions: The majority of ACM elements are congruent with standardized terminology, enabling EHR interoperability. Future requests for new concepts in SNOMED CT[®] and LOINC[®] should be pursued for asthma control parameters paramount to evidence-based practice.

Key Words

Respiratory Disease, Documentation, Data Standards, Interoperability, Mapping

Legend of Abbreviations

ACM - Asthma Care Map

HER – Electronic health record

EMR- Electronic medical record

FEV₁ - Forced Expiratory Volume in One Second

OLA - Ontario Lung Association

PCAP - Primary Care Asthma Program

LOINC - Logistical Observation Identifier Names and Codes

PEF - Peak Expiratory Flow

PRESTINE - Pan- Canadian Respiratory Standards Initiative for Electronic Health Records.

PFT - Pulmonary Function Test

SNOMED - Systematized Nomenclature of Medicine

INTRODUCTION

It is estimated that the economic burden of asthma ranks among the highest for chronic diseases.

(1) Interoperable electronic health records (EHRs) can improve the management of chronic disease and improve the healthcare of Canadians.(2) Data standards are the building blocks of interoperable EHRs, necessary to achieve timely sharing of precise information across organizations and jurisdictions.

In 2000, the Government of Ontario, Canada designed an integrated provincial Asthma Plan of Action to reduce the burden of asthma through health promotion, prevention, asthma management, surveillance and evaluation. (3) One of these initiatives was a multi-centre primary care pilot project comparing usual care to implementation of an evidence-based program,

including the Ontario Lung Association (OLA)'s asthma care map (ACM), action plan, and asthma management algorithm, plus program standards and spirometry.(4) At 12 months follow-up, results showed a significant reduction in emergency department visits due to asthma, school absences in children, daytime and nighttime symptoms and self-reported asthma exacerbations. (4) The Primary Care Asthma Program (PCAP) is now part of the provincial asthma strategy, implemented in over 150 locations.

Increasingly, the need to integrate the PCAP tools into EHRs has become apparent. In 2008, we incorporated sixty-nine data elements from the OLA's revised ACM into 2 stand-alone electronic medical records (EMRs). (5) In doing so, 2 primary care sites representing 27 locations were able to send de-identified patient data to a central secure server for analysis and report generation, heralding the ability to support program evaluation, outcome measurements and surveillance. A key learning from this initiative was the need for data definitions and data standards for elements to be integrated into approved primary care EMR applications. (5) Two of the reference terminology standards that have emerged as 'gold standards' are: Systematized Nomenclature of Medicine-Clinical Terms, now known as, (SNOMED CT[®]) and Logistical Observation Identifier Names and Codes (LOINC[®]). SNOMED CT[®] is a controlled licensed medical terminology providing a common language supporting clinical documentation and analysis. SNOMED CT[®] is owned and maintained by SNOMED International, a not-for-profit organization. It is endorsed as the clinical terminology standard by the United States, Canada, the United Kingdom, Australia and New Zealand and is in use in over 50 countries around the world.(6) Updated every six months, the current version contains 321.901 active concepts, each representing a single clinical thought. Concepts are arranged in hierarchical order

from the more general to the more granular. Descriptive synonyms attached to the concept offer alternative ways of capturing the same meaning, enabling users the ability to search and record clinical information in a variety of ways while representing a common meaning. Attribute relationships join concepts that are related in meaning providing a richer array of compositional ability.(6)

SNOMED CT[®] incorporates a wide array of clinical information that can be shared between different health care disciplines and locations, without altering the integrity of the health data. It allows clinical information to be stored, organized and retrieved for meaningful use and analysis. In addition, SNOMED CT[®] provides support for EMRs allowing for enhanced communication between physicians, decreasing duplication of services, providing updated prescription lists and reducing errors. The comprehensive terminology allows clinicians to search and extract clinical information based on customizable queries, enabling health care systems to realize optimal use of stored data. The ability for SNOMED CT[®] to provide quality data improves epidemiological research and disease monitoring. (6)

LOINC[®] is a terminology standard that supports the coding and capturing of laboratory test results, and other clinical observations. LOINC[®] codes use universal identifiers enabling consistent interpretation across health care organizations. LOINC[®] codes are unique identifiers that capture parameters that can be tested or quantified, such as represent laboratory tests, questions on a form, and clinical measurements. Clinical measurements are tests, observations or measurement of a patient that do not involve taking a specimen. It was devised, is maintained and is freely distributed by the Regenstreif Institute at the University of Indiana. The current

version released in February 2017, has 83,377 codes with 46,621 users in 166 countries. It continues to expand internationally, as approximately 600 new users are added per month. (7) The purpose of this project was to determine the extent to which the 169 ACM elements are congruent with the globally recognized terminologies SNOMED CT[®] and LOINC[®]. We hypothesized that the proportion of elements with full or partial matches would be approximately 50%.

METHODS

To determine the correct procedure for mapping the ACM data elements to SNOMED CT[®] and LOINC[®], a nurse expert in clinical documentation, an information technology manager at a tertiary-care centre, a standards expert from Canada Health Infoway and a Director of Clinical Informatics Consulting for SNOMED Terminology Solutions, USA were consulted. Experts suggested using free web-based browsers for SNOMED CT[®]. Available browsers utilized included: Apelon Mycroft, CIC CLUE/CliniCLUE, SNOB, and the Virginia-Maryland Regional College of Veterinary Medicine. LOINC[®] was available through the Regenstreif Institute to map laboratory tests.

Mapping Process and Rules

The source document for this mapping exercise was the paper version of the OLA's evidence-based ACM (2006) used in the electronic asthma record pilot project (5). The ACM is a four page tool that is divided into sections outlining the initial assessment and diagnosis, asthma history, risk factor assessment, triggers, and identified barriers. The form includes diagnostic tests, medical management, and education. Follow up visits and standards are recorded. (5) Mapping of the ACM was completed by a registered nurse (NJT) who was a Certified Asthma

Educator (CAE) expert in using the ACM in PCAP. The ACM's 169 data elements were entered into the SNOMED CT[®] concept search engine. Diagnostic elements, such as pulmonary function tests (PFTs) (e.g. peak expiratory flow (PEF), forced expiratory volume in one second (FEV₁) and methacholine challenge tests were also entered into LOINC[®]. Mapping consensus was achieved through collaborative discussion with a physician who specializes in asthma care (MDL), the Asthma Care Program Manager (JPM) and the CAE. Following completion of the mapping exercise, an external SNOMED CT[®] expert recommended by Canada Health Infoway provided feedback on the quality of the mapping process and results.

Mapping to SNOMED CT[®]

Each data element of the ACM was typed into the free SNOMED CT[®] concept search engine. Results were categorized as a *complete match*, *partial match* or *unmatched*. Elements were identified as a *complete match* if the wording of the concept and hierarchy category was an exact match for the intended meaning in the ACM. A *partial match* was assigned when the concept found was defined using alternate words or synonyms and the hierarchy definition was partially matched to or was not appropriate for the context of the care map. If asthma data elements were not found within the SNOMED CT[®] browser using synonyms or other agreeable terms, they were deemed *unmatched*. Matched concepts were further categorized by its 'hierarchy', which is described as a clinical finding, a procedure, an observable entity or a physical object. Subsequently, each concept was issued an identification number (ID) (Figure 1).

Results of the mapping were tabulated in a Microsoft Excel spreadsheet. The use of post-coordination, a compositional terminology language that joins concepts together to refine a concept meaning, was beyond the scope of this study. Post-coordination would require an EMR

with SNOMED CT[®] implemented onto the system and the collaborative help of a terminology expert.

Mapping to LOINC[®]

All ACM pulmonary function tests were cross-referenced to a downloaded free version of LOINC[®]. Results in LOINC[®] were categorized as: identification number, component, property, time aspect, system, scale, method, units, class, long common name etc.

RESULTS

Of the 169 ACM elements initially searched, there were 42% complete matches, 24% partial matches and 34% were unmatched in SNOMED CT[®] (Appendix A). There was strong congruency to SNOMED CT[®] and LOINC[®] for entire sections of the care map (Appendix A). One hundred percent of the 7 asthma control elements had a complete or partial match to SNOMED CT[®] with the exception of the dichotomous overall rating of Asthma Control Y/N (Table 1), although 4 of the 7 were only partial matches. There was a 92% complete or partial match for the PFT in SNOMED CT[®] and 83 in LOINC[®] (Table 2). In addition, smoking history elements had a 71% complete or partial match to SNOMED CT[®] (Table 3).

Complete Matches

Table 4 summarizes examples of complete matches. The ACM data element ‘Patient Name’ was matched within SNOMED as ‘Patient’s Name’ and categorized as an ‘observable entity’. There was a complete match for the sub-category ‘severity’ and one descriptor of severity (‘emergency department visit ever’). However, the search did not reveal matches for the other descriptors of severity, such as ‘hospitalized ever’, ‘near fatal episode’ or ‘prednisone use ever’. Similarly, some of the parameters of the subcategory ‘asthma control’ such as ‘physical

activity limited' and 'school work absences' had complete matches. There were no complete matches for the other asthma control parameters, including frequency of daytime or nighttime asthma symptoms, frequency of reliever use, FEV₁ or PEF <90% percent predicted or personal best, and exacerbation since last visit.

Partial Matches

Examples of partial matches are described in Table 5. If it was not possible to use exact terms, synonyms or key terms that best represented the under-lying concepts were used. 'Spirometry reversibility test' was found in the search and deemed a partial match, related to documentation of performance of the test rather than the outcome (magnitude of reversibility exceeding a 12% change in FEV₁). Likewise other elements were similarly matched. For example, the ACM data element 'regular furnace filter change' was partially matched to filter (device) as a concept and physical object in the SNOMED hierarchy.

Unmatched ACM Data Elements

Determining whether an ACM data element was 'unmatched' often required extensive searching (Table 6). For example, while there were 9 results for 'hospitalized', all were related to birth. Since none were related to asthma, this was deemed an 'unmatched variable'. A search for pregnancy, which is listed as a 'risk factor' in the ACM, revealed 1297 concepts in SNOMED CT[®]. Of these, 450 were reviewed, and none were related to asthma. The environmental controls in place (such as 'air conditioning in summer', as well as 'mattress and pillow cover in place') were largely unmatched at 64%. Similarly, environmental exposures which can exacerbate asthma were poorly matched with SNOMED CT[®].

DISCUSSION

Use of standardized data terminologies such as SNOMED CT[®] and LOINC[®] can enable data sharing between clinicians, across practice settings and geographic locations, and enable outcomes monitoring, benchmarking and disease surveillance. (6) EMR interoperability for chronic diseases such as asthma validates clinical practice and decision making, thereby ensuring patients receive optimal medical management. (8) This study revealed that the majority of OLA's ACM data elements were congruent with internationally-recognized standardized medical and laboratory terminology. Overall, sixty-six percent of the ACM elements were complete or partial matches to currently existing concepts in SNOMED CT[®].

Full or partial terminology matches were found for many elements which are fundamental to asthma management. Specifically, elements pertaining to the initial assessment and diagnosis, asthma and allergy history, smoking history, irritant triggers, and follow-up assessment were highly congruent with standardized terminology. The PFT data elements were also highly congruent with terminology in SNOMED CT[®] and LOINC[®]. Critical in the management of asthma is an assessment of symptom control, triggers, and severity.

The most notable unmatched item was asthma control. Practice guidelines recommend that asthma control be assessed at each visit, including an objective measure of lung function (spirometry or PEF). (9) Accurate documentation of control parameters (including frequency of symptoms, reliever use, and FEV₁ and/or PEF measures) and adherence to controller therapy are paramount to evidence-based practice. (9) A request to SNOMED CT[®] for asthma control parameters to be added or pre-coordinated as new concepts should be pursued. Mapping results for severity, occupational history, risk factors, trigger exposures were minimally to moderately

congruent with SNOMED CT[®]. Environmental factors can exacerbate asthma, the environmental controls in place were poorly mapped with SNOMED CT[®]. The process for requesting new concepts in SNOMED and LOINC should be explored for these and other significant elements that were only partially or not matched, such as smoking cessation.

There is a paucity of published literature with which to compare our findings. Notably, a literature search failed to uncover mapping asthma elements in care maps to SNOMED CT[®]. However, higher proportions of exact matches using SNOMED CT[®] have been reported by experts in standardized terminology for other conditions. Lau *et al.* (2008) found 68.2% of elements in a Homecare Minimum Data Set were exact matches to SNOMED CT[®] (10). Likewise, examining a heuristic method for encoding palliative care data sets, Lee *et al.* (2010) successfully mapped 84% of palliative care data set terms to SNOMED CT[®]. (11)

Major strengths of our study include the rigorous mapping process undertaken and verification of our findings by a data standards expert. Local, national and international experts, including clinical and administrative staff at a tertiary care centre, Canada Health Infoway, SNOMED CT[®] experts and the distributor of LOINC[®] were consulted and provided guidance. The mapping of terms was completed by a clinical expert who had extensive experience with the ACM. The clinician had used the ACM and was familiar with the development of the tool, definitions for the various data elements and best practice guidelines for asthma. (9) As a clinical expert, the educator understood the ‘context’ of how each data element was meant to be used in the primary care setting.

Conversely, a limitation of our study was that the clinician who completed this exercise was not a mapping expert. Every effort was made to consult with experts to understand and learn

the process, and the quality of the mapping was confirmed *post hoc* by a SNOMED CT[®] expert. To learn the fundamentals of SNOMED CT we attended online beginner courses in SNOMED CT[®] terminology. We accessed free browsers to map ACM elements to SNOMED CT[®] and followed up with experts for advice. User guides available on the browsers, and online courses were written for those versed in informatics. Manually searching the browsers for SNOMED concepts was time consuming and lacked a logical search process. Working alongside a terminology expert to facilitate searches that optimize results, and navigate complex algorithms, would have greatly benefitted our efforts.

Another theoretical methodologic limitation was lack of the use of post-coordination, which could have improved our congruency. While this process can improve mapping outcomes, it is complex and not intuitive. For example, in our study, ‘history of a parent with asthma’ was unmatched. A complete match could be achieved by post-coordinating ‘family history of asthma’ (a “situation”) with ‘parent’ (a “person”) if mapping rules are followed. However, asthma control presents a greater challenge to post-coordinate for a variety of reasons. Asthma control is a ‘summary’ variable, comprised of multiple individual indices of control (parameters), which vary between national and international guidelines. (9, 12) Four asthma control parameters that were only partially matched in our study, could theoretically be individually post-coordinated, creating post-coordinated expressions that combine numerous concepts. For instance, the parameter of “dyspnea, cough, wheeze, or chest tightness (≥ 4 days per week-yes; <4 days/week,-no)” requires joining ‘asthma daytime symptoms’ (a “finding”) with a total of eight qualifiers to achieve a complete match. Post-coordination would need to be completed also for the other partially matched parameters (“night time symptoms $>1/wk$ – yes; none- no”, “needs

reliever ≥ 4 doses per week-yes; <4 doses/week,-no”, and “FEV₁ or PEF $<90\%$ pr or personal best”), and then a summary variable for overall asthma control assigned. However, merging concepts through post-coordination can be achieved in more than one way, and contextual meaning can be lost. Post-coordination mapping requires access to a system where SNOMED CT[®] has been implemented into an EMR system, and reasoning software that can infer post-coordination algorithms. These reasoners determine the exact relationship between post-coordinated expressions and existing SNOMED CT[®] content. Post-coordinated concepts have an unspecified number of enhancements, making storage more difficult. Likewise, data entry is more burdensome for the users as there is a need to select and enter more codes. Presently there is little support available for descriptive logic guidelines to which one must adhere when attempting post-coordination. (13)

Lastly, access to a full dynamic version of SNOMED CT[®] mapper was not available at the time of this study. Access to a variety of free on-line browsers made the search possible as recommended by the experts. Although these free browsers contain all the SNOMED CT[®] concepts, they do not allow the user to have access to updates as they were made available. Three of the four browsers allowed the user to access the UK database while the fourth was designed primarily for use in veterinary setting. In 2010, Canada Health Infoway implemented what is known as ‘SNOMED TRACKER’, a list of SNOMED CT[®] initiatives, including a summary of the project and contact information. Implementation of standardized terminologies has been slow. Lee et al (2013) noted that in the 13 SNOMED CT[®] implementations internationally, none were sharing data beyond their enterprises. (14)

An important lesson learned is that utilization of the compositional capabilities of SNOMED CT[®] necessitates a close collaboration between technology and clinical experts. Rather than attempting or relying upon post-coordination, implementation experts recommend requesting SNOMED international develop new and pre-coordinated codes, particularly for key components of asthma management such as asthma control parameters. Dostaler *et al.* (15) determined that categorization of asthma control varies significantly, depending upon which parameters are included in the classification (particularly whether only subjective symptom parameters are used or symptoms plus objective measures of pulmonary function), and which definition is used for each parameter. This finding illustrates the need for international agreement on the parameters and definitions for composite indicators such as asthma control. (15) Although, post-coordination might improve the ACM mapping results, the post-coordinated expressions are cumbersome, relying on both technical and clinical input. In order for asthma control to be utilized in SNOMED CT as new or pre-coordinated concept, ideally there would first be international consensus on control parameters and their definitions.

Similarly, a review of 13 SNOMED CT implementations internationally concurred that post-coordination continued to be a challenge and greater success was achieved by developing extension sets for missing SNOMED concepts that could then be submitted to SNOMED International for formal inclusion into national extensions or SNOMED CT core. (14)

EHR interoperability has not yet been achieved. Clinicians and guideline developers could advance interoperability by stipulating elements and data definitions for inclusion in EHRs. This need was highlighted in a recent systematic scoping review Al Sallakh *et al.*, which identified large variations in algorithms used in EHRs to define asthma, asthma severity, asthma

control and asthma exacerbations. (8) EHR interoperability is not only an admirable goal for clinicians and administrators. Patients stand to benefit directly from improved health care delivery which results from timely, secure access to their patient record (including medications, allergy history and test results) and reduces or eliminates redundant tests(8).

Recently, the Canadian Thoracic Society (CTS), the national organization responsible for the development and dissemination of best practice guidelines for respiratory care, established a Pan-Canadian Respiratory Standards Initiative for Electronic Health Records (PRESTINE), to support the translation and maintenance of respiratory best practice guidelines and performance indicators for EMRs/EHRs across Canada. (16) In 2013, PRESTINE embarked on a pan-Canadian strategy to achieve consensus from respiratory and primary care health providers from across Canada on standardized respiratory data elements for EHRs beginning with asthma. The results of the current study will help inform this initiative.

CONCLUSION

In summary, the majority of the OLA's ACM elements including PFT variables are congruent with SNOMED CT® and LOINC®. There is much to accomplish before standardized terminology for the chronic diseases such as asthma is used routinely in clinical care. The next step in order to close the gap between evidence-based asthma/respiratory data elements and standardized nomenclature is for clinicians and terminology experts to collaborate on EHR data standards implementation initiatives, such as the Canadian Institute for Health Information's draft Pan-Canadian Primary Health Care Electronic Medical Record Content Standard. (17) Ensuring terminology standards exist for evidence-based respiratory care elements, in particular

asthma control and control parameters, will help facilitate EHR interoperability and optimal patient care.

Authors' contributions

Dr. Loughheed, the principal investigator for this study, had full responsibility for all aspects of this project including the design, implementation and evaluation. Janice Minard contributed to the above, managed the study and has been the primary author of the manuscript. Nicola Thomas was responsible for mapping the ACM to SNOMED CT[®] and LOINC[®] and provided significant input and feedback on the content of the manuscript. Nastasia Wasilewski and Alison Morra, assisted with review of the results, development of the tables and ongoing review of the manuscript.

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Conflicts of Interest

Dr. Loughheed has declared in the past 3 years, she has received grants outside the submitted work paid directly to Queen's University from the Ontario Lung Association, the Ontario Thoracic Society, the Government of Ontario's Innovation Fund, AllerGen NCE, Queen's University, MPEX, GlaxoSmithKline, Hoffman LaRoche and Janssen. Janice Minard reported that as the project manager for this study, her position was funded by the Government of Ontario. There are no other potential conflicts of interest to report.

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Appendix A

Asthma Care Map Mapped to SNOMED-CT®

	Exact Match	Partial Match	Unmatched	% Exact and Partial Match by Category
*Demographics (n = 3)	100%			
<i>Patient's name</i>	X			
<i>Date (DD/MM/YYYY)</i>	X			
<i>Date of Birth (DD/MM/YYYY)</i>	X			
	*Demographics not included in match count			
Initial assessment and diagnosis (n = 9)	78%			
<i>History</i>	X			
<i>Physical</i>	X			
<i>Asthma Diagnosis</i>			X	
<i>Date</i>	X			
<i>Confirmed by objective measures</i>				
<i>(i) ≥12-15% change in FEV₁ post bronchodilator (min 180mL)</i>		X		
<i>(ii) ≥20% change in FEV₁ after 10--14 day course of prednisone or ICS trial (min. 250mL)</i>	X			
<i>(iii) 20% diurnal variation of FEV₁/Peak flow post bronchodilator or overtime</i>			X	
<i>(iv) Methacholine challenge: 20% reduction in FEV₁ (PC₂₀) <8mg/mL</i>	X			
<i>Diagnosis: Suspected</i>		X		
Severity (n = 16)	X			37.5%
<i>(i) Hospitalized ever</i>		X		
<i>Total number of times</i>			X	
<i>Recent (<2 years)</i>			X	

Remote (>2 years)			X	
(ii) Emergency Department visits ever	X			
Total number of times			X	
Recent (<2 years)			X	
Remote (>2 years)			X	
(iii) Near fatal episodes (coma, intubated, ICU, CO₂)	X			
Total number of times			X	
Recent (<2 years)			X	
Remote (>2 years)			X	
(iv) Prednisone use ever	X			
Total number of times			X	
FEV₁ PEF <60% predicted		X		
Asthma Allergy (n = 19)			X	79%
Conjunctivitis	X			
Anaphylaxis	X			
Rhinitis	X			
Medication	X			
Eczema	X			
Food	X			
Skin prick test		X		
Cats	X			
Dogs	X			
Dust/dust mites	X			
Feathers	X			
Moulds	X			
Trees/grass/weed/pollen	X			

<i>Other</i>		X		
<i>Family history of allergy or asthma</i>	X			
<i>Parent</i>			X	
<i>Sibling</i>			X	
<i>Grandparent</i>			X	
Smoking History (n = 14)			X	71%
<i>Non-smoker</i>	X			
<i>Ex-smoker</i>			X	
<i>Quit when</i>	X			
<i>Pack years</i>	X			
<i>Current smoker</i>	X			
<i>Number of cigarettes you smoke/day on days you smoke</i>			X	
<i>Time frame for smoking</i>	X			
<i>Smokes within 5 minutes of waking</i>		X		
<i>Within 6--30 minutes</i>		X		
<i>31--60 minutes</i>		X		
<i>More than 60 minutes</i>		X		
<i>Don't know</i>		X		
<i>Smoking cessation consider Smoker's helpline</i>			X	
Occupational History (n = 3)			X	33%
<i>Occupational Work Exposure(s)</i>		X		
<i>Relation between asthma symptoms and work (Y/N)</i>			X	
<i>Started at work</i>	These descriptors are not included in the count because we could not find the main concept 'relation between asthma symptoms and work' in SNOMED-CT®			
<i>within days of an accidental spill or fire</i>				
<i>worsened at work</i>				
<i>chest symptoms (cough/wheeze/chest tightness/shortness of breath) different (less) on days off</i>				

<i>chest symptoms different (less) on holidays</i>				
Risk factors (n = 12)			X	42%
<i>Beta blockers</i>	X			
<i>Exposure to second hand smoke</i>	X			
<i>Home</i>			X	
<i>School/work</i>			X	
<i>Social</i>			X	
<i>GERD</i>	X			
<i>Menses</i>			X	
<i>Non-steroidal anti-inflammatory</i>	X			
<i>Pregnancy</i>			X	
<i>Sinusitis</i>	X			
<i>Other</i>			X	
Irritant triggers (n = 20)			X	85%
<i>Changes in weather</i>		X		
<i>Chemicals</i>			X	
<i>Cold air</i>	X			
<i>Colds/chest infections</i>		X		
<i>Emotions/stress</i>		X		
<i>Exercise</i>	X			
<i>Fireplace/woodstove</i>		X		
<i>Gas stove</i>		X		
<i>Outdoor pollution</i>		X		
<i>Ozone</i>		X		
<i>Windy Day</i>		X		
<i>Allergic triggers</i>		X		
<i>Cockroach</i>	X			

Dust	X			
Dust mites	X			
Mould	X			
Pets	X			
Pollens/trees/grasses	X			
Others			X	
Trigger exposure (n = 24)			X	38%
Birds			X	
Carpets and or stuffed animals			X	
Dust mites	X			
Cats		X		
Dogs		X		
Exposure to second- hand smoke	X			
Occupational exposure to fumes, dust, animals			X	
Other			X	
Date no longer exposed (DD/MM/YYYY)			X	
Environmental controls in place			X	
Air conditioning in summer	X			
Dehumidifier			X	
Central vacuum			X	
Hardwood/tile floors			X	
Heat exchanger	X			
Humidifier in winter		X		
Mattress cover			X	
Pillow covers			X	
Regular furnace filter change		X		

<i>Wash linens weekly in hot water</i>			X	
<i>Wash pets once a week</i>			X	
<i>Wear mask or respirator as needed</i>	X			
<i>Date put in place (DD/MM/YYYY)</i>			X	
Identified barriers (n = 6)	X			67%
<i>Adherence</i>	X			
<i>Cultural issue</i>			X	
<i>Financial issue</i>	X			
<i>Lack of family/friend/school/ work support</i>	X			
<i>Language</i>	X			
<i>Literacy</i>	X			
<i>Lack of drug plan</i>			X	
<i>Other</i>			X	
Client has communicated diagnosis of asthma, management (n = 1)			X	0%
Follow-up Assessment (n = 42)	X			86%
<i>Predicted FEV₁</i>		X		
<i>Personal Best PEF</i>		X		
<i>Date:</i>	X			
<i>Visit: Scheduled (S) or</i>			X	
<i>Urgent (U)</i>		X		
<i>Asthma Control (Y = uncontrolled asthma)</i>			X	
<i>Physical activity limited due to asthma Y/N</i>	X			
<i>Needs Reliever (≥ 4 doses/wk. – yes; < 4/wk. – no) Y/N</i>		X		
<i>Dyspnea, cough, wheeze, or chest tightness (≥ 4 days/wk. – yes; < 4 days/wk. – no)</i>		X		
<i>School/work absence since last visit Y/N</i>	X			

Night time symptoms (>1/wk. – yes; none – no)		X		
FEV₁ <90% of predicted or		X		
PEF <90% of predicted or personal best Y/N		X		
Exacerbations since last visit (hospital admission, Emergency Department visit, Walk-in Clinic) Y/N	X			
Spirometry/PEFR	X			
Spirometry (minimum 2x/yr.) print out attached		X		
PEFR (every visit),	X			
Value (best of 3) L/min		X		
Review:	X			
Definition of asthma Y/N		X		
Medications Y/N	X			
Adherence to medications Y/N	X			
Device technique optimal Y/N	<u>X</u>			
Prevention:			X	
Smoking cessation Y/N	X			
Immunization (flu) Y/N	X			
Triggers Y/N			X	
Environmental control Y/N			X	
Management:	X			
Coping strategies Y/N		X		
Action plan: written		X		
Action plan: revised	X			
Action plan: reviewed	X			
Asthma medications	X			

Reliever	X			
Controller	X			
Medication changes	X			
Referrals:		X		
Asthma Education		X		
Specialist		X		
Other			X	
Signature and Profession	Not counted in matches			
Total counts % (n)	42% 24% 34%	71/169 41/169 57/169		

Definition of abbreviations: DD = day, MM = month, YYYY = year, FEV₁ = forced expiratory volume in 1 second, PEF = peak expiratory flow, PC₂₀ = provocative concentration of methacholine which caused a 20% fall in FEV₁, ICS = inhaled corticosteroid, Y = yes, N = No

Table 1. Asthma Control Mapped to SNOMED CT®

	Complete	Partial	Unmatched
Asthma Control			X
Dyspnea, cough, wheeze, or chest tightness (≥ 4 days/wk. – yes; < 4 days/wk. – no)		X	
Nighttime symptoms (> 1 /wk. – yes; none – no)		X	
Physical activity limited due to asthma Y/N	X		
Exacerbations since last visit (hospital admission, ED visit, walk-in Clinic) Y/N	X		
School/work absence since last visit Y/N	X		
Needs reliever (≥ 4 doses/wk. – yes; < 4 /wk. – no)		X	
FEV ₁ or PEF $< 90\%$ predicted or personal best Y/N		X	

Definition of abbreviations: FEV₁ = forced expiratory volume in 1 second, N = No,

PEF = peak expiratory flow, Y = Yes, wk. = week

Table 2. ACM Pulmonary Function Test (PFT) Data Elements Mapped to SNOMED CT® and LOINC®

ACM PFT Data Elements	SNOMED CT®	LOINC®
Diagnostic Criteria		
≥ 12--15% change in FEV ₁ post bronchodilator (min. 180mL)	Partial	Partial
≥ 20% change in FEV ₁ after 10--14 day course of prednisone or ICS trial (min. 250mL)	Complete	Partial
20% diurnal variation of FEV ₁ / Peak Flow; 20% change post-bronchodilator or overtime	Unmatched	Unmatched
Methacholine challenge: 20% reduction in FEV ₁ (PC20) <8mg/mL.	Complete	Partial
Asthma Severity and Control Criteria		
Predicted FEV ₁	Partial	Complete
Personal Best PEF	Partial	Unmatched
FEV ₁ or PEF < 60% predicted	Partial	Complete
FEV ₁ ≤ 90% predicted	Partial	Partial
PEF ≤ 90% personal best	Partial	Partial
Spirometry (print out attached)	Partial	Complete
PEF every visit	Complete	Complete
PEF value, best of 3	Partial	Complete
% of PFT ACM data elements with complete and partial matches (n = 12)	92%	83%

Definition of abbreviations: FEV₁ = forced expiratory volume in 1 second,

PEF = peak expiratory flow, PC₂₀ = provocative concentration of methacholine

which caused a 20% fall in FEV₁

Table 3. Smoking History Mapped to SNOMED CT®

	Complete	Partial	Unmatched
Smoking History			X
Non-Smoker	X		
Ex-Smoker			X
Quit when? DD/MM/YYYY	X		
Pack Years: (packs/day X # yrs. smoked)	X		
Current Smoker	X		
Number of cigarettes you smoke/day on days you smoke			X
Time frame from waking	X		
Smoke		X	
•within 5min. of waking			
•within 6--30min.		X	
•31--60min.		X	
•more than 60min		X	
•don't know		X	
Smoking cessation: consider Smokers Helpline @ www.smokershelpline.ca or call 1-817-513-5333			X

Definition of abbreviations DD = day, MM = month, YYYY = year, yrs. = years, min = minute

Table 4. SNOMED-CT® Examples of Complete Matches

Asthma Care Map Main Heading	Asthma Care Map Element	SNOMED CT® Match	SNOMED CT® Concept	SNOMED CT® Hierarchy	SNOMED CT® Concept ID
Severity	Asthma Severity	Complete	Asthma Severity (regime/therapy)	Procedure	170642006
	ED visits ever, total number of times	Complete	Emergency admission, asthma	Procedure	183478001
Asthma Control	Physical activity limited due to asthma	Complete	Asthma restricts exercise (finding)	Clinical Finding	170655007
	School/work absence since last visit	Complete	Absent from work or school due to asthma	Clinical Finding	390921001
Allergy History	Anaphylaxis	Complete	Anaphylaxis (disorder)	Clinical Finding	39579001
	Eczema	Complete	Eczema (disorder)	Clinical Finding	43116000
Risk Factors	GERD	Complete	Gastro esophageal reflux disease (disorder)	Clinical Finding	235595009

Definition of abbreviations: ED = emergency department, GERD = gastro esophageal reflux disease.

Table 5. SNOMED CT® Examples of Partial Matches

Asthma Care Map Main Heading	Asthma Care Map Element	SNOMED CT® Concept	SNOMED CT® Hierarchy	SNOMED CT® Concept ID
Asthma Diagnosis	>12-15% Change in FEV ₁ post bronchodilator (min 180mL)	Spirometry reversibility test	Procedure	314979004
		Spirometry reversibility Positive finding	Clinical Finding	314981002
Severity	FEV ₁ or PEF <60% predicted	Decreased Forced Expiratory Volume	Clinical Finding	46154005
Asthma Control	Needs Reliever (≥4 doses/week-yes, <4 doses/week- no)	# of times bronchodilator used in one week	Clinical Finding	370213005
	Night time symptoms (>1/week- yes, None-no)	Asthma causes night time symptoms 1--2 days per month	Clinical Finding	370205009
Environmental Controls in Place	Regular Furnace filter change	Filter (device)	PhysicalObject	116250002

Definition of abbreviations: FEV₁ = forced expiratory volume in 1 second, PEF = peak

expiratory flow

Table 6. SNOMED CT® Examples of Unmatched ACM Data Elements

Asthma Care Map Main Heading	Unmatched Data Element
Severity	Hospitalized ever, total number of times, recent <2 years, remote >2 years
	Prednisone use ever, total number of times
Family history of allergy or asthma	Parent, sibling, grandparent
Smoking history	Link for “Smokers' Helpline”, a community smoking cessation resource
Trigger exposure	Date no longer exposed
Environmental controls in place	Date put in place
	Hardwood floors, central vacuum, dehumidifier, humidifier in winter (20-50% humidity desirable)
	Mattress/pillow covers, wash linens weekly in hot water, wear mask or respirator as needed

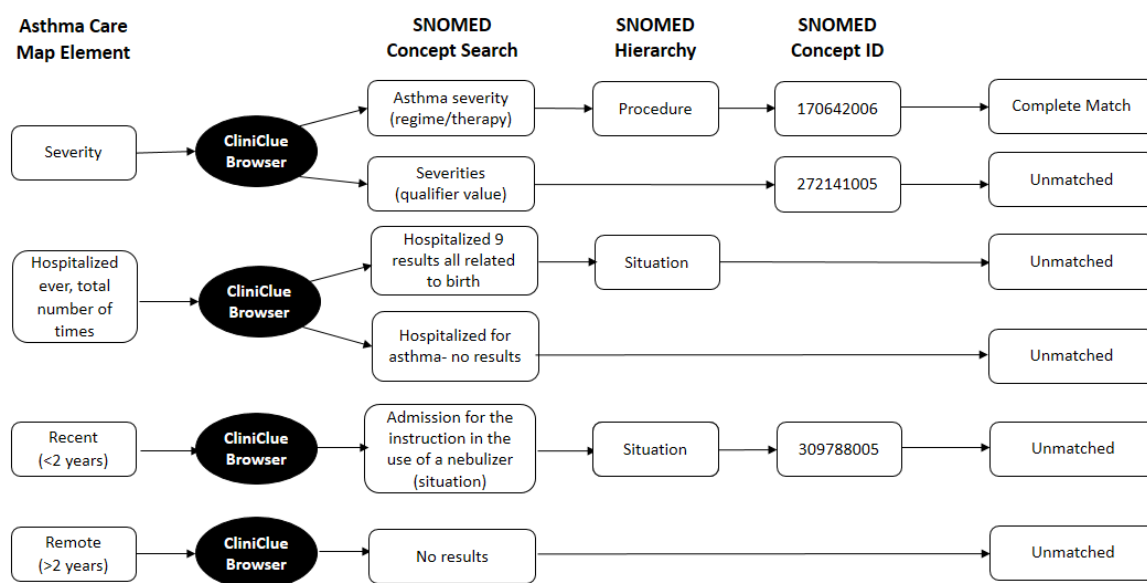


Figure 1. Asthma Care Map to SNOMED CT Mapping Process

Figure 1. An overview of the hierarchical mapping process of the Asthma Care Map elements to SNOMED CT® using the free Clinique Browser. SNOMED concept searches are categorized by description, hierarchy and a concept ID, from which a match is determined. The ACM element, “Asthma Severity” is a complete match in SNOMED. The concept (Asthma Severity, a regime/therapy) is in the hierarchy of procedures. Procedures represent interventions that are carried out in order to provide health care, including medication such as prednisone, and receipt of care in an Intensive Care Unit. In the ACM “Asthma Severity” is assessed by activities such as number of times hospitalized for asthma