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Two Algorithms for the Reorganisation of the Problem List by Organ System

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ABSTRACT

Objective Long problem lists can be challenging to use. Reorganisation of the problem list by organ system is a strategy for making long problem lists more manageable.
Methods In a small-town primary care setting, we examined 4950 unique problem lists over 5 years (24 033 total problems and 2170 unique problems) from our electronic health record. All problems were mapped to the International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) and SNOMED CT codes. We developed two different algorithms for reorganising the problem list by organ system based on either the ICD-10-CM or the SNOMED CT code.
Results The mean problem list length was 4.9±4.6 problems. The two reorganisation algorithms allocated problems to one of 15 different categories (12 aligning with organ systems). 26.2% of problems were assigned to a more general category of 'signs and symptoms' that did not correspond to a single organ system. The two algorithms were concordant in allocation by organ system for 90% of the unique problems. Since ICD-10-CM is a monohierarchic classification system, problems coded by ICD-10-CM were assigned to a single category. Since SNOMED CT is a polyhierarchical ontology, 19.4% of problems coded by SNOMED CT were assigned to multiple categories.
Conclusion Reorganisation of the problem list by organ system is feasible using algorithms based on either ICD-10-CM or SNOMED CT codes, and the two algorithms are highly concordant.

INTRODUCTION AND SIGNIFICANCE

The problem list is one of the four critical elements of the problem-oriented medical record, as described by Dr Lawrence Weed in 1968.[1] Weed[2] wrote that 'the first page of the patient record should consist of a numbered problem list. It is a 'table of contents' and 'index' combined, and the care with which it is constructed determines the quality of the whole record'. The electronic problem list is now a standard component of all electronic health records (EHRs). A turning point in the adoption of the electronic problem list occurred in the USA in 2014 when the Meaningful Use programme required providers to maintain an electronic problem list. The Meaningful Use programme defined the problem list as 'A list of current and active diagnoses as well as past diagnoses relevant to the current care of the patient'.[3] The widespread use of the electronic problem list has raised the issue of responsibility for ensuring that the problem list is complete and accurate.[4 5] A problem list that is incomplete or that is cluttered with numerous inactive problems may lack utility. Several studies have noted that problem lists are often incomplete.[6 7] On the other hand, as Holmes[8] commented, for some unhealthy patients, the problem list can '…grow to 30 or more lines of text, making a clear and quick understanding of the patient's health nearly impossible'. Reconciliation of long problem lists (making sure the problem list is complete and identifying inactive problems) is challenging and time-consuming. One strategy for dealing with long problem lists is to reorganise them by organ system. The reorganisation of problems by organ system could make long problem lists more manageable by facilitating the recognition of redundant problems, problems subsumed by other problems, missing problems and inactive problems.

On most problem lists, problems are not captured as free text, but rather as structured data coded as either the International Classification of Diseases (ICD) codes or SNOMED CT codes. Both International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) and SNOMED CT have an inherent structure that could allow the problem list to be reorganised by organ system. We have tested the hypothesis that the problem list can be reorganised algorithmically by using the inherent structure in ICD-10-CM and SNOMED CT.

METHODS
Setting
Your Community Health Center is a federally qualified health centre in rural Missouri with four primary care providers (one physician and three advanced practice nurses). During the study period, providers used eClinicalWorks V.10e (Westborough, Massachusetts) as their electronic medical record.

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EHR functionality

eClinicalWorks V.10e allows providers to add new problems, mark inactive problems as resolved or move inactive problems to medical history. Resolved problems are filtered out of the active problem list but can be retrieved by adjusting the filter settings. By organisational policy, providers are required to maintain a valid problem list on every patient to comply with the Meaningful Use of EHR programme.[3] A quality management report monitors compliance with this policy monthly. By organisational policy, problems must be entered as structured data (ICD-10-CM codes), and free-text problems are not permitted. eClinicalWorks V.10e can map ICD-10-CM codes to a supplementary problem list of SNOMED CT codes. However, since no one-to-one map from ICD-10-CM to SNOMED CT codes exists, the use of the SNOMED CT problem list requires some manual mapping of terms from ICD-10-CM to SNOMED CT. As a result, our providers use the problem list based on ICD-10-CM codes exclusively.

Problems

This study was based on 41 749 patient encounters between 22 April 2014 and 15 February 2019. Using the

Table 1 Reorganising algorithms for problems by organ systems

Organ system	Acronym	ICD-10-CM* (range)	SNOMED CT† (subsumption)
Cardiovascular	CV	I00–I52 I70–I99 O10–O16	|49601007|Cardiovascular disorder (disorder)
Endocrine and metabolic	END	E00–E89	|75934005| Metabolic disease (disorder) |70241007| Nutritional deficiency (disorder) |362969004| Disorder of endocrine system (disorder)
Ear, nose, throat	ENT	H60–H95 K00–K14 J00–J06 J30–J39	|232208008| Ear nose and throat disorder (disorder)
Eye	EYE	H00–H59	|128127008|Disorder of visual system (disorder)
Gastrointestinal	GI	K20–K95	|53619000|Disorder of digestive system (disorder)
Genito-urinary-breast	GUB	N00–N99 O91–O92	|42030000|Disorder of the genitourinary system (disorder) |79604008| Disorder of breast (disorder) |129103003| Endometriosis (disorder)
Haematological	HEM	D50–D78	|414022008|Blood disease (disorder) |362970003|Disorder of haemostatic system (disorder) |414027002|Disorder of haematopoietic structure (disorder)
Inflammatory or infectious	INF	A00–B99 O85–O87 D80–D89	|40733004| Infectious disease (disorder) |128139000| Inflammatory disorder (disorder)
Integumentary	INT	L00–L99	|128598002|Disorder of integument (disorder)
Musculoskeletal and injury	MS	M00–M99 S00–T88	|928000| Musculoskeletal disorder (disorder) |417163006| Traumatic and/or non-traumatic injury (disorder)
Neoplasms	NEO	C00–D49	|399981008|Neoplasm and/or hamartoma (disorder)
Neurological	NEU	G00–G99 F51 I60–I69	|118940003| Neurological disorder (disorder) |230461009| Headache disorder (disorder) |39898005| Sleep disorder (disorder)
Psychiatric	PSY	F20–F49 F60–F99	|74732009|Mental illness (disorder)
Respiratory	RSP	J09–J18 J20–J22 J40–J99	|50043002|Respiratory disease (disorder)
Signs and symptoms	SIGNS	R00–R99 F10–F19 F50–F59	|250171008| Clinical history and observation finding (finding) |441742003|Evaluation finding (finding)

*All ICD-10-CM codes that were within the listed ranges were included.
†All SNOMED CT codes that were subsumed by the listed SNOMED CT codes were included. See SNOMED CT documentation for the operational definition of subsumption.[12]
ICD-10-CM, International Classification of Diseases, 10th Revision, Clinical Modification.

eClinicalWorks eBO database tool, we took a snapshot of all problem lists in our EHR as of 15 February 2019. Data extracted included provider name, date problem was added, problem name, patient record number and ICD code. We reduced our initial data set of 34 757 problems by excluding problems coded as ICD-9-CM or with ICD-10-CM codes beginning with letters 'U' or 'Z'. This yielded a final data set of 24 033 problems, 4950 unique problem lists and 2170 unique problems (mean problem list length of 4.9±4.6 problems). Since no one-to-one map between ICD-10-CM and SNOMED CT exists, each of the 2170 ICD-10-CM codes was manually mapped to a corresponding SNOMED CT code.[9]

Algorithms for reorganising the problem list by organ system

Organ systems for the reorganising algorithms were selected to mirror the organisation of ICD-10-CM chapters[10] (see table 1). We developed two algorithms for reorganising the problem list by organ system. The first algorithm was based on parsing the ICD-10-CM codes according to the chapter organisation of ICD-10-CM (eg, codes beginning with 'G' are neurological, codes beginning with 'I' are cardiovascular; see also table 1). A second algorithm for reorganising the problem list by organ system was based on using subsumption within the hierarchy of SNOMED CT codes.[11] For example, most cardiovascular disorders are subsumed by the SNOMED CT concept |105969002| Cardiovascular disorder (disorder) (see table 1). Both algorithms were implemented in Python V.3.7 (www.anaconda.com). For the SNOMED reorganising algorithm, we used a transitive closure table (encompassing all subsumption relations) provided by SNOMED International.[12]

RESULTS

During the 5-year study period, providers used 2170 unique ICD-10-CM codes to add 24 033 problems. The top 20 problems accounted for more than 40% of all problems added (table 2). The top 5 problems by count were essential hypertension, nicotine dependence, anxiety disorder, major depression and obesity, similar in frequency to other studies of the problem list.[13]

Problems were reorganised into one of 15 different organ systems according to either the ICD-10-CM or SNOMED CT code algorithm (table 3). Table 4 demonstrates how a typical long problem list of 21 problems can be reorganised by organ system. Note that reconciliation of the problem list could eliminate at least five redundant problems from the problem list.

Table 2	Top 20 problems		
ICD-10-CM code	**Description**	**Count**	**Proportion of total (%)**
I10	Essential hypertension	1417	5.9
F17.200	Nicotine dependence	1221	5.1
F41.9	Anxiety disorder	992	4.1
F32.9	Major depressive disorder	865	3.6
E66.9	Obesity	831	3.5
K21.9	Gastro-oesophageal reflux disease	484	2.0
E11.9	Type 2 diabetes mellitus without complications	452	1.9
E03.9	Hypothyroidism	327	1.4
G89.29	Other chronic pain	322	1.3
J30.2	Seasonal allergic rhinitis	321	1.3
E66.01	Morbid obesity	311	1.3
G47.00	Insomnia	278	1.2
J30.9	Chronic allergic rhinitis	277	1.2
F43.10	Post-traumatic stress disorder	257	1.1
F33.1	Major depressive disorder	235	1.0
J44.9	Chronic obstructive pulmonary disease	229	1.0
G62.9	Polyneuropathy	211	0.9
F31.9	Bipolar disorder	199	0.8
E78.5	Hyperlipidaemia	194	0.8
F41.1	Generalised anxiety disorder	189	0.8
R03.0	Elevated blood pressure reading	186	0.8
	Total	9798	40.8

ICD-10-CM, International Classification of Diseases, 10th Revision, Clinical Modification.

Table 3 Concordance between ICD-10-CM and SNOMED CT reorganising algorithms

Organ system*	Assignment by ICD-10-CM algorithm (count)	Assignment by SNOMED algorithm (count)	Concordant assignments (count)	Concordant assignments as proportion of ICD-10-CM codes† (%)	Proportion of the total problems (%) (n=24 034)
CV	148	186	148	100	8.5
END	125	147	122	98	8.8
ENT	108	107	97	90	6.8
EYE	50	63	50	100	0.4
GI	144	159	138	96	4.6
GUB	153	168	144	94	3.8
HEM	35	50	34	97	0.7
INF	103	303	92	89	2.5
INT	96	128	90	94	2.0
MS	590	469	469	79	9.8
NEO	54	60	52	96	0.4
NEU	145	258	141	97	5.0
PSY	129	131	114	88	16.5
RSP	70	107	60	85	4.0
SIGNS	220	305	207	91	26.2
Total	2170	2641	1958	90	100.0

*For acronyms, see table 1.
†Column 4 counts divided by column 2 counts.
ICD-10-CM, International Classification of Diseases, 10th Revision, Clinical Modification.

Both algorithms were able to reorganise problems into one of the 15 categories (table 3). As a proportion of the total problems, the largest categories were signs and symptoms (26.2%), psychiatric (16.5%), musculoskeletal and injuries (9.8%), endocrine (8.8%), and cardiovascular (8.5%), reflecting the high prevalence of hypertension, diabetes, hypothyroidism, depression and anxiety (table 2). The two reorganising algorithms were concordant (defined as both algorithms assigning the problem to the same organ system) for 1958 of the unique problems (90%). The ICD-10-CM reorganisation algorithm returned one category for each problem, reflecting its structure as a monohierarchic classification system. The SNOMED CT reorganisation algorithm returned more than one category for 19.4% of the problems (table 4), reflecting its organisation as a polyhierarchical ontology. We considered the two algorithms concordant if at least one of the categories returned by the SNOMED CT algorithm matched the ICD-10-CM algorithm category.

DISCUSSION

The goal of the electronic problem list is to be accurate, complete and usable. Complete means that all actively managed problems are on the problem list. Accurate means that inactive or resolved problems have either been moved to medical history or filtered out of the active problem list. Usable means that the problem list is not so excessively long that the user finds it cumbersome to grasp and reconcile. Several studies have found that the electronic problem list is often incomplete.[6 7] Some studies have explored making the problem list more complete by using natural language processing,[14] importing claims data,[15] or implementing rules based on structured data or decision support tools.[16 17]

It is our opinion that long problem lists are an emerging challenge for healthcare providers. Problem list reconciliation (identifying missing problems and filtering out resolved problems) is time-consuming and cognitively demanding. At our institution, an analysis of 4951 problem lists showed that 10% have 10 or more problems, 4% have 15 or more problems, and 2% have 20 or more problems. The reasons for long problem lists are varied. At each patient encounter, EHRs facilitate the easy transfer of diagnoses from the progress note to the problem list. At subsequent visits, redundant problems (eg, *overweight* and *obesity*) may be inadvertently added to the problem list. As some problems become inactive, providers may fail to mark these problems as resolved. Signs or symptoms that have been transformed into ongoing problems (eg, *shortness of breath* becomes *asthma*) may remain on the problem list.[18] Importantly, providers may lack the time to reconcile these long lists. As Krauss *et al*[19] commented, 'even with a unified problem list policy in place, there is little incentive in many documentation workflows to curate problem lists'.

Table 4 Example of problem list in both alphabetical order and organ system order

Problem	ICD-10-CM	Alphabetical order	Organ system	ICD-10-CM	Organ system order
1	I70.0	Abdominal aortic atherosclerosis	CV	I10	Essential hypertension
2	F10.10	Alcohol abuse*	CV	I38	Systolic murmur
3	F10.20	Alcohol use disorder*	CV	I70.0	Abdominal aortic atherosclerosis
4	F41.1	Anxiety	CV	I73.9	Peripheral artery disease
5	F31.9	Bipolar 1 disorder*	END	E11.9	Diabetes
6	M51.26	Bulging of intervertebral disc between L4 and L5	END	E78.0	High cholesterol
7	K21.9	Chronic Gastro-oesophageal reflux disease*	GI	K21.9	Chronic Gastro-oesophageal reflux disease*
8	F32.9	Depression*	GI	K21.9	Gastro-oesophageal reflux disease without oesophagitis*
9	E11.9	Diabetes	GI	K29.50	Other chronic gastritis*
10	I10	Essential hypertension	GI	K58.0	Irritable bowel syndrome
11	K21.9	Gastro-oesophageal reflux disease without oesophagitis*	GI	K92.0	Haematemesis*
12	K92.0	Haematemesis*	MS	M51.26	Bulging of intervertebral disc between L4 and L5
13	E78.0	High cholesterol	NEU	G62.9	Neuropathy
14	K58.0	Irritable bowel syndrome	PSY	F10.10	Alcohol abuse*
15	G62.9	Neuropathy	PSY	F10.20	Alcohol use disorder*
16	F51.5	Nightmares	PSY	F25.0	Schizoaffective disorder, bipolar type*
17	K29.50	Other chronic gastritis*	PSY	F31.9	Bipolar 1 disorder*
18	I73.9	Peripheral artery disease	PSY	F32.9	Depression*
19	F25.0	Schizoaffective disorder, bipolar type*	PSY	F33.2	Severe episode of recurrent major depressive disorder*
20	F33.2	Severe episode of recurrent major depressive disorder*	PSY	F41.1	Anxiety
21	I38	Systolic murmur	PSY	F51.5	Nightmares

*Problems with asterisk (shaded boxes) can be reconciled to eliminate redundant problems and shorten problem list.
END, endocrine and metabolic; GI, gastrointestinal; ICD-10-CM, International Classification of Diseases, 10th Revision, Clinical Modification; MS, musculoskeletal and injury; NEU, neurological; PSY, psychiatric.

Table 5 Problems assigned to one or more organ systems by SNOMED CT algorithm

Number of organ systems	Frequency (count)	Proportion (%)
1	1793	81.6
2	320	15.7
3	43	2.0
4	10	0.4
5	4	0.2
Total	2170	100

Others have introduced the idea of reorganising the problem list by organ system to improve usability.[20 21] At least one terminology vendor has introduced software that will allow the reorganising of the problem list by organ system within some EHRs.[22] Our study demonstrates the feasibility of reorganising the problem list by organ system. We have shown that when problems are mapped to either ICD-10-CM codes or SNOMED CT codes, approximately 75% of the problems on typical problem lists can be categorised by organ system (table 3). When we examined 2170 unique problems in use at our health centre, the ICD-10-CM grouping algorithm assigned all but 295 ICD-10-CM codes to an organ system, and the SNOMED CT grouping algorithm assigned all but 305 SNOMED CT codes to an organ system (tables 1 and 3). Of the 2170 unique problems examined, the algorithms were concordant for 1958 of the problems (90%). Reasons for lack of concordance between the two reorganising algorithms are twofold. First, ICD-10-CM is a monohierarchy, whereas SNOMED CT is a polyhierarchy. Diseases and disorders are assigned to only one organ system in ICD-10-CM, whereas they may be assigned to one, two or more organ systems in SNOMED CT (see table 5). For example, diabetic neuropathy (E13.42) in ICD-10-CM is assigned to endocrine disorders, whereas SNOMED CT (SCT 230572002) assigns diabetic neuropathy to both neurological disorder and endocrine disorder. Second, SNOMED CT and ICD-10-CM handle signs and symptoms somewhat differently. ICD-10-CM defines 'R' codes as 'less well-defined conditions and symptoms that, without the necessary study of the case to establish a final diagnosis, point perhaps equally to two or more diseases or two or more systems…'.[10] SNOMED CT distinguishes between *clinical findings* and *disorders*. SNOMED CT defines *clinical findings* as 'normal/abnormal observations, judgments, or assessments of patients' and *disorders* as 'always and necessarily an abnormal clinical state'.[23] In general, SNOMED CT is more conservative and will not assign a *sign or symptom* to an organ system if it is compatible with more than one organ system.

Study limitations
We did not do any human factor studies to determine whether reorganising the problem list by organ system will facilitate problem list use or reconciliation. Further studies will be needed to address these issues. Another study limitation was the small number of providers studied. Other studies have shown significant interprovider differences in their approach to maintaining the problem list.[19] Furthermore, in a primary care setting such as ours, the primary care provider has sole ownership of the problem list and carries full responsibility for reconciliation of the problem list. The situation is more complicated in a multispecialty practice setting where a variety of providers are adding to the problem list and ownership of the problem list is shared. Nonetheless, we are of the opinion that reorganisation of the problem list by organ system will be even more valuable in a multispecialty setting by allowing each specialist to view easily those problems addressed by that specialty. Another study limitation is that we did not investigate other reorganisation algorithms, such as the ordering of problems by chronicity or acuity or the nesting of problems by subsumption. Finally, use of the SNOMED CT reorganisation algorithm assigns problems to multiple categories approximately 19% of the time. Users of the SNOMED CT algorithm are faced to choose between allowing a problem to appear in multiple categories or assigning that problem to a single category.

Generalisability of findings and implications for EHR design
Nearly all hospital and physician practices now use commercially available EHRs. Implementation of problem list reorganisation by organ system will require support from EHR vendors. We have demonstrated that easy-to-implement algorithms based on either SNOMED CT or ICD-10-CM codes can be used to reorganise the problem list by organ system. Although we have not yet performed usability studies, we believe that reorganisation of the problem list by organ system will make these problem lists easier to reconcile. These algorithms could be implemented in any EHR system that uses SNOMED CT or ICD-10-CM to encode the problem list. Physician burn-out related to use of the EHR is a growing problem.[24] We believe that the EHR should and will evolve so that more of the time-consuming work of maintaining accurate problem lists can be done algorithmically to conserve clinician time and effort.

CONCLUSIONS
With the increasing adoption of the problem list as a key element of the EHR, long problem lists are inevitable, especially in complex medical patients. One strategy for making long problem lists more usable is to reorganise these lists by organ system. We have demonstrated the feasibility of two algorithms to reorganise the problem list by organ system based on either ICD-10-CM codes or SNOMED CT codes. We found high levels of concordance between the two categorisation algorithms.

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