

MAPPING SNOMED CT TO THE INTERNATIONAL CLASSIFICATION OF HEALTH INTERVENTIONS (ICHI) OF THE WHO-FIC



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31 January 2026

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1. Executive Summary

This report documents the design, execution, and evaluation of a structured mapping between SNOMED CT procedure concepts and the World Health Organization's International Classification of Health Interventions (ICHI). The work forms part of the Belgian SNOClass project, commissioned within the national strategy to strengthen semantic interoperability and secondary use of electronic health record (EHR) data.

Background and rationale

Modern health systems increasingly depend on the reuse of clinical data for statistics, financing, public health monitoring and policy development. SNOMED CT is widely adopted for detailed clinical documentation in EHRs, while ICHI is designed as a statistical and administrative classification suitable for aggregation, international comparison and health system management.

However, the absence of a robust, validated map between these systems limits the ability to transform fine-grained clinical data into standardized intervention statistics. In Belgium, this challenge is amplified by the coexistence of multiple non-interoperable procedure coding (ICD-10-PCS) and billing (Nomenclature) systems. Establishing a high-quality SNOMED CT-to-ICHI map is therefore a prerequisite for semantic interoperability, alignment with WHO-FIC standards, and future integration of clinical, statistical and reimbursement data flows.

Objectives and research questions

Primary objective: To develop and evaluate a methodologically sound, semantically validated mapping from SNOMED CT procedure concepts to ICHI Stem codes and Inclusions.

Secondary objectives

- To assess the feasibility of automated or semi-automated mapping based on lexical and semantic techniques.
- To quantify mapping coverage, equivalence types, and mapping cardinalities.
- To identify methodological refinements and governance requirements for scaling the map.

Study design and methods

The study used a purpose-driven, unidirectional mapping design, aligned with WHO-FIC, ISO mapping standards, and SNOMED CT editorial guidance.

- Source concepts: 2,528 SNOMED CT procedure concepts derived from the ICD-9-CM Volume 3 to SNOMED CT legacy map issued by the National Library of Medicine, reflecting the historical conceptual basis of ICHI.
- Target system: ICHI "Interventions on Body Systems and Functions," including both Stem codes and Inclusion terms.
- Methods:

- Automated lexical candidate generation using a Whoosh-based search engine.
- Structured semantic evaluation of candidate maps by a domain expert.
- Classification of equivalence (exact, narrow-to-broad, broad-to-narrow, partial, no match).
- Reconciliation of Stem code and Inclusion-level mappings.
- Output in a Simple Standard for Sharing Ontological Mappings (SSSOM) format.

Key Findings

1. Overall coverage:
Of 2,528 SNOMED CT procedure concepts reviewed, 1,907 (75.4%) were successfully mapped to ICHI Stem codes or Inclusions.
2. Suitability for automation:
1,370 mappings were classified as exact or narrow-to-broad, making them suitable for automated transformation of EHR data into ICHI-based statistics.
3. Distribution across ICHI levels:
 - 647 exact or narrow-to-broad maps at Stem code level (12.1% of all relevant ICHI Stem codes).
 - 723 exact or narrow-to-broad maps at Inclusion level (8.9% of all relevant ICHI Inclusions).
4. Mapping structure:
One-to-many relationships were common, reflecting differences in granularity between SNOMED CT and ICHI. Inclusion-level mapping increased absolute coverage but required greater manual effort.
5. Partial maps:
Only 98 mappings were classified as partial; 87.5% of these could be resolved through ICHI post-coordination (“clustering”).

Interpretation and Meaning

The findings demonstrate that a large, clinically relevant subset of SNOMED CT procedures can be reliably aligned with ICHI using a combined lexical-semantic approach. The high proportion of exact and narrow-to-broad matches confirms that ICHI is conceptually capable of representing detailed clinical interventions when supported by structured mapping rules and post-coordination.

Differences in hierarchy depth and modeling philosophy explain most one-to-many and partial mappings and do not undermine statistical usability. Importantly, the results validate the ICD-9-CM–based source selection as an effective methodological bridge between SNOMED CT and ICHI.

Implications of the map

- Clinical and informatics: Enables systematic reuse of SNOMED CT-encoded EHR data for intervention statistics without re-coding at source.
- Policy and health system management: Supports alignment with WHO-FIC standards for international comparison, case-mix analysis, and performance monitoring.
- Belgian healthcare system: Provides a technical foundation for future convergence of clinical documentation, statistical reporting, and reimbursement frameworks.
- International relevance: Demonstrates a replicable approach for other countries seeking SNOMED CT-to-ICHI interoperability.

Recommendations

1. Scale the mapping to broader SNOMED CT procedure subsets, prioritizing national reference sets.
2. Institutionalize governance, including editorial oversight, version control, and release synchronization with SNOMED CT and ICHI updates.
3. Operationalize automation for mappings classified as exact or narrow-to-broad, with clear rules for post-coordination.
4. Feedback to WHO-FIC on identified content gaps to support iterative improvement of ICHI.
5. Integrate the map into national interoperability and health data strategies, particularly where adoption of ICD-11/ICHI or the new nomenclature is planned.

Conclusion

This study demonstrates that a substantial, policy-relevant mapping between SNOMED CT and ICHI is both feasible and methodologically robust. By successfully aligning over three-quarters of the evaluated SNOMED CT procedure concepts, most of them suitable for automated use, the project establishes a practical pathway toward semantic interoperability between clinical documentation and international intervention statistics. The work provides a scalable foundation for harmonized secondary use of health data across clinical, administrative and policy domains.

2. Introduction

As the need for harmonized healthcare data increases, mapping clinical reference terminologies such as SNOMED CT (Systematized Nomenclature of Medicine – Clinical Terms) to classifications such as ICHI (International Classification for Health Interventions) is essential for data aggregation and reuse. SNOMED CT is a richly structured clinical reference terminology used for precise documentation in Electronic Health Records (EHRs). ICHI is maintained by the World Health Organisation (WHO) and provides a classification system suitable for statistical purposes, finances, epidemiology, and resource management. Bridging these systems supports diverse use cases from case mix classification to health policy planning.

The Belgian National Release Center of the Federal Public Service Health, Food Chain Safety and Environment issued a project for mapping SNOMED CT to three standard classifications: ICHI, ICF (International Classification of Functioning, Disability and Health), and ICPC-3 (International Classification of Primary Care – 3rd Ed.) in 2024.

This report reflects the development of the map from SNOMED CT to ICHI.

Team

The Belgian [SNOClass](#) project started in early 2025. It consists of three sub-projects: mapping SNOMED CT to ICPC-3 (International Classification of Primary Care, version 3), WHO International Classification of Functioning, Disability and Health (ICF) and WHO International Classification of Health Interventions (ICHI).

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Bio: Dr Ameye is an expert in medical data management, with a specialization in the classification, reimbursement, and terminology of medical and surgical procedures. Following a career as a thoracic and vascular surgeon, he transitioned into medical informatics. He has contributed to national and international health data initiatives, including the development of mappings between SNOMED CT, ICD-10-PCS, and ICHI, as well as the digital transformation of medical procedure nomenclatures.

He currently works as a consultant, advising on the secondary use of administrative health data and the integration of standardized classifications of medical procedures into digital health systems. He remains active in research and publication within this domain.

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Bio: Joseph Roumier is trained in Computational Linguistics and Knowledge Engineering. He has participated and conducted research on multilingual linguistic and conceptual resources since 2003. His work focuses on health domain and semantic web concepts and tools. He works at Ghent University for the SNOClass project.

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Bio:

Robert Vander Stichele is a practicing family physician in Ghent, Belgium, since 1978. He combines his clinical practice with research projects since 1982. He obtained his PhD (in medical sciences) in 2004 and was appointed as teaching professor in the department of Pharmacology at the University of Ghent. He became a certified clinical pharmacologist in 2009. His interests are in information on and use of medicines. He is member of the Special Interest Group on Drug Utilization in the International Society for Pharmaco-epidemiology (ISPE). He is a senior researcher in the research alliance on “End-of-Life Care”, a consortium of the University of Ghent, Brussels, Amsterdam and Rotterdam. He is founding member of the Board of the Belgian Centre for Evidence-Based -Medicine (CEBAM). Currently, he works as an expert in Europe of the Department of Medical Informatics at the University of Ghent on medical terminology and electronic product information for medicines. His publication list comprises more than 200 scientific papers (referred to in Medline).

Prof. Dr. Pascal Coorevits

Bio: Pascal Coorevits is Associate Professor at the Faculty of Medicine and Health Sciences of the Ghent University and head of the Unit of Medical Informatics and Statistics at the Department of Public Health and Primary Care. His primary research interests lie in the domain of Electronic Health Records (EHRs) and are oriented towards various aspects of quality labelling and certification of EHRs, EHR data and mHealth apps (quality criteria, data quality indicators, quality labelling and certification models, tools/methodologies for EHR evaluation and conformance testing, EHR semantic interoperability aspects, EHR data harmonization, re-use of EHR data for research purposes). Lecturer-in-charge of several courses in biostatistics, methodology, evidence-based medicine, and medical informatics. Board member of the Belgian not-for-profit organisation RAMIT (Research in Advanced Medical Informatics and Telematics), an R&D spin-off platform of the Ghent University and Executive Board Member of the European Institute for Innovation through Health Data (i~HD). Participation in several EU -, national - and transatlantic eHealth projects (non-exhaustive list: ASSIST, EHRImplement, EHR-Q TN, ARGOS, HITCH, Antilope, EHR4CR, SemanticHealthNet, EURECA, EXPAND, HELICAL, RWD4BE, ...). Flemish coordinator of two VLIR-UOS SI projects “A pilot project on digitalizing the hospital patient trajectory and secondary use of Electronic Health Records (EHRs) in Rwanda” (2020-2022, Rwanda) and

“Strengthening training and research capacity in Epidemiology and biostatistics to enhance Public Health research at Mountains of the Moon University (MMU)” (2022-2024, Uganda). Co-promotor of a current Structural Institutional Partnership with Mountains of the Moon University (2024-2028, Uganda). Coordinator of the EDCTP3 project “Scaling up research in SSA countries in infectious diseases: African-European training network in integrated health informatics and data sciences” (acronym: BRIDGE NETWORK, 2024-2029), which is proposing a unique and innovative scalable training program and network that will produce empowered infectious diseases experts in six African countries (Benin, Ethiopia, Uganda, Kenya, Rwanda and South Africa) to lead and drive research from and for sub-Sahara Africa, at levels of early-stage career (post-graduate certification and doctoral) and mid-stage career (post-doctoral) in an integrated program of health informatics and data sciences.

Website

As part of the SNOClassproject, a dedicated website was developed at <https://snoclass.be/>. The site serves as a central hub for information about the project, including its objectives, methodology, and key results. It provides resources for professionals and stakeholders, such as downloadable materials, updates on outreach activities, and links to relevant standards. The website also supports transparency and engagement by offering easy access to project documentation and contact information for collaboration.

3. Purpose and Use Case of the Mapping

The purpose of the SNOMED CT to ICHI map is to support international health statistics, public health monitoring, and case mix funding schemes, based on the Electronic Health Record. It aids data transformation from clinical records to classifications and aligns national reporting with WHO standards.

4. Scope of the Mapping

The mapping focuses on the SNOMED CT Procedure hierarchy, particularly surgical and diagnostic procedures, mapped to the relevant ICHI Stem code and Inclusion labels, and the axial components (Target, Action, Means) of the classification. The scope excludes administrative or contextual concepts and is limited to ICHI Stem codes and Inclusions of Interventions on Body systems and Body functions.

5. Terminology and Classification Overview

5.1 SNOMED CT

SNOMED CT (Systematized Nomenclature of Medicine – Clinical Terms) is a multi-lingual compositional clinical terminology that supports fine-grained representation of healthcare activities. SNOMED CT concepts have a Fully Specified Name [FSN], Preferred Term and

Synonyms. It provides over 350.000 active, hierarchically structured concepts for representing clinical findings, observable entities, body structures, procedures, situations, and contexts. The procedure hierarchy contains 59.312 concepts in SNOMED CT International release 2025-01-01.

Concepts are defined within their hierarchy through 'IS A' relationships with parent or child concepts. Each concept may have multiple ascendants, making it a multi-hierarchical system.

Parents

- ▶ ☰ Biliary tract excision (procedure)
- ▶ ☰ Operation on gallbladder (procedure)

☰ Cholecystectomy (procedure) ☆ ↗

SCTID: 38102005

38102005 | Cholecystectomy (procedure) |

- en Cholecystectomy (procedure)
- en Cholecystectomy
- en Excision of gallbladder
- en Gallbladder excision
- en Removal of gallbladder

Method → Excision - action

Procedure site - Direct → G

Children (8)

- ▶ ☰ Cholecystectomy and exploration of bile duct (procedure)
- ▶ ☰ Cholecystectomy with intraoperative fluoroscopic cholangiography with contrast (procedure)

FIGURE 1: HIERARCHY OF THE 'CHOLECYSTECTOMY' CONCEPT

Each concept has its concept model with various attributes. The Procedure hierarchy includes attribute values for Method, Procedure site, Access and Using Access Device.

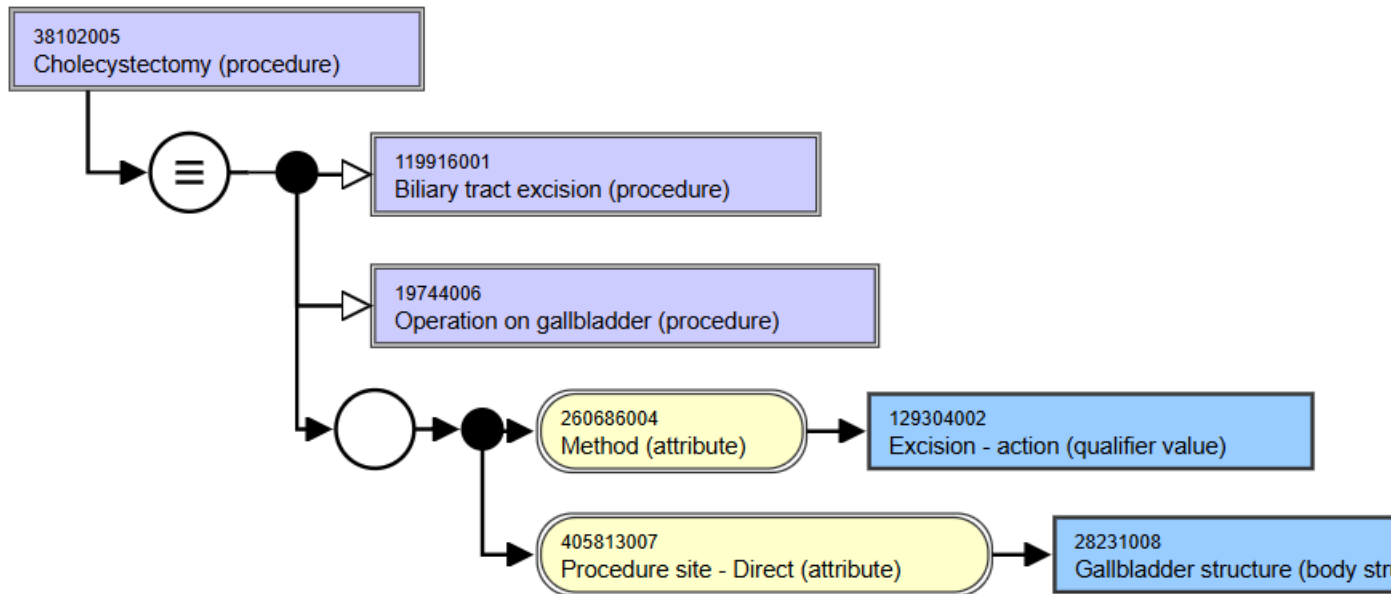


FIGURE 2: 'CHOLECYSTECTOMY' CONCEPT MODEL

Post-coordination, combining different concepts, enables detailed expression.

The terminology is maintained by SNOMED International and can be explored through its online browser [1]

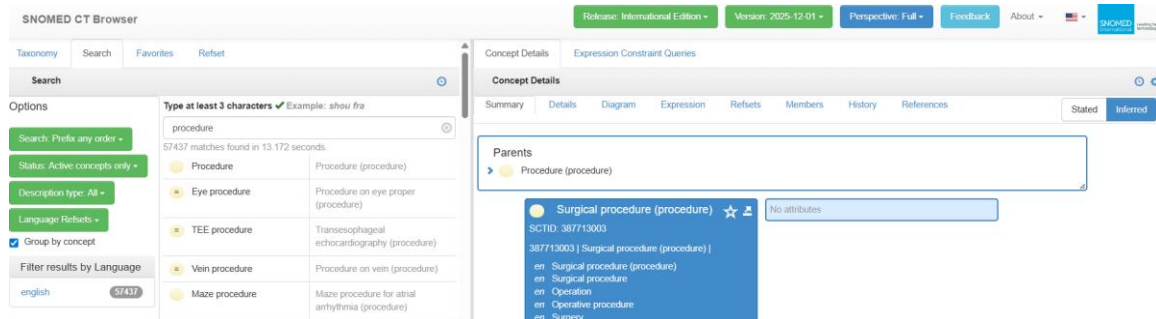


FIGURE 3: SNOMED CT BROWSER INTERFACE

Belgium is an official SNOMED International member through the Federal Public Service of Health, Food Chain Safety and Environment (FPS Public Health), which hosts the Belgian Terminology Centre within the Directorate-General for Health Care (DGGS) (<https://www.snomed.org/members/belgium>)

The Terminology Center coordinates the implementation, localization, and governance of clinical terminologies, including SNOMED CT, LOINC and ICD-10-CM/PCS, as part of the national eHealth and interoperability strategy (<https://www.ehealth.fgov.be/nl/page/actieplan-egezondheid-2025-2027>). Its mission is to ensure that clinical data recorded in EHRs can be meaningfully exchanged, aggregated,

and reused across systems, disciplines, and policy domains
(<https://apps.health.belgium.be/terminology-portal/home/nl>)

5.2 ICHI

For a contextual introduction to ICHI we refer to the Brochure, developed by the SNOClass team, available through: <https://snoclass.be/deliverables/>

5.2.1 Features

The World Health Organization (WHO) Family of International Classifications (WHO-FIC) includes three reference classifications, covering diseases, functioning and disability, and health interventions:

- International Statistical Classification of Diseases (ICD)
- International Classification of Functioning, Disability and Health (ICF)
- International Classification of Health Interventions (ICHI)

ICHI has been developed from 2007 by a wide range of people drawn from WHO-FIC Collaborating Centers in all WHO regions, as well as a number of WHO staff. ICHI covers all parts of the health system and contains a wide range of interventions not found in national classifications [2].

ICHI is a tri-axial classification consisting of 3 axes representing:

- Target - entity on which the Action is carried out.
- Action - deed done by an actor to the Target.
- Means - processes and methods by which the Action is carried out.

The classification encompasses interventions on body systems or functions, the environment, activities and participation domains, and health-related interventions. This project concentrates on the 'Interventions on body systems or functions. Post-coordination ('clustering') via Extension codes supports additional detail when required.

The ICHI classification is accessible through the ICHI browser [3].



FIGURE 4: ICHI BROWSER INTERFACE

The section Interventions on body systems of functions has 5.338 Stem codes and 8.090 Inclusions, based on the extraction of 2025 Feb 11.

Each intervention is defined by a Stem code (e.g., Appendectomy) or an Inclusion (e.g., 'Appendectomy, with drainage of appendiceal abscess).'

Search:

Foundation URI: <http://id.who.int/icd/entity/944529697>

KBO.JK.AA Appendicectomy

Parent
Interventions on appendix

Inclusions

- Appendicectomy with drainage of appendiceal abscess ⇒
- Other incidental appendicectomy ⇒

All Index Terms

- Appendicectomy
- Appendectomy
- Appendectomy, NOS
- Appendicectomy with drainage of appendiceal abscess ⇒
- Other incidental appendicectomy ⇒

ICHI Axes

Target: KBO Appendix
Action: JK Excision, total
Means: AA Open approach

FIGURE 5: PROCEDURE STEM CODE – INCLUSIONS - AXES

A Stem code has a 7-character code, representing Target, Action and Means, and a Stem code label. Stem codes may have a common expression format (e.g. Cholecystectomy) or a concatenated representation of the three axes (e.g., Partial excision of colon).

Inclusion terms are mostly common language expressions.

Both Stem codes and Inclusions have a Unique Resource Identifier (URI), referring to the underlying Foundation Model, which is common with the other members of the WHO Family of International Classifications: ICD-11 (International Classification of Diseases – 11th version) and ICF (International Classification of Functional Disability).

Search

[Advanced Search] Home Foundation Coding Tool Proposals Info

Foundation URI : <http://id.who.int/icd/entity/94452969>

KBO.JK.AA Appendicectomy

Parent

- Interventions on appendix

Inclusions

- Appendectomy with drainage of appendiceal abscess ⇒ <http://id.who.int/icd/entity/1324017582>
- Other incidental appendectomy ⇒ <http://id.who.int/icd/entity/1173289216>

All Index Terms

- Appendicectomy
- Appendectomy
- Appendicectomy, NOS
- Appendectomy with drainage of appendiceal abscess ⇒
- Other incidental appendectomy ⇒

ICHI Axes

Target: KBO Appendix
Action: JK Excision, total
Means: AA Open approach

FIGURE 6: STEM CODE AND INCLUSION URI'S

The WHO Family of International Classifications has a Foundation Component which is a medical knowledge base organized in a poly-hierarchy (in which an entity can descend from more than one branch or parent) that identifies relationships or connections among the entities. Foundation entities of interest are extracted based on use case to form a subset (called a linearization) from the Foundation in the form of a single hierarchy of entities and a corresponding code set. containing all entities from all three classifications such (ICD, ICF, and ICHI)—into a simplified, hierarchical list akin to traditional tabular formats [4].

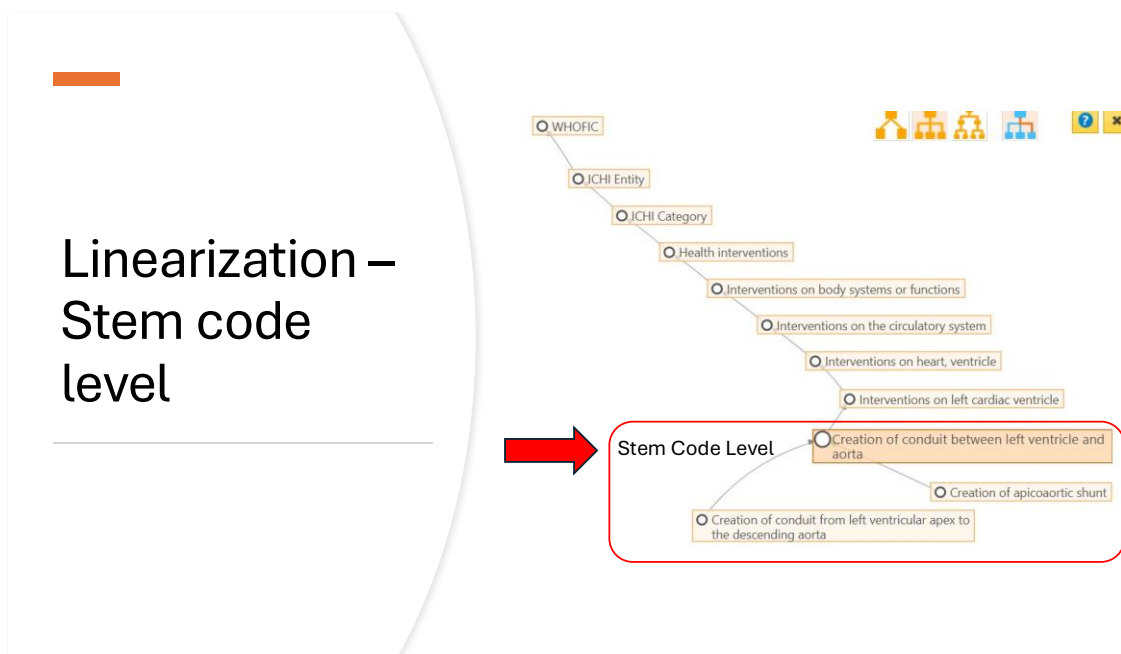


FIGURE 7: LINEARIZATION OF A STEM CODE

Linearization – Inclusion level

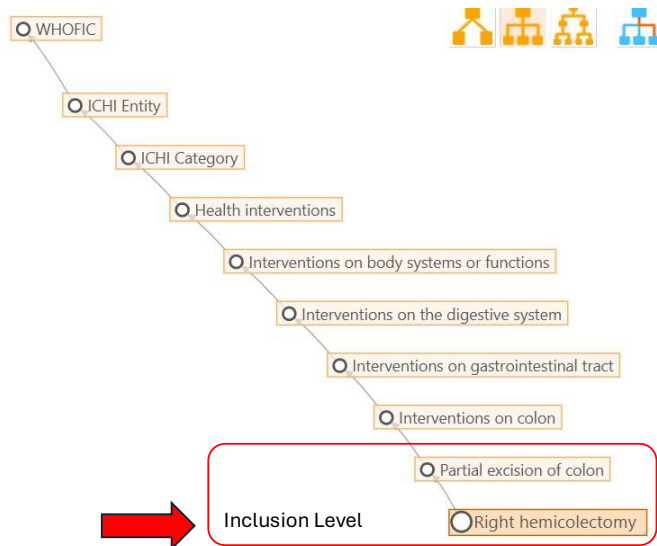


FIGURE 8: LINEARIZATION OF AN INCLUSION

5.2.2 Use cases

5.2.2.1 International comparisons

A comprehensive international classification of health interventions provides a sound base for comparisons, whether the international classification is used directly for collecting data, as a base for developing national classifications, or as a common structure to which codes in national classifications can be mapped for compiling international data. Previous work has shown that ICHI was adequate to support statistical reporting [5].

5.2.2.2 National uses of ICHI

ICHI is put forward as an international standard for countries that currently have no classification, countries that still use the ICD-9-CM Vol. 3 classification and countries willing to redevelop or extend their national classification using ICHI.

5.2.2.3 Sustainable Development Goals

To monitor progress against the health-related Sustainable Development Goals (SDG's) (<https://www.who.int/europe/about-us/our-work/sustainable-development-goals>) of the United Nations, and to assist in the development, financing and implementation of specific programs appropriate to each particular region and country, it is important to have a common classification that can be used to describe interventions across countries and regions.

5.2.2.4 Universal Health Coverage (UHC)

In providing a common structure and terminology for the description of interventions, ICHI together with ICD-11 and ICF will be valuable in specifying indicators for monitoring implementation of UHC.

5.2.2.5 Patient safety and quality

ICHI complements ICD and ICF in the analysis of patient safety and quality of care. It allows explicit coding of interventions related to adverse events, remediation actions, and quality improvement activities, thereby supporting systematic reporting and international learning.

5.2.2.6 Health System Performance

ICHI enables comprehensive recording of health system activities across hospital and non-hospital settings. Combined with ICD-11, it provides a foundation for health service planning, performance assessment, and case mix-based financing systems at national or international level.

5.2.2.7 Public Health Use Cases

ICHI serves as a planning and evaluation tool for public health programs by offering a structured menu of possible interventions. It supports measurement of public health outputs, linkage with expenditure, and comparison of program composition across regions and countries, strengthening the evidence base for public health policy.

6. Methodology

6.1 Mapping Design Principles

The mapping followed WHO-FIC [6, 7], ISO/TR 12300 [8] and SNOMED editorial rules [9] for mapping principles: purpose-driven, unidirectional mapping, transparent documentation, and expert validation. Post-coordination logic was applied where needed to preserve clinical meaning.

6.2 Selection of a relevant sample of SNOMED CT source concepts

Relevant SNOMED CT procedure concepts were extracted from the ICD-9-CM Vol. 3 Procedure Codes to SNOMED CT legacy Map (202412 Release), that can be downloaded from the website of the National Library of Medicine [10]. This map was designed to support a transition from the use of legacy ICD-9-CM procedure codes to SNOMED CT.

ICD-9-CM Procedure Codes to SNOMED CT

Download the Current Map

Version: December 2024

Derived from ICD-9-CM version: 2013

Derived from SNOMED CT version: September 2024 US Edition

[Download Release](#)

FIGURE 9: ICD-9-CM PROCEDURES TO SNOMED CT LEGACY MAP

The ICD-9-CM procedure coding system has been used since 1989 and is still the basis for the current procedure coding systems in countries like Italy, Poland and Israel today.

When developing the "Interventions on Body Systems and Functions" section of ICHI, the World Health Organization (WHO) used the content of ICD-9-CM Volume 3 (specifically the 2012 version) as a starting point [11].

The 2,528 SNOMED CT concepts in the NLM map were therefore considered sufficiently relevant for the research project.

6.3 Mapping methodology

6.3.1 Semantic Evaluation

Each SNOMED CT concept was reviewed using its FSN, attributes (Method, Procedure site, Access, Using access device), and definitional relationships.

6.3.2 Mapping cardinalities

Manual review was supplemented by lexical search, ontological alignment, and use of ICHI's structured browser. Simple 1:1 and complex maps (1: n) were supported using ICHI Stem codes and Inclusions.

6.3.3 Post-coordination strategy in ICHI

ICHI allows 'clustering' with extra Stem codes or Extension codes. Multiple codes were combined where procedures covered distinct actions or targets. Extra extensions were added to reflect complex SNOMED CT meanings.

7. Mapping Tools and Environment

Concepts in conceptual terminologies systems are represented by a label and a unique identifier. There may be a definition and/or a formal description of relationships between concepts. When mapping between two conceptual systems, one may explore the similarity of the label of concepts (by comparing the string of letters in the label) or the congruity of the semantic meaning of the concepts.

The comparison between the lexical strings of the labels may be exact or fuzzy, and may or may not take into account all the elements in multi-term expressions.

7.1 Browsers

Tools used for manual mapping or for assessing equivalences included the SNOMED CT and ICHI browsers.

7.2 Whoosh-based lexical Search Engine

We used an automated search engine based on Python Whoosh [12] to collect mapping candidates from source SNOMED CT to target ICHI. Whoosh may compare unfavourably to LLM techniques for mapping but is faster [13]. The latter was an important factor to be able to provide initial candidate mappings to work with and evaluate.

Using the Whoosh library indexing features, the target (All ICHI Stem codes and Inclusions) is indexed in a format optimized for text search: words that form ICHI Stem codes and Inclusions are transformed through stemming, replacing characters with accent with characters without accent, removing stop-words and normalizing words. Using this method, it is more likely to find matches with candidate labels coming from the source (SNOMED CT Fully Specified Names, without hierarchical tags).

We then used the Whoosh library search engine features and applied them to the list of SNOMED CT terms: each FSN is used as a search query. The search engine applies a BM25F algorithm [14] to score lexical similarity between these terms and the ICHI index created earlier, considering some context elements (e.g. FSN length, Index size). For each successful match, the score and context (which words correspond) are retained and stored in spreadsheet for expert evaluation.

We used two variants of the search engine to yield mapping candidates [15]:

1. AND: all words from the SNOMED CT FSN are searched in the ICHI index.
2. OR: a maximum number of words from the SNOMED CT FSN are searched in the ICHI index.

The results of this approach were presented in a spreadsheet to the mapping evaluator, see Figure 10: Whoosh output (AND-criterion) and Figure 11: Whoosh output (OR-criterion).

SNOMED_CID	SNOMED_FSN	ICHI_LABEL_1	Score_1	Context_1	FURI_1
21257002	Removal of foreign body from skull	Removal of internal device or foreign body from skull	19,40434769	<b class="match term0">Removal of internal device or <b class="match term1">foreign <b class="match term2">body from <b class="match term3">skull	http://id.who.int/icd/entity/1185678455
307822008	Endoscopic trachea biopsy	Endoscopic biopsy of trachea	19,36314539	<b class="match term0">Endoscopic <b class="match term1">biopsy of <b class="match term2">trachea	http://id.who.int/icd/entity/4498715
76263007	Excision of lesion of middle ear	Local excision of lesion of middle ear, not elsewhere classified	19,36306714	Local <b class="match term0">excision of <b class="match term1">lesion of <b class="match term2">middle <b class="match term3">ear, not elsewhere classified	http://id.who.int/icd/entity/2035019818

FIGURE 10: WHOOSH OUTPUT (AND-CRITERIUM)

SNOMED_CID	SNOMED_FSN	ICHI_CODE_1_Group	ICHI_LABEL_1_Group	Score_1_Group	Context_1_Group
31315002	Reduction of closed knee dislocation (procedure)	MMJ.LD.AH	Closed reduction of knee joint	13,22247371	<b class="match term0">Closed <b class="match term1">knee joint
446463003	Full mouth plain X-ray of teeth (procedure)	KAE.BA.BA	X-ray of teeth	13,19251495	X- <b class="match term0">ray of <b class="match term1">teeth
80496005	Total mandibulectomy with reconstruction (procedure)	MAG.JK.AA	Total mandibulectomy	13,1862625	<b class="match term0">Total <b class="match term1">mandibulectomy
171988007	Excision of lesion of thyroid gland (procedure)	EBA.JL.AA	Local excision of lesion of thyroid	13,16726647	Local <b class="match term0">excision of <b class="match term1">lesion of <b class="match term2">thyroid gland
726488007	Excision of left adrenal gland (procedure)	EBC.JL.AA	Local excision of lesion of adrenal gland	13,1656892	Local <b class="match term0">excision of <b class="match term1">lesion of <b class="match term2">adrenal gland
726489004	Excision of right adrenal gland (procedure)	EBC.JL.AA	Local excision of lesion of adrenal gland	13,1656892	Local <b class="match term0">excision of <b class="match term1">lesion of <b class="match term2">adrenal gland
1264277001	Treatment of root canal of tooth (procedure)	KAE.ML.AC	Root canal therapy	13,1413342	<b class="match term0">Root canal therapy
41536004	Revision of anastomosis of small intestine (procedure)	KBK.LB.AA	Anastomosis of small intestine, not elsewhere classified	13,12979097	<b class="match term0">Anastomosis of <b class="match term1">small intestine, not elsewhere classified
387709005	Removal of ectopic fetus from abdominal cavity (procedure)	NMR.JF.AA	Removal of ectopic pregnancy	13,1086603	<b class="match term0">Removal of <b class="match term1">ectopic fetus from abdominal cavity
371408002	Removal of foreign body of lower limb, except foot (procedure)	LAG.JD.AA	Removal of internal device or foreign body of skin and subcutaneous cell tissue of lower limb	13,09468346	<b class="match term0">Removal of internal device or <b class="match term1">foreign body of <b class="match term2">skin and subcutaneous cell tissue of <b class="match term3">lower limb
45885009	Open reduction of dislocation of wrist (procedure)	MFJ.LD.AA	Open reduction of wrist joint	13,09181948	Open <b class="match term0">reduction of <b class="match term1">dislocation of <b class="match term2">wrist joint
95397003	Open reduction of dislocation of elbow (procedure)	MEJ.LD.AA	Open reduction of elbow joint	13,06467467	<b class="match term0">Open <b class="match term1">reduction of <b class="match term2">elbow joint
2080003	Angiectomy with anastomosis of lower limb artery (procedure)	IFA.AE.AA	Exploration of artery of lower limb	13,05617895	Exploration of <b class="match term0">artery of <b class="match term1">lower limb
2488002	Prescription, fitting and dispensing of contact lens (procedure)	BBB.DK.AH	Application of bandage contact lens to cornea	13,01414679	Application of <b class="match term0">bandage contact lens to <b class="match term1">cornea
359548007	Open biopsy of small intestine (procedure)	KBK.AD.AA	Biopsy of small intestine, not elsewhere classified	12,94655624	<b class="match term0">Biopsy of <b class="match term1">small intestine, not elsewhere classified

FIGURE 11: WHOOSH OUTPUT (OR-CRITERIUM)

Separate files were generated for SNOMED CT procedure concepts to Stem codes and Inclusion terms.

TABLE 1: WHOOSH OUTPUT - OVERVIEW

	AND-mode		OR-mode	
	Iterations	Candidates	Iterations	Candidates
Stem codes	2	599	2	4.699
Inclusion terms	26	1.437	6	13.031

7.3 Whoosh output at Stem code level

The Whoosh engine delivered for the 2.528 SNOMED CT concepts of the NLM procedure source sample a set of 5.298 candidate maps at Stem code level. The engine used 2

iterations at AND-level and 2 iterations at OR-level for this purpose. Most candidate maps (74,22%) were of a 1 SNOMED CT concept to 2 ICHI Stem codes type.

TABLE 2: CARDINALITY STEM CODE CANDIDATE MAPS

Row Labels	Count	Perc
1	33	0,62%
2	3.932	74,22%
3	609	11,49%
4	724	13,67%
Grand Total	5.298	100,00%

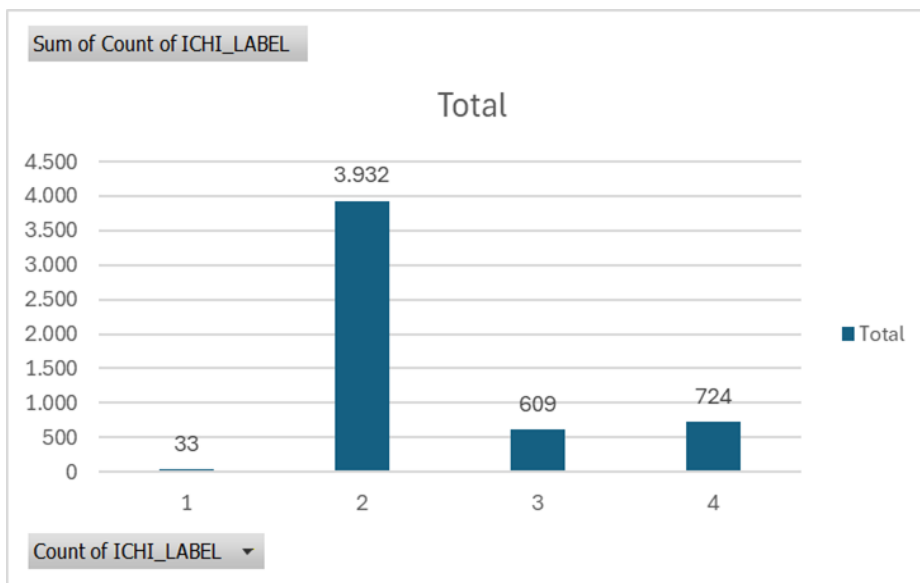


FIGURE 12: CARDINALITY OF SNOMED CT CONCEPTS TO ICHI STEM CODE CANDIDATES

High scores were obtained in the 'AND'-mode, dropping significantly in the 'OR'-mode.

TABLE 3: STEM CODE CANDIDATE MAPS - 'AND' vs. 'OR'-SCORES

Score	AND	OR
40-50	1	
30-40	16	5
20-30	186	127
10-20	371	1.534
0-10	25	3.033
Grand Total	599	4.699

7.4 Whoosh output at Inclusion level

After 26 iterations in the AND-mode and 6 iterations in the OR-mode, the Whoosh engine generated for the 2.528 SNOMED CT concepts a set of 14.468 ICHI candidate maps at Inclusion level. Most candidate maps (82,44%) were of a 1 SNOMED CT concept to 6 ICHI Inclusions type.

TABLE 4: CARDINALITY INCLUSION CANDIDATE MAPS

Candidates per concepts	Sum	Perct
1	52	0,36%
2	76	0,53%
3	87	0,60%
4	148	1,02%
5	335	2,32%
6	11.928	82,44%
7	1.232	8,52%
8	272	1,88%
9	90	0,62%
10	80	0,55%
11	55	0,38%
12	24	0,17%
13	52	0,36%
18	18	0,12%
19	19	0,19%
Total	14.468	100%

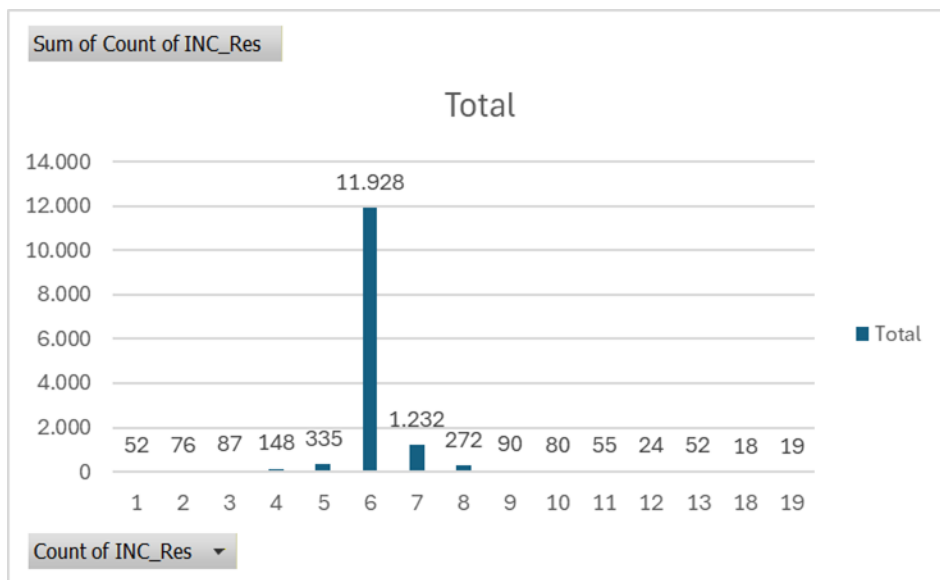


FIGURE 13: CARDINALITY OF SNOMED CT CONCEPTS TO INCLUSION CANDIDATE MAPS

Scores were significantly lower at the Inclusion level. with a large majority of candidate maps obtained from the 'OR'-mode with a <10 score.

TABLE 5: INCLUSION CANDIDATE MAPS SCORES

Row Labels	AND	OR
20-30	7	1
10-20	349	276
0-10	1.081	12.754
(blank)		
Grand Total	1.437	13.031

The higher output at the Inclusion level, with more candidates per SNOMED CT concepts and lower scores than the result at Stem code level, underlines the difference in workload for equivalence assessment of both files subsequently.

7.5 Result processing – output reduction – business rules

Automated rules were put in place to reduce the number of candidate maps for assessment.

7.5.1 Exact lexical string matches

A text formula allows the automated extraction of exact matches on the basis of identical lexical strings in SNOMED CT and ICHI.

NOMED	SNOMED_FSN	1_ICHI_C	INC_1_Res_1	IF_1
10281002	Scalenectomy	MAM.JK.AA	Scalenectomy	1
10788009	Percutaneous aspiration of semin	NGA.JB.AE	Percutaneous aspiration of se	1
112855003	Lysis of adhesions of tongue	KAB.FC.AC	Lysis of adhesions of tongue	1
112886005	Endoscopic insertion of stent into	KCO.LH.AD	Endoscopic insertion of stent i	1
112891005	Autotransplantation of thyroid tis	EBA.KD.AA	Autotransplantation of thyroic	1
12144001	Ligation of inferior vena cava	HIC.LA.AA	Ligation of inferior vena cava	1
12237002	Achillorrhaphy	MNT.MK.AA	Achillorrhaphy	1
12744005	Perineal urethroscopy	NAM.AE.AD	Perineal urethroscopy	1
14749004	Puncture of ventricular shunt tubi	AAE.AH.XE	Puncture of ventricular shunt t	1
172043006	Simple mastectomy	LCA.JK.AA	Simple mastectomy	1
172765003	Augmentation rhinoplasty	JAA.ML.AA	Augmentation rhinoplasty	1
173337005	Excision of dental lesion of jaw	MAG.JI.AA	Excision of dental lesion of jav	1
173788005	Pyloromyotomy	KBF.FA.AA	Pyloromyotomy	1
175974003	Incision of periurethral tissue	NAM.FA.AA	Incision of periurethral tissue	1
17669008	Removal of skull plate	MAA.JD.AA	Removal of skull plate	1
177594004	Piercing of ear lobe	CAC.FA.AA	Piercing of ear lobe	1
177784006	Decortication of lung	JBF.JJ.AA	Decortication of lung	1
177814005	Biopsy of periurethral tissue	NAM.AD.AA	Biopsy of periurethral tissue	1
182713008	Catalytic oxygen therapy	PZA.DD.AC	Catalytic oxygen therapy	1

FIGURE 14: EXACT STRING MATCHES BETWEEN SNOMED CT AND ICHI INCLUSION TERMS

7.5.2 Exclusion rules

Mutual exclusions can be applied through the absence or difference of specific elements in the source and target labels such as 'biopsy', 'excision types' (e.g. Total vs. Partial excision) or 'approach' (e.g. Thoracoscopic vs. Laparoscopic).

Rule_Id_Biopsy	FSN	ICHI	Valid
Biopsy_1	biopsy	biopsy	1
Biopsy_2	biopsy	no 'biopsy'	0
Biopsy_3	no 'biopsy'	biopsy	0

Rule_Id_Excision	FSN	ICHI	Valid
Excision_Type_1	Excision	Total excision	1
Excision_Type_2	Complete excision	Total excision	1
Excision_Type_3	Total excision	Total excision	1
Excision_Type_4	Partial Excision	Partial Excision	1
Excision_Type_5	Subtotal excision	Partial Excision	1
Excision_Type_6	Excision lesion	Excision lesion	1
Excision_Type_7	Local excision	Excision lesion	1
Excision_Type_8	Extended excision	Extended excision	1
Excision_Type_9	Radical excision	Extended excision	1

Rule_Id_Approach	FSN	ICHI	Valid
Approach_1	NULL	open	1
Approach_2	laparoscopic	laparoscopic	1
Approach_3	thoracoscopic	thoracoscopic	1
Approach_4	endoscopic	endoscopic	1
Approach_5	percutaneous	percutaneous	1
Approach_6	NULL	laparoscopic	0
Approach_7	NULL	thoracoscopic	0
Approach_8	NULL	endoscopic	0
Approach_9	NULL	percutaneous	0

FIGURE 15: MUTUAL EXCLUSIONS BETWEEN MAP CANDIDATES

8. Quality Assurance and Validation

The assessment of candidate maps follows the ISO 21564 Health informatics — Terminology resource map quality measures and requirements (MapQual) standards [16].

8.1 Expert Validation

The review of the candidate mappings for domain correctness and semantic equivalence was carried out by one single domain expert [17]. When necessary, extra input was obtained through the ChatGPT Large Language Model v4.0 for additional information on surgical techniques or other interventions (e.g., radiology, test, assessments, etc.)

8.2 Documentation of Equivalence

Equivalence was described as: exact, broader/narrower, partial, or unmatched.

Exact:

The definitions of the concepts mean the same thing (including when structural implications of meaning are considered) (i.e., extensionally identical).

Narrow-to-Broad:

The target mapping is broader in meaning than the source concept.

Broad-to-Narrow:

The target mapping is narrower in meaning than the source concept.

Partial:

The target mapping overlaps with the source concept, but source and/or target cover additional meaning, or the definitions are imprecise and it is uncertain whether they have the same boundaries to their meaning. The target may or may not need be 'clustered' with another ICHI Stem code or an Extension code to fully represent the meaning of the source concept.

No match/unmatched:

There is no match for this concept in the target code system.

Equivalences were established separately for Stem code and Inclusion level candidate maps and reconciled subsequently through merging both files. SNOMED CT has multiple hierarchical levels, whereas ICHI only has the Stem code level and the underlying Inclusion level.

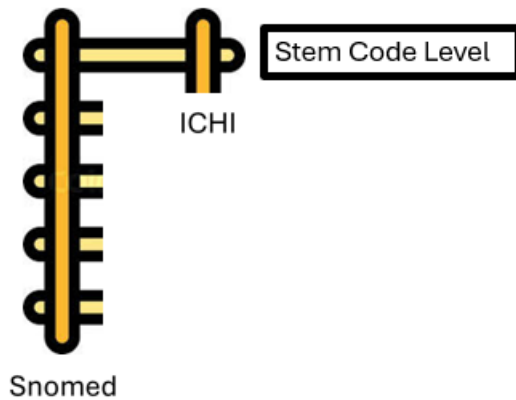


FIGURE 16: REPRESENTATION OF AN EXACT MATCH AT STEM CODE LEVEL

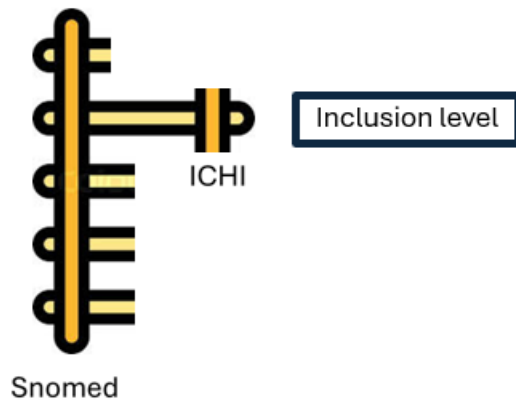


FIGURE 17: REPRESENTATION OF AN EXACT MATCH AT INCLUSION LEVEL

Through the linearization modem, an exact match at Inclusion level will therefore implicitly be a narrow-to-broad match at Stem code level, which requires reconciliation at a later stage of the analysis.

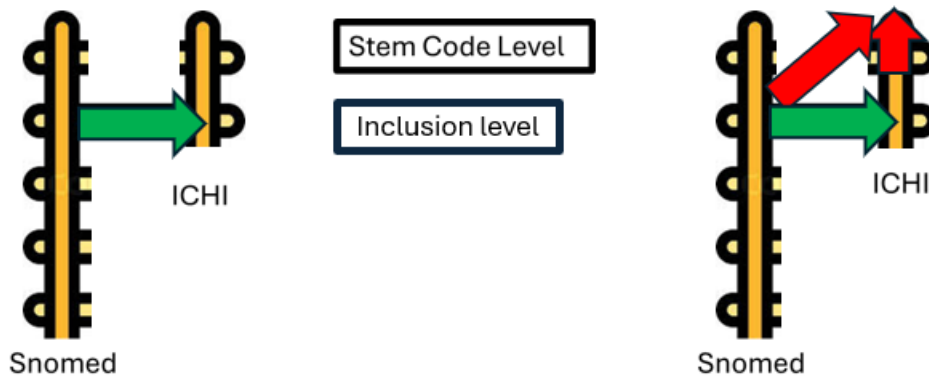


FIGURE 18: EXACT INCLUSION MATCH VS. NARROW-TO-BROAD STEM CODE MATCH

9. Results and Analysis

9.1 Stem code level

9.1.1 Stem code level – AND-mode

Equivalence assessment at Stem code level in the AND-mode had a high yield of Exact matches (54,59%).

TABLE 6: EQUIVALENCE ASSESSMENT OF STEM CODES - AND-MODE

Row Labels	Count	Perc
Broad to narrow	73	12,19%
Exact	327	54,59%
narrow to broad	23	3,84%
No map	175	29,22%
partial	1	0,17%
Grand Total	599	100,00%

9.1.2 Stem code level – OR-mode

Equivalence assessment of the Stem codes in the OR-mode, after eliminating the 599 duplicates obtained in the AND-mode, generated less exact matches than the AND-mode (243 vs. 327) at a considerable higher workload (4.101 vs. 599 candidate maps).

TABLE 7: EQUIVALENCE ASSESSMENTS OF STEM CODES - OR-MODE

Row Labels	Count	Perc
Broad to narrow	132	3,22%
Exact	243	5,93%
narrow to broad	249	6,07%
No map	3.371	82,20%
partial	106	2,58%
Grand Total	4.101	100,00%

9.1.3 Compiled Stem code AND-OR map scores

There is a clear drop in the generation of exact matches in line with the decreasing scores, up to where 2.807 (68,45%) of all the 'OR'-candidate maps with a <10 score, only generate 77 (2,74%) exact maps in this subgroup.

TABLE 8: COMPILED STEM CODE MAPS SCORES

Score	AND			OR	
	Equivalence	Count of Equivalence	Count of Equivalence2	Count of Equivalence	Count of Equivalence2
40-50		1	0,17%		0,00%
	Exact	1	100,00%		
30-40		16	2,67%	2	0,05%
	Exact	14	87,50%	1	50,00%
	narrow to broad	2	12,50%		0,00%
	No map		0,00%	1	50,00%
20-30		186	31,05%	90	2,19%
	Broad to narrow	9	4,84%	5	5,56%
	Exact	134	72,04%	20	22,22%
	narrow to broad	9	4,84%	10	11,11%
	No map	34	18,28%	45	50,00%
	partial		0,00%	10	11,11%
10-20		371	61,94%	1.202	29,31%
	Broad to narrow	55	14,82%	58	4,83%
	Exact	178	47,98%	145	12,06%
	narrow to broad	12	3,23%	109	9,07%
	No map	125	33,69%	836	69,55%
	partial	1	0,27%	54	4,49%
0-10		25	4,17%	2.807	68,45%
	Broad to narrow	9	36,00%	69	2,46%
	Exact		0,00%	77	2,74%
	narrow to broad		0,00%	130	4,63%
	No map	16	64,00%	2.489	88,67%
	partial		0,00%	42	1,50%
Grand Total		599	100,00%	4.101	100,00%

9.2 Inclusion level

9.2.1 Inclusion level – AND-mode

Equivalence assessment of candidate maps at the Inclusion level in the AND-mode generated 554 (38,55%) exact matches.

TABLE 9: AND-INCLUSION MAPS

Row Labels	Count	Percentage
Broad to narrow	427	29,71%
Exact	554	38,55%
narrow to broad	22	1,53%
No map	379	26,37%
Partial	55	3,83%
Grand Total	1.437	100,00%

The number of 554 exact matches at the Inclusion level is higher than the 327 exact maps at the Stem code level in absolute numbers but requires more effort for evaluating the sample. Of all Inclusion candidate maps, 38,55% are exact maps vs. 54.59% at Stem code level.

There is a clear drop in exact matches according to the decreasing map scores.

TABLE 10: AND-INCLUSION MAPS - SCORES

Row Labels	Count	Percentage
20-30	7	0,49%
Broad to narrow	1	14,29%
Exact	6	85,71%
10-20	349	24,29%
Broad to narrow	47	13,47%
Exact	235	67,34%
narrow to broad	5	1,43%
No map	56	16,05%
Partial	6	1,72%
0-10	1.081	75,23%
Broad to narrow	379	35,06%
Exact	313	28,95%
narrow to broad	17	1,57%
No map	323	29,88%
Grand Total	1.437	100,00%

9.2.2 Inclusion level – OR-mode

Further to the experience with the Stem code OR-maps, equivalences in Inclusion OR-candidate maps were only completely assessed in the first iteration and abandoned for candidates with a score less than 10 in the subsequent five iterations, to reduce the workload.

TABLE 11: OR-INCLUSION MAPS

Row Labels	Count	Percentage
Broad to narrow	64	3,02%
Exact	158	7,45%
narrow to broad	27	1,27%
No map	1.820	85,77%
Partial (blank)	53	2,50%
Grand Total	2.122	100,00%

TABLE 12: OR-INCLUSION MAPS - SCORES

Row Labels	I1-OR-1_Group	I1-OR-2_Group	I2-OR-1_Group	I2-OR-2_Group	I3-OR-1_Group	I3-OR-2_Group
20-30	1					
Exact	1					
10-20	184	75	16	1		
Broad to narrow	2	3	1			
Exact	49	2	10			
narrow to broad	1	1	2			
No map	113	66				
Partial	19	3	3	1		
0-10	1.853	2.169	2.104	2.238	2.159	2.231
Broad to narrow	58					
Exact	97					
narrow to broad	23					
No map	1.648					
Partial (blank)	27					
Grand Total	2.038	2.244	2.120	2.239	2.159	2.231

OR-inclusion candidate maps with a score less than 10 were no longer assessed from the second iteration onwards.

9.3 Reconciliation of Stem code and Inclusion map sets

Both the Stem code and Inclusion mapping files needed final reconciliation for consistency purposes. A number of prototype decisions were required to give priority and exclusiveness to exact matches.

9.3.1 Exact Inclusion and narrow-to-broad Stem code matches

84335004	Anastomosis of urethra, end-to-end	End to end anastomosis of urethra	NAM.LB.AA	Anastomosis of urethra	I	1	Exact
84335004	Anastomosis of urethra, end-to-end		NAM.LB.AA	Anastomosis of urethra	S	0	Narrow to broad

FIGURE 19: EXACT INCLUSION AND NARROW-TO-BROAD STEM CODE MATCHES

If a procedure concept has an exact map at the Inclusion level and a narrow-to-broad map at the Stem code level, only the exact Inclusion match was retained, and the narrow-to-broad Stem code match discarded. The linearization model subsequently links the URI's

automatically between the Inclusion term and the Stem code, ensuring statistical consistency.

9.3.2 Exact Stem code match and broad-to-narrow Inclusion match

241175004	Cholecystography	cholecystography	KCF.BA.BB	Cholecystography	I	0	Broad to narrow
241175004	Cholecystography	Intravenous cholecystography	KCF.BA.BB	Cholecystography	I	0	Broad to narrow
241175004	Cholecystography		KCF.BA.BB	Cholecystography	S	1	Exact

FIGURE 20: BROAD-TO-NARROW INCLUSION AND EXACT STEM CODE MATCHES

Broad-to-narrow matches at Inclusion level were discarded in favor of an exact match of the same concepts at Stem code level. The exact match at Stem code level takes priority, making the broad-to-narrow maps at Inclusion level redundant.

9.3.3 Multiple 'exact' Inclusion matches

398230002	Aspiration of middle ear	Aspiration of middle ear, not otherwise specified	CBA.JB.AC	Drainage of middle ear, not elsewhere classified	I	1	Exact
398230002	Aspiration of middle ear	Myringotomy with aspiration of middle ear	CBB.JB.AC	Myringotomy with insertion of tube	I	0	Exact

FIGURE 21: SIMILAR 'EXACT' INCLUSION MATCHES

Two 'exact' matches of a concept to two different Inclusion terms were reduced to one map in favor of the closest candidate. Two seemingly exact matches at the Inclusion level were reduced to one single exact map at the highest level of similarity, discarding the 'next best' option.

9.3.4 'New' Inclusions in ICHI

The map contains 78 concepts that do not feature in ICHI as Stem codes or Inclusion terms and therefore 'new' to the classification system. Out of this subset, 6 were mapped to a Stem code and the remaining to Inclusion terms. The majority (87,18%) are narrow-to-broad maps.

9.4 Final result

Out of the 2.528 SNOMED CT procedure concepts reviewed, 1.907 (75,4%) were successfully mapped to ICHI Stem codes or Inclusions.

Equivalence	StemCode	%SC	Inclusions	%I	Total	%Total
Broad to narrow	160	18%	279	27%	439	23%
Exact	467	53%	683	66%	1.150	60%
Narrow to broad	180	21%	40	4%	220	12%
partial	71	8%	27	3%	98	5%
Grand Total	878	100%	1.029	100%	1.907	100%

TABLE 13: FINAL RESULT

1.419 maps are on a one-to-many basis, 493 have a one-to-many cardinality.

1,370 maps are exact or narrow-to-broad matches, and therefore suitable for automated mapping from SNOMED CT terms in the Electronic Health Record to the ICHI standard classification.

On a higher level, the 1,907 SNOMED CT procedure concepts covered from the source set represent 3,21% of the Procedure hierarchy. At the Stem code level, 647 exact or narrow-to-broad maps were defined as suitable for automated mapping, representing 12,12% of all Stem codes in the Interventions on Body systems and functions in ICHI. Another 723 exact or narrow-to-broad maps were established at the Inclusion level, representing 8,94% of all Inclusions in the Interventions on Body systems and functions.

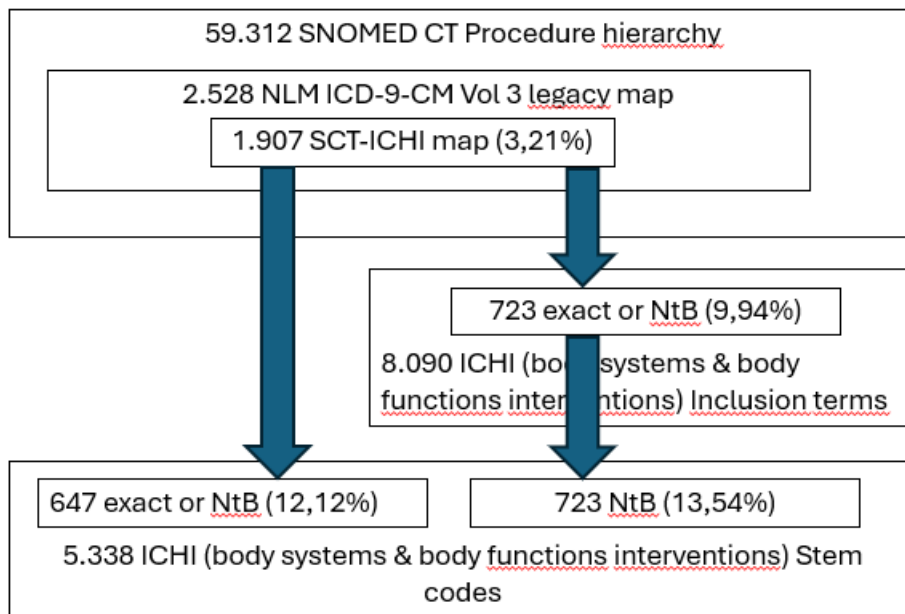


FIGURE 22: FINAL MAP RESULT VS. THE SNOMED CT TERMINOLOGY AND ICHI CLASSIFICATION FOR AUTOMATED MAPPING

9.5 Refinements

9.5.1 Clustering

Out of the 98 partial maps, 84 (87,5%) are amenable to ‘clustering’ or post-coordination, thereby covering the full meaning of the source concepts.

9.5.2 Conversion of broad-to-narrow Inclusion matches to narrow-to-broad stem code matches

At the Inclusion level, 219 (78,49%) broad-to-narrow maps can be converted to narrow-to-broad maps at Stem code level.

TABLE 14: REFINEMENTS

219 (79%)

Equivalence	StemCode	%SC	Inclusions	%I	Total	%Total
Broad to narrow	166	18%	279	27%	439	23%
Exact	411	53%	683	66%	1.150	60%
Narrow to broad	180	21%	40	4%	220	12%
partial	71	8%	27	3%	98	5%
Grand Total	878	100%	1.029	100%	1.907	100%

Postco
84 (86%)

10. Maintenance and Update Plan

The map will need updating in alignment with SNOMED CT and ICHI releases, requiring an editorial board to monitor and apply change management protocols.

In Belgium, the SNOMED CT National Release Center currently publishes a new Belgian SNOMED CT release every month. Each release concerns the Belgian extension and language reference sets (Dutch and French) that build on top of the SNOMED CT International Edition [18].

The Beta-3 version of ICHI was released in October 2020. The components relating to clinical interventions and functioning interventions have been finalized. The component on public health interventions is under final review and is finalized in 2023 [19]. New linearizations are released yearly, made available on <https://icd.who.int/dev11/downloads>

Upon release of a new national SNOMED CT release, the map will need to check on any updates. The mechanism is illustrated in the CORE Problem List Subset of SNOMED CT, made available on https://www.nlm.nih.gov/research/umls/Snomed/core_subset.html. This particular subset is the collation and analysis of datasets collected from health care institutions that utilize controlled vocabularies for data entry. All concepts are chosen from the following 4 hierarchies: Clinical finding, Procedure, Situation with explicit context, and Events.

The file can be updated by using a format that allows concepts to be retired, replaced, or added.

SNOMED_CID	SNOMED_FSN	SNOMED_CONCEPT_STATU	IS_RETIRED_FROM_SUBSET	LAST_IN_SUBSE	REPLACED_BY_SNOMED_CID
425196008	Insertion of peripherally inserted central catheter (procedure)	Current	FALSE	NULL	NULL
49795001	Total pneumonectomy (procedure)	Current	FALSE	NULL	NULL
392236004	Operative procedure on spinal structure (procedure)	Current	FALSE	NULL	NULL
424225000	Cardiovascular stress test using the dobutamine stress test protocol	Current	FALSE	NULL	NULL
179342005	Knee joint operation (procedure)	Current	FALSE	NULL	NULL
80635001	Cardiovascular stress test using treadmill (procedure)	Current	FALSE	NULL	NULL
84282008	Simple ligature of hemorrhoid (procedure)	Current	FALSE	NULL	NULL
425934009	Cardioverter defibrillator procedure (procedure)	Current	FALSE	NULL	NULL
425843001	Allogeneic peripheral blood stem cell transplant (procedure)	Current	FALSE	NULL	NULL
425983008	Autologous peripheral blood stem cell transplant (procedure)	Current	FALSE	NULL	NULL
274331003	Surgical biopsy of breast (procedure)	Current	FALSE	NULL	NULL
311764000	Family counseling (procedure)	Current	FALSE	NULL	NULL
46706006	Replacement of contraceptive intrauterine device (procedure)	Current	FALSE	NULL	NULL
313071005	Counseling for substance abuse (procedure)	Current	FALSE	NULL	NULL
428817001	Insertion of stent into ureter (procedure)	Current	FALSE	NULL	NULL
171007003	Counseling for bereavement (procedure)	Current	FALSE	NULL	NULL
313085000	Relationship counseling (procedure)	Current	FALSE	NULL	NULL
427752004	Excision of lamina of lumbar vertebra for decompression of spinal cc	Current	FALSE	NULL	NULL

FIGURE 23: EXTRACT OF CURRENTLY AVAILABLE CONCEPTS IN THE CORE PROBLEM LIST SUBSET OF SNOMED CT AT THE DATE OF RELEASE

SNOMED_CID	SNOMED_FSN	SNOMED_CONCEPT_STATU	IS_RETIRED_FROM_SUBSE	LAST_IN_SUBSE	REPLACED_BY_SNOMED_CID
243429009	Construction of standard ileal conduit (procedure)	Not current	TRUE	201705	243306000
308728002	Cervical smear biopsy taken (procedure)	Not current	TRUE	201805	767357000
410271002	Ostomy care education, guidance, and counseling (procedure)	Not current	TRUE	201805	410091003
64983004	History and physical examination, camp (procedure)	Not current	TRUE	201805	63332003
384633003	Postpartum examination and care of mother (procedure)	Not current	TRUE	201805	384634009
37894004	Evaluation and management of new outpatient in office or other	Not current	TRUE	201805	108220007
397139008	Plastic operation on tendon (procedure)	Not current	TRUE	201811	178155009
430698003	Replacement of total knee joint (procedure)	Not current	TRUE	201811	609588000
32537008	Psychiatric diagnostic interview, examination, history, mental s	Not current	TRUE	201811	10197000
315133002	Hepatitis B core antibody level (procedure)	Not current	TRUE	202005	59582004
5,71611E+14	Administration of varicella live vaccine (procedure)	Not current	TRUE	202005	871898007
275849001	Infective hepatitis immunization (procedure)	Not current	TRUE	202005	243789007
31312004	Complete denture, including adjustments (procedure)	Not current	TRUE	202105	1144279009
397956004	Prosthetic arthroplasty of the hip (procedure)	Not current	TRUE	202105	398010007
112816004	Valvuloplasty of aortic valve (procedure)	Not current	TRUE	202105	232834008
45965006	Implantation of automatic cardioverter/defibrillator, total syste	Not current	TRUE	202111	233170003
69031006	Excision of breast tissue (procedure)	Not current	TRUE	202305	1231734007
252575000	Auditory testing (procedure)	Not current	TRUE	202205	398171003

FIGURE 24: EXTRACT OF CONCEPTS RETIRED AND REPLACED IN THE CORE PROBLEM LIST SUBSET OF SNOMED CT AT THE DATE OF RELEASE

Concepts that have retired from the subset, are flagged and timestamped, with a referral to the new appropriate concept.

11. Governance and Documentation Standards

Mapping can be governed by the SNOClass working group with defined roles for mappers, reviewers, and coordinators. All decisions and rules are controlled.

The publication of the map follows the Simple Standard for Sharing Ontological Mappings (SSSOM) format [20]. SSSOM is an easy-to-use standard for mapping between different representations of the same or similar objects in different databases, favoring data integration and interoperability. It has a machine-readable vocabulary to describe metadata that documents mappings and a table-based format convenient for data science pipelines, removing the need for parsing ontologies, compatible with Linked Data standards.

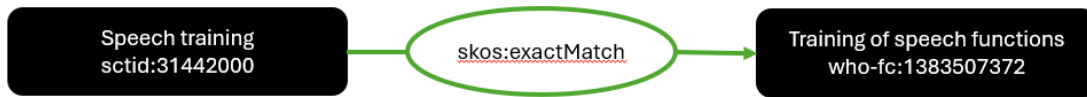


FIGURE 25: TRIPLET OF SUBJECT - PREDICATE – OBJECT

The basis elements are the triplets of subjects (SNOMED CT concepts), the predicate (equivalence assessment) and object (ICHI Stem code or Inclusion)

subject_id	subject_label	subject_t	predicate_id	object_id_stemcode	object_label_stemcode
sctid:49326008	Creation of conduit between left ventricle and aorta	procedure	skos:exactMatch	http://id.who.int/icd/entity/1805871090	Creation of conduit between left ventricle and aorta
sctid:33481008	Mechanical fragmentation of secondary membrane	procedure	skos:exactMatch	http://id.who.int/icd/entity/204787880	Mechanical fragmentation of secondary membrane
sctid:70590006	Elevation of skull fracture fragments	procedure	skos:exactMatch	http://id.who.int/icd/entity/1762199113	Elevation of skull fracture fragments
sctid:27129009	Aspiration of bone marrow from donor for transplai	procedure	skos:exactMatch	http://id.who.int/icd/entity/1727511656	Aspiration of bone marrow from donor for transplant
sctid:50915009	Submucous resection of nasal septum	procedure	skos:exactMatch	http://id.who.int/icd/entity/696627505	Submucous resection of nasal septum
sctid:83019005	Removal of intraluminal foreign body from pharynx	procedure	skos:exactMatch	http://id.who.int/icd/entity/829758286	Removal of intraluminal foreign body from nasal pharynx without incision
sctid:52930005	Manual removal of retained placenta	procedure	skos:exactMatch	http://id.who.int/icd/entity/1438046961	Manual removal of retained placenta
sctid:47823003	Pressure measurement of sphincter of Oddi	procedure	skos:exactMatch	http://id.who.int/icd/entity/1080957275	Pressure measurement of sphincter of Oddi
sctid:72221006	Intraspinal nerve root division	procedure	skos:exactMatch	http://id.who.int/icd/entity/1515308108	Division of intraspinal nerve root
sctid:11707008	Lung volume reduction surgery	procedure	skos:exactMatch	http://id.who.int/icd/entity/1833963209	Lung volume reduction surgery
sctid:386827007	Packing of external auditory canal	procedure	skos:exactMatch	http://id.who.int/icd/entity/372553759	Packing of external auditory canal
sctid:66258007	Arterial switch operation	procedure	skos:exactMatch	http://id.who.int/icd/entity/821645	Arterial switch operation

would be to aim for a complete map of the Belgian Procedures reference set, which is under construction.

12.2 Refining stepwise approach

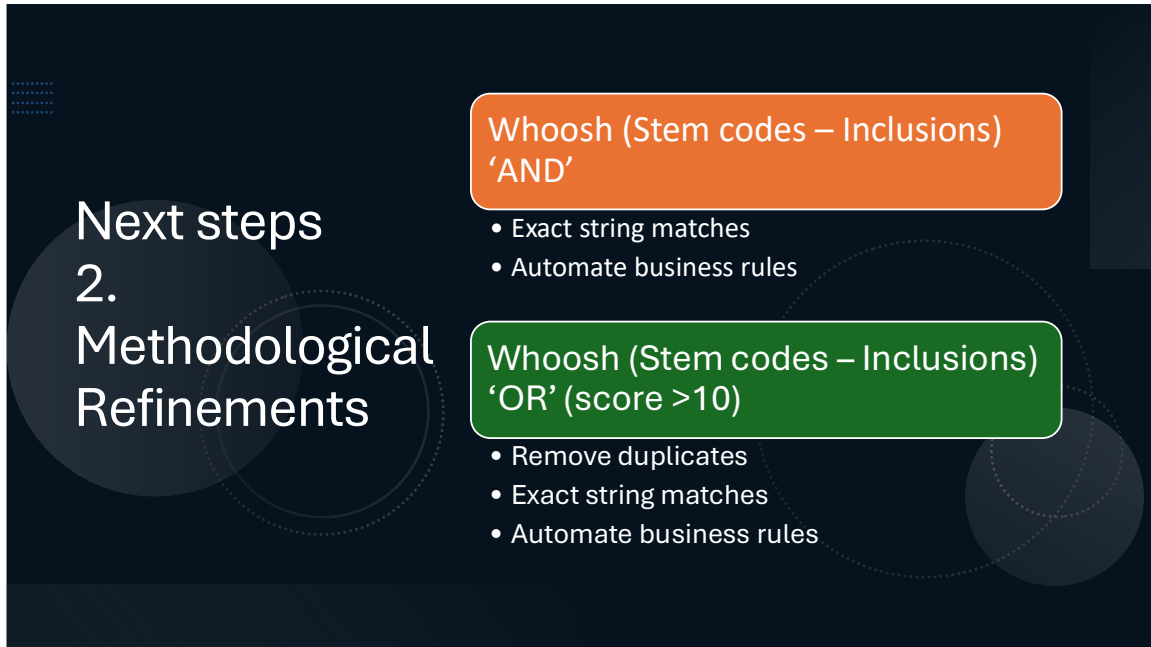





FIGURE 29: REFINING THE STEPWISE APPROACH

The optimization of the mapping process consists of a stepwise approach. Stem code and Inclusion candidate maps need to be compiled to avoid reconciling the two separate files. Exact string files matches can be extracted and other candidate maps with the same SNOMED CT concepts removed simultaneously. Standardized business rules and the elimination of <10 score candidates reduce the number of candidates for assessment.

12.3 Explore hierarchies

Exploring descending SNOMED CT hierarchies may generate new candidate maps. A descendant of a broad-to-narrow map may generate an exact map, the descendant of an exact map may generate a narrow-to-broad map and a descendant of a narrow-to-broad map may generate an additional narrow-to-broad map. These new candidate maps need adjusting subsequently to the Stem code or Inclusion level.

Next steps: 3. Hierarchies

- 
 - **Broad to narrow**
→→ exact
- 
 - **Exact**
→→ extra narrow to broad
- 
 - **Narrow to broad**
→→ extra narrow to broad

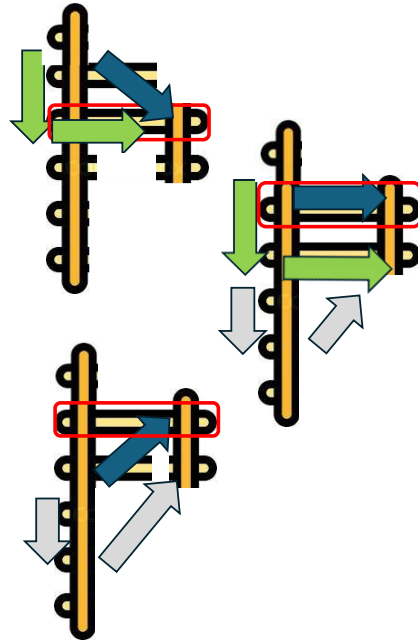


FIGURE 30: NEW MAP-CANDIDATES AT STEM CODE LEVEL THROUGH EXPLORATION OF SNOMED CT CONCEPT HIERARCHIES

This example shows how two broad-to-narrow maps can be tailored down to a narrow-to-broad or an exact map through descendants of the original SNOMED CT concept. Broad-to-narrow matches or many-to-one matches may be refined by looking at the first descendant of the SNOMED CT concepts.

- **Incision of fascia (87633005)**
 - >Incision of ligament or fascia of hand or finger
 - >Incision of ligament or fascia of lower leg
- **Bone graft (80983001)**
 - >Bone graft to coccyx
 - >Bone graft to humerus

FIGURE 31: ONE-TO-MANY BROAD-TO-NARROW STEM CODE MAPS OF 'INCISION OF FASCIA' AND 'BONE GRAFT PROCEDURES'

Both Incision of fascia (Procedure) and Bone graft (Procedure) have 2 broad-to-narrow maps with different Stem codes

- **Incision of fascia (87633005)**
 - ↳ **87633005 |Incision of fascia of hand (procedure)**
< MGL.FA.AA Incision of ligament or fascia of hand or finger
- **Bone graft (80983001)**
 - ↳ **38527006 |Grafting of bone of humerus (procedure)|**
= MEB.ML.AA Bone graft to humerus

FIGURE 32: NARROW-TO-BROAD AND EXACT MAPS OF SNOMED CT DESCENDANT CONCEPTS

Each concept has a descendant that matches on a narrow-to-broad or exact basis with a unique Stem code.

12.4 UMLS

Concepts from the source set that were not recognized by Whoosh may be reprocessed using the accepted synonyms in SNOMED CT or UMLS (Unified Medical Language System) [23], a repository of biomedical vocabularies developed by the US National Library of Medicine

12.5 Automation – ‘AI as a judge’

Next steps

4. Automated Equivalence Assessments

- **Target:**
 - *Is a stereotactic procedure always a brain operation?*
 - *Are all mastoidectomies always “cortical mastoidectomies”?*
- **Action:**
 - *Is plasmapheresis always therapeutic?*
 - *Is aquapheresis always therapeutic?*
- **Means:**
 - *Is an electromyography always performed with needles?*
 - *Is a vertebroplasty always percutaneous?*
 - *Is there another way to perform a cervix amputation than transvaginal?*
 - *Is a myringoplasty via postaural or endaural approach considered an open approach?*
- **Substance:**
 - *Are there other injections of peripheral nerves than neurolytic injections?*



FIGURE 33: CHATGPT PROMPTS FOR EQUIVALENCE ASSESSMENTS

During the manual curation of the candidate maps, multiple entries needed further information for full comprehension of the intervention, which was retrieved through ChatGPT v4.0. Requests typically concentrated around one or more axes of the ICHI system.

Additional information was occasionally required on devices or substances. A considerable number of questions on eye surgery, congenital heart surgery and psychological/psychiatric assessments needed to be solved with the Large Language Model support.

12.6 Mapping interface

Stem code and Inclusion candidate maps were assessed separately and reconciled subsequently. Joining both files and ranking the scores before equivalence assessment can be displayed in a uniform interface or tool, allowing concept per concept handling and dual mapping according to standard mapping methodology.

SCT_Id	FSN	ICHI_term	I/S	Score	Equivalence	Fin
57398002	Accessory-hypoglossal nerve anastomosis	Accessory-hypoglossal anastomosis	I	10,10288	Exact	1
57398002	Accessory-hypoglossal nerve anastomosis	Anastomosis of cranial nerve	S	7,921842	Narrow to broad	0
57398002	Accessory-hypoglossal nerve anastomosis	Anastomosis of peripheral nerve	S	7,921842	No map	0
57398002	Accessory-hypoglossal nerve anastomosis	Accessory-facial anastomosis	I	7,870118	No map	0
57398002	Accessory-hypoglossal nerve anastomosis	Excision of accessory spleen	I	4,398217	No map	0
57398002	Accessory-hypoglossal nerve anastomosis	Hypoglossal-facial anastomosis	I	3,956221	No map	0
57398002	Accessory-hypoglossal nerve anastomosis	Supraorbital nerve block	I	2,759944	No map	0
57398002	Accessory-hypoglossal nerve anastomosis	Pleurothecal anastomosis	I	1,727575	No map	0

FIGURE 34: MAPPING TOOL

This example shows how the ‘Accessory-hypoglossal nerve anastomosis’ SNOMED CT concept has an exact match with the ‘Accessory-hypoglossal anastomosis’ Inclusion term, as suggested by the highest map score. The next best option is a narrow-to-broad match with the ‘Anastomosis of cranial nerve’ Stem code. The latter will not be withheld in the final result, since the exact match takes priority over the narrow-to-broad Stem code match. The link between the Inclusion and Stem code is made through the linearization available in the linearization.

15 Contributing to the evolution of SNOMED CT and ICHI

During SNOClass, ICHI linearization release version of January 2025 was used. The linearization release file contains limited details on ICHI Stem Codes. WHO-FIC API does not provide access to ICHI data (but does for ICF). Access to ICHI details is only possible through the ICHI web browser. The results of this study are based on data collected from the ICHI Browser on October 28, 2025.

ICHI linearization release file contains 14,461 Stem Codes, data for almost all (14,452) was retrieved, except for 9 that caused ICHI Browser to enter an infinite loading loop:

- Phototherapy to skin and subcutaneous cell tissue of trunk (454850798)
- Phototherapy to skin and subcutaneous cell tissue, not elsewhere classified (709087800)
- Phototherapy to skin and subcutaneous cell tissue, not elsewhere classified (492754672)
- Preparation of skin (679903938)
- Replacement of internal device of temporomandibular joint (1670193737)
- Proprioceptive strapping or taping, not elsewhere classified (75122245)
- Acquisition of information in relation to indoor air quality (1997455234)
- Acquisition of information in relation to outdoor air quality (662005297)
- Restrictions through enactment of laws or standards in relation to water safety behaviours (1744530406)

31 other linearization Stem Codes yielded special results:

- 2 are structural codes: ICHI Intervention Code (1153570334) & ICHI Category (1190112446)
- 5 were “not found” in ICHI Browser, and no cause for this is obvious:
 - Mental functions, unspecified (757825081)
 - Right recurrent laryngeal nerve (1563621155)
 - Left recurrent laryngeal nerve (1682594403)
 - Pulmonary artery (2034447649)

- Environmental remediation or decontamination of outdoor air (2125335299)
- 24 were in the linearization, but not available as a linearized item. They all correspond to extension codes and do not impact our results:
 - XA2HA5 Superior laryngeal nerve (98057805)
 - XA2BL2 Chorda tympani (161520262)
 - XA99Q6 Genital branch of genitofemoral nerve (182870946)
 - XA4W18 Greater petrosal nerve (426851658)
 - XA4Q30 Tympanic nerve (442802430)
 - XA2260 Optic ganglion (510397860)
 - XA74N6 Submandibular ganglion (885000506)
 - XA0ER1 Pterygopalatine ganglion (954976611)
 - XA9FV5 Mylohyoid nerve (1008141435)
 - XA9CT5 Deep petrosal nerve (1068830395)
 - XA1QU6 Cochlear nerve (1110011206)
 - XA0P44 Auricular branch of vagus nerve (1170226664)
 - XA1F17 Trigeminal nerve, mandibular branch (1225723477)
 - XA1AL7 Vestibular nerve (1254968767)
 - XA95V8 Supratrochlear nerve (1431465238)
 - XA69Y7 Nerve to the stapedius (1506687547)
 - XA7F87 Posterior auricular nerve (1626693707)
 - XA9PU5 Afferent arteriole of the interlobular artery (1693767745)
 - XA8KJ5 Trigeminal nerve, maxillary branch (1734330325)
 - XA1SG6 Ciliary ganglion (1819911366)
 - XA48Z8 Petrous ganglion (1826529298)
 - XA9LP4 External laryngeal nerve (2014787874)
 - XA6UK8 Internal laryngeal nerve (2028165478)
 - XA95Y8 Trigeminal nerve, ophthalmic branch (2075472868)

Reporting of these Stem Codes to WHO-FIC is planned as a contribution to their resource and will benefit future mapping efforts from SNOMED CT to ICHI.

16 Conclusion

A map between SNOMED CT and ICHI secures the semantic interoperability between both systems and allows direct reuse of clinical data for statistical, epidemiological or healthcare management purposes. The ICD-9-CM Volume 3 procedure classification – SNOMED CT legacy map constitutes an appropriate and methodologically sound source for this study, as it represents the conceptual ancestor of the ICHI system.

Out of the 2.528 concepts included in the source set, 1.907 could be mapped to ICHI Stem codes or Inclusions, corresponding to 3,21% of the SNOMED CT Procedure hierarchy. Of these, 1.370 mappings were classified as exact or narrow-to-broad at either the Stem code level (12,12% of all Stem codes) or the Inclusion level (9,94% of all Inclusions), and therefore suitable for automated mapping.

Scaling up these results, in combination with the additional methodological refinements described in this report, creates a realistic pathway toward the development of a comprehensive map between the Belgian SNOMED CT procedure subset and the World

The transition of ICD-10-CM/PCS to the ICD-11/ICHI diagnosis/procedure classification and the development of the new nomenclature (NGV v0 to NGV v1) based on the structure of ICHI are a golden opportunity for the alignment of both systems. A legacy map from ICD-10-PCS to ICHI is feasible through axis alignment of both systems. The SNOMED CT to ICHI map presented in this study can then become the 'highway' for billing and coding of medical and surgical procedures along the same lines with a common standard classification standard and terminology.

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