Evaluation of the Content Coverage of SNOMED CT Representing ICNP Seven-axis Version 1 Concepts

H. A. Park1; C. Lundberg2; A. Coenen3; D. Konicek2
1Research Institute of Nursing Science, College of Nursing, Interdisciplinary Program of Medical Informatics, Seoul National University, Seoul, South Korea;
2SNOMED Terminology Solutions, Deerfield, Illinois, USA;
3School of Nursing, University of Wisconsin, Milwaukee, Wisconsin, USA

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Summary
Objectives: The purpose of this study is to evaluate the ability of SNOMED CT (Systematized Nomenclature of Medicine Clinical Terms) to represent the concepts of the ICNP version 1 – the seven-axis model.
Methods: The first author mapped 1658 concepts of the ICNP version 1 to SNOMED CT using CLUE browser 5.0. The second author from SNOMED Terminology Solutions – with a team of SNOMED CT experts – and the third author from the ICN with a team of ICNP experts validated the mapping result. If there was any disagreement during the validation process, the three of us convened online meetings to reach a consensus.
Results: In total, SNOMED CT covered 1331 out of 1658 (80%) ICNP seven-axis model concepts ranging from a 61% coverage rate of the Actions Axis concepts to a 94% coverage rate of the Judgment axis concepts.
Conclusions: SNOMED CT can represent most (80%) of the ICNP version 1 concepts. However, improvements in the ICNP version 1 in terms of concept naming and definition, and the addition of missing concepts to SNOMED CT, would lead to a greater harmonization of the ICNP seven-axis model version 1 concepts with SNOMED CT.

1. Introduction
Standardization in the field of health information is becoming important as computer-based information systems and electronic health records are being rapidly introduced to health care facilities around the world. A variety of standard development activities are happening in International Standard Development Organizations such as the ISO, HL7 and CEN. Standardized health care terminologies and classifications are the most important standard for data quality, data sharing and exchanging, and decision support [1].

Unfortunately, most application packages and institution-based systems have their own terminologies, resulting in overlooked synonymy and semantic collisions among concepts, which in turn produce non-interoperable data. Furthermore, most countries have designated more than one health care terminology and classification standard for institution-based and interoperable medical records, instead of recommending a single terminology and classification [2]. For example, the United States, the United Kingdom, Canada, and Australia recognize more than one health care terminology and classification. Thus, the critical challenge is to link terminologies and classifications used in existing clinical information systems to standardized terminologies and classifications for data sharing and exchange. One solution for this problem is to map different terminologies to a broader health care terminology such as the Systematized Nomenclature of Medicine Clinical Terms (SNOMED CT) before storing data in a database.

SNOMED CT is the most widely used health care terminology in electronic health record (EHR) because it is richer than other alternatives, capable of more granular expressions, more familiar to clinicians, hierarchical, and group-able and susceptible to concatenation, which are ideal qualities for decision support analysis and population-based clinical and public health intervention [3]. The International Classification for Nursing Practice (ICNP) is the most widely used nursing terminology in electronic nursing records because it allows for communicating and comparing nursing data across settings, countries, and languages [4].

SNOMED CT is a systematically organized computer-processable collection of health care terminology covering diseases, clinical findings, and procedures. It is designed to capture granular detail and provides a common language for clinical data to be indexed, stored, retrieved, and aggregated across specialties and sites of care. The clinical expressiveness of SNOMED CT supports clinical care and drives decision support technology. It is designed for use in electronic medical records, reducing the variability in the way data is captured,
encoded, and used for the clinical care of patients and research.

SNOMED CT is comprised of concepts, terms, and relationships to precisely represent clinical knowledge across the scope of health care. The core terminology of SNOMED CT is composed of more than 300,000 active concepts with formal logic-based definitions organized into 19 top-level hierarchies. SNOMED CT contains more than 777,000 active English descriptions for flexibility in expressing clinical concepts, and more than 924,000 defining relationships for consistency of data retrieval and analysis. SNOMED CT is a reference terminology that provides a means of integrating healthcare classification and terminologies from different healthcare disciplines. Many healthcare classifications have been mapped to SNOMED CT, such as ICD-9-CM Epidemiological/Statistical Mapping, ICD-03, ICD-10 (UK edition), OPCS-4 (UK edition), NIC, NOC, and PND [5–9].

The ICNP® is a unified nursing language system. It is a compositional terminology for nursing practice that facilitates the development of and the cross-mapping among local terms and existing terminologies. The ICNP version 1 is comprised of 7 axes; Focus, Judgment, Means, Action, Time, Location, and Client [10]. The definitions of each of the seven axes are as follows: Focus is the area of attention that is relevant to nursing (e.g., pain, homelessness, elimination, life expectancy, and knowledge). Judgment is the clinical opinion or determination related to the focus of nursing practice (e.g., decreasing level, risk, enhanced, interrupted, and abnormal). Means is a manner or method of accomplishing an intervention (e.g., bandage, bladder-training technique, nutritionist service). Action is an intentional process applied to or performed for a client (e.g., educating, changing, administering, monitoring). Time is the point, period, instance, interval, or duration of an occurrence (e.g., admission, child birth, chronic). Location is the anatomical and spatial orientation of a diagnosis or intervention (e.g., posterior, abdomen, school, community health center). Client is the subject to which a diagnosis refers, who is the recipient of an intervention (e.g., newborn, caregiver, family, community). The ICNP seven-axis concepts are used to represent nursing diagnoses (client status, problems, needs, and strengths), nursing interventions (or nursing actions), and nursing outcomes. The seven-axis version 1 model is intended to facilitate the composition of nursing diagnoses, interventions, and outcomes statements. These statements can be organized into meaningful sets for nursing practice, which are called ICNP catalogues [11]. ICNP catalogues are smaller groups of nursing diagnoses, interventions, and outcomes for selected nursing specialties, areas of practice, and client conditions to guide nurses in the use and application of the ICNP in practice. The ICN is encouraging nurses around the world to develop catalogues by providing the Guidelines for ICNP® Catalogue Development. Currently, ICNP catalogues on ‘Palliative Care for Dignified Dying’ and ‘Partnering with Individuals and Families to Promote Adherence to Treatment’ are available from the ICN.

In order to support the interoperability of nursing concepts with other health care concepts, it is important to have a collaborative effort to come up with principles, processes, and strategies to integrate, map, and/or model nursing concepts within wider healthcare-related concepts [12]. The ICNP and SNOMED CT have had a long history of collaboration. This collaboration has developed into a worldwide need to identify how the ICNP would integrate within SNOMED CT.

As a part of this described collaborative effort, ICNP seven-axis version 1 concepts were mapped to SNOMED CT in order to evaluate the ability of SNOMED CT to cover ICNP concepts. This work will provide a crosswalk between the ICNP and SNOMED CT. This process will hopefully contribute valuable feedback to the ICN regarding refining the definitions and hierarchies of ICNP version 1 concepts. The study will also hopefully inform the International Health Terminology Standard Development Organization (IHTSDO) about the benefits of providing ICNP content to the participating member organizations.

2. Methods

From January 2007 through May 2007, the first author mapped the 1658 ICNP seven-axis model version 1 concepts with the concepts of SNOMED CT using Apelon’s TermWorks and CLUE browser 5.0 with the 2007 January release of SNOMED CT. ICNP concepts were matched with SNOMED CT based on concept labels. Label matching involves putting the label into a canonical form by stemming and tokenization; comparing the equality of labels; and matching sub-strings [13]. Concept names with suffixes such as verb variation (ex, assessing vs assessment or assesses) and singular versus plural (ex, site vs sites), use of prepositions (ex, monitoring vs monitoring for), American English versus British English (ex, diarrhea vs diarrhoea), compound words with or without spaces (well being vs wellbeing), and compound words with or without hyphens (ex, self toilet vs self-toilet) were treated as linguistically identical. Apelon’s TermWorks was used for this phase.

If a concept in the ICNP version 1 matched linguistically with a concept in SNOMED CT, the next phase was the structural matching of concepts based on the similarities of their context or vicinities in the hierarchy of concepts. In structural matching, parents, sibling, and children concepts were examined. If a concept in the ICNP version 1 matched with a concept in SNOMED CT linguistically and structurally, then it was classified as mapped. CLUE browser 5.0 with SNOMED CT 2007 July release was used for this phase.

If a concept in the ICNP version 1 did not match linguistically or structurally with a concept in SNOMED CT, the next phase was the semantic matching of concepts. Semantic matching is an approach where semantic relations are examined between concepts (not between labels) based on textual definitions or usage in nursing practice and the hierarchical relationship of the concept with other concepts [14, 15].

For semantic matching, we traced back to the original source of the ICNP version 1 concepts, examined the display names of the concepts in the source language, and then tried to map the display names to
SNOMED CT concepts. Again, CLUE browser with the SNOMED CT 2007 July release was used for this phase.

Mapping results were classified as shown in Fig. 1. If an ICNP version 1 concept matched linguistically and structurally to a SNOMED CT concept, it was classified as lexically mapped. If an ICNP version 1 concept matched semantically to a SNOMED CT concept, it was classified as semantically mapped. If an ICNP version 1 concept matched to a more general SNOMED CT concept, it was classified as mapped to a broader concept. If an ICNP version 1 concept matched to a more specific SNOMED CT concept, it was classified as mapped to a narrower concept. If a concept was a compound concept or had a text definition describing more than one concept, we mapped it to more than one concept of SNOMED CT (ex, ‘Craving’ mapped to ‘Craving for food or drink’ and ‘Craving for drugs’, ‘Self dressing or undressing’ mapped to ‘Ability to dress’ and ‘Ability to undress’). In these cases, we classified the concepts as one-to-many mapped. However, we tried as much as possible not to map to either broader or narrower concepts. Otherwise, the concept was classified as not mapped.

The mapping was validated by a team of SNOMED CT and ICNP experts – including the second and third authors – through more than fifteen sessions of web conferencing on venues such as GoToMeeting, each lasting from 1 to 2 hours, and four two-day face-to-face meetings. If there was any disagreement during the validation process, we convened another meeting to reach a consensus.

During mapping, we used the text definitions of ICNP concepts as our first mapping criteria. If an ICNP concept did not have a working definition, we tried to find where the term came from and how it is being used in nursing practice. If we could not find how it is being used in nursing practice, we did not attempt to map the concept. If possible, we tried not to map to either broader or narrower concepts.

3. Results

Table 1 shows the relationship between the ICNP seven-axis and SNOMED CT hierarchies. Concepts in the Focus axis...
were mapped to more than one SNOMED CT hierarchy. In detail, Focus concepts describing diseases, disorders, signs, and symptoms were mapped to concepts in the Findings hierarchy of SNOMED CT. Focus concepts describing community, law, and policy were mapped to the Community Resource findings of the Findings hierarchy. Focus concepts with neutral connotations such as ‘process’, ‘status’, and ‘pattern’ were mapped to concepts in the Observable entity hierarchy of SNOMED CT. ‘System’ concepts of the Focus axis were mapped to concepts in the Body structure hierarchy of SNOMED CT (ex: cardiovascular system, gastrointestinal system, integumentary system, and musculoskeletal system). Morphological abnormalities without any judgment or body sites were mapped to concepts in the Morphologic abnormality hierarchy of SNOMED CT, which is part of the Body structure hierarchy (ex: ulcer, infection, fracture, inflammation, and congestion). Focus concepts describing pressure, radiation, light, and weather were mapped to concepts in the Physical force hierarchy of SNOMED CT. Focus concepts describing abuse, suicide, and environmental events such as flood, earthquake, and wind were mapped to concepts in the Event hierarchy of SNOMED CT. Focus concepts describing agricultural, industrial, residential, recreational development, infrastructure, food supply, and foul odors were mapped to concepts in the Environment hierarchy of SNOMED CT. Focus concepts describing body secretions, gastric contents, body fluids, and body materials were mapped to concepts in the Substance and Product hierarchy of SNOMED CT. Concepts describing animals, microorganisms, and plants were mapped to concepts in the Organism hierarchy of SNOMED CT. Specimen concepts were mapped to the Specimen hierarchy of SNOMED CT. Social status concepts were mapped to the Social context hierarchy of SNOMED CT. Focus concepts describing Service (ex: funeral service, housing service) rates and ratios were mapped to concepts in the Qualifier value hierarchy of SNOMED CT.

Concepts in the Judgment axis describing negative or positive judgments and states were mapped to concepts in the Qualifier value hierarchy of SNOMED CT.

Concepts in the Means axis consisting of artifact, care provider, health service, material, technique, and therapy were mapped to more than one SNOMED CT hierarchy. Artifact concepts were mapped to the Physical object and Qualifier value hierarchies, care provider concepts to the Social context hierarchy, health service concepts to the Qualifier value hierarchy, material concepts to the Substance and Product hierarchies, and technique and therapy concepts to the Procedure hierarchy of SNOMED CT.

Concepts of the Action axis used to describe attending, determining, informing, managing, and performing activities were mapped to concepts of the Procedure hierarchy of SNOMED CT.

Concepts in the Time axis were mapped to more than one SNOMED CT hierarchy. Concepts describing duration, frequency, onset, developmental period, time point, interval, and time sequence in the Time axis were mapped to concepts of the Qualifier value hierarchy. Event concepts in the Time axis such as birth, death, and fall were mapped to concepts of the Event hierarchy of SNOMED CT.

Concepts in the Location axis were mapped to more than one SNOMED CT hierarchy. The Location axis consisted of construction, position, and structure-related concepts. Construction-related concepts were mapped to the Environment hierarchy of SNOMED CT. Position-related concepts were mapped to the Qualifier Value and Findings hierarchies of SNOMED CT. Structure-related concepts were mapped to the Body structure hierarchy, including the Morphological abnormality, Qualifier value, and Physical object hierarchies of SNOMED CT.

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\text{Table 1: Relationship between ICNP version 1 seven axis and SNOMED CT hierarchies}
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<table>
<thead>
<tr>
<th>ICNP Seven Axis</th>
<th>SNOMED CT Hierarchy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Clinical findings (diseases, disorders, signs/symptoms)</td>
</tr>
<tr>
<td></td>
<td>Observable entity (ability, process, vital signs)</td>
</tr>
<tr>
<td>Body structure</td>
<td>Normal anatomy, morphologically abnormal structure</td>
</tr>
<tr>
<td></td>
<td>Environments or Geographical locations (environment)</td>
</tr>
<tr>
<td>Event</td>
<td>Abuse, natural disaster</td>
</tr>
<tr>
<td>Substance</td>
<td>Body substance, air, water</td>
</tr>
<tr>
<td>Organism</td>
<td>Animal, plant</td>
</tr>
<tr>
<td>Physical force</td>
<td>Weather, pressure, sun light</td>
</tr>
<tr>
<td>Specimen</td>
<td>Specimen</td>
</tr>
<tr>
<td>Qualifier value</td>
<td>Services, ratio, rate</td>
</tr>
<tr>
<td>Judgment</td>
<td>Qualifier value (size, risk)</td>
</tr>
<tr>
<td>Means</td>
<td>Physical object (device)</td>
</tr>
<tr>
<td></td>
<td>Procedures including Regime/Therapy (technique)</td>
</tr>
<tr>
<td></td>
<td>Social context – occupation (care provider)</td>
</tr>
<tr>
<td></td>
<td>Substance (material)</td>
</tr>
<tr>
<td></td>
<td>Product (drug/medication)</td>
</tr>
<tr>
<td></td>
<td>Staging and scales including Assessment Scales (questionnaire)</td>
</tr>
<tr>
<td></td>
<td>Qualifier value (protocol, plan, technique)</td>
</tr>
<tr>
<td>Action</td>
<td>Procedure including Regime/Therapy</td>
</tr>
<tr>
<td>Time</td>
<td>Qualifier value (duration, onset, time point)</td>
</tr>
<tr>
<td></td>
<td>Event (death, fall)</td>
</tr>
<tr>
<td>Location</td>
<td>Body structure including Morphological abnormality (stoma, wound)</td>
</tr>
<tr>
<td></td>
<td>Environment (place)</td>
</tr>
<tr>
<td></td>
<td>Qualifier value (route, topology)</td>
</tr>
<tr>
<td></td>
<td>Findings (body position)</td>
</tr>
<tr>
<td></td>
<td>Physical object (prison)</td>
</tr>
<tr>
<td>Client</td>
<td>Social context including Person (family, group, community, patient, sister)</td>
</tr>
</tbody>
</table>
Concepts in the Client axis were mapped to concepts of the Social context hierarchy of SNOMED CT.

Table 2 shows the mapping results. In total, 1331 (80%) out of 1658 concepts were exactly and completely mapped. Mapping rates vary from axis to axis. While most concepts in the Judgment and Location axes were mapped to concepts of SNOMED CT (94%), the Action axis had the lowest mapping rate (61%).

Out of 1658 concepts, 50 concepts were partially mapped: 27 concepts mapped to broader SNOMED CT concepts, 17 mapped to narrower SNOMED CT concepts, and six mapped to more than one SNOMED CT concept. Examples of ICNP concepts mapped to broader concepts include 'Fracture Pain' mapped to 'bone pain' in the Findings hierarchy and 'Hot Pack' mapped to 'Non-electric heating pad, device' in the Physical object hierarchy of SNOMED CT. Examples of ICNP concepts mapped to narrower concepts include 'Parent Child Attachment' mapped to 'parent-infant attachment behavior', 'Emotional Recovery' mapped to 'abuse recovery status: emotional', and 'Physical Recovery' mapped to 'abuse recovery status: physical' in the Observable hierarchy of SNOMED CT. Examples of ICNP concepts mapped to more concepts include 'Parental Witnessing' mapped to 'witnessing', 'Emotional Support' mapped to 'social support', and 'Physical Support' mapped to 'physical support' in the Social context hierarchy of SNOMED CT.

There were 277 ICNP concepts not mapped to SNOMED CT concepts. Ninety nine of these not-mapped concepts do not have any usage in nursing. One group of these not-mapped concepts consists of grouper concepts used to organize other concepts in the ICNP, such as ‘Positive or negative judgment’, ‘Absorbing or Collecting Device’, ‘Heating Cooling Device’, ‘Bathing Device’, ‘Invasive Device’, ‘Grooming Device’, ‘Body opening’, ‘Structure’, ‘Social structure’, and ‘Diagnostic department’. Another group of these not-mapped concepts consists of atomic-level concepts in the Action axis used as building blocks to populate nursing intervention catalogue concepts, rather than actual nursing interventions or nursing activities (ex: facilitating, promoting, and collaborating). These verb concepts can be used only when they are combined with concepts from other axes.


### 4. Discussion

A large percentage of ICNP seven-axis model version 1 concepts (80%) were able to be mapped to SNOMED CT exactly and completely. If 99 ambiguous ICNP concepts are disregarded, the coverage rate of ICNP concepts by SNOMED CT will increase to 85%. This is lower than the content coverage of SNOMED CT to represent the most common nonduplicated patient problems seen at the Mayo Clinic [16] and the content coverage of SNOMED CT to represent ICNP catalogue statements [17]. In the nonduplicated patient problem list comparing research, SNOMED CT, when used as a compositional terminology, can represent 92.3% of the terms used commonly in medical problem lists. In the ICNP catalogue statements mapping study, 87% of the nursing diagnosis statements and 98% of the nursing intervention statements were mapped to SNOMED CT. The
lower mapping rate could be due to the fact that the ICNP version 1 seven-axis model is a building block that can be used to generate nursing diagnoses, nursing interventions, and nursing outcomes statements. Thus, a concept can be very ambiguous and left unused before combining with concepts from other axes.

Mapping rules were created during the process to guide decisions for mapping and recommendations to improve future mapping. However, mapping ICNP seven-axis model version 1 concepts to SNOMED CT was a very challenging task because the two terminologies cover different domains. The ICNP is a nursing terminology and SNOMED CT is a much broader healthcare terminology covering other healthcare domains as well. Thus, a concept with the same label can have different meanings in the two different terminologies. For example, 'depression' in the medical domain means 'depressive disorder', however 'depression' in nursing means 'sadness'. The same concept label was found in different hierarchies of SNOMED CT. Also, we found that SNOMED CT lacks concepts describing community health, such as health services, health policy, community resources, population statistics (e.g., mortality rate, incidence rate, immunization rate, infant death rate, unemployment rate), industrial health, value belief, and psychological finding. This can be explained by the history and scope of the two terminologies. The ICNP was developed to describe not only clinical care settings, but community health as well; however, the focus of SNOMED CT has been the clinical care setting.

Mapping ICNP seven-axis model version 1 concepts to SNOMED CT was also very challenging because the two terminologies have different structures. The ICNP consists of seven axes (Focus, Judgment, Means, Action, Location, Time, and Client) to represent nursing diagnoses, nursing interventions, and nursing outcomes; SNOMED CT consists of 19 hierarchies to represent diagnoses, procedures, anatomy, chief complaints, vital signs, physical findings, plans, problem lists, history, allergies, immunizations, and medication management. Thus an ICNP concept can be mapped to multiple SNOMED CT concepts from different hierarchies. For example, 'specimen' can be mapped to concepts in the Substance hierarchy and the Specimen hierarchy. The 'Societal Status' concepts — with home ownership, income, and social isolation as children concepts — can be mapped to concepts of the Observable entity hierarchy and the Social context hierarchy. Concepts describing services can be mapped to the Regime/Therapy hierarchy and the Qualifier value hierarchy of SNOMED CT. When mapping the ICNP to SNOMED CT, sometimes parent and child concepts were mapped to different hierarchies. For example, 'weight' of the Focus axis was mapped to 'Weight' in the Observable entity hierarchy; however 'overweight', which is a child concept of 'weight', was mapped to 'overweight' in the Findings hierarchy.

We mapped the ICNP concepts to SNOMED CT concepts based on the definitions and/or locations of the concept in the hierarchy. Descriptive definitions of ICNP concepts were very helpful when mapping to SNOMED CT; however, there are quite a few concepts without textual definitions (ex: environmental process), with ambiguous definitions (ex: obstruction), or with more than one definition (ex: informal settlement). The definitions of ICNP concepts need to be clarified, or new definitions need to be added in order to improve mapping to SNOMED CT.

During the mapping process we found that there was a hierarchy problem between ICNP parent and child concepts. For example, 'Integrity' was a concept describing a trait of a person; however, 'Skin integrity', a child concept of 'Integrity', was a concept describing a physical aspect of skin. There are ICNP concepts placed in the wrong axes. For example, 'Pregnancy prevention' and 'Pregnancy promotion' are in the Focus axis. These concepts should be in the Action axis or the nursing intervention catalogue. Also, there are catalogue concepts in the seven-axis model. Examples are 'Alcohol life style prevention', 'Contamination prevention', and 'Fall prevention' in the Action axis. They should be in the nursing intervention catalogue.

We also found that there are many synonyms in the ICNP version 1 concepts (ex: 'rash' and 'exanthema', 'autonomic dysreflexia' and 'dysreflexia', 'care plan' and 'critical pathway', 'guideline' and 'protocol'). There are ICNP concepts that are hard to distinguish from one another even though their concept labels are different (ex: 'Tissue perfusion vs Tissue perfusion status', 'teaching vs educating vs instructing', 'dressing vs getting dressed or undressed' vs 'putting on clothes vs taking off clothes').

We also found that there are compound ICNP concepts which are used as groupers; these concepts need to be renamed or divided into two different concepts. Examples are 'Positive or negative judgment' from the Judgment axis, 'Self dressing or undressing' from the Focus axis, 'Eating or drinking' from the Focus axis, 'Absorbing or collecting device' from the Means axis, 'Muscle or joint exercise technique' from the Means axis, and 'Heating cooling device' from the Means axis.

When an ICNP concept is not mapped to a SNOMED CT concept and is being used in nursing practice, we can either model the concept in SNOMED CT or post-coordinate the concept by combining existing SNOMED CT concepts. Examples are pain-related concepts such as arthritis pain, cancer pain, and ischemic pain. They can be added as new concepts under 'Pain (finding)', or they can be post-coordinated by combining 'Pain' in the Findings hierarchy with another concept from another hierarchy. SNOMED CT has atomic concepts as well as pre-coordinated concepts. Thus, it is hard to decide whether to add a new concept or to post-coordinate it by combining two concepts. However, for the ICNP seven-axis model version 1 concepts, we have decided to model the concepts in SNOMED CT rather than post-coordinating them. When we model a concept in SNOMED CT, we recommended an unambiguous fully specified name of the concept and location within the hierarchy.

The mapping was completed through a iterative process in which the first author mapped ICNP concepts to SNOMED CT, and the second and third authors validated each mapping. This study would be further interesting if three authors with different expertise in different terminology systems complete the mapping independently and interrater reliability is measured.
5. Conclusions

SNOMED CT can represent most (80%) ICNP version 1 concepts. Through this study, draft mapping principles, processes, and strategies that were necessary to consistently integrate ICNP seven-axis model version 1 concepts within SNOMED CT were developed. Improvements in the ICNP version 1 in terms of concept naming and definition, and the addition of missing concepts to SNOMED CT, would lead to a greater harmonization of the ICNP seven-axis model version 1 concepts with SNOMED CT.

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