# Implementing ICD-11 for mortality statistics: translation of decision tables embedded in the automated coding system Iris

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## Abstract

*Iris is a system for causes-of-death coding, based on the International Classification of Diseases, 10th revision (ICD-10). As coding rules, Iris uses a knowledge base consisting in a large number of relations between ICD-10 codes. In 2019, WHO approved a new revision of the ICD, the ICD-11, which greatly differs from the previous. In order to let Iris code with this new version, each single rule contained in the knowledge base need to be translated into ICD-11.*

*This article describes the findings of a pilot project carried out in order to evaluate the feasibility of this translation. The project highlighted that part of the rules can be automatically translated using the mapping tools provided by WHO between ICD-10 and ICD-11.*

*However, most of the rules need to be manually revised. The pilot project identified the rules that need to be prioritised in the translation process since they are very frequently used in real data coding.*

**Keywords:** International Classification of Diseases - ICD, automated coding, Iris, decision tables, causes of death, mortality statistics, underlying cause.

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## 1. Background[4]

Mortality statistics are based on causes of death reported by physicians on death certificates. These data are coded according to the provisions of the International Classification of Diseases (ICD) of the World Health Organization (WHO), which allows to make these statistics comparable at an international level. The ICD is periodically revised to take into account medical, epidemiological, technical development. Currently, the 10th revision (ICD-10) is in use worldwide (WHO, 2019*a*), but in May 2019 the 72nd World Health Assembly approved the 11th revision (ICD-11) which will become the new standard (WHO, 2019*b*).

In order to guarantee standardisation in data collection, ICD recommends a standard format of the death certificate, which comprises two parts. In Part 1 the sequence of events leading to death should be reported. This part includes different lines: in the first one the immediate (terminal) cause should be reported and in the lowest the condition that started the sequence leading to death. In the other filled lines, intermediate causes should be reported. Conditions reported on a line of Part 1 should be caused by conditions reported in the line below. Part 2 includes other relevant conditions contributing to death but not part of the sequences reported in Part 1.

For cause-of-death data production, an ICD code is attributed to each medical condition. The whole set of ICD codes of each certificate is referred to as "multiple cause". From this set, one single code is selected and used for international comparisons, the so-called underlying cause of death (UC), defined by WHO as the "disease or condition that initiated the train of events leading directly to death or the circumstances of the accident or violence

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All authors contributed to the writing and revision of the text. In particular: Daniele De Rocchi, Francesco Grippo, Chiara Orsi and Luisa Frova contributed to the development of methodology and analysis of data concerning the measure of frequent due to in real data and provided analysis for ICD-10-ICD-11 translation. Mihai Horia Popescu and Vincenzo Della Mea contributed to the translation from ICD-10 to ICD-11 and to the development of IT tools. Francesco Grippo and Vincenzo Della Mea are co-last authors.

causing the fatal injury" (WHO, 2019*a*). The ICD provides a system of rules that allows selecting the UC taking into account all codes in the certificate.

The multiple cause coding and the selection of the UC are generally performed with the use of automated coding systems, in order to increase comparability and quality of data. Automated coding systems greatly increase the comparability of death statistics, since they reduce the variability due to the different interpretation of rules by manual coders. However these systems cannot code automatically all certificates, so a certain rate of manual intervention is unavoidable.

The main automated coding system used at an international level is Iris (www.iris-institute.org), which is based on the international death certificate and coding rules provided by ICD-10. The core component of Iris are the "decision tables" (Iris Institute, 2019). Decision tables are a knowledge base for the correct application of the UC selection process and consist in a list of all plausible relations between all ICD codes. Once a code is attributed to each condition, the selection process is entirely based on ICD codes.

In summary, the process of UC selection can be seen as an algorithm in whose nodes it is necessary to assess relations between codes. Decision tables list all possible relations between codes and are used as a reference for this evaluation. Relations in decision tables are called rules. There are different types of rules, the most used is DUETO, which corresponds to causal relation, *i.e.* it indicates which codes can be considered a plausible consequence of another given code.

The decision tables were first developed by the NCHS (US National Center for Health Statistics) for the ACME automated coding system (Israel, 1990; CDC, 2015). Successively they have been embedded in Iris and updated on the basis of the recommendations of the Mortality Reference Group, which operates in the network of the World Health Organization Collaborating Centres for the Family of International Classifications - WHO-FIC (Navarra *et al.*, 2020, and 2016).

## 1.1 Objectives

With its adoption by the 72nd World Health Assembly in May 2019, the 11th revision of ICD (ICD-11) (WHO, 2019*b*) will become the new standard for mortality coding. In order to produce mortality statistics with ICD-11, a transition of Iris to this new classification is needed. A pilot project has been carried out to assess feasibility of this transition, in particular the translation of decision tables from ICD-10 to ICD-11 (Della Mea *et al.*, 2019).

Focussing on the rule type DUETO, the objective of this paper is to describe methods identified in the pilot project for the translation of rules contained in decision tables and to quantify the number of them that can be automatically translated. Provided that there are rules that need to be manually translated, the pilot project also aimed at identifying the rules mostly used for real data coding in order to prioritise these during the translation to ICD11. Additionally, it was investigated if there are relations frequently reported by physicians on certificates, but not included in decision tables.

In a future project, the methods identified in the pilot project and described in the paper would be applied to decision tables, with the aim of providing the effective decision tables translation in ICD-11.

## 2. Materials and methods

For this analysis, the 2019 decision tables were considered, since they include the most recent ICD-10 updates.

### 2.1 DUETO rule and other rules

When a certifier reports two conditions on different lines of Part 1, he implicitly indicates that there is a causal relation between them, *i.e.* the condition reported in the line above is “due to” the condition in the line below. In general, given a condition A, all conditions reported in lines above can be considered due to A. On the other hand, A can be considered due to conditions reported below. Nevertheless, sometimes certifiers report conditions in a causal order by mistake, or because they report several conditions and, by chance, they happen to be positioned in different lines.

DUETO rules in decision tables can be defined as follows: code A is DUETO code B if B is an acceptable cause of A according to ICD provisions; A is called *codeDef* and B *subcodeDef*. This rule type is used in several steps of the UC selection algorithm, when it is necessary to identify the causal sequence leading to death reported in Part 1.

There is a causal relation between two codes A and B (B is cause of A) if A is reported on a higher line of Part 1 of the certificate respect to B and A can be “due to” B, *i.e.* the decision tables contain the rule “B DUETO A”. Decision tables, hence, contain a list of all relations between ICD codes of the type “B DUETO A” considered acceptable by the ICD provisions. For example, the rule “C79.9 DUETO C34.9” (C79.9 is the ICD-10 code for metastasis, C34.9 is the code for lung cancer) is included in the decision tables, as the causal relation “metastasis due to lung cancer” is plausible. On the other hand, the rule “C34.9 DUETO J18.9” (J18.9 is the code for pneumonia) is not included in the decision tables, as the causal relation “lung cancer due to pneumonia” is not plausible, as a cancer cannot be caused from other diseases. Therefore, even if a physician reports the code C34.9 on a higher line of the certificate respect to J18.9, the causal relation between these two codes is not taken into account from the UC selection algorithm. The idea behind decision tables is that there are some causal relations that cannot be considered acceptable (for example cancer due to other diseases), all the others are considered plausible and therefore accepted if reported by physicians.

This paper focusses on DUETO rules, which are the most represented in decision tables (more than 20,000,000) however other rule types are included in the decision tables. They are listed in Table 1, which shows also their number. Besides *codeDef*, *subcodeDef*, and rule type, decision tables contain other variables that increase the complexity of the system, but this additional information is not described in the present paper.

It is important to remark that DUETO rules apply only to Part 1 of the certificates, as the causal sequence leading to death should be reported in this part. Other rule types take into account also relations with codes reported in Part 2, but they are not treated in this paper.

**Table 1 - List of the rule types included in decision tables, with the steps of the UC selection algorithm in which are used and the number of rules**

| Rule | Description | Step of UC selection | Number of rules (a) |
|---|---|---|---|
| DUETO | Due to | SP3-SP5 | 20,433,525 |
| DS | Direct Sequel | SP6 | 2,026,631 |
| DSC | Direct Sequel with Combination | | 17,257 |
| IDDC | Ill-defined in Due to with Combination | SP7 | 2,250 |
| IDMC | Ill-defined with mention with combination | | 127 |
| LDC | Linkage in Due to with Combination | M1 | 50,682 |
| LDP | Linkage in Due to with Preference | | 6,194 |
| LMC | Linkage with Mention with Combination | | 31,608 |
| LMP | Linkage with Mention with Preference | | 36,697 |
| SDC | Specificity in Due to with Combination | M2 | 5,504 |
| SMC | Specificity with Mention with Combination | | 1,513 |
| SMP | Specificity with Mention with Preference | | 46,830 |

Source: Our processing
(a) 2019 edition.

## 2.2 Translation method

Along with ICD-11, the WHO releases the mapping table between ICD-10 and ICD-11, *i.e.* a table that reports, for each ICD-10 code, the corresponding ICD-11 code/codes. Mappings can be classified based on cardinality as follows (the cardinality is indicated with axb, where "a" is the cardinality of ICD-10 codes and "b" is the cardinality of ICD-11 codes):

- 1x1 (equivalent, ≡), the ICD-10 code is translated in one ICD-11 code;

- 1xn (⊒), the ICD-10 code is translated in more ICD-11 codes;
- nx1 (⊑), more ICD-10 codes are translated in the same ICD-11 code;
- nxn, the structure of the classification changes.

From former evaluations of the transition between previous revisions of ICD (in particular from ICD-9 to ICD-10) (Anderson *et al.*, 2001), it is known that the transition to a new revision will have an impact and the mapping will not be enough to completely automatise the transition. The mapping table allows translating single codes. However, when rules are considered, we cannot translate codes separately, but we need to interpret the relation from a logical point of view and consider the impact that the different mapping cardinality of the two codes involved has on the translation process.

In order to identify DUETO rules that can be automatically translated, the first step is to verify if a mapping exists for both *codeDef* and *subcodeDef*. Mapping could be missing since the knowledge on diseases evolves: some ICD-10 codes may have no mapping to the ICD-11 since the concept is no longer used, and some ICD-11 codes may have no mapping from the ICD-10 since they are new.

The second step is, for DUETO rules with existing mapping for both *codeDef* and *subcodeDef*, to assess if the rule can be automatically translated. A rule can be automatically translated if both *codeDef* and *subcodeDef* can be automatically translated; this is established on a logical point of view, taking into account the mapping cardinality of codes.

Based on the analysis results, a prototype of a web tool for translation was developed to help and guide the experts in the translation process.

## 2.3 Analysis of due to in real data

As seen, in decision tables there are several millions of rules involving all codes of ICD. Nevertheless, not all of them are used during coding, since many refer to rare causes of death not (or very rarely) reported on death certificates. Therefore, we developed a method for understanding which rules are the most relevant and more frequently applied in data coding.

For this purpose, we analysed multiple cause data referring to years 2016-2018 from different countries (table 4). All countries collected data using the international certificate and Iris as coding tool. This resulted in the same data format for all countries, containing all codes representing the medical conditions reported on the death certificate, and the position of each code on the certificate. Overall, 4,812,100 certificates were analysed. For the analysis, only Part 1 of certificates was taken into account, as DUETO rules refer only to this part. Nearly all death certificates collected (4,811,844 out of 4,812,100) contained at least one code in Part 1.

First, for each pair of codes A and B reported on the certificates, we calculated the frequency of certificates reporting A as "due to" B, *i.e.* A on a higher line respect to B.

Successively, provided that the death certificates could contain two given conditions reported in both directions (A "due to" B as well as B "due to" A) we developed a method for the identification of recurrent causal patterns in multiple cause-of-death data.

We applied the following two steps.

1. Analysis of association between codes. Two different codes (A and B) may appear jointly on the same certificate by chance depending on their frequency in the total sample of certificates. We tested the null hypothesis by a $X^2$ test, comparing the observed frequency of certificates showing the joint presence of codes A and B with the expected one. This step allowed identifying codes positively associated, *i.e.* reported on certificates more than expected.
2. Analysis of DUETO relations. For codes positively associated, we wanted to understand if there is a preferred direction of the DUETO relation. For this step, we used only cases in which the two codes are reported in different lines (sometimes codes can be placed on the same line). If codes were randomly reported on certificates' lines, we would expect half of cases in which code A is DUETO B and half the contrary (null hypothesis – expected frequency). With a $X^2$ test we compared this expected frequency with the observed one and we identified DUETO relations reported more than expected.

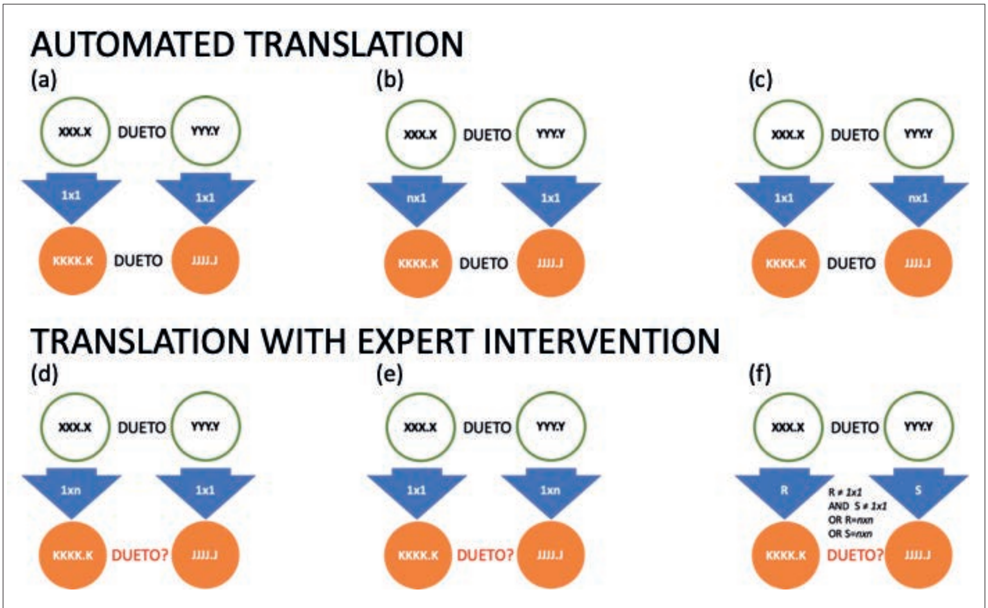
For DUETO relations reported more than expect, we checked if the corresponding DUETO rule is included in the decision tables.

## 3. Results

### 3.1 Translation

Rules in which both codeDef and subcodeDef have equivalent mapping (1x1) can be always automatically translated. On the other side, if codeDef and/or subcodeDef have a mapping with cardinality nxn, translation will always be manual. The other cases provide some chance of automated translation. Figure 1 shows all possible cases. In the high part of the Figure, cases that can always be automatically translated (a) and those that only in some cases require a manual revision (b and c) are shown. For example, rules included in case (b) can be automatically translated only if all the n codeDef have the DUETO rule with the subCodedef in ICD-10. If at least one of the n codeDef does not have the DUETO rule with the subCodedef in ICD-10 the corresponding rule in ICD-11 need a manual revision. The same applies for case (c). The low part of the Figure shows cases that always require a manual revision (d, e, f).

**Figure 1 - Summary of translation cases**




Source: Our processing

Table 2 shows examples of cases (a) (b) and (c) of Figure 1. Table 3 shows examples of cases (d) and (e). In these cases, ICD-11 classifies with a finer detail the concept coded by ICD-10. An expert should confirm if it is possible to extend the relation, valid for a broader concept in ICD-10, to all the detailed concepts in ICD-11.

**Table 2 - Examples of cases (a), (b), and (c) in Figure 1**

| Case | ICD-10 rule | Mappings involved | ICD-11 rule |
|---|---|---|---|
| (a) | A01.0 (Typhoid fever) DUETO C33 (Malignant neoplasm of trachea) | A01.0 ≡ 1A07 (Typhoid fever)<br>C33 ≡ 2C24 (Malignant neoplasms of trachea) | The ICD-11 rule 1A07 DUETO 2C24 can be automatically included in ICD-11 decision tables |
| (b) | F03 (Unspecified dementia) DUETO R54 (Senility) | F03 ⊑ 6D8Z (Dementia, unknown or unspecified cause)<br>R54 ≡ MG2A (Old age)<br>*But also:*<br>*F00 (Dementia in Alzheimer disease) ⊑ 6D8Z*<br>*F01 (Vascular dementia) ⊑ 6D8Z* | The ICD-11 rule 6D8Z DUETO MG2A must be revised as the ICD-10 rule F01 DUETO R54 is included in ICD-10 decision tables, but the rule F00 DUETO R54 is not included in ICD-10 decision tables |
| (c) | J96.9 (Respiratory failure, unspecified) DUETO F03 | J96.9 ≡ CB41.2 (Respiratory failure, unspecified as acute or chronic)<br>F03 ⊑ 6D8Z<br>*But also:*<br>*F00 ⊑ 6D8Z*<br>*F01 ⊑ 6D8Z* | The ICD-11 rule CB41.2 DUETO 6D8Z can be automatically included in ICD-11 decision tables as all the rules J96.9 DUETO F00, J96.9 DUETO F01, J96.9 DUETO F03 are included in ICD-10 decision tables |

Source: Our processing

**Table 3 - Examples of cases (d) and (e) in Figure 1**

| Case | ICD-10 rule | Mappings | ICD-11 rule |
|---|---|---|---|
| (d) | I46.9 (Cardiac arrest, unspecified DUETO R26.3 (Immobility) | I46.9 ⊒ MC82 (Cardiac arrest)<br>I46.9 ⊒ MC82.0 (Ventricular tachycardia and fibrillation cardiac arrest)<br>I46.9 ⊒ MC82.1 (Bradycardic cardiac arrest)<br>I46.9 ⊒ MC82.2 (Asystolic cardiac arrest)<br>I46.9 ⊒ MC82.3 (Cardiac arrest with pulseless electrical activity)<br>R26.3 (Immobility) ≡ MB44.3 (Immobility) | An expert should check if all types of cardiac arrest can be due to immobility |
| (e) | I27.9 (Pulmonary heart disease, unspecified) DUETO B44.1 (Other pulmonary aspergillosis) | I27.9 ≡ BB0Z (Pulmonary heart disease or diseases of pulmonary circulation, unspecified)<br>B44.1 ⊒ CA82.4 (Aspergillus-induced allergic or hypersensitivity conditions)<br>B44.1 ⊒ 1F20.12 Chronic pulmonary aspergillosis) | An expert should check if Pulmonary heart disease can be due to both CA82.4 and 1F20.12 can cause. |

Source: Our processing

Examples are not provided for mixed situations involving nxn cardinality that are very complex. Further details on the translation methodology can be found in the pilot project report (Iris Institute, 2019).

By exploring the distribution of mapping types in the coding rules, we established that the number of DUETO rules needing manual intervention varies between 3 and 6 million out of about 20 million.

For the prototype tool implementation, we choose a web-based model where experts can work collaboratively from different locations and that can assure the consistency of results. The tool identifies rules that require an expert intervention. In these cases, the tool provides the list of mappings for all the codes involved in the rule and, if possible, a proposal of the rule translation. Where possible, rules with the same *subcodeDef* are grouped to ease the translation and facilitate maintenance over time.

## 3.2 Due to in real data

Table 4 shows the results of some descriptive analyses of real certificates. The total number of different codes reported on certificates varies from 1,405 in United Kingdom to 5,553 in United States; considering all countries, 6,786 different codes were found on certificates. The total number of different codes reported in Part 1 (therefore considered for the present analysis) varies from 1,102 in United Kingdom to 5,008 in United States; considering all countries, 6,292 different codes were found in Part 1. The overall average number of codes per certificate is 3.2; it varies from 1.7 in South Africa to 4.6 in Hungary. The overall average number of codes in Part 1 per certificate is 2.4; it varies from 1.6 in United Kingdom to 3.4 in Italy and Hungary.

**Table 4 - Death certificates analysed**

| Country | Number of cases | Number of different codes reported | Number of different codes reported in Part 1 | Average number of codes per death certificate | Average number of codes in Part 1 per death certificate | Source |
|---|---|---|---|---|---|---|
| Italy (IT) | 618,083 | 4,029 | 3,576 | 4.4 | 3.4 | Italian National Institute of Statistics; |
| South Africa (ZA) | 473,938 | 3,17 | 3,169 | 1.7 | 1.7 | Downloaded from Statistics South Africa – Stats SA website; |
| Spain (ES) | 424,523 | 3,577 | 3,326 | 3.7 | 3.1 | Instituto Nacional de Estadística – INE; |
| Mexico (MX) | 307,433 | 2,539 | 2,375 | 2.9 | 2.4 | Ministry of Health/General Direction of Health Information/Mexican WHO-FIC CC (CEMECE); |
| Hungary (HU) | 131,668 | 3,204 | 2,775 | 4.6 | 3.4 | Hungarian Central Statistical Office – KSH; |
| United Kingdom (UK) | 36,421 | 1,405 | 1,102 | 2.7 | 1.6 | Office for National Statistics – ONS; |
| United States (US) | 2,820,034 | 5,553 | 5,008 | 3.2 | 2.2 | Downloaded from Centers for Disease Control and Prevention – CDC website |
| All countries | 4,812,100 | 6,786 | 6,292 | 3.2 | 2.4 | |

Source: Our processing

Table 5 shows the results of descriptive analyses about DUETO relations. Almost 464,000 different DUETO relations are reported on death certificates analysed. Of them, more than 50,000 are observed more than expected. The agreement with decision tables is high: 78% of the relations reported more than expected are included in the tables.

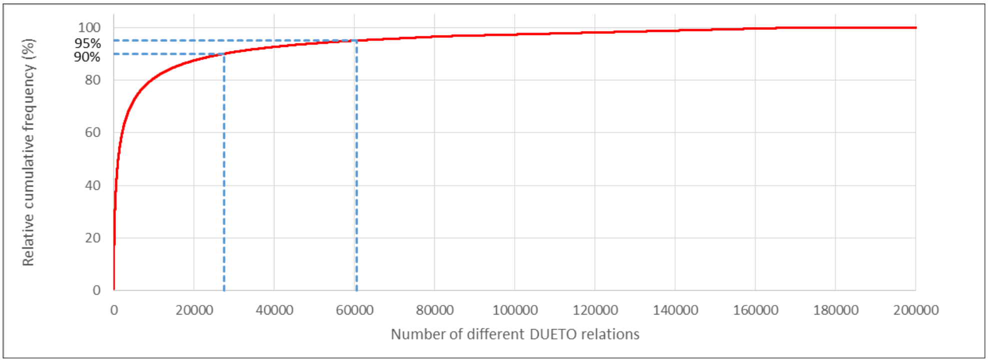
**Table 5 - Results of due to analysis**

| | N | % |
|---|---|---|
| Number of different ordered pairs found in death certificates | 463,939 | |
| Of which | | |
| Pairs reported in a given causal order (due to) more than expected ($X^2$ test, p<0,05) | 51,059 | 100.0 |
| Of which: | | |
| In agreement with decision tables | 39,819 | 78.0 |
| In disagreement with decision tables | 11,240 | 22.0 |

Source: Our processing

Figure 2 shows the cumulative frequency for DUETO relations ordered by decreasing frequency on certificates. On the x-axis the number of different DUETO relations reported on certificates, starting from the most frequent, is shown. On the y-axis the percentage of DUETO relations reported is shown. For example, from the Figure, we can see that 27,000 and 60,000 different DUETO relations represent respectively 90% and 95% of all DUETO relations reported on certificates. The curve allows estimating the percentage of completeness of translation we can reach starting the translation from the most frequent relation. The curve shows that if the first 27,000 most frequent DUETO are translated, about 90% of all DUETO reported on certificates is translated. If the first 60,000 most frequent DUETO are translated, it is possible to reach 95% of completeness.

**Figure 2 - Cumulative frequency curve for DUETO relations ordered by decreasing frequency**




Source: Pooled cause-of-death statistics Italian National Institute of Statistics - Istat; Statistics South Africa – Stats SA; Instituto Nacional de Estadística – INE, Spain; Ministry of Health/General Direction of Health Information/ Mexican; Collaborating Centres for the WHO Family of International Classifications, WHO-FIC; CC (CEMECE); Hungarian Central Statistical Office – KSH; Office for National Statistics – ONS, UK; Centers for Disease Control and Prevention – CDC, U.S.A.

Figure 3 shows DUETO relations reported on real certificates more than expected, distinguishing between those included in decision tables (left part, graph A) and those not included in decision tables (right part, graph B). On the x-axis the *codeDef* are reported and on the y-axis the *subcodeDef*. Even if it is not possible to interpret the meaning of each point in the Figure, this representation allows making general observations and considerations on specific groups of relations.

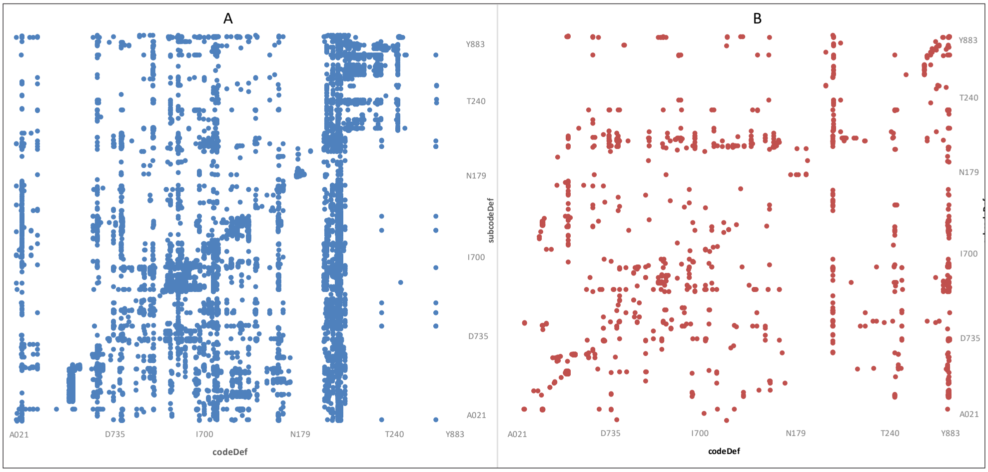
Among relations not included in the tables, it is possible to highlight different situations:

1. medically, the causal relation may exist but the classification explicitly provides not to accept the due to, for instance cancers due to some risk factors or viral diseases; such provisions of ICD are established for public health reasons and for making clear and comparable the counts of some specific diseases;
2. wrong reporting by certifiers such as:
   a. well defined diseases reported as due to symptoms or ill-defined conditions, for example stomach cancer reported due to gastritis
   b. chronological order preferred over causal order such as chronic obstructive pulmonary disease due to hypertension
   c. different clinical stages, for example neoplasm of unspecified behaviour causing malignant neoplasm;
4. diseases due to a very similar disease (diagonal in the graph).

We can also note that DUETO relations involving symptoms and signs are often not accepted by decision tables although they are frequently reported in death certificates. A frequent case is senility (R54) reported as due to many other conditions; this indicates that the mention of senility on the certificates should be seen as a synonym of "general frailty" and should be accepted as due to other conditions. Another frequent case is hemorrhage (R58) due to injuries and external causes.

Moreover, relations involving complications of medical and surgical care are reported, but these conditions are not included in tables as they are complicate cases that Iris cannot completely solve automatically.

**Figure 3 - DUETO relations found in death certificates included in current decision tables (A) and not included (B)**




Source: Pooled cause-of-death statistics Italian National Institute of Statistics - Istat; Statistics South Africa – Stats SA; Instituto Nacional de Estadística – INE, Spain; Ministry of Health/General Direction of Health Information/ Mexican; Collaborating Centres for the WHO Family of International Classifications, WHO-FIC; CC (CEMECE); Hungarian Central Statistical Office – KSH; Office for National Statistics – ONS, UK; Centers for Disease Control and Prevention – CDC, U.S.A.

## 4. Discussion and conclusion

Some results of the pilot project have been presented in a previous paper, mostly focussed on describing the logical knowledge needed to distinguish rules that can and cannot be automatically translated (Della Mea *et al.*, 2020). The results of the analyses showed in the present paper allow giving an idea of the efforts needed for the translation of decision tables in ICD-11.

The results show that the big majority of DUETO rules can be translated automatically, but the number of rules that require an expert intervention is anyway high. Nevertheless, the translation could in a first moment focus on the most frequent relations.

In the future project, a more precise estimation of the efforts needed should be carried out, using the methods identified in the pilot project and described in the present paper. Moreover, results from the two analyses can be combined in order to make decisions on how many and which rules should be translated. An evaluation of cost-effectiveness of different possible choices can also be made.

The results of the analyses on DUETO relations frequently reported by physicians but not included in decision tables could be useful to revise the tables and solve some issues, if necessary, during the translation process. Nevertheless, it should be taken into account that for some causes of death, such as external causes and injuries, tables might be not complete since Iris does not manage these cases. This incompleteness can be the origin of the differences between reported data and relations in the tables.

This transition is expected to need a big effort, also in terms of human resources, and to have a big impact on the system transition and use. Moreover, revising ICD and changing coding rules have a big impact on the comparability of cause-specific mortality statistics over the time. However, periodic revision of the ICD is essential to stay abreast of advances in medical science and changes in medical terminology (Boerma *et al.*, 2016; WHO, 2019*c*). Institutionally, revision of the ICD requires an enormous investment of national resources to revise software, training, publications, edit procedures, *etc.* (Anderson *et al.*, 2001). For the Iris transition to ICD-11, classification and coding experts are needed. To support their work, formal procedures are needed to ensure the correctness of the transition and validation of the system.

The main limitation of this research is that only DUETO rules are considered. For the complete translation of decision tables the same analyses need to be applied also to the other rule types, which take into account also Part 2 of certificates.

In conclusion, the presented methods seem suitable for supporting the process of transition of Iris from ICD-10 to ICD-11, however it further needs expert validation to correctly estimate the workload needed and to be applied to the other rule types.

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