

Review article

Analysis of root causes of problems affecting the quality of hospital administrative data: A systematic review and Ishikawa diagram

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ABSTRACT

Introduction: Administrative hospital databases represent an important tool for hospital financing in many national health systems and are also an important data source for clinical, epidemiological and health services research. Therefore, the data quality of such databases is of utmost importance. This paper aims to present a systematic review of root causes of data quality problems affecting administrative hospital data, creating a catalogue of potential issues for data quality analysts to explore.

Methods: The MEDLINE and Scopus databases were searched using inclusion criteria based on two following concept blocks: (1) administrative hospital databases and (2) data quality. Studies' titles and abstracts were screened by two reviewers independently. Three researchers independently selected the screened studies based on their full texts and then extracted the potential root causes inferred from them. These were subsequently classified according to the Ishikawa model based on 6 categories: "Personnel", "Material", "Method", "Machine", "Mission" and "Management".

Results: The result of our investigation and the contribution of this paper is a classification of the potential (105) root causes found through a systematic review of the 77 relevant studies we have identified and analyzed. The result was represented by an Ishikawa diagram. Most of the root causes (25.7%) were associated with the category "Personnel" – people's knowledge, preferences, education and culture, mostly related to clinical coders and health care providers activities. The quality of hospital documentation, within category "Material", and aspects related to financial incentives or disincentives, within category "Mission", were also frequently cited in the literature as relevant root causes for data quality issues.

Conclusions: The resultant catalogue of root causes, systematized using the Ishikawa framework, provides a compilation of potential root causes of data quality issues to be considered prior to reusing these data and that can point to actions aimed at improving data quality.

1. Introduction

Administrative hospital databases are an important tool in national health systems around the world for hospital planning and budgeting, as well as for clinical, epidemiological and health services research [1].

These hospital administrative databases usually have nationwide

coverage and contain comprehensive information, including demographic, clinical, administrative and reimbursement hospitalization data. The information results from the abstraction of structured and unstructured information documented in clinical records (including discharge summaries, surgical reports, pathology and image studies) and administrative records covering each patient's episode of care [2].

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The clinical information gathered and registered during the episode of care is classified using clinical classification systems, such as International Classification of Disease 10th Revision (ICD-10), which, along with demographic data, is used to group episodes of care into Diagnosis-Related Groups (DRGs) - coherent groups regarding clinical terms and resources utilization [3].

For a number of reasons (errors, lack of standards, financial interests) error-prone data can be included in these types of databases, eliciting data quality problems. This can potentially compromise hospital financing/reimbursement and their reutilization for epidemiological or health services research [4-6]. Within the research context, hospital administrative data entails enormous potential. In fact, it is systematically collected, encompassing a large population and a broad geographic coverage. Sometimes, it is the only feasible source available to study specific subgroups or to allow international comparisons. It may also provide important insights that can be used to improve the quality of care provided to patients, reducing access disparities, improving patient outcomes, and better allocating resources [7]. To maximize the application of these data in view of the much-appreciated potential, the highest level of quality must be pursued, considering the perspectives of the different stakeholders. Thus, we follow the definition of “*fitness for use*” of data quality in this work. This definition emphasizes the users’ viewpoint and intended application of the data in a given context of use, while requiring the judgment of various data quality dimensions for a given dataset [8].

There are numerous studies identifying data quality issues in hospital administrative databases, mainly related to accuracy problems [9-11]. However, as data quality goes beyond the accuracy or completeness dimensions, other dimensions not usually considered, such as credibility, currency and consistency, should also be addressed when it comes to identifying root causes of data quality-related problems in the healthcare services domain, an area where a systematic compilation and analysis is lacking. We felt motivated to conduct an investigation to bridge this gap, aiming to systematically identify causes of problems affecting the quality of administrative hospital data, whether these relate with hospital financing, epidemiological or health services research, and to propose the Ishikawa framework to derive and analyze a list of root causes [12].

2. Methods

2.1. Protocol

This study implemented a systematic review, following a previously published PRISMA-based protocol [13,14]. This protocol defined the methodology for the analysis of root causes that may affect the quality of administrative hospital data, considering two stages: 1) a systematic review to extract root causes of data quality from the scientific literature and the use of the Ishikawa diagram to support the analysis, reasoning and structure of root causes; and 2) a Delphi technique to analyze the relevance of root causes and to map them into data quality dimensions.

2.2. Information sources and search strategy

The MEDLINE and Scopus scientific research databases have been searched to identify potentially relevant studies reporting causes of data quality problems of hospital administrative databases. The search was performed on studies published from 1990 to 2019, given that this attests to some degree of quality of the studies and reflects the period when this type of data had a wide implementation around the world. The search was concluded on 31st September 2019. The drafted search strategy was based on two concept blocks: (1) administrative hospital databases and (2) data quality. The final search strategy for MEDLINE can be found as [supplementary material](#) (appendix A, Table A1). The search results have been exported into EndNote X9.2, where most of the duplicates were handled.

2.3. Eligibility criteria

The studies were subsequently screen according to the following inclusion criteria:

- Peer-reviewed studies (including conference papers), written in English.
- Studies referring to data quality of administrative hospital databases. This might include inpatient or outpatient hospital episodes and systematic or random failures resulting in data quality issues of these databases, including those originated in processes regarding data generation/acquisition, processing (e.g. clinical coding), storage, and utilization of these databases and their data sources (e.g. medical records), or encompassing the different perspective of producers, custodians and users (e.g. clinical coders, physicians, hospital managers, health ministry agents, researchers).
- Claims or billing data are to be included because data quality problems of these and the administrative databases share the same root causes [15-17], namely those related to the process of deriving clinical codes from hospital encounters.

The following criteria were then applied to further exclude studies that had met the inclusion criteria:

- Studies in which the authors were not explicit about the potential root causes of data quality problems of the administrative hospital database.
- Studies covering data regarding emergency, primary care or long-term care settings, or studies focusing databases of patient/disease registries, health surveys, or clinical trials data.
- Studies in which the full-text was not available.

Evaluation of the quality of the studies was not considered as an exclusion criterion as we prioritized comprehensiveness over study quality. We believe that the quality of the studies will have a small impact in our conclusions since our goal was to systematically identify potential root causes of problems affecting the quality of administrative hospital data, regardless of the study quality.

2.4. Selection of sources of evidence and data charting

Three reviewers (ARO, ML, MO) independently screened the titles and abstracts, two for each study. The Rayyan online free application assisted the screening phase [18]. Three reviewers (ML, MO, RC) then read all the full texts of the studies retained in the screening phase, applying the same eligibility criteria. Disagreements in each phase were resolved by consensus between three reviewers.

Data-charting consisted in extracting information relevant for the study of root causes of data quality problems. This was accomplished using a predefined form including several items: 1) study title, 2) type of study (i.e. observational, experimental, qualitative), 3) country of origin of the data, 4) data reporting years, 5) study description, 6) applicable coding systems 7) the name of the root cause, 8) the description of root causes identified, including, when possible, an example of the root cause, 9) a sequential identification number, and 10) the study where the root cause had been extracted from. For this task, a root cause has been defined as any identifiable process explicitly asserted as prone to result in data quality problems of administrative hospital databases and it was abstracted from the studies citing the manuscripts’ texts as much as possible.

Three reviewers independently charted the data (ML, MO, RC). One of the reviewers (RC) collated the root causes extracted by each of the reviewers into a single list of root causes, removing repeated root causes extracted from the same study by different reviewers, and matching root causes across studies. Any doubts about this process were solved by consensus among the three reviewers.

The assessment of the quality and risk of bias of the eligible studies was carried out by four reviewers (RC, ML, MO, ARO) using a 27-item checklist created for this purpose that combined recommendations from three evaluation statements: SQUIRE 2.0, STARE-HI and RECORD statements [19-21]. The choice of these tools was motivated by the fact they accommodate the different study types (e.g. observational studies, qualitative studies) of the eligible studies, and have been developed to suit research regarding health informatics and routinely collected data. Each study was assessed by two reviewers and disagreements were solved by consensus among the four reviewers. Studies that met more than 66% of the items of our checklist have been classified as “HIGH”; those that met fewer than 33% of the items have been classified as “LOW”; and the remainder of the studies have been classified as “MODERATE”.

2.5. Strategy for data synthesis

After matching duplicates across studies, we analyzed the list of root causes of data quality problems by mapping them into major and sub-categories. For the major categories, we borrowed six categories from the Ishikawa diagram framework:

- Personnel - everything that has to do with people’s knowledge, preferences, education, culture;
- Material - includes raw material, consumables, and information;
- Method – processes performed in the making or treatment of the data;
- Machine- tools/technology available to generate/collect and use data;
- Mission - purpose, environment;
- Management - everything related to leadership.

The Ishikawa diagram is a cause analysis tool typical of management research areas, although it has also been applied in healthcare studies [22-24]. By providing structure to the synthesis analysis of this systematic review, graphically arranging the many possible causes for data quality problems according to conventional categories, the Ishikawa diagram enhances reasoning about sources of data quality problems [25].

Each root cause was independently assigned to one and only one Ishikawa diagram branch by three reviewers. Any conflicts were discussed and solved by consensus. If 1 out of 3 reviewers had a different opinion from the others this would be considered a disagreement. The inter-rater reliability was assessed using the overall Fleiss’ kappa statistic, calculated using the statistical software IBM SPSS v.27.

The subcategories were not part of the Ishikawa framework. These were subjectively conceived by the reviewers, based on the studies themselves and the work of Nouraei *et al.* [26], in efforts to specify similar groups of root causes within each branch (see column 3, Tables 1–6 for a list of all of the considered subcategories). This provides further insights about the causes of data quality issues while affording some detail of the individual root causes without being as exhaustive as the full list.

3. Results

From the total of 2009 retrieved studies, 238 studies were assessed for eligibility based on their full-texts and 77 studies were included for extraction of root causes (Fig. 1). Most full texts were excluded either due to wrong type of data (n = 48), wrong study type or research field (n = 3), wrong outcomes (n = 92), or a combination of these reasons. Of the 77 included studies, 4 were judged to be low quality, whereas 24 and 49 studies were respectively deemed as moderate and high quality studies (Appendix C). Overall, the main points of non-compliance were the absence of an ethical statement in the methods section; the lack of information regarding any event that may have influenced study design

Table 1

Root causes of data quality of hospital administrative databases assigned to the Ishikawa’s Machine branch (N = 13).

Ishikawa subcategory	Root Cause #	Root cause name	References	Number of root causes
Clinical coding classification	1	Complexity of coding classification/rules	[27-29]	4
	2	ICD terminology limitations/lack of discriminatory detail	[7,30-33]	5
	3	Inefficient management of reviewed/discontinued ICD codes	[34,35]	2
	4	Transition between coding classification systems	[27,36]	2
	5	Use of two classifications	[37]	1
Guidelines and consensus	6	Deficient guidelines for coding comorbidities	[38]	1
	7	Lack of guidelines and consensus	[27]	1
	8	Multiple sources of advice	[39]	1
	9	Unstandardized/ambiguous coding guidelines	[39,40]	3
Tools related with source information	10	Impossibility of making explanatory drawings in EHR	[41]	1
	11	Inadequate discharge summaries standards	[42]	1
	12	Increased information technology adoption	[43]	1
	13	Limitations of the computer system	[41,44,45]	3

and/or results; the lack of other analysis such as subgroup or sensitivity analysis; and the absence of other information including authors’ contributions, competing interest, appendices. All low quality studies were narrative reviews.

The characteristics of the studies are presented in Table B1, appendix B. According to Table B1, the included studies cover several study types and reflect root causes perceived in data from countries like the USA (31.2%), UK (14.3%), Portugal (10.4%), Australia (9.1%) and France (5.2%).

The included studies initially yielded 258 potential root causes of data quality problems. Specifically, root causes related to financial incentives or disincentives (n = 24), incomplete or missing documentation (n = 15), poor-quality documentation (n = 13) and miscoding/misclassification (n = 12) had the highest number of duplicates. After the sorting and combination of the duplicates we achieved a final set of 105 unique root causes (Tables 1–6). The full description and examples for each root cause can be found in appendix B, Table B2.

After three reviewers have independently attributed one Ishikawa’s category to each root cause, where a moderate overall agreement was reached (Fleiss’ kappa statistic 0.486 IC95%=[0.433,0.539]), the analysis of root causes was further structured into categories subcategories (Table 1–6). Most (25.7%) root causes were associated with people’s knowledge, preferences, education and culture – “Personnel”, and the fewest (6.7%) were associated with purpose or environment – “Mission” (Fig. 2). However, we found a large number of duplicated root causes regarding financial incentives and disincentives within the Mission branch.

Within the Ishikawa branch “Personnel”, three subcategories related with the professionals involved in generating, collecting and processing the health information (i.e. the clinical coders, and the health care providers) were abstracted. Within the “Machine” branch, three subcategories have emerged. These covered root causes related with tools

Table 2
Root causes of data quality of hospital administrative databases assigned to the Ishikawa’s Personnel branch (N = 27).

Ishikawa subcategory	Root Cause #	Root cause name	References	Number of root causes
Coders and health care providers	14	Limited awareness of the impact of inaccurate complication coding	[39]	1
	15	Mismatch of coding terminology and clinical language	[39,46,47]	4
	16	Polarized perspectives of coders and physicians	[28]	1
	17	Coders’ experience	[33,39,48-50]	5
Clinical coders	18	Coders’ insufficient clinical knowledge	[42,51]	2
	19	Coders’ lack of education	[52]	1
	20	Coders’ lack of knowledge on a specific condition	[30,33,53,54]	4
	21	Coding bias	[38]	1
	22	Coding infrequent events	[55,56]	2
	23	Coding learning curve	[57]	1
	24	Coding subjectivity and variability	[26,31,55,58-60]	6
	25	Definition of secondary diagnosis is subject to interpretation	[61]	1
	26	Inadequate procedural coding education	[62]	1
	27	Inter-coder variation	[44,57,63,64]	4
	28	Lack of knowledge of coding guidelines	[45,65]	2
	29	Lack of understanding of procedure coding	[59]	1
	30	Medical record administrators’ lack of education	[49]	1
	31	Poor training and support interventions to coders	[47,66,67]	3
	32	Reluctance to record more than one code	[48]	1
	Health care providers	33	Clinicians’ experience	[68]
34		Clinicians’ lack of awareness/ education on the coding process and purpose	[30,34,42,51,69,70]	6
35		Clinicians’ lack of time and motivation to document records	[34,71]	2
36		Clinicians’ unawareness of documentation needs	[72]	1
37			[30,32,37,73,74]	5

Table 2 (continued)

Ishikawa subcategory	Root Cause #	Root cause name	References	Number of root causes
		Difficulties/ uncertainty in establishing a diagnosis		
	38	Lack of assertiveness in diagnostic documentation	[41,60]	2
	39	Student documentation	[75]	1
	40	Undercoding of diagnoses and morbidities	[51,76,77]	3

assisting on the information collection such as clinical coding classification (e.g. ICD terminology limitations), guidelines and consensus (e.g. unstandardized coding guidelines) and tools related with information management (e.g. limitations of the computer system). The “Management” branch was subdivided into three subcategories: leadership involvement which included root causes such as lack of feedback and lack of senior leadership involvement; limited resources, which included any root causes related with budget or human resources constraints; and a miscellaneous subcategory (e.g. lack of incentives for comprehensive coding). The “Material” branch included six subcategories describing different issues that have been reported about the data in health records – the data sources of the DRG-based administrative hospital databases. These subcategories were: incomplete/missing information, inconsistent information (e.g. ‘Principal diagnosis: childbirth’ and ‘sex: male’), information fragmentation (e.g. Uncoordinated or redundant data entries into different data sources in electronic health records, EHR), medical record factors (e.g. Poor documentation or organization of medical notes), readability and other information issues (e.g. duplicated episodes). The “Method” branch comprised four subcategories of processes related to health records’ data collection and abstraction into the database, the latter mostly covering issues that arise in the coding process of clinical information. Finally, within the “Mission” branch, the three considered subdivisions encompass root causes linked to the envisioned utilization of data (i.e. “coding purpose”, “financial incentives or disincentives”) which promote particular documentation practices (e.g. documenting information used to establish hospital payments and information used to compare hospital performance), as well as root causes linked to the environment in which data is collected, such as variability of practices induced by different hospital contexts.

4. Discussion

This study provides a comprehensive list of potential root causes of data quality problems affecting administrative hospital databases and proposes a framework (the Ishikawa classification) for deriving and analyzing such list.

Root causes related to documentation issues (“Material”) and to financial incentives or disincentives (“Mission”) play an important role in contributing to data quality problems, being highly present in the retrieved literature (57 articles). In fact, we obtained a high number of duplicates for these causes. Regarding the documentation issues, we found that missing or incomplete documentation of diagnostic information and poor-quality of documentation were the most frequently encountered causes of data quality problems in administrative hospital databases. Other sources of data quality problems included in the “Material” category are also linked to documentation issues such as inconsistent or fragmented information, and lack of readability of health records. The transition from paper to electronic health records has improved the legibility of health records as well as their information

Table 3

Root causes of data quality of hospital administrative databases assigned to the Ishikawa's Management branch (N = 14).

Ishikawa subcategory	Root Cause #	Root cause name	References	Number of root causes
Leadership involvement	41	Lack of feedback	[67]	1
	42	Lack of knowledge of health information management systems	[65,78]	2
	43	Lack of senior leadership involvement	[65,78]	2
	44	Lack of support and respect for the coding function	[65,78]	2
	45	Pressure from administration and health care actors	[79]	1
	46	Unsatisfactory education and engagement of hospital administrator, information technologists and researchers	[80]	1
Limited resources	47	Coders' quotas and expectations	[58]	1
	48	Coders' time constraints and workload	[33,45,46,48,81]	5
	49	Lack of budget and time	[40]	1
	50	Poor investment in documentation/education of physicians	[65,78]	2
	51	Priority of coding	[71]	1
Other	52	Condition not formally acknowledged as to complicate the clinical care of the patient	[61]	1
	53	Lack of incentives for comprehensive coding	[46]	1
	54	Lack of routine and systematic internal coding audits	[27,34,82,83]	4

Table 4

Root causes of data quality of hospital administrative databases assigned to the Ishikawa's Material branch (N = 23).

Ishikawa subcategory	Root Cause #	Root cause name	References	Number of root causes
Incomplete/missing information	55	Incomplete/missing documentation of diagnostic information	[34,38,41,42,44,46,50,52,58,72,84-86]	15
	56	Lack of contextual information	[85]	1
	57	Lack of meaningful codes	[63,64]	2
	58	Limited clinical and socio-economic detail	[73,82]	2
	59	Missing/incorrect codes or values	[56,71,73,83,87,88]	6
Inconsistent information	60	Inconsistency	[84,87,88]	3
	61	Inconsistent/conflicting information in the record	[31,81]	2
	62	Inconsistent or incomplete racial/ethnic classification	[89,90]	3
Information fragmentation	63	Information fragmentation/lack of a standard organization of EHR	[85]	1
	64	Information fragmentation/lack of unique patient identifier	[73]	1
Medical record factors	65	Availability of notes	[68]	1
	66	Medical record organization	[58,68,81]	3
	67	Poor-quality documentation	[15,31,39,40,45,53,54,56,68,77,81,83,91]	13
Other information issues	68	Ambiguous documentation	[60]	1
	69	Duplicated episodes	[88]	1
	70	Imprecise discharge summary values for DRG grouping	[84]	1
	71	Incorrect or absent documentation of a procedure	[59]	1
	72	Lack of standardized recognition and documentation of transfers	[80]	1
	73	Non-verifiable ex post information	[92]	1
	74	Updates to definitions of clinical diagnoses	[61]	1
Readability	75	Illegibility	[41,58]	2
	76	Unreadability	[33,48]	2
	77	Use of abbreviations/acronyms/synonyms/nonstandard terminology	[30,34,37,41,50,69]	7

organization and presentation. However, electronic records remain susceptible to the use of abbreviations, acronyms and non-standard terminology, and are prone to create other problems such as the use of copy and paste, also identified in our literature review, that may lead to the repetition of large uninformative chunks of text, sometimes including erroneous information, making coding more difficult and more time-consuming [41,85]. Moreover, the definition of a standard content for medical records that is fit for coding purposes has also been suggested to address problems of missing/incomplete information [41,85].

Hospital administrative data are primarily used for billing and reimbursement purposes, hence clinical coding is frequently financially driven. Among the studies reporting root causes related to the financial incentives or disincentives, upcoding (the misreporting of episodes of care into higher payment DRGs) was the most frequently assessed root cause. Upcoding may result from different coding practices with varying legal implications, including coding comorbidities comprehensively to raise treatment costs; substituting the primary diagnosis by a secondary

diagnosis; and adding comorbidities that are not documented. The case of upcoding through birth weight of newborns was documented in several studies [7,92,99]. This information is used to determine the DRG of a hospitalization, with hospitalizations of newborns documented with low birth weight yielding substantially higher payments. Unlike other upcoding situations that can be mitigated by instituting routine and systematic coding audits, birthweight is virtually impossible to verify [92].

A large number of root causes identified are related to the coding activity. Besides upcoding, several studies reported issues in the selection of codes as a potential root cause of data quality issues of hospital administrative data ("Miscoding/misclassification"). This encompasses coding unsupported by the clinical record, the assignment of generic codes when information exists to assign more specific codes, assignment of incorrect codes according to the governing rules, or assignment of codes without the physician attesting to their accuracy [50,83,95]. Other data issues associated with coding arise from coders' subjectivity, bias, learning curve, different experience and training, which are

Table 5

Root causes of data quality of hospital administrative databases assigned to the Ishikawa's Method branch (N = 21).

Ishikawa subcategory	Root Cause #	Root cause name	References	Number of root causes
Basis for coding	78	Ambiguous classification criteria	[93]	1
	79	Code sequencing rule	[64]	1
	80	Coding based on case notes only	[94]	1
	81	Coding based on codebook	[33,48]	2
	82	Coding based on discharge summary	[94]	1
	83	Coding based on face sheet and memory -based coding	[48]	1
	84	Coding team	[70]	1
	85	No checks with physicians for clinical relevance	[39]	1
	86	Poor usage of coding materials	[49]	1
	Coding errors	87	Errors at the point of attestation	[50]
88		Induction errors/Misspecification	[50,52,95,96]	5
89		Miscoding/Misclassification	[35,39,44,50,54,72,76,80,83,88,90,95]	12
90		Resequencing	[50,95,96]	3
91		Unbundling	[50,62]	2
Quality of filling	92	Errors assigning information	[87]	1
	93	Transcription errors	[50]	1
	94	Use of copy and paste	[41,85]	2
Retrospective information	95	Point in time of the initial classification	[93]	1
	96	Retrospective coding/Information collected at discharge	[63]	1
	97	Retrospective queries for coding	[34]	1
	98	Retrospective writing of discharge summary	[94]	1

Table 6

Root causes of data quality of hospital administrative databases assigned to the Ishikawa's Mission branch (N = 7).

Ishikawa subcategory	Root Cause #	Root cause name	References	Number of root causes
Coding purpose	99	Coding purpose	[70]	1
	100	Misclassification of severity/risk	[82]	1
Financial incentives or disincentives	101	Financial incentives or disincentives	[7,35,39,50,53,55,57,62,63,66,70,73,74,92,93,97-100]	24
	102	Reimbursement system	[32]	1
Variability of practices	103	Fast turnover and day-case nature	[69]	1
	104	Variability in coding practices	[32,33,60]	3
	105	Variability of the quality of health records	[41]	1

accompanied by variability of coding practices across different specialties and across hospitals. Adequate guidelines and terminologies could help reduce the impact of some of these root causes. However, issues in these tools have also been identified as potential root causes of data quality problems of administrative hospital databases. For example, the lack of discriminatory of ICD-9-CM, the inefficient process used to manage ICD codes' modifications, the lack of specific rules concerning the coding of co-morbidities have been reported leading to problems in the utilization of diagnostic and procedure codes [30,33-35,38].

4.1. Potential solutions to the root causes

To achieve the greatest value, it is essential that data has the highest possible levels of quality. Through the Ishikawa diagram, a widely used framework to identify and analyze root causes of problems, it was possible to discern categories with causal links to data quality issues of the hospital administrative databases, capable of capturing the different aspects of the process of information generation in these databases and allowing a better representation and analysis of which causes to address in efforts to improve their data quality. For example, root causes linked to "Personnel" could be mitigated through training programs and incentives aimed at raising awareness of the purpose of the data and the implications of data quality issues, as well as improving skills with existing tools and the communication between the different actors involved in the data generation [47,66,83]. Moreover, root causes linked with "Method" and "Machine" could be solved with the creation or improvement of tools used to generate/collect data, such as text processing instruments to omit repeated text generated through copy

and paste, or automated coding processing applications [101]. Within this regard, artificial intelligence could be of great value. According to Kaur, R. the increasing prominence of EHRs has prompted the development and adaptation of natural language processing and machine learning algorithms for clinical coding. By taking clinical records as inputs and providing the clinical code automatically after inferring the unstructured data in the form of free text without human intervention, these types of algorithms foster clinical classification standards compliance [102-104]. Furthermore, within the "Management" branch, a leadership that is involved with the coding team, that manages to improve communication and education among the different professionals and that negotiates incentive schemes (bilaterally), will have a positive impact in the motivation, dedication and in the meeting of deadlines of the collaborators [65,78]. Finally, within the "Mission" branch increasing information technology adoption through, for example, systems that can alert the coding professional on-the-fly for unusual combinations of codes could more efficiently improve the quality of data for the envisioned purpose by minimizing upcoding [43,97,100]. The lack of sufficient resources adds to the pressure that clinical coders experience to meet quotas and does not allow for an adequate auditing process that is the most reliable way to detect upcoding [105]. However, for the acceptance of computer-assisted tools, it is crucial to have clinical coding professionals involved in their development, as this would likely lead to a solution tailored to their actual needs, thus increasing the potential of engagement and minimizing the risk of alert fatigue [106,107].

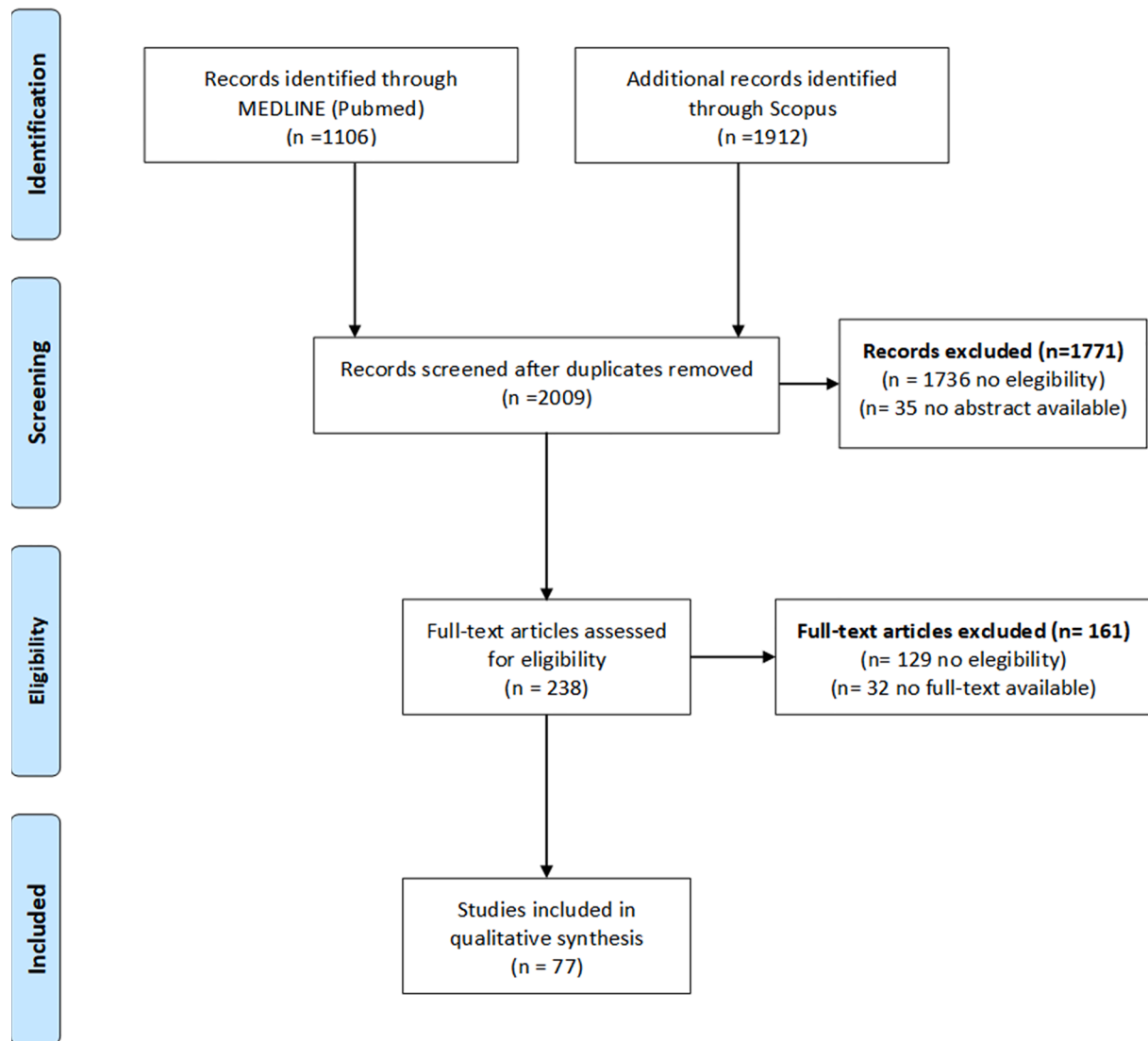


Fig. 1. PRISMA flow diagram for the work conducted in this investigation.

4.2. Strengths and limitations

One of the main strengths of this study is the use of an Ishikawa diagram to display the results of the review, a distinct and useful model for analysis of the root causes that affect the quality of routinely collected data in many health systems.

Furthermore, rather than using a typical discussion or brainstorming process the diagram is completed by using peer-reviewed data with pre-established criteria covering an interval of almost 30 years. As far as we know, the only publication similar to ours is a systematic scoping review by Pongpirul *et al.* that considered three categories of approaches that lead to DRG system manipulation, the corporate, clinical and coding practices, and created a list of possible hospital DRG manipulations, using literature from 1918 to 2010 [108]. To the interested reader, this study could be a complement to our work, although our approach is more comprehensive and detailed – creating a list of 105 potential root causes of data quality problems in hospital administrative databases.

This review has limitations. We have only searched studies in two databases and have not included grey literature. This raises the question whether we have reached a saturation point, however, given the diversity of root causes and the high number of duplicates encountered, extending our search to other databases is likely to add very little insights regarding additional root causes. Furthermore, by considering

publications that are indexed and peer-reviewed, we ensure replicability and rigor of the evidence and less vulnerability to publication bias.

Some root causes are very specific of certain contexts such as procedural codes that are used in the United States only. On the other hand, some root causes may no longer apply in some countries. For example, “ICD terminology limitations/lack of discriminatory detail” has been addressed with the transition from the ICD-9-CM to the ICD-10-CM, which resolved many of these issues. Nevertheless, awareness of this issue is important when comparing/combining data from different time periods or when using different classification systems.

Additionally, in the presented Ishikawa diagram we assigned a root cause to one and only one branch/category and subcategory. Despite the fact that the root causes would be the same, the diagram and respective table of results would have been very different if we would have had a more flexible approach and assigned root causes to more than one category. In this case, this process of mutually excluding causes was demanding and most decisions were made via consensus. While this might introduce some inconsistencies in the classification of root causes, it was performed in a systematic and replicable manner. We believe that the alternative approach would be equally valuable but would have produced a more unresolved and confusing catalogue of root causes.

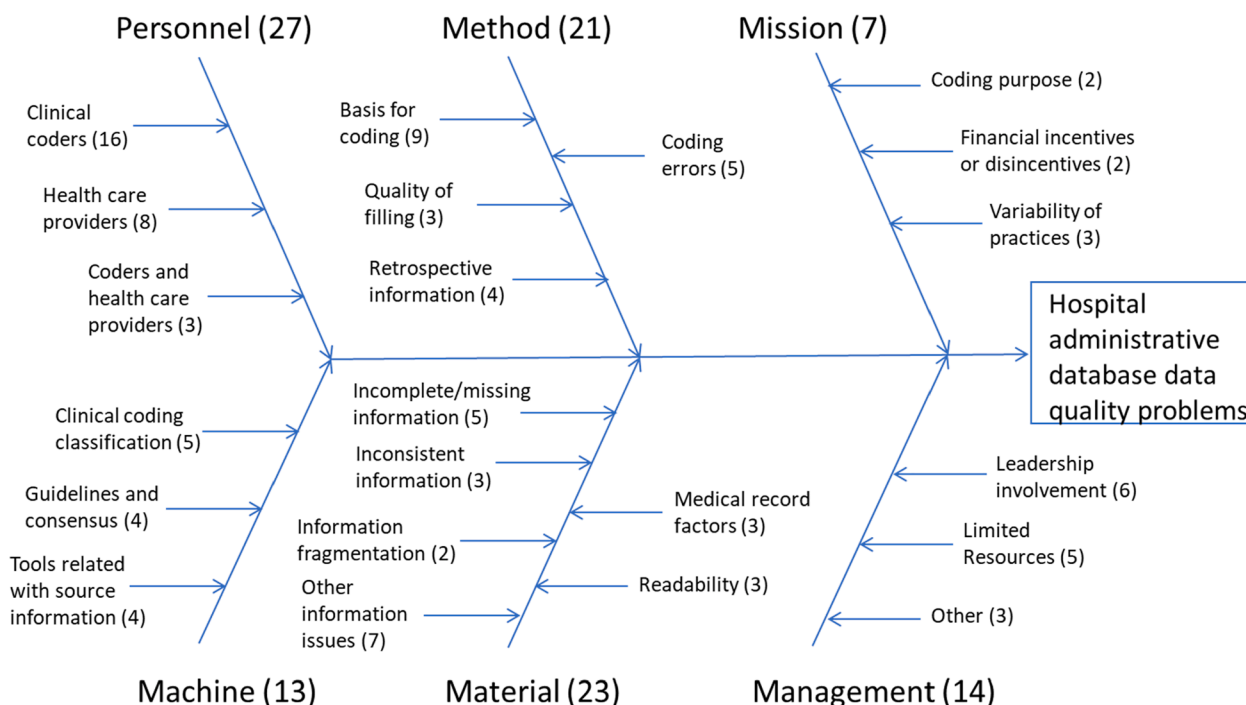


Fig. 2. Ishikawa diagram of root causes of data quality problems affecting hospital administrative data: (n) number of root causes identified in each category and subcategory.

4.3. Implications of the results and future research

The quality of administrative hospital databases is paramount to hospital financing but also for its reutilization in research, holding potentially valuable insights that can improve health care practice and planning. Future research could consider improving the methodology for identifying root causes of data quality problems. Besides considering other literature search engines and extending the review to the grey literature, another potentially relevant follow-up on our research would be to validate and estimate the relevance of root causes. In this study, we assume all root causes having the same impact or criticality. Qualitative methods using structured interviews/questionnaires (e.g. focus groups, Delphi process, survey) could be used to validate root causes according to a panel of experts while subjectively informing on their criticality [27,28,40,41,58], whereas quantitative methods could be used to objectively assess the extent of root causes and the data quality problems [38,53,63,80]. As an example, Souza *et al.* described the individual impact of under-coding comorbidities on DRG classification and hospital funding in the context of respiratory and cardiovascular diseases [38]. In addition, further research could investigate the impact of possible solutions to some of the causes of problems. Several examples in the searched literature have assessed specific corrective measures comparing the data quality before and after the introduction of a certain measure [15,34,46]. For example, Aiello *et al.* showed that a physician-led coding initiative aimed at educating clinicians had a positive impact on documentation issues by comparing documentation regarding hospital episodes of patients undergoing certain procedures before and after implementing the initiative [15].

5. Conclusions

The presented systematic review sets forward a catalogue of 105 individual root causes of data quality problems affecting administrative hospital databases. Through the Ishikawa categorization this catalogue of root causes is represented in a meaningful way, generalizable to other countries collecting this type of data, and in terms that allow for the tackling of these issues, with a potentially significant impact on

improving hospital funding and health care research.

Authors contributions

All authors have made a substantial, direct, intellectual contribution to this systematic review.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Summary table

What was already known on the topic?

- Hospital administrative data is important for hospital financing and for clinical, epidemiological and health services research.

- Error-prone data is included in these types of databases, eliciting data quality problems.

What this study added to our knowledge?

- This is the first systematic review of root causes of data quality problems affecting hospital administrative databases, identifying 105 different root causes.
- The Ishikawa framework allows for a useful categorization of root causes that improve the attainment of solutions to these problems.

Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijmedinf.2021.104584>.

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