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Review of deaths correction methods and quality dimensions of the underlying cause for accidents and violence in Brazil

Adauto Martins Soares Filho [1]
Juan José Cortez-Escalante [2]
Elisabeth França [3]

Abstract *This review article aims to perform analysis and critical discussion about the literature on methods correcting mortality from accidents and violence reported to the Brazilian Mortality Information System. We consulted Medline and SciELO databases, as well as the Global Burden of Disease site, using time filter for the 1996-2015 interval. Of the 77 studies identified, we selected 29, and 14 met the corrections production criteria for cases of underreporting: underreporting of deaths in the Mortality Information System, deaths declared as ill-defined causes or deaths from external causes declared with non-specific codes. We found that the underreporting of external causes was not significantly different from what occurs in total deaths and sometimes was higher in small and medium-sized municipalities. The reclassification of ill-defined causes of death corrected external causes to non-negligible values. The selected studies differ on proposals for correction of unspecified external causes. Evidence supports interventions to improve the quality of data, and the availability of correction procedure of external causes that bring together application conditions.*

Key words *Information systems, Mortality records, External causes, Underreporting, Review*

[1] Departamento de Vigilância de Doenças e Agravos não Transmissíveis e Promoção à Saúde, Secretaria de Vigilância em Saúde, Ministério da Saúde. SAF, trecho 2, Lote 05/06, Bloco F, Torre 1, Edifício Premium, Setor de embaixadas. 70070-600 Brasília DF Brasil. adauto.filho@saude.gov.br
[2] Organização Pan-Americana da Saúde-OPAS. Brasília DF Brasil.
[3] Programa de Pós-Graduação em Saúde Pública, Faculdade de Medicina. Belo Horizonte MG Brasil.

Introduction

Public health mortality information is frequently affected by problems expressed in completeness and reliability of the recorded data, in particular the incomplete filling out of causes of death forms. These factors can substantially impair the monitoring, analysis and evaluation of the health situation and induce improper choices and decisions in the management of public health actions and policies[1-3].

The assessment of Brazilian mortality levels and patterns requires the development of strategies that minimize information bias due to underreporting of deaths in the Mortality Information System-SIM, either because of death not informed, death informed with ill-defined cause (IDC) or even causes of deaths with unspecific or incomplete diagnosis. This recommendation also applies to deaths from accidents and violence, which are better reported and classified than other causes[4].

There is a non-negligible amount of deaths from external causes, which should be thoroughly investigated. In the 1990s, more than one million people died from these causes in Brazil, of which about 40% were due to homicide. External causes have been the third leading cause of death in the country since the early 2000s and are a serious social problem having a severe impact on personal and public health[5].

Administration acts regulate the law by establishing that no burial should be performed without certificate[6]. The Federal Council of Medicine[7] and the Ministry of Health[8,9] edited acts regulating the medical responsibility of providing death certificates (DC) for public records and to feed the SIM, noting that the DC should be provided by the forensic medical services – FMS in cases of non-external deaths. Even in places without medical assistance, the DC should be completed in police stations or in registry offices, reporting that the death was from an external cause. These legal provisions favor a better capture of violent deaths[10].

Methods based on demographic techniques have been used to assess death registration completeness[11,12]. However, literature does not indicate a single most appropriate methodology for estimating "true" mortality[13]. In addition, these methods are not continuous as would be required to assess health interventions. More recently, the active search for deaths has been a promising strategy to identify deaths not captured by the SIM. Survey conducted in the Northeast and Legal Amazon[14] is a study model capable of producing correction factors and consistent and reliable estimates from the methodology of the retrieval of information associated with statistical models, adding generalizability of results.

In 2011, 1,170,498 deaths were reported in Brazil to the SIM. The estimated underreporting decreased from 9% to 6% between 2000 and 2011, while ill-defined registered deaths fell from 14% to 7%[15]. This was due to a set of actions that regulated deadlines for data transfer by establishing rules for the suspension of the transfer of funds[9,16]. Despite the high national completeness and reduced IDCs, the system shows less favorable conditions in the North and Northeast regions, with the proportion of IDCs in 2011 of 11% and 8%, respectively[15].

It is therefore necessary to also measure the extent of IDCs and seek redistribution methodologies, ascertaining their impact on mortality from external causes. There is no consensus, however, on how to deal with this issue. Some researchers have proposed the redistribution of IDC-related deaths based on the proportional distribution of causes among deaths from defined causes. However, this methodology has not been satisfactory, particularly in the case of exclusion of external causes from violence and accidents which have been found among IDCs investigated[10,17-19].

The relationship between the SIM completeness and the proportion of IDCs has been reversed in general: a comparison between 1980-1991 and 2000-2010 periods demonstrated an increased completeness of deaths from 80% to 95% in the country, with IDCs reduced by 53%[12]. These two factors would perform synergistically in improving the quality of information from external causes. On the other hand, the migration of deaths could occur, as suggested by a study about a possible error in the classification of suicides under unintentional poisoning in the United States[20].

The DC from external causes do not always bear accurate information on the type of accident or violence leading to death. In 2012, 21% (n = 152,013) of external causes were recorded as being of undetermined intent or incomplete diagnoses[21]. The significant number of deaths from undefined external causes may be one of the main indicators of poor records produced by the forensic system, to the extent that it reflects its inability to adequately assess the reason leading to death, as well as limited access to reference services for the clarification of death in the municipalities.

The correct completion of the cause of death

relies on the quality of the forensic medical report, which, in turn, depends on the infra-structure and working conditions, periodic training for professionals and collection of detailed information about the scene of the event. Forensic physicians quite often only state the nature of the injury on the certificate, neglecting the type of external cause. This has led the Ministry of Health to include variables in the DC to inform the likely circumstances of the external cause of death, which, however, are not always filled out[22,23]. Some studies, however, found that the FMIs usually have detailed data, but do not transcribe them in the DC[4,23-25]. A similar condition was observed in a study that validates the causes of deaths in Barcelona[26].

Thus, while external causes are usually better informed and notified, there may be some underreporting of these deaths due to loss of cases arising from deaths not captured by the SIM, or hidden between IDC and undefined external causes. So, it is important to assess the quality of data on deaths from external causes recorded in the SIM and the proposed data correction methods. The objective of this study was to perform an analysis with critical discussion of the literature on mortality corrective methods for accidents and violence reported to the SIM. We sought to provide a comprehensive overview of these methods to identify issues that require evidence, assisting in the guidance for future research.

Methodology

The literature review on the proposed theme followed three steps. First, we tried to explain how the problem at hand was investigated, especially from a methodological standpoint. Then, we identified contributions to the knowledge on the subject, the main gaps, theoretical and/or methodological hindrances, and methods to correct external causes of mortality, condensing evidence and key points of the problem. At the end of which, it was possible to enhance the quality and extent of research through critical analysis and synthesis of selected information[27].

The term "external causes" refers to factors external to the human body caused by accidents and violence. Accidents are characterized as an unforeseen and generally undesirable event, which produces traumatic injuries. Violence is characterized by a brutal and despotic action that usually involves use of force, weapons or other aggressive means. They can be self-harm (suicide) or inflicted by another person (homicide)[28].

Deaths from undefined external causes are divided into two groups, adapted from the Mello-Jorge et al proposal[4]. The first, namely the totally undefined, occur when it is impossible to determine whether deaths were due to accident, self-inflicted injury or assault. They are the events of undetermined intent, codes Y10-Y34, from the 10th Revision of the International Classification of Diseases (ICD-10)[29]. The other is incomplete diagnoses in external causes: unspecified traffic accidents (V87-V89, V99); other unspecified accidents (unspecified fall-W19), unspecified drownings-W74, exposure to unspecified type of fire or flame-X09, accidents by exposure to unspecified factors-X59); suicide by unspecified means (X84); homicide by unspecified means (Y09).

The identification of publications was performed with a search for information in the databases of electronic libraries Medline and SciELO, as well as in the Global Burden of Disease (GBD) publications' website, with filter for open access complete articles in Portuguese, English or Spanish published between 1996 and 2015. This period was defined due to the beginning of ICD-10 use in Brazil in 1996. Descriptors in the search were: *information systems and Brazil*, *mortality records and Brazil external causes and Brazil*, *underreporting and Brazil*, and *cause of death and Brazil*. Publications were selected according to the criteria of being studies that analyzed the quality of the cause of death provided by the SIM and at the same time produced estimates enabling the correction of external causes recorded in the SIM. Using keywords, literature revision was based on titles, abstracts and dynamic reading of the text. After selection, all papers were evaluated with thorough reading and careful analysis of the full text. Publications unrelated to deaths from external causes in the SIM or which did not propose correction methods for these deaths, or did not publish the proposed values for correction were excluded.

The publications' survey was included in a file of read texts and used as an instrument for the systematization of reading notes[30]. The exploration of content of papers included in the review allowed for notes that were used to reference studies mentioned at the time of discussion, and also for comparison and analysis of methodological aspects and important evidence in the estimation and correction of deaths from accidents and violence.

Papers were organized into three major thematic groups: 1) papers with estimates of under-

reporting of external causes among deaths not reported to the SIM; 2) papers with identification of external causes among ill-defined causes reported to the SIM; and 3) papers with reclassification of undefined external causes or external causes with incomplete diagnoses reported to the SIM. Each large group was characterized as per procedures used, summary of main findings, including estimated values for correction of deaths, place and time of collection and limitations. In turn, the methodological aspects and correction procedures of mortality from external causes were classified as: 1) methods based on statistical models, and 2) methods based on the retrieval of information, for field research or pairing databases.

Results and Discussion

The literature review led to the initial selection of 77 papers, with 30 of which selected for full reading, 17 with a central theme of correction of mortality from external causes and 13 addressed the quality of mortality data from external causes. Finally, we selected 14 articles published between 1999 and 2014, which best fitted the subject of this study (Figure 1).

The three major published thematic groups showed homogeneous profile, each having at least four investigations from the 1990s on. The largest group of studies mainly used field study methods for the retrieval of information and referred to local information (n=11), having thus reduced ability to generalize the results. Other investigations extended the correction of deaths from external causes to a national level (n = 3), mainly using statistical models. Some papers were published more than 10 years ago, but most are from 2005 on (Chart 1). The underreporting of deaths from external causes is therefore a recent concern of researchers, with still relatively few studies in the country, a situation possibly conditioned by the conviction that this type of death is better informed[4]. On the other hand, improved SIM records[15], the reduced number of certain deaths in population health, such as child and maternal[38,39], and the increased participation of external causes in the epidemiological profile[5], gain ground in the political, management and research agenda for more careful consideration of the production of accidents and violence records. It is also worth noting that these causes were only admitted as health sector issues by international organizations from the 1990s on, which is a relatively recent period[33].

In the first thematic group (Chart 2), of the four reviewed studies on deaths underreporting, three retrieved information from field research, with different procedures: active search in cemeteries to identify records not collected by the SIM in the capital of Ceará[34]; retrieval in the civil police investigation records in a medium-sized municipality of Minas Gerais[35]; and retrieval of deaths from various sources of information in a sample of 10 small- and medium-sized municipalities of Minas Gerais[36]. One survey proposed mathematical methods through Bayes estimators, checking underreporting per federal unit[37].

Studies of this first group show the model's advantages and drawbacks. Active search field research in broad geographic locations and varied sources such as Campos et al[36] paper require more logistics and higher costs. This study showed losses of 32% in predominantly rural areas. The retrieval of information in a specific municipality[34,35] and restriction to only research source, particularly cemeteries[34], brought the drawback of capturing deaths with a high proportion of ill-defined causes (IDC) or ignored causes (54%). In addition, certain sources can lead to increased retrieval of a particular type of cause, such as the civil police investigations[35] that favor more the identification of homicides. The easy implementation of the statistical model[37] has the disadvantage of being based on modeling from the occurrence of defined causes reported in the SIM, but, on the other hand, enables the evaluation of the level of coverage of deaths by age group in small areas[38] (Chart 2).

While selected studies show proposals to correct underreporting of external causes in the SIM for different geographic and time cutouts, it is still possible to compare the findings in the two different methods. Data retrieved from cemeteries[34] identified 13.6% underreporting of deaths from external causes in the capital of Ceará in 2000, while the paper that used statistical models[37] published 7.6% underreporting for the Northeast in 2001. The first study found a much higher correction proportion than the second, particularly more evident because it is a correction of a capital's data, where it is expected that data are better reported, in line with research that shows SIM increased coverage according to the growing population of municipalities[14]. This may indicate that the statistical model underestimates deaths from external causes in the Northeast. In the Southeast, the method that worked with verbal autopsy[36] found 55 deaths from external causes (26.7%) of all deaths not reported in the

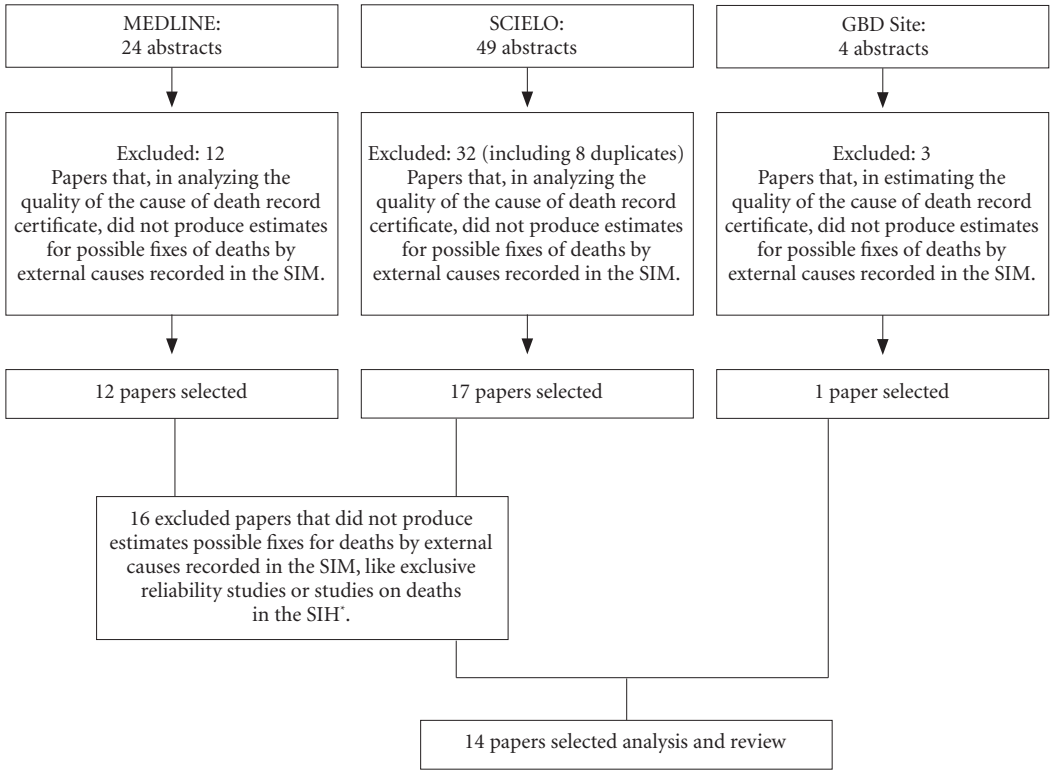

Figure 1. Flowchart of search and selection of studies on methods for the correction of mortality from accidents and violence reported to the Mortality Information System.

* Hospital Information System of the Unified Health System (SUS).

small- and medium-sized municipalities of the Northeastern macro-region of MG in 2007. The investigation of Civil Police records[35] identified 21% underreported deaths from external causes in the medium-sized municipality of Viçosa-MG from 2000 to 2009, with higher underreporting values for homicides. This evidence highlights the need to consider issues in the capture of deaths from accidents and violence, especially in smaller municipalities. The assumption that such deaths are best captured by the SIM than those of natural causes[2,3,39] (Chart 2) should therefore be seen with caution.

Field investigations showed the supplementary benefit of pointing out factors that most contributed to portray the underreported volume, addressing material flaws and deadlocks of the process of clarification of deaths from external causes. Depending on the source used, one cause of death may be typically more collected than another, such as police data that are most sensitive to the identification of violent causes. Cemeteries can be good deaths retrieval sources, but have limitations in recording causes. Cerqueira[22] also considers a type of underreporting of homicides in certain cities, where it would not be unusual to see victims' bodies disappear at the hands of drug traffickers and militiamen.

In the second thematic group, papers on IDCs recorded in the SIM corrected the underreporting deaths from external causes from field investigations for the retrieval of information and reclassification of IDCs[10,17,18,36]. Different strategies were used to determine the cause of death, from consultation to a data source such as the Hospital Information System-SIH[17], or a variety of sources, such as hospital records, Forensic Medicine Institutes (FMI) and data collection in households' interviews[10] or verbal autopsy[36], as well as retrieval of information on deaths investigated in the SIM[18] (Chart 3).

Of these studies, three applied procedures in

Chart 1. Summary of selected publications on the quality of the cause of death by accident and violence record certificate in the Mortality Information System-SIM, Brazil.

Large thematic groups	Number of publications	Method type	Year(s) of publication
1. Fix of underreporting of deaths from external causes	Total 4 studies on estimates of deaths that fix underreporting of external causes; 3 refer to local information and one to national data.	3 applied methods based on the retrieval of information, and one based on statistical models.	2003[34], 2007[37], 2010[36], 2014[35].
2. Reclassification of ill-defined causes of death, specifically with the classification of external causes	Total 4 studies of reclassification of death from ill-defined causes, that fix external causes; 3 refer to local information and one to national data.	4 applied methods based on the retrieval of information.	2002[10], 2006[17], 2010[36], 2014[18].
3. Fix of misclassification of external causes of death	Total 6 studies of specific causes of mortality from external causes, that fix misclassification; 5 refer to local information and one to national data.	4 applied methods based on the retrieval of information, and 2 based on statistical models	1999[24], 2002[4], 2007[40], 2012[22,41], 2014[42].

specific locations. Hospital records cannot be ignored, but the isolated use of the relationship of nominal records of the SIH with the SIM[17] for the reclassification of IDCs may affect the correction of underreporting of external causes, data which explained only 16% of the causes of investigated deaths. Moreover, less than 40% of deaths from external causes occurred in hospitals in 2013[21]. The verbal autopsy survey did not investigate 25% of IDCs, losses more prevalent in rural 6 Another paper[10] which used various sources of research did not clarify about a third of deaths. The study using the national database of deaths investigated in the SIM[18] may have been affected by the underestimation of investigations[43] due to flow errors or data processing.

The information retrieval method used by Mello-Jorge et al[10] in 15 municipalities of the states of São Paulo, Mato Grosso and Sergipe in 2002 reclassified 6% of IDCs in external causes, correcting the underreporting of mortality from violence and accidents by 1.2%. The SIH[17] provided the identification of 5.4% of external causes among IDCs, increasing these causes by 0.7% in the state of Rio de Janeiro in 2006. A verbal autopsy study[36] defined 85.4% (n=129) of the IDCs investigated in 2007 and 14.7% of the defined causes were reclassified as external causes, raising these causes to 76%. Reclassification of IDCs based on research in the SIM[18] found 9.3% of external causes for Brazil, correcting this kind of cause by 1.3% in 2010. By identifying external causes among deaths with IDCs, studies reinforce the non-acceptance of procedures that consider only natural causes in the redistribution of IDCs.

The third thematic group of this study proposes methods to correct specific causes of accidents and violence (Chart 4). Of the six studies evaluated, four used information retrieval from FMI[4,24,40], while another gathers information from news published by newspapers[41]. These studies differ in the scope of deaths from misclassified external causes, and most[24,40,41] analyzed the deaths of undetermined intent (ICD-10 codes Y10-Y34) and unspecified accidents (code X59). Mello-Jorge et al[4] considered other incomplete diagnosis events. Study by Drumond Jr. et al[24] showed a high proportion of deaths that remained with undetermined intent after investigation (66.4%). Mello-Jorge et al[4] included the household as an additional search source, and were more efficient in qualifying ill-classified external causes, since they clarified almost 79% of these causes, performance slightly higher than Matos et al.[40] results (70%). A study from newspaper news pointed limitations related to this source, as overvaluation of unenlightened aspects and the non-disclosure of suicides[41].

Two studies applied statistical models to predict specific external causes[22,42]. One of them

Chart 2. Details of publications with estimates of underreporting of external causes among deaths not reported to the Mortality Information System-SIM, Brazil.

Reference (authors/ year of publication)	Study design and method	Main findings	Locations and collection period	Limitations
Façanha et al., 2003[34].	Retrieval of information: field research about deaths in eight cemeteries of Fortaleza and metropolitan region of Ceará; - Source: cemetery records	- Deaths underreporting in Fortaleza: 1,382 (10.6%) in 1999, and 1,502 (12.5%) in 2000, coverage of 89.4% and 87.5%; - External causes among retrieved deaths: 191 (11.7%) and 184 (9.5%); - underreporting of external causes: 11% (1999) and 11.4% (2000).	Fortaleza-CE. Data from 1999 to 2000.	- Cemeteries did not have good records on the cause of death (54% of ill-defined or ignored causes); - The study does not have the fix proportions of deaths by causes.
Cavalini e Leon, 2007[37].	Statistical model: deaths underreporting fix techniques through empirical Bayes James-Stein Estimators, modified for events in specific geographical areas, with fixes applied to municipalities (the mesoregion).	- Deaths underreporting: 5.9% Brazil, coverage 94.1%; Ceará fix of 8%, mesoregion of the capital 3.4% (coverage 92% and 96.6%); MG fix of 6.9%, mesoregion of the capital 3.6% (coverage 93.1% and 96.4%); - Underreporting of external causes: 5.7% Brazil; 4.8% SE; 5.4% S; 5.5% MW; 5.9% N; and 7.6% NE.	Brazil, regions, Federal Units. Data from 2001.	- Based on modeling of the occurrence of reported causes, and not the retrieval of information after field research; - Depends on population data, in particular, by population in-between census years estimations.
Campos et al., 2010[36].	Retrieval of information: field research of deaths in 10 municipalities (sample) with use of verbal autopsy (verbal information and records) for the definition of causes of death of deaths not notified to the SIM; - Sources: Epidemiology Service; death investigation committees; hospital; health centers; key informants; registry; cemetery; City Hall department responsible for burials; and the four forensic medicine stations (PML) in the region.	- Deaths underreporting: 206 (26.4%), coverage 73.6%; DC located 121 (58.7%); - External causes among retrieved deaths: 55 (26.7%), with 37 DC located and 18 events investigated; - Underreporting of external causes: 68.8%; increase from 25 to 80 cases.	Municipalities of the Northeastern macro-region of MG. MG, Data from 2007.	- Failure to carry out verbal autopsy in areas without Family Health Program (PSF) / Community Health Workers (CHW), especially in rural areas (32% loss); - Provisional list of deaths reported to state SIM.
Melo et al., 2014[35].	Retrieval of information: field research of deaths from external causes in Police Investigation records of the municipality and, complementarily, articles of local newspaper; these data were matched with SIM records; - Source: Police investigation.	- Underreporting of external causes: 104 (21%) from a total of 495; - Of external causes retrieved: 60 (57.7%) are assaults, 19 (18.3%) undefined intentions and 14 (13.5%) traffic accidents; 7 (6.7%) suicide, 4 (3.8%) other accidents; - Underreporting by causes: 60 (36.8%) homicide, 14 (11.2%) traffic accidents, 7 (12.3%) suicide, and 4 (8.5%) other accidents.	Viçosa, MG. Data from 2000 to 2009.	- Due to the impossibility of distinguishing the residence of the victims in the Police Investigation Records, all deaths were considered from Viçosa, regardless of municipality of residence of the victim.

Chart 3. Details of publications identified with external causes among ill-defined causes in the Mortality Information System-SIM, Brazil.

Reference (authors/ year of publication)	Study design and method	Main findings	Locations and collection period	Limitations
Mello-Jorge et al., 2002[10].	Retrieval of information: field research of 256 basic ill-defined causes (IDC), excluding losses (13%); - Sources: interviews in households, hospitals, Forensic Medicine Institutes.	- Classification after investigation: 4.3% (11) of external causes among investigated (256); - Reclassified ICD: 6% (11) of external causes among investigated with defined cause (182); - Increase of 1.2% of external causes, from 951 to 962; sub-information 1.1%.	15 Municipalities (SP, SE and MT). Data from the 4th Quarter of 2000	- 28.9% (74) of deaths remained ill-defined, excluding losses.
Teixeira et al., 2006[17].	Retrieval of information: probabilistic linkage of 10,692 IDC records in the SIM (excluding losses, 15%) with 1997 and 1998 SIH/SUS records; - Source: SIH/SUS.	- Classification after investigation: 1.1% (116) of external causes among investigated (10,692); Reclassified ICD: 5.4% (116) of external causes among investigated with defined cause (2,133); - Increase of 0.7% of external causes, from 15,822 to 15,938; sub-information 0.7%.	State of RJ. Data from 1998.	- 80.1% (8,564) of deaths remained ill-defined, excluding losses.
Campos et al., 2010[36].	Retrieval of information: field research de 151 IDC, excluding losses (25%), in 10 municipalities (sample), - Source: trained general practitioners analyzed verbal autopsy forms (verbal and records information).	- Classification after investigation: 12.6% (19) of external causes among investigated (151), remaining ICD 14.6% (22); - Reclassified ICD: 14.7% (19) of external causes among investigated with defined cause (129); - Increase of 76% of external causes, from 25 to 44; sub-information 43.2%.	Municipalities of the Northeastern Macro-region of MG. Data from 2007.	- Failure to carry out verbal autopsy in areas without Family Health Program (PSF) / Community Health Workers (CHW), especially in rural areas (32% loss); - Provisional list of deaths reported to state SIM.
França et al., 2014[18].	Retrieval of information: ICD reclassification based on field research recorded in the SIM, 29.486 (30.3%) deaths with ICD under investigation; - Source: Deaths investigated in the SIM.	- Classification after investigation: 6.1% (1,796) of external causes among investigated (29,486); - Reclassified ICD: 9.3% (1,796) of external causes among investigated with defined cause (19,303); - Increase of 1.3% of external causes, from 141,360 to 143,156; sub-information 1.3%.	Brazil. Data from 2010.	- 34.5% (10,183) of deaths remained ill-defined, excluding losses. – The SIM may underestimate the investigated deaths. The system only records the original and final root cause when it informs that there was an investigation. When an investigation is not informed in the SIM, the original root cause is lost, and thus both the original and final root cause are the same.

verifies[22] the characteristics associated with each violent incident to predict the intent of the event, reclassifying undetermined intents. However, it excluded traffic accidents from the model and

was not satisfactory for predicting suicides. The other work, namely, the Global Road Safety Facility[42] based on the GBD-2010 study[44], tests various statistical models to estimate traffic deaths and, therefore, has the added difficulty of being complex, with not-so-easily-replicable models. Furthermore, the GBD-2010 study proposed some correction factors that were possibly not adequate to the Brazilian reality, such as the reclassification of 40.98% of assaults by unspecified means as aggression with sharp objects[44], different from Brazilian data that indicate firearms as the main cause (71.1%)[21].

Drumond Jr. et al.[24] reclassified most accidents without specification (66%) and a smaller part of undetermined intents (33.6%), correcting road traffic accidents (RTA) (7%), falls (13.4%), suicides (2.2%) and homicides (0.8%). Mello-Jorge et al.[4] clarified 82.3% of undetermined intents, classifying most under homicides and road traffic accident, and 76.1% of incomplete diagnoses. Unspecified RTAs (code V89) migrated to vehicle occupant (41.2%), motorcyclist (20.6%), pedestrian (11.8%) and cyclist (2.9%). The reclassification of the set of undefined causes of external causes increased traffic accidents by 67%, homicides by 40.6% and suicides by 23.5%. Matos et al.[40] clarified 82.9% of unspecified accidents, 79% were reclassified under accidental causes and 70.7% of undetermined intents were reclassified mainly under homicides. The highest increase after the investigation was for motor

Chart 4. Details of publications with the reclassification of mortality from undefined external causes in the Information System

Reference (authors/ year of publication)	Study design and method	Main findings	Locations and collection period	Limitations
Drumond Jr, 1999[24].	Retrieval of information: field research of 550 deaths, excluding losses (3.3%), 297 (54%) unspecified accidents (X59/ICD-10) and 253 (46%) events of undetermined intent (Y10-Y34); - Sources: Forensic Medicine Institute (FMI) documents (police reports, accompanying the bodies, conclusions of autopsy reports, and hospital body referral records or the Coroner's Service).	- Classification after investigation X59: 66% (196) received better qualification; road traffic accidents-RTA (32.6%), falls (14.5%), homicides (7%) and suicides (2%); 13.1% (39) remained X59 e 20% (62) migrated to Y10-Y34; - Reclassification X59: 49.5% (97) RTA, 21.9% (43) falls, 10.7% (21) homicides and 3.1% (6) suicides, among investigated with defined cause; - Classification after investigation Y10-Y34: 33.6% (85) received better qualification; falls (10,6%), RTA (9,1%), homicides (7,5%) and suicides (2%); - Reclassification Y10-Y34: 31.8% (27) falls, 27.1% (23) RTA, 22.4% (21) homicides and 5.9% (5) suicides, among investigated with defined cause; - Increase of 7% de RTA (sub-information 6.6%), 13.4% falls (sub-information 12%); 2.2% suicides (sub-information 2%); 0.8% homicides (sub-information 1%).	Municipality of SP. Data from 1996.	- 66.4% (168) of deaths remained with undetermined intent; - Analyzing year 1996, when SIM shifted use from ICD-9 to ICD-10. Atypical transition period, which can influence coding.

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Chart 4. continuation

Reference (authors/ year of publication)	Study design and method	Main findings	Locations and collection period	Limitations
Mello-Jorge et al., 2002[4].	Retrieval of information: field research of 156 deaths from two groups of undefined external causes: 83 totally undefined (Y10 to Y34/ ICD-10); and 73 incomplete diagnoses: unspecified RTA (V89); other unspecified accidents (falls-W19, deaths drownings-W74, accidents with fire and flames-X09, accidental exposure to factors-X59); unspecified suicides (X84); and unspecified homicides (Y09). - Sources: Forensic Medicine Institutes and Police Stations (reports and police reports) and home of the deceased.	- Clarification of almost 79% of undefined causes, 82,3% among totally ill-defined, and 76.1% among incomplete diagnoses; - Classification after investigation Y10-Y34: 82.3% (68) received better qualification; homicides (32.4%), traffic accident (27.9%), other accidents (13.2%) and suicides (5.9%); excluding losses (18.1%); - Reclassification Y10-Y34: 39.3% (22) homicides, 33.9% (19) traffic accidents, 16.1% (9) other accidents, and 7.1% (4) suicides, among investigated with defined cause; - Classification after investigation: unspecified RTA (V89): 76.5% (26) received better classification, 41.3% motor vehicle occupant, 20.6% motorcyclist, 11.8% pedestrian, and 2,9% cyclists; - Reclassification V89: 53.9% (14) motor vehicle occupant, 26.9% (7) motorcyclist, 15.4% (4) pedestrian, and 3.9% (1) cyclists, among investigated with defined cause; - Increase of 67% of traffic accidents (sub-information 40.1%), 66.7% other accidents (sub-information 40%), 23.5% suicides (sub-information 19%), 40.6% homicides (sub-information 28.9%).	15 Municipalities (SP, SE and MT). Data from the 4th Quarter of 2000	

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vehicle occupant (33.3%), falls (28.4%), suicides (12.9%) and homicides (5.7%). Villela et al.[41] reclassified 67% of undetermined intents, increasing traffic accidents by 14.3% and homicides by 5.6%. While differing in the order and level of reclassification of causes, these investigations showed that the FMI did not use information available at its own Institute to fill the DC in the capitals of southeastern Brazil and in other cities of São Paulo, Mato Grosso and Sergipe.

Cerqueira[22] estimated for the state of Rio de Janeiro 3% of deaths from accidents higher than recorded data, and 22% of hidden homicides between 2002 and 2006. In the first case, underreporting would have risen to about 6% from 2008, and reached 62.5% of homicides in 2009. The unrecorded deaths by suicide ranged from 44% to 115.6% between 2000 and 2009, even with the model underestimation for this cause. In the Global Road Safety Facility study[42], 20.5% RTA-related deaths were corrected in 2010 in the country, increasing from 36,499 to 43,985 deaths[41]. SIM recorded 42,844 RTA-related deaths[21] in that year.

Chart 4. continuation

Reference (authors/ year of publication)	Study design and method	Main findings	Locations and collection period	Limitations
Matos et al., 2007[40].	Retrieval of information: Field research of 445 deaths, excluding losses (22%); 70 unspecified accidents (X59/CID-10), e 375 events of undetermined intent (Y10-Y34; - Sources: FMI document (Medical Examination Report, request for Coroner's Report, medical body referral reports and results of toxicological tests).	- Classification after investigation X59: 82.9% (58) received better qualification, mainly accidents (68.6%), traffic accidents (34.3%), falls (18.6%), other specified accidents (12.8%), homicides (10%), and suicides (2.9%); - Reclassification X59: 41.4% traffic accidents (24), 22.4% falls (13), 15.5% other specified accidents (9), 12.1% homicides (7), and 3.4% suicides (2), among investigated with defined cause; - Classification after investigation Y10-Y34: 70.7% (265) received better qualification, mainly accidents (40.3%), homicides (20.8%), traffic accidents (19.5%), falls (12.8%), suicides (9.3%), and other accidents (6.4%); - Reclassification Y10-Y34: 29.4% homicides (78), 26% traffic accidents (69), 18.1% falls (48), 13.2% suicides (35), and 9,1% Other accidents (24); - Greatest increase in motor accidents (33.3%) and falls (28.4%), and also, 12.9% more suicides and 5.7% more homicides.	Belo Horizonte-MG. Data from 1998 to 2000.	
Cerqueira D, 2012[22].	Statistical model: mathematical modeling (econometric) of the characteristics associated with each violent incident defines the probabilistic prediction about the intention of the event among the causes of undetermined intent (Y10-Y34); - multinomial logistic regression model reclassifies the deaths from undetermined cause in homicides, suicides or accidents (excluding traffic accidents); -Source: SIM	- Predictive capacity of the model was considerable, R2 of 82.3%. The model matched 97.1% and 99% of cases involving accidents and homicides, respectively, with much lower accuracy compared to suicides, 51.7%; - From 2002 to 2006, the model predicted that the number of deaths from accidents would be about 3% higher than recorded. As of 2008, this difference would be about 6%. From 2000 to 2006, about 22% of homicides were "hidden". From 2007, this difference increased substantially, reaching 62.5% in 2009.	State of RJ. Data from 2000 to 2009.	- The model was not very satisfactory for suicides, and excluded traffic accidents.

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Chart 4. continuation

Reference (authors/ year of publication)	Study design and method	Main findings	Locations and collection period	Limitations
Villela et al., 2012[41].	Retrieval of information: field research of 153 death from external causes in three state newspapers of wide circulation and one national newspaper; - Source: printed press.	- Following investigation, 33% (7) remained as undetermined intents (Y10-Y34), and 12 were qualified as assaults (6) and traffic accidents (5), and the 16 unspecified traffic accidents were qualified; - Among investigated deaths, traffic accidents hiked 14,3%, with an increase of 220% (n=22) in motor vehicles accidents and 100% motorcycles accidents (n=6), and 5.6% (n=76) homicides.	Belo Horizonte-MG. Data from 2008.	- Suicides are not generally published in newspapers; - The media can overvalue aspects still unproven or not yet clarified; - Incomplete information of victims in considerable part of the press reports.
Global Road Safety Facility, 2014[42].	Statistical model: *The Global Burden of Disease-GBD* on motorized road transport is based on the 2010 GBD, using the *Cause of Death Ensemble Modeling-CODEm* to estimate mortality from traffic injuries worldwide. - The CODEm is an analytical tool used in the 2010 GBD and tests a wide range of possible statistical models of causes of death and creates a combined "set" of models that offers the best predictive performance.	- It estimated for Brazil 43,985 deaths from traffic accidents (CI 35,301-52,857) in 2010, and reported as official data 36,499 deaths (they consider the WHO definition of death within 30 days).	Brazil. Data from 2010.	- Sophistication and complexity of a variety of statistical models.

One study on the reliability of the SIM[45] reinforces the findings of this review, identifying external causes among IDCs and clarifying external causes of incomplete diagnosis from FMI's data. DCs must be filled in by forensic examiners according to recommended standards, and corpses' removal documents must be fully completed in hospitals and police stations when forwarding to the Institute[46].

Regions with worse socioeconomic status and access to services, including the FMI, may have greater underreporting of deaths from external causes due to additional constraints related to precarious health facilities and public safety, especially in small- and medium-sized municipalities[35,36]. Especially in these municipalities, the underreporting of overall deaths and deaths from external causes were not so clear-cut. This evidence questions commonly accepted interpretations that external causes are best reported in any context, because there is still much to be gained while forensic examiners do not reach an ideal stage in completing DCs[4].

While deficiencies persist, it is necessary to strengthen the daily search of additional information at the FMIs, as well as in additional sources, such as the SIH, police stations, cemeteries, verbal autopsy use, the press[14,17,34,36,41] and even the SINAN in the case of work accidents[47], composing a list of different sources that allows

qualifying the completion of different variables of the DC[48-50]. In the specific case of suicide, the 35 poison control centers are specialized sources of improvement of suicides records in the SIM, as per study that identified suicide from exogenous intoxication among IDCs and undetermined intents[19].

Final Considerations

The reviewed studies show significant evidence of underreporting of deaths from accidents and violence in the SIM resulting from unreported deaths, hidden events among IDCs and misclassification of the recorded external causes. The reviewed literature supports a list of proposed designs for analysis and methods to correct these deaths.

Underreporting was found in small-, medium- and large-sized population municipalities, including capitals where better coverage of the system is expected, with the retrieval of deaths data from varied sources of information. Similarly, deaths from external causes were identified among IDCs, including natural causes. These problems reinforce the need to implement measures to improve mortality data from external causes and the use of data correction for reliable estimates.

Easy access to data and the recognition of the importance of monitoring and management of public management investment in the improvement of vital information resulted in increased database collected by the SIM and better recording of the underlying cause of death in the DC[14]. These elements provide a favorable environment for research and system management towards improving the SIM, including more systematic incorporation of the evaluation of the reliability of the selection of the underlying cause of death[28]. Immediate commitment to the demand for use of corrective measures for data of mortality from external causes through the implementation of appropriate procedures and methods is imperative. Thus, we would support the construction of more appropriate indicators for decision-making in the management and implementation of violence prevention and health care actions and programs.

Work fronts can be implemented by association, since they are complementary and not mutually exclusive: one front could be the application of methods to correct mortality from external causes for the production of public health indicators; the other could be institutionalizing the investigation of deaths from external causes not defined in the scope of death surveillance services in the municipalities, especially in cities with access to the FMI, since evidence points to underuse of information available at the Institute[4,23-25]. The use of models to correct external causes enables more reliable calculations of indicators, without prejudice to the continuation of managers' efforts toward effective reduction of underreporting of deaths from accidents and violence.

These efforts should be prioritized, as information retrieval methods are simple, affordable and feasible and should be implemented or strengthened for the purpose of the desired improvement of mortality statistics and understanding of the process involved in the production of information in places with precarious data. This will enable the possibility of mapping issues in the flow and operation of the SIM at the local level, allowing the adjustment of conduct and their improvement[4,14,36,51], conditions that demonstrate great capacity for the qualification of external causes data.

Collaborators

AM Soares Filho participated in the conception and design, data interpretation, article writing, critical review and approval of the version to be published; E França participated in the design, article writing, critical review and approval of the version to be published; JJ Cortez-Escalante participated in the conception, design and approval of the version to be published.

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