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Factors associated with unspecified and ill-defined causes of death in the State of Amazonas, Brazil, from 2006 to 2012

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Abstract *This study aimed to investigate factors associated with unspecified and ill-defined causes of death in the State of Amazonas (AM), Brazil. This is a cross-sectional study on 90,439 non-fetal deaths of residents in AM from 2006 to 2012. The hierarchical multinomial logistic model estimated odds ratios of unspecified and ill-defined causes of death. Ill-defined and unspecified causes of death proportional mortality was, respectively, 16.6% and 9.1%. Ill-defined causes showed a decreasing trend over the years, while unspecified causes only decreased in the last two years. Unspecified causes of death were associated with residence and death outside the capital, public roads, female gender, age group 10-49 years, brown skin color and when certified by forensic doctors. Ill-defined causes of death were associated with residence and occurrence outside capital, at home, ages 40 years and older, non-whites, not being single, low schooling, under medical care and when examiner was unknown. Ill-defined and unspecified cause mortality in the State of Amazonas decreased between 2006 and 2012 in AM and was associated with space and time, demographic and socioeconomic factors and medical care at the moment of death.*

Key words *Mortality, Death certificate, Underlying cause of death, Health information systems, International classification of diseases*

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Introduction

Mortality records are traditionally used in the elaboration of health indicators. In Brazil, such records are available in the Mortality Information System (SIM) of the Ministry of Health established in 1975. SIM data originate from the Death Certificate (DC) – a nationwide standardized document – completed by doctors for each case of death in the country[1].

In view of the importance of health indicators based on mortality measures in the context of public health, the evaluation of mortality information systems has been the subject of studies worldwide[2-4], especially with regard to the coverage of the systems and data quality. Information on the underlying cause of death is particularly relevant. The description of the mortality profile of a population according to the underlying cause guides the implementation and evaluation of preventive measures. Therefore, its correct classification is essential[5,6].

The proportion of ill-defined deaths, grouped in Chapter XVIII of the Tenth Revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) under the heading "Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified" has traditionally been used as an indicator for assessing the quality of mortality information by cause[7]. The accuracy of cause-related mortality data can also be assessed by enumerating incomplete diagnoses or nonspecific causes. The consequences or complications of the underlying cause of death (such as septicemia, heart, kidney and liver failures, etc.) and organ diseases declared as heart disease, liver disease and nephropathy are incomplete diagnoses. Unlike ill-defined causes, nonspecific causes are distributed throughout the ICD-10, corresponding to the so-called garbage codes of several chapters[8].

When considered together, the proportion of deaths due to ill defined or nonspecific causes enables a more comprehensive analysis of the quality of mortality information, particularly with regard to the accuracy of data on causes of death[9]. The identification of factors related to the occurrence of deaths due to ill-defined and nonspecific causes helps to direct efforts aimed at improving mortality records.

Although SIM is the most evaluated health information system in Brazil, the studies carried out are focused on few regions and states of the country[10], and there is no reference to studies focused specifically on the evaluation of mortality information in the State of Amazonas. This study aimed to analyze factors associated with mortality from unspecified and ill-defined causes in the State of Amazonas from 2006 to 2012.

Methods

The State of Amazonas is located in the northern region of Brazil and is the largest federative unit of the country with a total area of 1,559,161 km^2 divided into 62 municipalities. According to the 2010 demographic census, it had 3,483,985 inhabitants with 79% of the population living in urban areas and 21% in rural areas, of which 1,802,525 (52%) living in the capital Manaus[11].

An exploratory, cross-sectional study was developed based on a series of SIM death records under the management of the Information Systems Center of the Amazonas Health Surveillance Foundation (NUSI/FVS AM). The database was generated in November 2014. Non-fetal deaths of residents in Amazonas which occurred in the State between 2006 and 2012 and with data on the underlying cause were included.

The underlying cause of death originally recorded in the DC (variable causabas_o of SIM) was classified as well-defined, nonspecific or ill-defined, based on the typology proposed by Naghavi et al.[12]. Nonspecific causes correspond to "garbage" codes defined in the Global Burden of Disease study, including indefinite or incomplete diagnoses, of limited public health use for the planning and evaluation of preventive measures[8,13]. They are subdivided into four groups composed of garbage ICD10 codes, namely: 1) causes that cannot be an underlying cause (excluding ill-defined causes – chapter XVIII); 2) intermediate causes; 3) terminal causes; and 4) unspecified causes[12]. Ill-defined causes correspond to the categories and subcategories of Chapter XVIII of ICD-10[7].

Municipalities were classified into three categories: capital, regional health office reference and other municipalities[14]. For purposes of analysis, the "Entorno de Manaus and Rio Negro" regional health office was subdivided into its micro-regions and the municipalities of Manaus and São Gabriel da Cachoeira were classified, respectively, in the "capital" and "reference municipalities" categories (Figure 1).

Proportional mortality for nonspecific and ill-defined causes, total mortality and mortality by categories of the selected explanatory variables[15] were calculated. The most frequent ICD-

10 categories (with three characters) were identified among nonspecific and ill-defined causes, according to the type of municipality where the death occurred and for the whole state. Odds ratios for nonspecific and ill-defined, crude and adjusted were then estimated using a hierarchical multinomial logistic regression model[16,17]. The first model included distal variables, which are the realms of space (municipality of residence) and time (year of occurrence). The intermediate individual demographic (gender, age and marital status) and socioeconomic (ethnicity / skin color and schooling) variables were added. The third model introduced proximal variables regarding the context in which the causes of death were certified, namely: medical care and/or diagnostic confirmation at the time of death (defined by the combination of responses to the medical care variables, laboratory diagnostic confirmation tests, surgery and necropsy), place of occurrence, examining physician and municipality of occurrence. The "not applicable" category was established for the schooling variable, referring to the deaths of less than six years. The other categories refer to the current DC model up to 2010, in relation to which the 2011 records onwards were converted by SIM[18]. As for the medical examiner, the category of death verification services (DVS) was disregarded due to lack of these services in AM.

The three hierarchical levels were defined to characterize and differentiate the distal factors, explained by the space and time realms and their variations, related to mortality patterns; intermediate, based on the premise of the validity of social inequalities in health, through socioeconomic and demographic variables; and proximal, represented by variables indicating conditions related to medical care at the time of death.

In the multinomial logistic regression model, the categories of the explanatory variables were inserted as indicator variables (dummy)[16]. The inclusion of the "did not answer/ignored" category was aimed at verifying the association between failure to complete the different DC fields and the quality of information about the underlying cause of death. The statistical significance of the association with unspecified and/or ill-defined causes was set at 20% and 5% levels, respectively, for the entry and retention of explanatory vari-

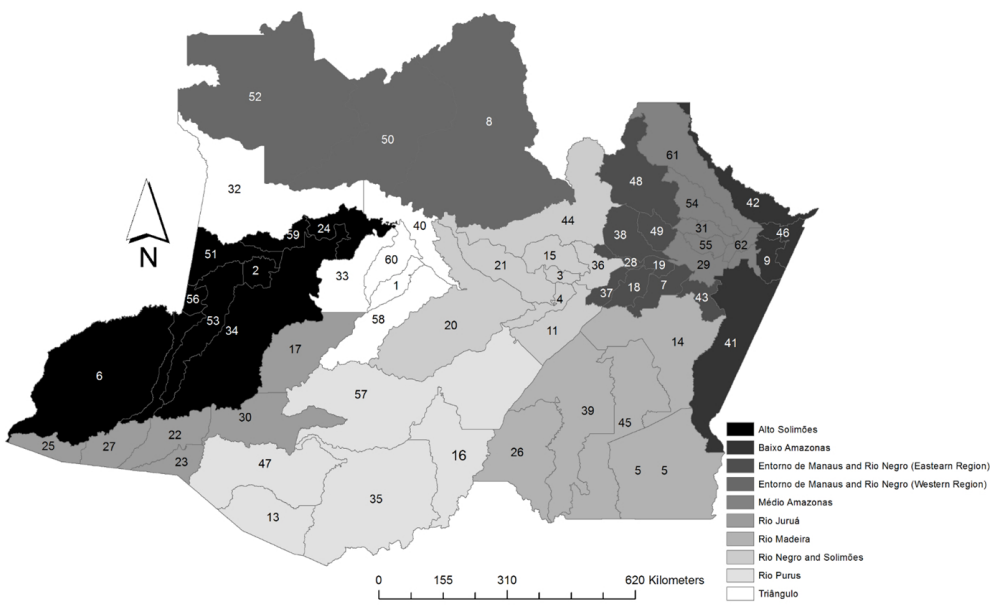

Figure 1. Health regions and municipalities in the state of Amazonas.

ables in the model[19]. Statistical significance was established by the Wald test and the goodness of fit of the final model by the analysis of deviance measures[19]. The Stata 12[20] program was used for all analyses.

The Research Ethics Committee of the Hospital Alfredo da Mata Foundation (FUAM) approved the study.

Results

The study population comprised 90,439 death records. Between 2006 and 2012, proportional mortality due to ill-defined and unspecified causes in the State of Amazonas (AM) was 16.6% and 9.1%, respectively. The proportion of deaths from ill-defined causes in regional health offices locations and in other municipalities were over twofold and threefold that of the capital, respectively. The proportion of unspecified causes showed a small variation according to the type of municipality of occurrence, corresponding to 9.1% in AM. Among the non-specific causes, intermediate causes (5.3%), followed by unspecified causes (1.9%) and causes that cannot be an underlying cause (1.5%) prevailed. Terminal causes corresponded to 0.3% of all deaths in AM. Although evidencing different proportions in relation to the State, this ranking remained unchanged according to the type of municipality where the death occurred, except in the regional health office references, where the causes that cannot be an underlying cause were more frequent than the unspecified causes (Table 1).

Among the non-specific causes, the categories "heart failure" (I50), "other sepsis" (A41) and "essential (primary) hypertension" (I10) took turns in the first three spots, totaling 1% to 2% of all deaths. Higher proportions of deaths due to the two categories belonging to diseases of the circulatory system were observed outside the capital, where septicemia held first spot. In relation to ill-defined causes, totaling approximately 15% in AM, "unattended death" (R98) and "other ill-defined and unspecified causes of mortality" (R99) prevailed, respectively in the first and second spots, except in the capital, where spots were reversed. Taking turns in third place were "other symptoms and signs involving the circulatory and respiratory systems" (R09) and "senility" (R54) (Table 2).

The odds of nonspecific causes of death in AM decreased in the last two years of the period analyzed. Residing outside the capital proved to be positively associated with nonspecific causes, with higher odds in municipalities that are not regional health offices locations (Table 3).

Among women's deaths, nonspecific causes were 10% more likely compared to men. There was no association with lack of gender information. Ages between 10 and 49 years were associated with lower odds of nonspecific causes, especially the 20-29 years group, in which reduction was approximately 65% in relation to the 0-9 years group. Brown was the only class among ethnicity/skin color categories with an association, with around 10% reduction in relation to white. As for schooling, the "not applicable" and "did not answer/ignored" categories were associ-

Table 1. Proportional mortality (%) according to the underlying cause type* and municipality of death occurrence, State of Amazonas, 2006 to 2012.

Causes of death	Municipality of occurrence			Total Amazonas
	Capital	Reference of Health Regional Office	Other municipalities	
Well-defined causes	79,5	69,9	58,2	74,3
Ill-defined causes	11,6	20,6	32,6	16,6
Non-specific causes	8,9	9,5	9,2	9,1
Causes that may not be the underlying cause	1,3	2,0	1,8	1,5
Intermediate causes	5,4	5,5	4,6	5,3
Terminal causes	0,2	0,4	0,7	0,3
Unspecified causes	2,0	1,6	2,1	1,9
Total	100,0	100,0	100,0	100,0

* Naghavi et al.[12].
Source: Mortality Information System (SIM), Health Information Systems Center, Amazonas Health Surveillance Foundation - SIM / NUSI / FVS-AM.

Table 2. Proportional mortality (%) according to more frequent ICD10 categories*, due to non-specific and ill-defined causes** and type of municipality of occurrence, State of Amazonas, 2006 to 2012.

Causes of death**	Municipality of occurrence	Rank	ICD10* categories		Number of deaths	Proportion (%) of deaths	Total deaths
Non-specific causes	State of Amazonas	1	I50	Heart failure	1.211	1,3	90.439
		2	A41	Other sepsis	1.003	1,1	
		3	I10	Essential (primary) hypertension	986	1,1	
	Capital	1	A41	Other sepsis		1,2	61.866
		2	I50	Heart failure	713	1,2	
		3	I10	Essential (primary) hypertension	558	0,9	
	Reference of Regional Health Office	1	I50	Heart failure	214	1,8	12.194
		2	I10	Essential (primary) hypertension	202	1,7	
		3	A41	Other sepsis	130	1,1	
	Other municipalities	1	I50	Heart failure	284	1,7	16.379
		2	I10	Essential (primary) hypertension	226	1,4	
		3	A41	Other sepsis		0,9	
Ill-defined causes	State of Amazonas	1	R98	Unattended death	8.584	9,5	90.439
		2	R99	Other ill-defined and unspecified causes of mortality	4.773	5,3	
		3	R09	Other symptoms and signs involving the circulatory and respiratory systems	662	0,7	
	Capital	1	R99	Other ill-defined and unspecified causes of mortality	3.696	6,0	61.866
		2	R98	Unattended death	2.685	4,3	
		3	R54	Senility	345	0,6	
	Reference of Regional Health Office	1	R98	Unattended death	1.724	14.1	12.194
		2	R99	Other ill-defined and unspecified causes of mortality	477	3,9	
		3	R54	Senility	115	0,9	
	Other municipalities	1	R98	Unattended death	4.175	25,5	16.379
		2	R99	Other ill-defined and unspecified causes of mortality	600	3,7	
		3	R09	Other symptoms and signs involving the circulatory and respiratory systems	327	2,0	

* International Statistical Classification of Diseases and Related Health Problems, 10th Revision.

** Naghavi et al.12.

Source: Mortality Information System, Health Information Systems Center, Amazonas Health Surveillance Foundation - SIM / NUSI / FVS-AM.

Table 3. Adjusted Odds Ratios (ORs) for non-specific and ill-defined underlying causes of death* according to distal, intermediate and proximal factors, related to time and space, of demographic and socioeconomic nature and referring to death context, State of Amazonas, 2006 to 2012.

Level/Variable	Underlying cause of death					
	Non-specific			Ill-defined		
	OR	IC 95%		OR	IC 95%	
Constant	**0,2**	**0,1**	**0,3**	**0,0**	**0,0**	**0,1**
Distal						
Year of death						
2006	1,0	---	---	1,0	---	---
2007	1,0	0,9	1,1	0,9	0,8	0,9
2008	1,0	0,9	1,1	0,7	0,7	0,8
2009	1,0	0,9	1,1	0,7	0,7	0,8
2010	1,0	0,9	1,0	0,7	0,6	0,7
2011	0,9	0,8	0,9	0,6	0,6	0,7
2012	0,9	0,8	1,0	0,6	0,6	0,7
Municipality of residence						
Capital	1,0	---	---	1,0	---	---
Regional Office Location	1,2	1,1	1,3	1,7	1,6	1,8
Other municipalities	1,4	1,3	1,5	2,8	2,7	3,0
Intermediate						
Sex						
Male	1,0	---	---	1,0	---	---
Female	1,1	1,1	1,2	1,0	1,0	1,1
Did not answer/Ignored	1,5	0,7	3,4	1,4	0,7	2,6
Age group						
0-9 years	1,0	---	---	1,0	---	---
10-19 years	0,6	0,4	0,7	0,8	0,6	1,1
20-29 years	0,3	0,3	0,4	0,7	0,5	0,8
30-39 years	0,4	0,3	0,6	1,0	0,8	1,3
40-49 years	0,7	0,6	0,9	1,5	1,2	1,9
50-59 years	0,8	0,7	1,1	1,9	1,5	2,4
60-69 years	0,9	0,7	1,2	2,0	1,6	2,6
70-79 years	1,0	0,8	1,3	2,6	2,1	3,3
80-89 years	1,2	1,0	1,6	3,8	3,0	4,8
90-99 years	1,4	1,1	1,8	6,1	4,8	7,7
100 anos e mais	1,4	1,0	2,1	7,9	5,8	10,6
Did not answer/Ignored	0,7	0,4	1,3	4,9	3,1	7,6
Ethnicity/skin color						
White	1,0	---	---	1,0	---	---
Black	1,2	1,0	1,3	1,4	1,2	1,6
Yellow	0,8	0,5	1,1	1,0	0,7	1,4
Brown	0,9	0,9	1,0	2,0	1,9	2,1
Indigenous	0,9	0,8	1,0	3,1	2,8	3,4
Did not answer/Ignored	1,0	0,8	1,1	1,1	1,0	1,3
Marital satatus						
Single	1,0	---	---	1,0	---	---
Married	1,1	1,0	1,1	0,7	0,6	0,7
Widowed	1,0	0,9	1,1	0,7	0,6	0,7
Separated	0,9	0,8	1,1	0,6	0,5	0,7
Common-law	0,9	0,7	1,0	0,8	0,7	0,9
Did not answer/Ignored	1,1	1,0	1,2	0,7	0,6	0,8

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Table 3. Adjusted Odds Ratios (ORs) for non-specific and ill-defined underlying causes of death* according to distal, intermediate and proximal factors, related to time and space, of demographic and socioeconomic nature and referring to death context, State of Amazonas, 2006 to 2012.

Level/Variable	Underlying cause of death					
	Non-specific			Ill-defined		
	OR	IC 95%		OR	IC 95%	
Constant	**0,2**	**0,1**	**0,3**	**0,0**	**0,0**	**0,1**
Schooling						
Illiterate	1,0	---	---	1,0	---	---
1st-4th grade	1,2	0,9	1,6	1,0	0,8	1,3
5th-8th grade	1,1	0,8	1,5	0,9	0,7	1,2
Secondary School	1,0	0,8	1,4	0,8	0,6	0,9
Incomplete Higher Education	1,1	0,8	1,4	0,7	0,5	0,8
Complete Higher Education	1,1	0,8	1,5	0,5	0,4	0,6
Not applicable	0,5	0,3	0,7	0,9	0,6	1,2
Did not answer/Ignored	1,4	1,0	1,8	0,6	0,5	0,8
Proximal						
Municipality of occurrence						
Capital	1,0	---	---	1,0	---	---
Regional Health Office Reference	1,2	1,0	1,3	1,5	1,2	1,9
Other municipalities	1,3	1,2	1,5	1,5	1,3	1,8
Place of occurrence						
Hospital	1,0	---	---	1,0	---	---
Other health facilities	1,4	1,1	1,8	3,5	2,9	4,2
Home	0,9	0,8	0,9	6,3	5,9	6,7
Public road	0,2	0,2	0,3	1,0	0,9	1,2
Other	0,8	0,7	0,9	2,5	2,3	2,8
Did not answer/Ignored	1,2	0,6	2,2	4,4	2,9	6,7
Medical care and/or diagnostic confirmation						
No	1,0	---	---	1,0	---	---
Yes	0,9	0,8	1,0	0,2	0,1	0,2
Did not answer/Ignored	1,1	1,0	1,3	0,9	0,8	1,0
Certifying Physician						
Assistant	1,0	---	---	1,0	---	---
Substitute	1,0	0,9	1,1	1,0	0,9	1,1
Forensic Doctor (IML)	0,5	0,4	0,5	7,2	6,5	7,9
Other	0,8	0,8	0,9	1,5	1,4	1,7
Did not answer/Ignored	0,8	0,8	0,9	9,2	8,4	10,0

* Naghavi et al.[12].

** OR: Odds Ratio; CI95%: 95% confidence interval.

Source: Mortality Information System, Health Information Systems Center, Amazonas Health Surveillance Foundation - SIM / NUSI / FVS-AM.

ated with 52% lower and 37% higher odds, than the group that never attended school, respectively. There was no association with marital status (Table 3).

The event of death outside the capital increased the odds of mortality due to nonspecific causes by around 16% and 31%, respectively, in regional health offices locations and in other municipalities. Regarding hospital deaths, the odds of nonspecific causes was 1.4 times higher when deaths occurred in other health facilities, and lower among home deaths (14%), that occurred in other locations (21%) and, mainly, in public roads (80%). Compared with assistant physicians, the odds of nonspecific causes were about 50%, 18% and 17% lower when the deaths

were certified, respectively, by forensic doctors from the Forensic Medicine Institute (IML), other doctors and when there was no information about the certifying doctor. Completion of DC by substitute physicians and registration of medical care did not interfere with the odds of mortality due to nonspecific causes (Table 3).

The odds of mortality due to ill-defined causes decreased over the analyzed period. In relation to 2006, the fall was around 15% in 2007, 25% in 2008 and 2009, and between 30% and 40% as of 2010. Residing in the regional health office references and in other municipalities increased 1.7 and 2.8 times the odds of ill-defined causes, respectively, in relation to capital (Table 3).

There was no association with gender. Regarding age, the probability of death due to ill-defined causes decreased in the 20-29 years age group by 35% regarding the first decade of life. Higher and increasingly ascending odds were observed from the age of 40, achieving values approximately fourfold, six-fold and eightfold in the 80-89, 90-99 and 100 years and over age groups, respectively, against the 0-9 years age group. The lack of age registration resulted in almost fivefold odds of ill-defined causes. When marked in the DC, black, brown and indigenous ethnicity / skin color categories were associated with around 40%, 100% and 210% greater odds, respectively, when compared to whites. In relation to single status, 30-40% reductions were observed for the categories "married", "widowed", "separated" and lack of information on the marital status, and 18% for "common-law marriage". The odds of ill-defined causes varied inversely in relation to schooling levels, from the category of "secondary school" to "full higher education". Unreported schooling resulted in 40% lower odds (Table 3).

Dying outside the capital, regardless of the type of municipality, entailed 1.5 times higher odds of ill-defined causes. Dying outside hospitals, except when on public roads, was also associated with higher odds, 6.29 times more likely among home deaths. The lack of information on the place of death increased by 4.4 times the odds of ill-defined causes. Registration of medical care and/or diagnostic confirmation at the time of death reduced the odds of ill-defined causes by 84%, while completion of death certificates by forensic doctors and other physicians increased 7.2 times and 1.5 times this likelihood, respectively. In the statements without information on the medical examiner, odds was 9.2 times higher than the ones certified by the assistant physician (Table 3).

Discussion

On average, about one in four deaths of residents of AM and occurring in the state between 2006 and 2012 showed some level of indeterminacy in the registration of the underlying cause in the SIM, with a predominance of ill-defined causes over unspecified causes. Of the factors investigated, only marital status and medical care were not associated with the occurrence of nonspecific causes, and gender with that of ill-defined causes.

Ill-defined causes were concentrated in two categories, unattended deaths, notably outside the capital, and other ill-defined and unspecified causes of mortality, most frequently certified in Manaus. The predominance of the two categories, as well as their respective reverse ordering in Manaus and outside the capital were also observed in the analysis of mortality in the Brazilian elderly population[21]. In Belo Horizonte, Minas Gerais, other ill-defined and unspecified causes of mortality (R99) were certified in 5% of deaths between 2011 and 2013[22]. Regarding the most frequent nonspecific causes in AM between 2006 and 2012, essential (primary) hypertension (I10) and unspecified sepsis (A41.9) showed similar proportions in Belo Horizonte[22] and heart failure (I50) was prominent among deaths of Brazilian elderly[21].

The results described so far should be interpreted in the light of the relationships between the factors associated with cause of death indeterminacy, conceived according to the formulated hierarchical regression model. At the distal level, the realms of time and space reflect the influence of health policies and actions implemented on the health system and information on mortality.

The quality of information on the causes of death in the capital was better than in the rest of the state. Similar variation was reported by Kanso et al.[21] for the elderly population in AM. Nevertheless, the proportionate mortality from ill-defined causes observed in Manaus is high, both in this study and by other authors, standing at around 12%, fourfold the national average and the highest among Brazilian capitals[22].

Nonspecific causes occurred less frequently compared to ill-defined causes in AM, with negligible variation between the capital and other municipalities, as previously observed for the elderly population of the state in 2007[21]. A highest estimate (18.5%) was reported by Ishitani et al.[22] between 2011 and 2013, more than twofold that observed in this study, possibly due to methodological differences in the selection of ICD-10 codes.

The reduced occurrence of ill-defined causes was accompanied by a drop in underreported deaths in AM, from 21.0% in 2006 to 13.4% in 2012[23]. While only in 2011 and 2012, the occurrence of nonspecific causes also declined. Results from different studies based on different methodologies are converging towards increased SIM coverage and improved quality of information on the causes of death in the last decades throughout the country, with significant advances in the Northern and Northeastern States in more recent periods[24,25]. Additional investigations are required to clarify the extent to which information was improved because of the capture of initially unrecorded deaths - reduced underreporting - accompanied by the determination of the underlying causes and/or whether the investigation of deaths recorded without a definite cause resulted in retrieved information about the underlying cause.

SIM improvement is a result of initiatives undertaken in the last decades in order to qualify the continuous mortality records in Brazil[25,26]. However, the high proportional mortality due to ill-defined causes in AM observed in this study, as well as by other authors in the same period reinforces the need for continuous investments with a view to their downsizing, as well as reducing underreporting and irregular information. In 10% of municipalities in the state of AM, proportional mortality due to ill-defined causes was higher than 47.2% between 2008 and 2010, making it the worst situation among federal units[25].

The greater coverage of the health network, as well as the concentration of greater complexity care in Manaus can serve as an explanation for higher odds of undetermined registration of the underlying cause of death outside the capital. The increased probability of nonspecific and ill-defined causes between regional health offices locations and other municipalities, and of these in relation to the capital possibly reflects the structural variations of the health care network. In particular, association between ill-defined causes and residence outside the capital, more intense in municipalities that are not regional references may be indicative of the existence of restricted provision of and/or access to health services[27] – when in place – in the municipal offices. In AM, there are also long distances to be traveled, usually by waterway and often subject to seasonal and financial limitations[28].

The high proportions of "unattended deaths" (R98) and "other ill-defined and unspecified causes of mortality" (R99)[29], as well as the significant increases in the odds of ill-defined causes in DC not filled by doctors – in situations where there is no doctor in the location and at the time of death – and among deaths occurring outside hospitals, except on public roads, as well as its intense reduction in the presence of medical care and/or diagnostic confirmation at the time of death reinforce the assumption about the relationship with the restricted provision of and/or access to health services. On the other hand, as they are characterized by incomplete diagnoses, nonspecific causes presuppose the certification of death by medical professionals, which may explain the lack of association with the existence of medical care at the moment of death or not. Similar relationships between hospital occurrence and quality of certification of causes of death were observed in Belo Horizonte (MG)[22], as well as in the Brazilian elderly population[21].

Adjusted by distal variables, the associations identified at the intermediate level express the relationships between demographic and socioeconomic inequalities and the quality of information on mortality by causes.

The relationship between mortality by defined causes and age is in agreement with that reported from different studies conducted in the country. Among the possible explanations is the difficulty of establishing an underlying cause in concomitant multiple morbidities, a common situation among the elderly[30,31]. Lower odds of nonspecific causes in the 10-49 years age range and in males may be associated with the occurrence of deaths due to non-natural causes, which is known to be higher among young male adults[32]. External causes tend to be better defined in relation to natural ones, either at the time of certification or coding, when additional information is usually available regarding the circumstances of the accident or violence that produced the fatal injury, recorded in police reports or accessible in newspapers and other means of dissemination, such as the internet[33,34].

The association between ill-defined mortality and socioeconomic factors, such as non-white skin color and low schooling was also reported by different authors[21,31,35], reflecting situations of exclusion and restricted access to health services. Differently from what was observed in AM, these studies also evidenced high mortality with undetermined cause in women, but not in relation to the marital status.

Compared to single status, all marital status categories were associated with lower probability of ill-defined causes. In the case of common-law

marriage, the magnitude of reduction was intermediate when compared to categories married, widowed and separated. The influence of the possible shift of records previously marked as single[18] in 2010, when the common-law marriage option was introduced in the DC should be considered.

The association between single status and higher risk of ill-defined causes was also reported in an occupational cohort study conducted in the USA, attributed to isolation in the lack of parental ties, and intensified with the occurrence of home death without the presence of other people[36]. However, the association between mortality and single status does not seem to be limited to ill-defined causes, as reported in other studies[37,38]. Specific behavioral patterns, as well as the potential impact of the psychological consequences related to single status were suggested as possible explanations[38].

In the Brazilian elderly population, nonspecific causes, albeit to a lesser extent were associated with non-white skin color/ethnicity and low schooling[21], in disagreement with results for AM. Among possible explanations for discordant results, one must consider the methodological differences between the two studies, such as the target populations and the periods analyzed, as well as the different definitions of nonspecific causes used. On the other hand, confounding structures could justify the lack of association with socioeconomic level indicators, such as the higher concentration of indigenous population in municipalities that are not regional references.

After adjusting for distal and intermediate levels, associations with proximal variables indicate the influence of medical care and/or diagnostic confirmation on the quality of mortality records.

Increased odds of ill-defined causes in relation to death certification by IML is possibly related to the lack of death verification services (DVS) in AM. In the State of São Paulo, the lower proportional mortality due to ill-defined causes in the municipalities with DVS was explained by the high frequency of necropsies performed among deaths initially evaluated as due to natural causes, resulting in the clarification of the *causa mortis* in more than 90% of the cases[39]. In João Pessoa (PB), implantation of DVS was followed by 78% reduction of deaths without definite cause[40]. In Pernambuco, in addition to explaining the causes of death, DVS' contribution was extended to improve epidemiological surveillance through timely notification of notifiable diseases, maternal, fetal and infant deaths[41]. However, the cost-effectiveness of the implantation of a DVS network in AM should be considered, especially in municipalities other than the capital, characterized by low demographic density, long distances from municipal headquarters and mobility constraints.

Expanded primary care network through the family health strategy (ESF) that is ongoing throughout the country can contribute to improved death causes records[26,42]. Once the principles of integrality and continuity of health care have been realized by family health teams, especially if supported by a network of outpatient and hospital diagnostic and therapeutic support services, one would expect improved health system's diagnostic capacity. In addition to the deployment of a DVS network, the expanded ESF carries the potential for a better certification of the causes of death, especially in the face of home deaths and in municipalities that are not regional references in AM, largely devoid of medical care coverage.

ESF's inadequate coverage in AM during the period analyzed so far – about 32% in Manaus and 48% in the remaining municipalities[43] – can explain, at least in part, the increased probability of ill-defined causes among deaths occurring at home and outside the capital. On the other hand, the implantation of the investigation of deaths from ill-defined causes[44], as well as SIM's coordination decentralization to the Indigenous Special Health Districts (DSEI)[45] may have contributed to lower levels of ill-defined causes observed since 2006.

However, additional research is required to evaluate the effective participation of these actions in the qualification of the SIM in AM and throughout the country. Considering that this study used data from the mortality information system, it is important to note that elements such as underreporting and incomplete records may interfere in the results, given their probable non-random nature[46]. The positive association between the incomplete records in the sections referring to different explanatory variables selected in this study and ill-defined causes suggests that poor certification of the causes of the medical death certificate tends to be accompanied by an inadequate completion of DCs in broader fashion. Similar results were observed in the Brazilian elderly population as reported by Kanso et al[21]. Doctors' insufficient commitment to complete the DC, especially the causes of death, points to the need for permanent awareness and training, starting from undergraduate

levels[8,43]. However, the influence of managerial aspects on the occurrence of errors, as well as incompleteness, such as changes in the DC model and SIM's updates, and in infrastructure, related to the network transmission of the data should be considered.

This study has limitations, among which the secondary nature of death records used. In particular, validity of the information on the underlying cause of death can be compromised in different ways, either due to flaws in the diagnosis process, cause of death certification, coding[47], processing or transfer of databases. In the case of AM, while in decline, underreporting of deaths was still significant in the period analyzed in this study. The results, therefore, should be understood as restricted to the subset of deaths recorded in the SIM.

Conclusion

Findings of this study point to improved quality of the information on cause of death in AM from 2006 to 2012, despite persistent high proportional mortality due to undetermined underlying causes. The distribution of deaths due to ill-defined and nonspecific causes was not random and was associated with space and time realms, demographic and socioeconomic factors, and medical care at the time of death.

Regarding factors associated with mortality due to ill-defined and nonspecific causes, the predictive model proposed here should be considered by the health system at its different levels in order to improve the quality of cause of death records in AM. The importance of the development of specific analysis models for the different socioeconomic, demographic and health settings is important, considering the scarcity of studies on the quality of mortality information, focused on the reality of the Brazilian northern region.

The relevance of good quality mortality records should be constantly emphasized in medicine undergraduate courses and through initiatives aimed at continuing education, highlighting the responsibility of the physician for the correct completion of the death certificate. Concepts related to recording causes of death, such as underlying, intermediate, terminal, contributing and associated causes should be periodically reviewed and discussed, whenever possible, in the light of daily experiences accumulated throughout medical practice.

Collaborations

PCS Balieiro, LCF Silva, VS Sampaio, EX Monte and EMS Pereira participated in the design of the study, data review and interpretation and paper drafting. LAF Queiroz and R Saraiva collaborated in data review and interpretation, and paper drafting. AJL Costa participated in the design of the study, data review and interpretation and paper drafting and review.

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