Assessing state level variation in signature authority and cause of death accuracy, 2005–2017

J. Dalton Stevens [*], Scott D. Landes

Department of Sociology and Aging Studies Institute, Maxwell School of Citizenship and Public Affairs, Syracuse University, USA

ARTICLE INFO

ABSTRACT

This study utilized a convergent mixed-methods design to examine whether variation in death certificate certifier type predicts the accuracy of cause of death reporting in the US. We analyzed the content of state statutes, amendments, and policies concerning cause of death signature authority in 2005–2017 to create the Cause of Death Signature Authority (CoDSA) database. After merging the CoDSA data with 2005–2017 National Vital Statistics System Multiple Cause of Death Mortality files for adults with cerebral palsy (CP) ($N = 29,996$), we employed logistic regression models to determine the likelihood that different certifier groups made one particular type of death certification error – inaccurately reporting CP as the underlying cause of death (UCOD). The content analysis provided evidence of significant liberalization of cause of death signature authority, with 23 states expanding signature authority to include physician extenders. Logistic regression analysis revealed differences in UCOD accuracy based on certifier type. Compared to medical examiners, the likelihood of CP being reported as the UCOD, was: 41% higher (CI 1.12, 1.78) for coroners; 25% higher (1.05, 1.49) for mixed-system death investigators; 24% higher (1.08, 1.42) for physicians; and 16% higher (1.00, 1.34) for physician extenders. Inaccuracies limit public health efforts aimed at improving the health and longevity for disadvantaged populations, such as people with CP. Poor performance among cause of death certifiers may indicate systemic problems with death certification that should be addressed with more robust training for all professional groups with signature authority.

1. Introduction

Since 1960, the United States National Center for Health Statistics (NCHS) has coordinated official death records for the country through the decentralized National Vital Statistics System (NVSS) (Hetzel, 1997). NCHS reports about 2.5 million deaths annually, providing mortality data from 57 jurisdictions including all 50 states, Washington D.C., and US territories (Ventura, 2018). US death certificates provide certified underlying and multiple causes of death, other medical information, and demographic information (Ventura, 2018), that researchers, policy-makers, and public health officials use to determine the most prevalent causes of death and develop interventions aimed at improving population health and longevity. However, state-level differences in death certification is a chief concern of the NCHS as variation in data collection and reporting threatens data uniformity and overall accuracy

(Hetzel, 1997; Ventura, 2018). While death certificate format and instructions are nationally standardized (U.S. Department of Health and Human Services, 2003), research has rarely examined state policies concerning *who* certifies causes of death, leaving a potential threat to data quality unaddressed (McGivern et al., 2017; Ruiz et al., 2018; American Association of Nurse Practitioners, 2018).

In 2018, the US Department of Health and Human Services published a report on vital statistics data collection, emphasizing the importance of uniformity and standardization of death certification (Ventura, 2018). The report identifies only three types of cause of death certifiers – physicians, coroners, and medical examiners (Ventura, 2018). Neglected in this report is the fact that physician extenders, most commonly physician assistants and advanced practice registered nurses, are increasingly responsible for medical certifications of death across the US (American Association of Nurse Practitioners, 2018; Ruiz et al., 2018;

McGivern et al., 2017; Keepnews, 2010). Several studies suggest that some certifier characteristics may influence data validity and accuracy, and death certificate training, familiarity, and experience are salient to accurate cause of death reporting (McGivern et al., 2017; Lakkireddy et al., 2004; Lloyd-Jones et al., 1998; Messite and Stellman, 1996; Pritt et al., 2005; Schuppener et al., 2020; Johnson et al., 2012; McCaw-Binns et al., 2015). Only one of these studies (McGivern et al., 2017) has assessed differences in death certificate completion accuracy by certifier type, inclusive of nurse practitioners; however, the study is geographically limited to the State of Vermont. The remaining studies have focused on solely one type of certifier (Lakkireddy et al., 2004) or are geographically limited to one state (Lloyd-Jones et al., 1998; Messite and Stellman, 1996; Pritt et al., 2005; Schuppener et al., 2020; Johnson et al., 2012). Research suggests that among professionals who certify cause of death statements on death certificates, medical examiners receive the most training in identifying causes of death and completing the death certificate (Ruiz et al., 2018; Timmermans, 2006). Alternatively, physicians and other health care providers receive little or no formal training on death certification (Messite and Stellman, 1996; Schuppener et al., 2020; Johnson et al., 2012), and training for coroners varies substantially throughout the US (Ruiz et al., 2018; Timmermans, 2006; CDC, 2015; Jentzen, 2009; Hanzlick, 1996, 2006).

We employ a convergent mixed-methods approach (Creswell et al., 2009) relying on content analysis (Krippendorff, 1989; Elo and Kyngäs, 2008) and logistic regression analysis to examine differences in the accuracy of reporting the underlying cause of death (UCOD) by type of certifier across the US. To determine differences in accuracy by certifier type, we initially constructed a US state-level database on cause of death certifiers with signature authority from 2005 to 2017, the Cause of Death Signature Authority (CoDSA) database. CoDSA identifies legal cause of death certifiers by state, resulting from our content analysis of 2005–2017 state statutes, amendments, and policies regulating death certification. We then combined the original database with 2005–2017 NVSS Multiple Cause of Death Mortality data for analysis. Utilizing the combined databases, we examine potential differences in one type of substantial (McGivern et al., 2017) and deleterious (Landes et al., 2019) death certificate error – inaccurate reporting of cerebral palsy (CP) as the UCOD – between medical examiners, coroners, mixed-system death investigators, physicians, physician extenders, and unknown certifiers.

While cause of death certifiers report various inaccurate UCODs, we selected CP for this study because it is a particularly egregious error. CP has been identified as an inaccurate UCOD by those studying disability (Landes et al., 2019, 2020; Trollor et al., 2017), and a 'type 1 garbage code' by those studying the Global Burden of Disease (Naghavi et al., 2010; Lozano and Naghavi, 2012), meaning it is an International Statistical Classification of Disease, Tenth revision (ICD-10) code that cannot and should not be considered as an UCOD. CP is not a not a disease, but rather is a disability diagnosis that does not cause death as it refers to a group of lifelong disorders, typically identified shortly after birth, that are attributable to a variety of injuries to the developing brain, often affecting movement, posture, and activity (Turk et al., 2019; Rosenbaum et al., 2007). Unlike type 2 (e.g. heart failure), type 3 (e.g. cardiac arrest), and type 4 (e.g. unspecified bacterial infection) garbage codes, using a type 1 garbage code as the UCOD involves mistaking a risk factor that should never appear in the cause of death statement for the UCOD. Lastly, miscoding the UCOD is a major error with significant impacts on the interpretation of cause of death information (McGivern et al., 2017). The cumulative effects of this misattribution have obscured what we know about the cause of death patterns of this population (Landes et al., 2019).

2. Methods

2.1. Overview

This mixed-methods project utilized a convergent design to bring together two unique databases with a shared variable, Federal Information Processing Standard (FIPS) codes, to: 1) provide a holistic accounting of state statutes concerning cause of death certification; and 2) measure the effects of different certifiers on death certificate errors (Creswell et al., 2009). FIPS numeric codes are two-digit numbers assigned to each US state or territory by the National Institute of Standards and Technology for the purposes of identification. The researchers created the CoDSA database from the content analysis of state statutes concerning cause of death certification. We include a full methodological appendix for the CoDSA database, fully elaborating the systematic data gathering and analysis, as supplemental material. The second dataset is from the restricted 2005–2017 NVSS Multiple Cause of Death Mortality files that include state identifiers. Because analysis is focused on one particular type of death certification error, erroneous reporting of CP as the UCOD, we included decedents aged 18–104 at the time of death that also had an ICD-10 code for CP (G80.0-G80.9) on the death certificate. Our sample includes 29,996 adult decedents for the 13-year period.

2.2. Content analysis

The CoDSA database is the outcome of the content analysis of 341 key excerpts from state statutes, amendments, and policies concerning cause of death certification, death investigation, and physician licensing requirements across 50 states and Washington, D.C. in 2005–2017. Through an in-depth and systematic search and review of state codes, respective legislative histories, and policies available on states' websites, we identified 583 documents that focused on cause of death certifiers, fully accounting for professional groups to whom all 51 states extend signature authority. Upon initial review, we determined 242 of the originally collected documents were not applicable to the research question and excluded them from the content analysis (Elo and Kyngäs, 2008). The excluded documents focused on other aspects of the death process, such as the disposition of bodies, or were redundant due to statute organization.

In the first review of the included excerpts, the researchers identified each certifier group across all 51 states, cataloging groups identified in the documents by state and year. This process included the review of amendments affecting the section of state codes pertaining to cause of death certification. We carried out initial analysis inductively, developing certifier groups based on the data (Krippendorff, 1989; Burla et al., 2008).

During the second review of the selected excerpts, we applied a quantitative and deductive frame to the certifier groups to begin building the quantitative database for statistical analysis, iteratively moving from induction to deduction (Krippendorff, 1989; Elo and Kyngäs, 2008; Timmermans and Tavory, 2012). If the excerpts for a state indicated a specific group was responsible for cause of death certification for a given year, the certifier type was assigned a 1 for the respective state and year. If the statute indicated a certifier could only certify the medical cause of death under certain conditions (e.g. *in the absence of the physician, the certificate may be completed and signed by…*), the certifier type was assigned a 2 for the respective state and year. If the statute did not mention a specific certifier group identified in the initial analysis, the certifier type was assigned a 0 for the respective state and year. The resulting database gives insight to legal mandates between 2005 and 2017 that grant signature authority over cause of death certification to certain groups. Interrater-reliability using Cohen's Kappa formula $\kappa = \mathscr{P}_o - \mathscr{P}_e / 1 - \mathscr{P}_e$ where $\mathscr{P}_o$ is the relative observed agreement between two raters and $\mathscr{P}_e$ is the hypothetical probability of chance agreement, based on yes or no assigned to each established certifier code across 13 years, was 0.78, indicating substantial agreement for the complex analysis (Krippendorff, 1989; Burla et al., 2008; Lombard, 2005).

The last step of the content analysis was organizing the CoDSA data for statistical analysis. The researchers refined the 57 categories derived

from the qualitative content analysis through consensus discussions into six categories based on professional credentials and roles, fitting the CoDSA data with the 2005–2017 NVSS mortality data. Since the NVSS data limits analysis to three potential certifier categories – medical examiner/coroner, physician, and other – we had to deduce the best way to consolidate the 57 categories. The consolidated categories used here include physicians, death investigators (e.g. medical examiners, coroners, and deputies/assistants), physician extenders, medical professionals, other medical professionals, and law enforcement. The full list of legal certifiers in 2017 by grouping appears in Table 1. We rely on CoDSA data to make two substantive changes to the NVSS data. First, we determined who certified deaths originally coded as coroner/medical examiner for 34 of the 51 states by matching the certifier to states' death investigation system, creating discrete groups of medical examiners, coroners, and mixed-system death investigators (medical examiners and coroners). Second, we were able to determine who likely certified causes of death on death certificates labeled "other" for 37 states. These 37 states only extend signature authority beyond death investigators and physicians to physician extenders. For remaining states, "other" certifiers are simply unknown. Unfortunately, the NVSS mortality data is missing certifier information for year 2013, categorized in this study as unknown certifier.

2.3. Statistical analysis

After assessing the frequency of death certifications by certifier type, we conducted multiple multivariate logistic regression models to determine the comparative likelihood medical examiners, coroners, mixed-system death investigators, physicians, physician extenders, and unknown certifiers reported CP as the UCOD. All models controlled for age at and year of death. The first model used the original certifier variable (medical examiner/coroner, physician, other). Conversely, the second model uses the CoDSA revised certifier variable (medical examiner, coroner, mixed-system death investigator, physician, physician extender, and unknown). As they receive the most training in death certification, and typically have the most experience in certifying death certificates, we designate medical examiner as the reference group

(Timmermans, 2006; Jentzen, 2009; Hanzlick, 1996, 2006). We present adjusted odds ratios in the language of comparative risk to facilitate interpretation. We conducted all statistical analyses in Stata 16.0 (College Station, Texas, USA).

Mortality data derived from death certificates contain various errors. We utilized a specific type of substantive error (McGivern et al., 2017) as our illustrative case for this study – the inaccurate reporting of CP as the UCOD (Landes et al., 2019, 2020). A 2019 study reports that nearly 60% of US death certificates of people with CP in 2012–2016 report CP as the UCOD (Landes et al., 2019). Many experts agree that CP is an inaccurate UCOD as it is a disability, not a disease or illness, and encompasses numerous conditions that have variable effects on movement posture, and activity, originating from different etiologies (Landes et al., 2019, 2020; Lozano and Naghavi, 2012; Duruflé-Tapin et al., 2014). Lending credence to the assessment that CP is an inaccurate UCOD, the Global Burden of Disease project, a leading global public health research effort, considers CP and other paralytic/palsy syndromes "type 1 garbage codes," ICD-10 codes that cannot and should not be considered an UCOD, and redistributes deaths attributed to CP to more useful and appropriate ICD-10 codes (Naghavi et al., 2010; Lozano and Naghavi, 2012). Moreover, erroneous UCOD reporting is considered a major error (McGivern et al., 2017), and often limits information that can inform public health efforts (Landes et al., 2019, 2020; Naghavi et al., 2010).

3. Results

3.1. State statute content analysis

A description of the primary certifier categories and specific certifier list derived from inductive analysis of state statues is provided in Table 1. On average, eleven documents were required to identify the legal certifiers for each state – at the extremes, as few as three documents for California, and as many as 30 documents for Kentucky. The variation is explained by diverse legislative histories and statute structure. For example, California had not altered the statute regarding death certification since 1995, and medical examiner and coroner statutes for the state appeared in the same section of the state code. Kentucky, on the

Table 1
Frequency of certifiers across US states by professional credentialing role, Cause of Death Signature Authority database, 2017.

Physicians (#)	Death investigators (#)	Physician extenders (#)	Medical Professionals (#)	Other Medical Professionals (#)	Law Enforcement (#)
Attending physician (51)	Medical examiner alternative (32)	Nurse practitioner (30)	Hospice registered nurse (4)	Chiropractor (7)	Sheriff (3)
Osteopathic physician (50)	County medical examiner (30)	Physician assistant (23)	Registered nurse (4)	Dentist (4)	Deputy Sheriff (2)
Other physician (37)	Deputy coroner (29)	Nurse midwife (18)	Nursing supervisor (1)	Other chiropractor (4)	Tribal law enforcement authority (1)
Other osteopathic physician (35)	Coroner (27)	Advanced practice registered nurse (16)	Hospital administrator (1)	Midwife (4)	
Chief medical officer of nursing home (27)	State medical examiner (27)	Certified nurse specialist (15)		Naturopathic physician (4)	
Chief medical officer of hospital (26)	Deputy medical examiner (23)	Certified registered nurse anesthetist (15)		Anyone having knowledge (3)	
Physician performing autopsy (22)	Local health officer (8)	Other nurse practitioner (14)		Other dentist (3)	
Coroner's physician (11)	Local registrar (4)	Other physician assistant (11)		Other Naturopathic physician (3)	
Physician pronouncing death (3)	Justice of the peace (3)	Chief medical officer alternative (10)		Other employee (2)	
Department chair of clinical department (1)	Certified child pathologist (1)	Other nurse midwife (10)		Podiatrist (2)	
Resident physician (1)	Prosecuting attorney having jurisdiction (1)	Other APRN (8)		Other midwife (1)	
	State registrar (1)	Other certified nurse specialist (8)		Other podiatrist (1)	
		Other CRNA (8)		Optometrist (1)	
		Health care provider designee (2)			

other hand, had five statutory changes between 2005 and 2017. More-over, Kentucky statutes appeared in subsections that are separate documents while California listed all subsections in one document.

For the study period, all states designated that the physician last in attendance of a decedent can certify the cause of death for natural deaths. Eighteen states extended signature authority to physicians other than the attending, most of which do so only under certain conditions, such as obtaining permission from the attending physician. Hawaii, Nevada, and New Jersey allow any physician, regardless of attending designation, to certify the cause of death statement. Other specified physicians across the 51 states include physicians performing autopsies, physicians pronouncing death, clinical department chairs in hospitals, resident physicians, surgeons, chief medical officers, and physicians hired by coroners. Each state has a death investigation system for un-natural or unattended deaths that rely on coroners (10 states), medical examiners (24 states), or a mixture of the two (17 states), many extending signature authority to deputy coroners (29 states) or deputy/assistant medical examiners (23 states). Minnesota and Arizona were the only states to make statutory changes affecting unnatural death investigation during the study period, Minnesota adding county medical examiners to their coronial system in 2006 and Arizona adding alternative medical examiners to their medical examiner system in 2007.

Most states limit the definition of physician to Doctors of Medicine or Doctors of Osteopathic Medicine, but there are exceptions. Arkansas, Florida, Illinois, Kentucky, Nebraska, Oklahoma, and Oregon, for example, consider chiropractors physicians, and Oklahoma, North Carolina, Pennsylvania, and Kentucky consider dentists physicians. Arizona and Oregon also consider Doctors of Naturopathic Medicine physicians. Wyoming, the only state to remove signature authority from any group considered physicians in the state, removed signature authority from chiropractors explicitly in 2013.

Twenty-three states made statutory changes to their state codes extending signature authority. The most frequent statutory change granted signature authority to physician extenders including physician assistants and advanced practice registered nurses (e.g. nurse practitioner). All twenty-three liberalizing states granted signature authority through state statute to at least one of these groups of physician extenders. Of the twenty-three states, all made these changes between 2007 and 2017. Comparatively, only three states extended signature authority to physicians other than the attending; Georgia extended signature authority to registered nurses, hospice nurses, and nursing supervisors under certain conditions in 2009; Arizona added midwifes in 2012; and Virginia added "an individual to whom the physician has delegated authority" in 2013. Wyoming was the only state to reduce the number of legal certifiers in 2005–2017.

3.2. Coding errors by certifier

We now turn to our statistical analysis. We first determined the rates at which medical examiners, coroners, mixed-system death investigators, physicians, physician extenders, and unknown certifiers signed the cause of death statement among our sample of 29,996 adult

Table 2
Frequency of death certification by certifier group, National Vital Statistics System Multiple Cause of Death Mortality files and Cause of Death Signature Authority database, 2005–2017 ($N = 29,996$).

Type of certifier	N	%
Physician	15,295	50.99
Medical Examiner	920	3.07
Coroner	474	1.58
Mixed System Death Investigator (Medical Examiner and Coroner)	1,254	4.18
Physician Extender, e.g. Nurse Practitioner, Physician's Assistant	5,944	19.82
Unknown	6,109	20.37
Total	29,996	

decedents with CP. Table 2 displays the frequency at which the different certifier groups signed the cause of death statement on the death certificate. Of the 29,996 deaths, physicians and physician extenders, the first and third most frequent certifiers, certified 50.99% and 19.82% of the cause of death statements respectively. Unknown certifiers were the second most common certifier group and completed 20.37% of the death certificates. The fourth most frequent certifier group was mixed-system death investigators, completing 4.18% of the death certifications in the sample. Medical examiners (3.07%) and coroners (1.58%) completed a minority of the death certificates.

Results from the multiple logistic regression analysis were used to determine the comparative likelihood a certifier group erroneously coded CP as the UCOD (Table 3). Model 1 relies on the original NVSS variable for cause of death certifier – medical examiner/coroner, physician, and other certifiers. Adjusted odds ratios reveal no statistical differences in the likelihood that medical examiner/coroners, physicians, and other certifiers inaccurately reported CP as the UCOD on the death certificate. Model 2 relies on the CoDSA revised certifier variable that adds more specificity to the model (medical examiner [referent], coroner, mixed-system death investigator, physician, physician extender, and unknown certifier). Use of the more specified classification of certifier revealed heterogeneity between groups. Compared to medical examiners, coroners were 41% more likely (CI 1.12, 1.78), mixed-system death investigators were 25% more likely (1.05, 1.49), physicians were 24% more likely (1.08, 1.42), physician extenders were 16% more likely (1.00, 1.34), and unknown certifiers were neither more or less likely to erroneously code CP as the UCOD on the death certificate.

4. Discussion

4.1. Effects of statutory liberalization of cause of death signature authority

Findings from this study suggest that state-level differences in statutory signature authority may contribute to inaccuracies in US mortality

Table 3
Adjusted odds ratio of reporting cerebral palsy as the underlying cause of death by certifier group, combined National Vital Statistics System Multiple Cause of Death Mortality Files and Cause of Death Signature Authority Database, 2005–2017 ($N = 29,996$).

Model 1			Model 2		
Cause of death certifier	NVSS certifier measure		Cause of death certifier	CoDSA certifier measure	
	Odds ratio	95% CI		Odds ratio	95% CI
Certifier[1]			*Certifier*[2]		
Physician	1.05	(0.96, 1.14)	Physician	1.24**	(1.08, 1.42)
Other	0.95	(0.87, 1.04)	Coroner	1.41**	(1.12, 1.78)
Unknown	0.97	(0.86, 1.08)	Mixed-system death investigator	1.25*	(1.05, 1.49)
			Physician extender	1.16*	(1.00, 1.34)
			Unknown certifier	1.09	(0.95, 1.26)
Controls			*Controls*		
Age	0.98	(0.98, 0.98)	Age	0.98***	(0.98, 0.98)
Year	1.00	(1.00, 1.01)	Year	1.00	(1.00, 1.01)
Constant	3.32***	(3.02, 3.65)	Constant	2.81***	(2.44, 3.24)

*<0.05, **p ≤ 0.01, ***p ≤ 0.001; [1]: Reference group for model 1 is medical examiner/coroner based on original NVSS reporting; [2]: Reference group for model 2 is medical examiner based on the CoDSA revision.

data, especially when considering myriad professional groups that can certify the cause of death. Of the 34 states that extend signature authority to physician extenders, 23 states granted authority in 2005–2017. Inaccuracies in the certification of death certificates are widespread and were present prior to states extending signature authority to physician extenders. Thus, liberalization cannot be identified as a primary cause of inaccuracies within the data. However, evidence from this study indicates that statutory liberalization has reproduced systemic issues in cause of death reporting.

In the context of statutory liberalization, it is imperative to note that physicians and physician extenders certified the majority of the causes of death statements investigated, but were significantly more likely to erroneously report CP as the UCOD compared to medical examiners. The findings suggest that physician extenders play an increasingly important role in vital statistics data collection as they facilitated the completion of nearly 20% of the death certificates analyzed, but the findings also suggest that their introduction to the death certification system has not improved cause of death accuracy.

Although not certifying as many death certificates as physicians or physician extenders, coroners were also more likely than medical examiners to inaccurately report CP as the UCOD. The 10 states with purely coronial systems may improve the accuracy of their death certificates by following the lead of Minnesota and begin integrating medical examiners into their death investigation systems. However, this approach is limited insofar as coroners certify considerably fewer deaths than physicians and physician extenders. While using the original NVSS certifier variable suggested no statistically significant differences in the likelihood of assigning CP as the UCOD by certifier type, use of the more robust CoDSA certifier variable revealed statistically significant differences in this death certification error that would have otherwise been hidden.

4.2. Public health implications

Public health efforts to reduce premature mortality depend on accurate cause of death reporting, and the results from this study demonstrate significant differences in the accuracy of cause of death certifications on US death certificate by certifier type. The standardized death certificate, and therefore the NVSS certifier variable, includes only three certifier categories – medical examiner/coroner, attending physician, and attending/pronouncing physician. Our use of the CoDSA revised certifier variable demonstrates the limitation of the NVSS variable, as results from this study revealed marked differences in the accuracy of death certificate coding between the more specified cause of death certifier categories. In light of these findings, we contend that death certificates should provide a broader list of professional categories for certifiers in Section 31a that should be apparent in the NVSS mortality data. This would address the mismatch between liberalizing state-level statutory signature authority and the federally standardized death certificate.

The poor performance of certifiers assigning UCODs for this population suggests that the problem of determining the UCOD is more systemic and calls for more formal death certificate training. While prior studies emphasize the need for improved training on death certificate completion for physicians (McGivern et al., 2017; Messite and Stellman, 1996; Johnson et al., 2012), results from this study demonstrate that this does not take into account statutory liberalization, and as a result, severely underestimates the systemic nature of the problem. As inaccuracies are common across the array of certifiers with signature authority, including physician extenders who have more recently been afforded certifying privileges in some states, it is crucial to ensure proper death certificate training for all professions who have certification privileges. Training should focus on death trajectories, selecting an UCOD among available information, and reporting conditions present at death but not contributing to the cause of death. Specifically for developmental disabilities like CP, this means that certifiers should

strive to accurately identify the disease or injury that lead to death, then report CP in Part II of the death certificate, as a comorbid condition present at the time of death but not part of the sequence of events leading to death (Landes et al., 2019, 2020).

5. Conclusion

The UCOD is arguably the single most important statistic gathered through death certificates. Results from this study reveal that problems with death certificate accuracy extend across types of certifiers, including physician extenders, a group that has only more recently been permitted to certify in some states. The findings suggest that errors in cause of death certification are systemic. Thus, efforts to improve the performance of medical providers certifying death certificates should include, but extend beyond, physicians to account for expansion of cause of death signature authority to other medical professions such as physician extenders. To further clarify the full scope of this problem, and particular training needs, future research should utilize the CoDSA database to investigate whether certifier type predicts other inaccurate UCODs (Naghavi et al., 2010) or types of death certification errors (McGivern et al., 2017).

CRediT authorship contribution statement

J. Dalton Stevens: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing - original draft, Writing - review & editing. **Scott D. Landes:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Validation, Writing - review & editing.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2020.101309.

References

American Association of Nurse Practitioners. Issues at a glance: Signature authority. Policy Briefs Underst Policy to Help Shape NP Pract. 2018;(1):1-4.

Burla, L., Knierim, B., Barth, J., Liewald, K., Duetz, M., Abel, T., 2008. From text to codings: intercoder reliability assessment in qualitative content analysis. Nursing Res. 57 (2), 113–117. https://doi.org/10.1097/01.NNR.0000313482.33917.7d.

CDC. Death Investigation Systems. Public Health Law: Coroner and Medical Examiner Laws. https://www.cdc.gov/phlp/publications/coroner/death.html. Published 2015. Accessed January 27, 2020.

Creswell, J.W., Plano-Clark, V.L., Designing and Conducting Mixed Methods Research. 2nd ed. (Creswell JW, Plano-Clark VL, eds.). Los Angeles, CA: SAGE Publications; 2009.

Duruflé-Tapin, A., Colin, A., Nicolas, B., Lebreton, C., Dauvergne, F., Gallien, P., 2014. Analysis of the medical causes of death in cerebral palsy. Ann. Phys. Rehabilitation Med. 57 (1), 24–37. https://doi.org/10.1016/j.rehab.2013.11.002.

Elo, S., Kyngäs, H., 2008. The qualitative content analysis process. J. Adv. Nurs. 62 (1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x.

Hanzlick, R., 1996. The role of medical examiners and coroners in public health surveillance and epidemiologic research. Annu. Rev. Public Health 17 (1), 383–409. https://doi.org/10.1146/annurev.publhealth.17.1.383.

Hanzlick, R., 2006. Death Investigation: Systems and Procedures. CRC Press, New York, New York.

Hetzel, A., U.S. Vital Statistics System: Major Activities and Developments, 1950-95. Hyattsville, MD; 1997. https://www.cdc.gov/nchs/data/misc/usvss.pdf.

Jentzen, J., 2009. Death Investigation in America: Coroners, Medical Examiners, and the Pursuit of Medical Certainty. Harvard University Press, Cambridge, MA.

Johnson, C.J., Hahn, C.G., Fink, A.K., German, R.R., 2012. Variability in cancer death certificate accuracy by characteristics of death certifiers. Am. J. Forensic Med. Pathol. 33 (2), 137–142. https://doi.org/10.1097/PAF.0b013e318219877e.

Keepnews, D.M., 2010. Implementing health reform and moving past "turf wars". Policy, Politics, & Nursing Practice 11 (2), 87–88. https://doi.org/10.1177/1527154410383685.

Krippendorff, K., Content Analysis. In: Barnouw E, Gerbner G, Schramm W, Worth TL, Gross L, eds. International Encyclopedia of Communicatio. Vol 1. 1st ed. New York: Oxford University Press; 1989:403-407. doi: 10.1002/9781118541555.wbiepc065.

Lakkireddy, D.R., Gowda, M.S., Murray, C.W., Basarakodu, K.R., Vacek, J.L., 2004. Death certificate completion: how well are physicians trained and are cardiovascular causes overstated? Am. J. Med. 117 (7), 492–498. https://doi.org/10.1016/j.amjmed.2004.04.018.

Landes, S.D., Stevens, J.D., Turk, M.A., 2019. Obscuring effect of coding developmental disability as the underlying cause of death on mortality trends for adults with developmental disability: a cross-sectional study using US Mortality Data from 2012 to 2016. BMJ Open 9 (2), 1–10. https://doi.org/10.1136/bmjopen-2018-026614.

Landes, S.D., Turk, M.A., Lauer, E., 2020. Recommendations for accurately reporting intellectual and developmental disabilities on death certificates. Am. J. Preventive Med. 59 (6), 892–895. https://doi.org/10.1016/j.amepre.2020.05.028.

Lloyd-Jones, D.M., Martin, D.O., Larson, M.G., Levy, D., 1998. Accuracy of death certificates for coding coronary heart disease as the cause of death. Ann. Intern. Med. 129 (12), 1020–1026. https://doi.org/10.7326/0003-4819-129-12-199812150-00005.

Lombard, M., Practical Resources for Assessing and Reporting Intercoder Reliability in Content Analysis Research Projects. Analysis. https://www.researchgate.net/publication/242785900_Practical_Resources_for_Assessing_and_Reporting_Intercoder_Reliability_in_Content_Analysis_Research_Projects. Published 2005.

Lozano, R., Naghavi, M., Appendix to Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380:Supplemental 1-765. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Supplementary+appendix#1.

McCaw-Binns, A., Holder, Y., Mullings, J., 2015. Certification of Coroners cases by pathologists would improve the completeness of death registration in Jamaica. J. Clin. Epidemiol. 68 (9), 979–987. https://doi.org/10.1016/j.jclinepi.2014.11.026.

McGivern, L., Shulman, L., Carney, J.K., Shapiro, S., Bundock, E., 2017. Death certification errors and the effect on mortality statistics. Public Health Rep. 132 (6), 669–675. https://doi.org/10.1177/0033354917736514.

Messite, J., Stellman, S.D., 1996. Accuracy of death certificate completion: The need for formalized physician training. J. Am. Med. Assoc. 275 (10), 794–796. https://doi.org/10.1001/jama.275.10.794.

Naghavi, M., Makela, S., Foreman, K., O'brien, J., Pourmalek, F., Lozano, R., 2010. Algorithms for enhancing public health utility of national causes-of-death data. Popul. Health Metrics 8 (1). https://doi.org/10.1186/1478-7954-8-9.

Pritt, B.S., Hardin, N.J., Richmond, J.A., Shapiro, S.L., 2005. Death certification errors at an academic institution. Arch. Pathol. Lab. Med. 129 (11), 1476–1479. https://doi.org/10.1043/1543-2165(2005)129[1476:DCEAAA]2.0.CO;2.

Rosenbaum, P., Paneth, N., Leviton, A., et al. A report: The definition and classification of cerebral palsy April 2006. Dev Med Child Neurol. 2007;49(SUPPL.109):8-14. doi: 10.1111/j.1469-8749.2007.tb12610.x.

Ruiz, L., Posey, B.M., Neuilly, M.A., Stohr, M.K., Hemmens, C., 2018. Certifying death in the United States. J. Forensic Sci. 63 (4), 1138–1145. https://doi.org/10.1111/1556-4029.13689.

Schuppener, L.M., Olson, K., Brooks, E.G., 2020. Death certification: errors and interventions. Clin. Med. Res. 18 (1), 21–26. https://doi.org/10.3121/cmr.2019.1496.

Timmermans, S., 2006. Postmortem: How Medical Examiners Explain Suspicious Death. University of Chicago Press, Chicago, IL.

Timmermans, S., Tavory, I., 2012. Theory construction in qualitative research: from grounded theory to abductive analysis. Sociol. Theory 30 (3), 167–186. https://doi.org/10.1177/0735275112457914.

Trollor, J., Srasuebkul, P., Xu, H., Howlett, S., 2017. Cause of death and potentially avoidable deaths in Australian adults with intellectual disability using retrospective linked data. BMJ Open 7, 13489. https://doi.org/10.1136/bmjopen-2016.

Turk, M.A., Fortuna, R.J., Health status of adults with cerebral palsy. In: Prasher VP, Janicki MP, eds. Physicial Health of Adults with Intellectual and Developmental Disabilities. Second. Cham, Switzerland; 2019:87-126.

U.S. Department of Health and Human Services. Physician's Handbook on Medical Certification of Death. Washington, DC; 2003. http://www.cdc.gov/nchs/data/misc/hb_cod.pdf%5Cnpapers3://publication/uuid/93E811C7-82FB-4DA3-B7C3-139F0B316B5B.

Ventura, S.J., The U.S. National Vital Statistics System: Transitioning Into the 21st Century, 1990-2017. Hyattsville, MD; 2018. https://www.cdc.gov/nchs/data/series/sr_01/sr01_062.pdf.