Artificial Intelligence and the Measurement and Projection of Mortality Experience

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Few issues are so fundamentally important for the advancement of public health as the compilation of statistics on causes of death. Nonetheless, despite the development of a highly structured protocol for cause-of-death reporting in the United States, considerable evidence suggests that causes of death are frequently reported inaccurately. Causes of death reported on death certificates in the United States are compiled, along with other relevant information about decedents, for incorporation in databases contained in the WONDER (Wide-ranging ONline Data for Epidemiologic Research) system maintained by the Centers for Disease Control and Prevention (CDC) (Centers for Disease Control and Prevention, 2023), which are made freely available to researchers. Multiple studies (e.g., Cheng et al., 2012, Gamage et al., 2021, Landes and Peek, 2013, and McGivern et al., 2017) have indicated that causes of death are frequently reported with error on death certificates. There is no systematic, nationally applied protocol in place to examine death certificates for such errors before the information presented on them is collected for inclusion in CDC databases. Some studies examining the incidence of such errors also consider their effects on mortality statistics (e.g., McGivern et al., 2017).

Beyond their clear importance for public health research, statistics on mortality by cause of death play an important role in the work of actuaries. Cause-specific mortality probabilities are used in pricing insurance products and benefit programs that provide different levels of benefits for different causes of death. They are also used to assess the efficacy of insurers' underwriting. Beyond that, trends in cause-specific mortality rates may be used to forecast rates of mortality improvement, as in Villegas et al. (2024). The actuarial profession thus has a strong interest in improving the quality of reporting of causes of death on death certificates.

The existence of errors in reporting causes of death has been noted in medical and public health literature for decades. Studies published in the first half of the last century (such as Swartout, 1934, Swartout & Webster, 1940, and Pohlen & Emerson, 1942) focused on discrepancies between autopsy findings and reported causes of death. Perhaps because autopsies are now less common than they once were, more recent publications have focused upon apparent inconsistencies between decedents' medical records and the causes of death reported on their death certificates. A good example is provided by McGivern et al. (2017), who compared the causes of death reported on 601 death certificates submitted in the Electronic Death Registration System (EDRS) of the State of Vermont with those determined by medical examiners after reviewing the medical records of the decedents. The medical examiners completed "mock" death certificates that were compared to those filed in the Vermont EDRS. To the extent that differences pointed to errors in the original certificate, the errors were categorized as follows (McGivern et al., 2017, p. 670):

> Grade 1: Minor error (limited impact on interpretation)
>
> 1a. Inappropriate information included on death certificate
>
> 1b. Abbreviations

Grade 2: Minor error (potential impact on interpretation)

2a. Errors of sequencing (regardless of whether an underlying cause was provided)

2b. Multiple underlying causes of death in Part I

Grade 3: Major error (impact on interpretation of contributing causes)

3a. Major comorbidities/contributing cause(s) absent or wrong

Grade 4: Major error (impact on interpretation of cause and manner of death)

4a. Underlying cause listed as contributory cause (in Part II)

4b. No underlying cause in Part I

4c(1). Wrong underlying cause

4c(2). Underlying cause not on last line of Part I

4d. Wrong manner of death

It was found that 305 of 601 death certificates reviewed contained major errors, and 59 contained minor errors. Of the 59 that had minor errors, only 14 did not contain a major error as well. It was also determined that certificates completed for deaths taking place in hospitals and non-hospital care facilities were more likely, to statistically significant degrees, to contain misspecifications of the cause of death than certificates completed for deaths in decedents' homes. Interestingly, there was no statistically significant difference between physician and non-physician certifiers' rates of major or minor error (McGivern et al., 2017, p. 671).

Investigators have offered different explanations for this problem. Some have suggested that a lack of training is a primary cause. Lakkireddy et al. (2004), in commenting on a study in which they found very high rates of error in medical residents' specification of the cause of death in a case study, call for more and better training of physicians in this task. However, others are less sure that additional training would help. McGivern et al. (2017, p. 673) note that the State of Vermont takes many steps, including training, to foster accuracy in the completion of death certificates but seems to have little to show for it:

> Inaccuracies in death certification are common, but our findings indicate that Vermont has a similar or higher percentage of major errors compared with other regions as reported in the literature. The OCME [Office of Chief Medical Examiner] takes an active role in reviewing all death certificates and providing feedback to certifiers either through email or a telephone call. The OCME offers education to medical students, pathology residents, and interns on proper death certification. Vermont's EDRS requires first-time users to complete a brief tutorial about death certification. EDRS provides feedback to certifiers through "soft" and "hard" edits when information is missing or a cause is nonspecific or suggests a nonnatural death. The edits require the certifier to stop and review the cause of death for accuracy, completeness, and Medical Examiner consideration. Despite these efforts, the error rate is still high.

Other factors that have been cited as contributing to the frequency of errors in stating causes of death include the fact that certification is often left to a hospitalist, a nursing home doctor, an emergency room physician, or another type of practitioner who has not been involved in the decedent's care at earlier stages and could therefore have difficulty specifying the chain of causation that is supposed to be shown. Hanzlick (1997, pp. 267-268) observed that physicians generally receive no compensation for completing death certificates, and the "demands of clinical

practice may give death-related issues a lower priority than other educational and patient-related activities." In their focus-group-based study of physicians who certify causes of death, Morgan et al. (2022) encountered opinions such as "[t]o me, it is just a piece of paper that gets you buried or cremated," which bespeaks a remarkable disregard for—or ignorance of— the importance for public health purposes of the death certification process.

Based on the scholarly literature on the subject, it appears that changing physicians' practices in ways that will significantly improve the accuracy of their certifications of causes of death could be rather difficult. However, three factors suggest that an automated system of checking involving the use of artificial intelligence tools to review death certificates could significantly improve cause-of-death reporting in the United States, as well as other countries.

First, the CDC has encouraged the development and implementation of electronic death registration systems (EDRS) in the 57 reporting entities that issue death certificates in the United States and its territories. The CDC has called attention to several advantages that an EDRS has relative to the traditional methods of submitting death certificates. Among the more important ones are their capacity to "incorporate error-checking applications to improve data quality," their enabling of "users to complete the death registration process faster and with fewer errors," and their facilitation of "electronic processing of death certificate amendments" (Centers for Disease Control and Prevention, National Center for Health Statistics, 2022, December 29). Rosenbaum et al. (2021, p. 538) reported that just four states – Connecticut, North Carolina, Rhode Island, and West Virginia – had not implemented EDRS immediately prior to the outbreak of the COVID-19 pandemic, but examination of the websites of these states' departments of health reveals that all four have since implemented EDRS (Connecticut Department of Public Health, 2021, North Carolina Department of Health and Human Services, 2023, Rhode Island Department of Health, 2022, West Virginia Department of Health & Human Resources, 2021). Zhu et al. (2022) have written about the potential for neural networks to perform sophisticated error-checking on cause-of-death reporting. In particular, they report on the development of a tool that can check for errors in the sequence of the causes of death shown on a death certificate. This is a frequent source of error in specifying underlying causes of death. The potential to perform error-checking at this level suggests that automated error-checking of information entered in EDRSs has the potential for significant enhancement.

Second, legislation enacted in the United States over the past two decades has strongly encouraged the implementation of electronic healthcare recordkeeping. In particular, the American Recovery and Reinvestment Act (ARRA) of 2009, the Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009, and the 21st Century Cures Act of 2016 all promoted the use of electronic medical recordkeeping.

Third, and perhaps most importantly, artificial intelligence tools have shown great promise in the diagnosis of illnesses based on medical records. Kohane (2023) has described the power of ChatGPT-4 to make difficult diagnoses correctly using medical records, recounting its astonishing ability to quickly diagnose a complex – and exceedingly rare – condition in a pediatric patient. It is not hard to imagine that physicians tasked with determining causes of death in patients in whose treatment they have only been briefly involved—or in patients whose multiple medical conditions make identifying "the" underlying cause of death difficult—could be greatly aided by tools powered by artificial intelligence. Moreover, it is possible to imagine connections of both EDRSs and electronic healthcare records to such tools so that certifications of causes of death that appear inconsistent to one degree or another with decedents' clinical records could immediately be questioned. This would represent a significant advance over the tool developed by Zhu et al. (2022) described above, which checks cause-of-death sequencing based on "training" on which sequences are logical rather than through reviews of individual decedents' records.

There seems to be little question that the use of artificial intelligence tools in the medical care of the living will grow significantly in the future. While there is plenty of need for informed human oversight of such use, its "superhuman clinical performance," as described by Kohane (2023), makes this extremely likely. There is no reason why it cannot also be used, with similar human oversight, in the evaluation of decedents' causes of death, which may be expected to result in the improvement of statistics on mortality by cause of death and projections of future improvements in

mortality. Logistical and legal questions exist as to the extent and manner of sharing information on decedents' medical histories with artificial intelligence tools, but similar or identical issues will have to be addressed in the application of artificial intelligence to the medical care of live patients. In future writings, I—and others—will address these issues.

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