Improper cause-of-death statements by specialty of certifying physician: a cross-sectional study in two medical centers in Taiwan

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Improper cause-of-death statements by specialty of certifying physician: a cross-sectional study in two medical centers in Taiwan

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ABSTRACT

Objective: To determine whether frequencies of improper cause-of-death (COD) statements reported on death certificates differed by specialty of the certifying physicians.

Design: Cross-sectional descriptive study.

Setting: Two medical centers in Tainan, Taiwan.

Participants: A total of 2,520 death certificates issued by 230 physicians.

Main outcome measures: Five types of error in COD statements based on the level of specificity and appropriateness of the COD causal sequence.

Results: The overall error rate was 31% (779/2520). The error rate was 11% (151/1361) and 54% (628/1159) among death certificates with and without mention of cancer. Of 779 death certificates with error in COD statements, two-fifths (314/779) of them sustained major error 3, i.e., reported mechanisms of death only. The error rate varied greatly by specialty of the certifying physician, ranging from 69% (45/65) among infectious diseases physicians and 67% (77/115) among physicians of respiratory medicine to 9% (87/995) among oncologists.

Conclusions: The frequency of improper COD statements varied greatly by specialty of the certifying physicians because physicians with different specialties manage different types of diseases and conditions with contrasting complexities in the determination of the underlying COD. Educational intervention should target specialties with a high frequency of error in COD statements.

Article focus

- Do the frequencies of error in cause-of-death statements differ by specialty of the certifying physicians?

Key messages

- The error rate was the highest among infectious diseases physicians and physicians of respiratory medicine and the lowest among oncologists.
- The most often occurred error was reporting mechanisms of death only.

Strengths and limitations

- Compared with previous similar hospital-based studies, this study has the largest sample size, which allowed us to stratify the error rates by sub-specialties.
- The case-mix and physicians' certification behaviors in the studied hospital might differ from other hospitals.

INTRODUCTION

Issuing a death certificate is a common practice of medical physicians; however, most physicians are not well-educated on how to correctly complete the cause-of-death (COD) statement on the death certificate.[1] In order to design a relevant teaching program on how to complete COD statements correctly, we need to understand what kinds of improper COD statements most often occur and by what kinds of physicians.

Despite many studies demonstrating various types of improper COD statements on death certificates (we did not include COD validity studies using other sources of data as the gold standard and studies using case histories for COD certification),[2–12] very few studies have examined the frequency of errors in COD statements by specialty of the certifying physicians. Among the studies examining errors in COD statements, only broad categories were used, such as general practitioners, specialists and resident medical officers in Peach & Brumley's study,[3] general practitioners, internists and surgeons in *Lu et al*'s study,[4] and internists vs. non-internists in *Burger et al*'s study.[10] Only one study classified certifying physicians into six departments (medicine, surgery, oncology, family medicine, pediatrics and critical care trauma unit);[2] however, they did not further assess the error rates by sub-specialty. A recent study also suggested that internists with different sub-specialties have different quality in COD statements and determination of the underlying COD in given case histories.[13]

To identify certifying physicians with a high frequency of reporting improper COD statements as the target education group, this study aimed to determine the frequencies of various types of improper COD statements on death certificates by specialty of the certifying physicians in two medical centers in Tainan, Taiwan.

METHODS

Setting and data source

This descriptive cross-sectional study was conducted in Tainan, a major city located in southern Taiwan, with a population of 1.87 million. There are only two medical centers in Tainan. In 2009, there were 1150 beds in Chi-Mei Medical Center and 1100 beds in National Cheng Kung University Hospital. We retrospectively reviewed all death certificates issued from January 1, 2009 to December 31, 2009 in these two medical centers.

Determining errors in COD statements

We defined five types of error in COD statements based on the level of specificity and appropriateness of the COD causal sequence. The examples of each type of error are illustrated in Table 1. Of the five types of error, major error 3, “only mechanisms of death reported” is the most serious error affecting the quality of COD statistics because no specific COD information is given.

Authors TJC and THL reviewed all death certificates to determine whether the COD statement was acceptable or sustained one of the five types of error. TJC is a senior neurologist and THL is a senior family physician and both of them in charge of the teaching of how to correctly report the COD statements on the death certificate for residents in the two medical centers.

Data analysis

We first calculated the overall error rate and the frequency of five types of error in the COD statements. Since the complexity of determination of the underlying COD differed by diseases and conditions, we separated death certificates by whether or not there was mention of cancer and computed error rate of these two categories. We then calculated the frequency of errors by specialty of the certifying physicians.

RESULTS

In 2009, a total of 2,520 death certificates were issued by 230 physicians in two medical centers in Tainan, Taiwan. The overall error rate was 31% (779/2520) and the frequency of each type of error is illustrated in Table 2. The error rate was 11% (151/1361) and 54% (628/1159) among death certificates with and without mention of cancer. Of 779 death certificates with error in COD statements, two-fifths (314/779) sustained major error 3, i.e., reported mechanisms of death only.

The overall error rate varied greatly by specialty of the certifying physician, ranging from 69% (45/65) among infectious diseases physicians and 67% (77/115) among physicians of respiratory medicine to 9% (87/995) among oncologists (Table 3). The rate of major error 3 was the highest among physicians of respiratory medicine (44%, 51/115), followed by nephrologists (33%, 15/45). Respiratory failure, sepsis and pneumonia were the three mechanisms of death most often reported by physicians of respiratory medicine, and renal failure was the mechanism of death most often reported by nephrologists.

DISCUSSION

Main findings

The findings of this study indicate that the frequency of error in reporting COD statements varied greatly by specialty of the certifying physicians. Physicians of different specialties manage different types of diseases and conditions with contrasting complexities in the determination of the underlying COD. For example, most patients treated by oncologists have cancer, and the determination of the underlying COD is comparably straightforward. Oncologists therefore had the lowest error rate (9%) in this study. On the contrary, physicians specializing in infectious diseases, critical care, respiratory medicine and nephrology work mostly with patients with diseases or conditions lacking a specific etiology, such as pneumonia, sepsis, respiratory failure or renal failure, and thus sustained a higher error rate in COD statements.

Interpretations in relation to previous studies

One Canadian study also indicated different error rates by departments of certifying physicians, the overall and major error rates being 61% and 40% in medicine, 65% and 35% in surgery, 50% and 17% in oncology, 27% and 15% in family medicine, 38% and 30% in pediatrics, and 56% and 22% in the critical care trauma unit.[2] Unfortunately, because of the small sample size they did not further analyze the error rates by sub-specialties. Consistent with the results of that

study, the oncologists in this study had the lowest major error rate. Nevertheless, very few family physicians issued death certificates in medical centers in Taiwan.

Previous studies have presented different distributions of various types of error. The most commonly sustained error was the reporting of an unspecific COD in four studies,[3–5,7] the reporting of an incorrect COD causal sequence in two studies,[2,10] and the reporting of mechanisms of death only in one study.[11] One of the explanations of the above-mentioned variation is the differences in disease patterns encountered in different countries and in different medical settings. Another explanation is that the certifying physicians in different countries or settings have different COD certification behavior patterns.

In Taiwan, the most commonly sustained error was found to be the reporting of unspecified COD statements in a population-based study,[4] but it was the reporting of mechanisms of death only in this medical center-based study. One of the explanations of this discrepancy was that 'pneumonia' was defined as an unspecified COD in the previous Taiwan study and was defined as a mechanism of death in this study. The rationale for defining 'pneumonia' as a mechanism of death was based on the revision of International Selection Rule 3 (p.29) in the *Second Edition of the Instruction Manual of the International Classification of Diseases* set by the World Health Organization.[14] Furthermore, according to the casual sequence Decision Tables compiled by the US National Center for Health Statistics, all

diseases or conditions could result in pneumonia, similar to other mechanism of death (such as sepsis, respiratory failure, acidosis, etc.).[15]

Strengths and limitations

Compared with previous similar hospital-based studies, this study has the largest sample size, which allowed us to stratify the error rates by sub-specialties. This study used very detail classification of types of errors, which would provide very practical information for medical education and training.

One of the limitations of this study was that we collected only the death certificates issued in two medical centers, the case-mix and physicians' certification behaviors in the two medical centers studied might be different from other hospitals. Another limitation was that we were unable to differentiate whether COD statements were reported by junior residents or senior attending physicians, because of the co-signature system used in the two medical centers studied.

Conclusion

In conclusion, the frequencies of improper COD statements varied greatly by specialty of certifying physicians because physicians with different specialties manage different types of diseases and conditions with contrasting complexities in the determination of the underlying COD. Educational intervention should target specialties with a high frequency of error in COD statements.

Contributors T.C., F.L. and T.L. researched the data and wrote the manuscript. S.L. reviewed/edited the manuscript, contributed to the discussion.

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Competing interests None declared.

Ethics approval This study was approved by the Institution Review Boards of Chi-Mei Medical Center (09909-004) and National Cheng Kung University Hospital (ER-99-170).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

REFERENCES

1. Aung E, Rao C, Walker S. Teaching cause-of-death certification: lessons from international experience. *Postgrad Med J* 2010;86:143–52.
2. Jordan JM, Bass MJ. Errors in death certificate completion in a teaching hospital. *Clin Invest Med* 1993;16:249–55.
3. Peach HG, Brumley DJ. Death certification by physicians in non-metropolitan Victoria. *Aust Fam Phys* 1998;27:178–82.
4. Lu TH, Shou WY, Shih TP, et al. Factors associated with errors in death certificate completion: a national study in Taiwan. *J Clin Epidemiol* 2001;54:232–8.
5. Swift B, West K. Death certification: an audit of practice entering the 21st century. *J Clin Pathol* 2002;55:275–9.
6. Hanzlick R. Quality assurance review of death certificates: a pilot study. *Am J Forensic Med Pathol* 2005;26:63–5.
7. Pritt BS, Hardin NJ, Richmond JA, et al. Death certification errors at an academic institution. *Arch Pathol Lab Med* 2005;129:1476–9.
8. Lu TH, Walker S, Johansson LA, et al. An international comparison study indicated physicians' habits in reporting diabetes in Part I of death certificate affected reported national diabetes mortality. *J Clin Epidemiol* 2005;58:1150–7.
9. Lu TH, Hsu PY, Bjorkenstam C, et al. Certifying diabetes-related cause-of-death: a

comparison of inappropriate certification statements in Sweden, Taiwan and the USA. *Diabetologia* 2006;49:2878–81.

10. Burger EH, van der Merwe L, Volmink J. Errors in the completion of death notification form. *S Afr Med J* 2007;97:1077–81.
11. Katsakiori PF, Panagiotopoulou EC, Sakellaropoulos GC, et al. Errors in death certificates in a rural area of Greece. *Rural Remote Health* 2007;7:822.
12. Lu TH, Anderson RN, Kawachi I. Trends in frequency of reporting improper diabetes-related cause-of-death statements on death certificates, 1985 to 2005: an algorithm to identify incorrect causal sequences. *Am J Epidemiol* 2010;171:1069–78.
13. Lu TH, Kwok CF, Ho LT. Whether to report diabetes as the underlying cause-of-death? a survey of internists of different sub-specialties. *BMC Endocr Disord* 2010;10:13.
14. World Health Organization. *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision. Volume 2 Instruction Manual the Second Edition*. Geneva: World Health Organization; 2004. http://www.who.int/classifications/icd/ICD-10_2nd_ed_volume2.pdf accessed at September 8, 2010.
15. National Center for Health Statistics. *Instruction Manual Part 2c- ICD-10 ACME Decision Tables for Classifying Underlying Causes of Death, 2008*. Hyattsville, MD: National Center for Health Statistics; 2008. http://www.cdc.gov/nchs/data/dvs/2008Final2C.pdf, accessed at September 8, 2010.

Table 1 Examples of five types of error in cause-of-death (COD) statements

Minor error 1: One unspecific COD reported and the causal sequence was correct		
Example 1	Example 2	Example 3
a. Hepatic failure	a. Sepsis	a. Respiratory failure
b. Liver tumor	b. Pneumonia	b. Aspiration pneumonia
c.	c. Stroke	c.
d.	d.	d.
Minor error 2: One specific COD reported but the causal sequence was incorrect		
Example 4	Example 5	Example 6
a. Lung cancer with metastasis	a. Sepsis	a. Cerebral infarction
b. Pneumonia	b. Ischemic heart disease	b. Pulmonary failure
c. Sepsis	c. Pneumonia	c.
d. Respiratory failure	d.	d.
Major error 1: Multiple specific COD reported and the causal sequence was correct		
Example 7	Example 8	Example 9
a. Arrhythmia	a. Heart failure	a. Sepsis
b. DM, Hypertension, COPD	b. Lung ca, Bladder ca	b. Pneumonia
c.	c.	c. GI bleeding
d.	d.	d. Liver cirrhosis, DM
Major error 2: Multiple specific COD reported but the causal sequence was incorrect		
Example 10	Example 11	Example 12
a. Renal failure	a. Respiratory failure	a. Pneumonia
b. COPD	b. Lung cancer	b. Pulmonary TB
c. Ischemic heart disease	c. Diabetes mellitus	c. Liver cancer
d.	d.	d. Prostate cancer
Major error 3: Only mechanisms of death reported		
Example 13	Example 14	Example 15
a. Cardiopulmonary failure	a. Sepsis	a. Arrhythmia
b. Renal failure	b. Pneumonia	b. Acidosis
c. Bacteriemia	c.	c.
d.	d.	d.

Ca = cancer; COPD = chronic obstructive pulmonary disease, DM = diabetes mellitus; TB = tuberculosis

Table 2 Frequencies of various types of error in cause-of-death (COD) statements among death certificates (with or without mention of cancer)* issued in two medical centers in Tainan, Taiwan, 2009.

	All death certificates (n = 2520)		With mention of cancer (n = 1361)		Without mention of cancer (n = 1159)	
Type of error	No.	%	No.	%	No.	%
Minor error 1: One unspecific COD reported and the causal sequence was correct	211	8.4	52	3.8	159	13.7
Minor error 2: One specific COD reported but the causal sequence was incorrect	145	5.8	53	3.9	92	7.9
Major error 1: Multiple specific COD reported and the causal sequence was correct	36	1.4	15	1.1	21	1.8
Major error 2: Multiple specific COD reported but the causal sequence was incorrect	46	1.8	26	1.9	20	1.7
Major error 3: Only mechanisms of death reported	341	13.5	5	0.4	336	29.0
Total	779	30.9	151	11.1	628	54.2

*Cancer being reported in Part II of the death certificate was also included.

Table 3 Frequency of error in cause-of-death statements by specialty of the certifying physician in two medical centers in Tainan, Taiwan, 2009.

Specialty of certifying physician	No. of death certificates issued	Overall error		Major error 3*	
		No.	%	No.	%
Oncology	995	87	8.7	15	1.5
Critical care medicine	433	200	46.2	112	25.9
General surgery	161	51	31.7	9	5.6
Gastroenterology	157	59	37.6	10	6.4
Cardiology	125	57	45.6	32	25.6
Emergency	123	62	50.4	35	28.5
Respiratory medicine	115	77	67.0	51	44.3
Infection	65	45	69.2	19	29.2
Other internal medicine	64	25	39.1	14	21.9
Pediatrics	56	23	41.1	14	25.0
Neurosurgery	52	20	38.5	0	0.0
Nephrology	45	29	64.4	15	33.3
Neurology	44	16	36.4	5	11.4
Cardiac surgery	34	6	17.6	2	5.9
Others	19	5	26.3	2	10.5
Obstetrics & gynecology	11	6	54.5	2	18.2
Urology	11	5	45.5	0	0.0
Orthopedics	10	6	60.0	4	40.0
Total	2520	779	30.9	341	13.5

*Major error 3 denotes those death certificates reporting mechanisms of death only.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	No missing data
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	No sampling
		(*e*) Describe any sensitivity analyses	No
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	No follow-up
		(b) Give reasons for non-participation at each stage	No non-participation
		(c) Consider use of a flow diagram	No flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	No missing data
Outcome data	15*	Report numbers of outcome events or summary measures	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	No adjusted estimate
		(*b*) Report category boundaries when continuous variables were categorized	No
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	No RR
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	No
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Improper cause-of-death statements by specialty of certifying physician: a cross-sectional study in two medical centers in Taiwan

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ABSTRACT

Objective: To determine whether the frequency of improper cause-of-death (COD) statements reported on death certificates differed by specialty of the certifying physician.

Design: Cross-sectional descriptive study.

Setting: Two medical centers in Tainan, Taiwan.

Participants: A total of 2,520 death certificates issued by 230 physicians.

Main outcome measures: Five types of improper COD statements based on the criteria of correctness of the COD causal sequence and the level of specificity.

Results: Of 2520 death certificates analyzed, 779 had at least one type of improper COD statement, an improper statement rate of 31% (779/2520). Of the 779 death certificates with improper COD statements, 62% (486/779) sustained a major error, in which the mechanism of death (such as respiratory failure, heart failure, sepsis, acidosis, pneumonia, etc.) would be selected for mortality tabulation and would provide no useful information for the prevention of death. The improper reporting rate was highest among infectious diseases physicians (69%, 45/65), followed by physicians of respiratory medicine (67%, 77/115), and was lowest among oncologists (9%, 87/995).

Conclusions: The frequency of improper COD statements varied greatly by specialty of the certifying physician, because physicians in different specialties manage different types of diseases and conditions with contrasting complexities in terms of determining the specific COD.

Article focus

- Do the frequencies of improper cause-of-death statements differ by specialty of the certifying physician?

Key messages

- Three-fifths of improper cause-of-death statements resulted in the selection of the mechanism of death for mortality tabulation, which provides no useful information for the prevention of death.
- The improper reporting rate varied greatly by specialty of certifying physician and was highest among infectious diseases physicians and physicians of respiratory medicine and lowest among oncologists.

Strengths and limitations

- Compared with previous similar hospital-based studies, this study has the largest sample size, which allowed us to stratify the improper rate by sub-specialties.
- The case mix and physicians' certification behaviors in the studied hospital might differ from other hospitals.

INTRODUCTION

Recording cause of death (COD) statements on the death certificate is a common practice of medical physicians; however, many physicians might not know how the recorded COD statements are translated into COD statistics. It is the underlying COD that is designated for primary tabulation of COD statistics. The underlying COD has been defined as (a) the disease or injury that initiated the train of morbid events leading directly to death, or (b) the circumstances of the accident or violence which produced the fatal injury.[1, p.23] This definition is from the standpoint of prevention of death; it is necessary to break the chain of events or to effect a cure at some point, and the most effective public objective is to prevent the precipitating cause from operating.

To facilitate the selection of the underlying COD when two or more COD are recorded, an international standard form of death certificate (Figure 1) has been designed and recommended by the World Health Organization.[1, p.23, 24] Part I of the form is for diseases related to the train of events leading directly to death, and Part II is for unrelated but contributory conditions. It is the responsibility of the medical practitioner signing the death certificate to indicate which morbid conditions led directly to death and to state any antecedent conditions giving rise to this cause.

However, medical practitioners, on some occasions, might not properly record the train of events leading directly to death. The Selection Rules set by the World Health Organization

should be used to select the underlying COD.[1, p.25-36] Furthermore, if certifying physicians do not provide specific information on the death certificate it is difficult to provide useful information for the prevention of death.

Despite many studies demonstrating various types of improper COD statements on death certificates, very few studies have examined the frequency of improper COD statements by specialty of the certifying physician.[2–14] Information on which specialties have a higher percentage of recording improper COD statements could help to identify physicians with a high priority for education and training in how to properly complete COD statements. This study aimed to determine the frequencies of various types of improper COD statements on death certificates by specialty of the certifying physician in two medical centers in Tainan, Taiwan.

METHODS

Setting and data source

This descriptive cross-sectional study was conducted in Tainan, a major city located in southern Taiwan with a population of 1.87 million. There are only two medical centers in Tainan. In 2009, there were 1150 beds in Chi-Mei Medical Center and 1100 beds in National Cheng Kung University Hospital. We retrospectively reviewed all death certificates issued from January 1, 2009 to December 31, 2009 in these two medical centers.

Determination of improper COD statements

After a thorough review of the different classification schemes used in previous studies,[2-14] we used two criteria—correctness of the COD causal sequence and level of specificity—to define five types of improper COD statements. Examples of proper and five types of improper COD statements are illustrated in Table 1. Determination of the correctness of the COD causal sequence is according to *Decision Table D* in the *Instruction Manual Part 2c* compiled by the US National Center for Health Statistics, which includes all acceptable causal sequences between diseases or morbid conditions.[15]

Level of specificity was classified as specific COD, unspecific COD and mechanism of death. Specific COD is defined as providing specific information on the etiology and body region, such as lung cancer, esophageal varices bleeding, hepatitis B infection, cerebrovascular infarction, etc. Unspecific COD denotes those providing unspecific

information on etiology (stroke without specifying whether it is due to infraction or hemorrhage, or tumor without specifying whether is benign or malignant) or on body region (gastrointestinal bleeding without specifying whether the bleeding occurred in the esophagus, stomach, intestine or colon). Mechanism of death is defined as a physiologic derangement or a biochemical disturbance produced by a COD, such as congestive heart failure, respiratory failure, various arrhythmias, bacteriemia, sepsis, acidosis etc. The mechanism of death does not provide etiology-specific information and therefore should not be the underlying COD.[16,17]

In this study, we defined pneumonia as a mechanism of death. The rationale for defining pneumonia as a mechanism of death was based on the revision of International Selection Rule 3 in the *Second Edition of the Instruction Manual of the International Classification of Diseases, Tenth Revision* (ICD-10) set by the World Health Organization, which denotes that "any pneumonia in ICD-10 code J12-J18 should be considered an obvious consequence of conditions that impair the immune system. Pneumonia in ICD-10 code J18.0 and J18.2-J18.9 should be considered an obvious consequence of wasting diseases (such as malignant neoplasm and malnutrition) and diseases causing paralysis (such as cerebral hemorrhage or thrombosis), as well as serious respiratory conditions, communicable diseases and serious injuries. Pneumonia in ICD-10 code J18.0 and J18.2-J18.9, J69.0 and J69.8 should also be considered an obvious consequence of conditions that affect the process of swallowing".[1, p29]

Furthermore, according to *Decision Table D* in the *Instruction Manual Part 2c*, all diseases or conditions could result in pneumonia, similar to other mechanisms of death (such as sepsis, respiratory failure, acidosis, etc.).[15]

Proper COD statements include one correct causal sequence and one specific COD reported on the lowest used line (examples 1–3 in Table 1). Type 1 improper COD statements comprise one correct causal sequence and only an unspecific COD reported (examples 4–6 in Table 1). Liver tumor without specifying whether malignant or benign, stroke without specifying whether it was infarction or hemorrhage, and aspiration pneumonia without specifying whether it was due to milk or sputum or food are examples of an unspecific COD reported on the lowest used line and would be selected as the underlying COD.

Type 2 improper COD statements consist of one correct causal sequence and one mechanism of death reported on the lowest used line (examples 7–9 in Table 1). Some mechanisms of death (pneumonia in example 7, sepsis in example 8 and renal failure in example 9) were incorrectly reported by certifying physicians on the line below the specific COD (acute myocardial infarction in example 7, gastric bleeding in example 8 and cerebral infarction in example 9). However, the reported causal sequence is acceptable according to *Decision Table D* in the *Instruction Manual Part 2c*,[15] and therefore the underlying COD selected would be the mechanism of death (i.e., pneumonia in example 7, sepsis in example 8 and renal failure in example 9).

Type 3 improper COD statements contain more than one correct causal sequence and the specific COD reported on the lowest used line (examples 10–12 in Table 1). According to the Selection Rules, the first-mentioned COD will be selected as the underlying COD, i.e., diabetes in example 10, lung cancer in example 11 and liver cirrhosis in example 12. However, the intended underlying COD of the certifying physician might not be the first-mentioned COD.

Type 4 improper COD statements comprise an incorrect causal sequence and one specific COD reported on the lowest used line (examples 13–15 in Table 1). There were some specific COD (ischemic heart disease in example 13, diabetes mellitus in example 14 and prostate cancer in example 15) incorrectly reported on the line below another specific COD (obstructive lung disease in example 13, lung cancer in example 14 and liver cancer in example 15). Because the specific COD on the lower line could not result in the specific COD on the upper line, therefore the specific COD on the upper line will be selected as the underlying COD according to the Selection Rules. However, the intended underlying COD of the certifying physician might be the specific COD on the lower line.

Type 5 improper COD statements involve only mechanisms of death being reported (examples 16–18 in Table 1). The underlying COD selected would be the mechanism of death in type 2 and type 5 improper COD statements, which provides little information for the prevention of death. We therefore combined type 2 and type 5 improper COD statements

as major errors and type 1, 3 and 4 as minor errors.

Authors TJC and THL reviewed all the death certificates to determine whether the COD statement was acceptable or sustained one of the five types of error. TJC is a senior neurologist and THL is a senior family physician and both are in charge of teaching in how to correctly report COD statements on the death certificate for residents in the two medical centers.

Data analysis

We first calculated the frequencies of the five types of improper COD statements among the death certificates analyzed. We then computed the improper rate (containing at least one type of improper COD statement) and the major error rate (type 2 and type 5 improper COD statements combined) by specialty of the certifying physician. We classified 19 sub-specialties in this study. ~~Owing to the complexity of determination of the underlying COD differing by diseases and conditions, we separated death certificates by whether or not there was a mention of cancer and computed the error rate of these two categories~~.

RESULTS

In 2009, a total of 2,520 death certificates were issued by 230 physicians in two medical centers in Tainan, Taiwan. There were 779 death certificates that sustained at least one type of improper COD statement, with an overall improper statement rate of 31% (779/2520). The frequency of each type of improper COD statement is illustrated in Table 2. Of 779 death certificates with improper COD statements, 62% (486/779) sustained a major error (145 type 2 and 341 type 5 combined), in which the mechanism of death would be selected for mortality tabulation.

The improper rate varied greatly by specialty of the certifying physician, ranging from 69% (45/65) among infectious diseases physicians and 67% (77/115) among physicians of respiratory medicine to 9% (87/995) among oncologists (Table 3). Major errors were highest among physicians of obstetrics & gynecology (55%, 6/11), followed by physicians of respiratory medicine (49%, 56/115) and nephrologists (42%, 19/45). Respiratory failure, sepsis, renal failure and pneumonia were the mechanisms of death most often reported by physicians.

DISCUSSION

Main findings

The findings of this study indicate that almost one-third of death certificates sustained at least one type of improper COD statement. Three-fifths of improper cause-of-death statements resulted in selecting the mechanism of death for mortality tabulation, which provides no useful information for the prevention of death. The improper rate varied greatly by specialty of the certifying physician and was highest among infectious diseases physicians and physicians of respiratory medicine and lowest among oncologists.

Interpretations in relation to previous studies

Previous studies have presented different distributions of various types of improper COD statements. The most common error was found to be the reporting of an unspecific COD in four studies,[5–7,9] the reporting of an incorrect COD causal sequence in two studies,[4,12] and the reporting of mechanisms of death only in one study.[13] One of the explanations of the above-mentioned variations is the differences in disease patterns encountered in different countries and in different medical settings. Another explanation is that certifying physicians in different countries or settings have different COD certification behavior patterns.

One previous Taiwanese study indicated that unspecific COD statements was the most common improper COD statement,[6] but it was found to be the reporting of mechanisms of death only in this Taiwan medical center-based study. The main reason for the inconsistency

was that pneumonia was defined as an unspecific COD in the previous Taiwanese study and was defined as a mechanism of death in this study. Another explanation was the differences in the settings of the two studies: the previous study was a nationwide population-based study, while this study focused on two medical centers in Southern Taiwan, and the case mix of the deceased would certainly differ.

Despite many studies having examined improper COD statements, few have assessed the improper rate by specialty of the certifying physician. One Canadian study indicated that the overall and major error rates were 61% and 40% in medicine, 65% and 35% in surgery, 50% and 17% in oncology, 27% and 15% in family medicine, 38% and 30% in pediatrics, and 56% and 22% in the critical care trauma unit.[4] Unfortunately, because of the small sample size, they did not further analyze the error rates by sub-specialties. Consistent with the results of that study, the oncologists in this study had the lowest major error rate. Nevertheless, very few family physicians issue death certificates in medical centers in Taiwan.

Physicians of different specialties manage different types of diseases and conditions with contrasting complexities in terms of the determination of the underlying COD. For example, most patients treated by oncologists have cancer, and the determination of the underlying COD is comparably straightforward. Oncologists therefore had the lowest improper rate (9%) in this study. On the contrary, physicians in charge of infectious diseases, critical care, respiratory medicine and nephrology work mostly with patients with diseases or conditions

lacking a specific etiology, such as pneumonia, sepsis, respiratory failure or renal failure, and thus sustained a higher error rate in the COD statements.

As indicated by Kircher and Anderson,[16] most physicians tend to confuse cause and mechanism because medical therapy often attempts to modify or ameliorate mechanisms rather than causes. For example, digoxin is often highly effective in ameliorating the symptoms of congestive heart failure (mechanism) but does nothing to modify the underlying coronary artery disease (cause). It is rather difficult for physicians of infectious diseases, respiratory medicine or nephrology to specify the etiological causes of sepsis, pneumonia and renal failure.

Implications of this study

Almost one-fifth (486/2520) of death certificates analyzed in this study resulted in selection of the mechanism of death for mortality tabulation, which will certainly threaten the quality of COD statistics. Further studies are needed to retrospectively review the medical records for those death certificates in which only the mechanisms of death were reported to reassign a more specific COD as the underlying COD.

With regards to intervention, a review study of educational interventions targeted at improving the quality of COD certification suggested that printed educational material alone is the intervention with the least educational impact and interactive workshops are the most effective intervention.[18]

Another way to improve the quality of COD statistics is to query the certifier who reported vague or incomplete information on the death certificate for clarification. A study in the US suggested that fifty-one of the 52 registration areas queried either demographic or COD information, and almost 90% of queries were returned. The underlying COD changed in approximately 68% of these cases.[19] The Bureau of Health of Tainan city could query death certificates in which only the mechanism of death is reported to obtain more specific information to improve the quality of COD statistics.

Strengths and limitations

Compared with previous similar hospital-based studies, this study has the largest sample size, which allowed us to stratify the improper rates by sub-specialties. This study used very detailed classification of types of improper COD statements, which could provide very practical information for the design of materials for medical education.

One of the limitations of this study was that we analyzed only the death certificates issued in two medical centers, and the case mix and physicians' certification behaviors in the two medical centers studied might differ from those in other hospitals. Another limitation was that we were unable to differentiate whether COD statements were reported by junior residents or senior attending physicians, because of the co-signature system used in the two medical centers studied. The five types of improper COD statements were by no means complete, but were by far the most complete classification as compared with previous studies.

Conclusion

In conclusion, the frequencies of improper COD statements varied greatly by specialty of the certifying physician because physicians with different specialties manage different types of diseases and conditions with contrasting complexities in terms of the determination of a specific COD. Educational intervention and queries should target specialties with a high frequency of improper COD statements.

Contributors T.C., F.L. and T.L. researched the data and wrote the manuscript. S.L. reviewed/edited the manuscript and contributed to the discussion.

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Competing interests None declared.

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Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

REFERENCES

1. World Health Organization. *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision. Volume 2 Instruction Manual the Second Edition*. Geneva: World Health Organization; 2004. http://www.who.int/classifications/icd/ICD-10_2nd_ed_volume2.pdf accessed at September 8, 2010.

2. Leadbeatter S. Semantics of death certification. *J R Coll Phys London* 1986;20:129-32.

3. Zumwalt RE, Ritter MR. Incorrect death certification—an invitation to obfuscation. *Postgrad Med* 1987;81:245-54.

4. Jordan JM, Bass MJ. Errors in death certificate completion in a teaching hospital. *Clin Invest Med* 1993;16:249–55.

5. Peach HG, Brumley DJ. Death certification by physicians in non-metropolitan Victoria. *Aust Fam Phys* 1998;27:178–82.

6. Lu TH, Shou WY, Shih TP, et al. Factors associated with errors in death certificate completion: a national study in Taiwan. *J Clin Epidemiol* 2001;54:232–8.

7. Swift B, West K. Death certification: an audit of practice entering the 21st century. *J Clin Pathol* 2002;55:275–9.

8. Hanzlick R. Quality assurance review of death certificates: a pilot study. *Am J Forensic Med Pathol* 2005;26:63–5.

9. Pritt BS, Hardin NJ, Richmond JA, et al. Death certification errors at an academic

institution. *Arch Pathol Lab Med* 2005;129:1476–9.

10. Lu TH, Walker S, Johansson LA, et al. An international comparison study indicated physicians' habits in reporting diabetes in Part I of death certificate affected reported national diabetes mortality. *J Clin Epidemiol* 2005;58:1150–7.
11. Lu TH, Hsu PY, Bjorkenstam C, et al. Certifying diabetes-related cause-of-death: a comparison of inappropriate certification statements in Sweden, Taiwan and the USA. *Diabetologia* 2006;49:2878–81.
12. Burger EH, van der Merwe L, Volmink J. Errors in the completion of death notification form. *S Afr Med J* 2007;97:1077–81.
13. Katsakiori PF, Panagiotopoulou EC, Sakellaropoulos GC, et al. Errors in death certificates in a rural area of Greece. *Rural Remote Health* 2007;7:822.
14. Lu TH, Anderson RN, Kawachi I. Trends in frequency of reporting improper diabetes-related cause-of-death statements on death certificates, 1985 to 2005: an algorithm to identify incorrect causal sequences. *Am J Epidemiol* 2010;171:1069–78.
15. National Center for Health Statistics. *Instruction Manual Part 2c- ICD-10 ACME Decision Tables for Classifying Underlying Causes of Death, 2008*. Hyattsville, MD: National Center for Health Statistics; 2008. http://www.cdc.gov/nchs/data/dvs/2008Final2C.pdf, accessed at May 1, 2012.
16. Kircher T, Anderson RE. Cause of death: proper completion of the death certificate

JAMA 1987;258:349-52.

17. Hanzlick R. The Medical Cause of Death Manual: Instructions for Writing Cause of Death Statements for death due to natural causes. Northfield, IL: College of American Pathologists, 1994.

18. Aung E, Rao C, Walker S. Teaching cause-of-death certification: lessons from international experience. *Postgrad Med J* 2010;86:143–52.

19. Hoyert DL, Lima AR. Querying of death certificates in the United States. Public Health Rep 2005;120:288-93.

Table 1 Examples of five types of improper cause-of-death (COD) statements.

Proper: One correct causal sequence and one specific COD reported on the lowest used line		
Example 1	Example 2	Example 3
a. Esophageal varices bleeding	a. Coma	a. Uremia
b. Portal hypertension	b. Congestive heart failure	b. Hydronephrosis
c. Liver cirrhosis	c. Myocardial infarction	c. Retention of urine
d. Hepatitis B	d. Hypertension	d. Hypertrophy of prostate
Type 1: One correct causal sequence and only an unspecific COD reported		
Example 4	Example 5	Example 6
a. Hepatic failure	a. Sepsis	a. Respiratory failure
b. Liver tumor	b. Pneumonia	b. Aspiration pneumonia
c.	c. Stroke	c.
d.	d.	d.
Type 2: One correct causal sequence and one mechanism of death reported on the lowest used line		
Example 7	Example 8	Example 9
a. Sepsis	a. Gastric bleeding	a. Cerebral infarction
b. Acute myocardial infarction	b. Sepsis	b. Renal failure
c. Pneumonia	c.	c.
d.	d.	d.
Type 3: More than one correct causal sequence and a specific COD on the lowest used line		
Example 10	Example 11	Example 12
a. Arrhythmia	a. Heart failure	a. Sepsis
b. Diabetes, Hypertension	b. Lung and Bladder cancer	b. Pneumonia
c.	c.	c. GI bleeding
d.	d.	d. Liver cirrhosis, Diabetes
Type 4: Incorrect causal sequence and one specific COD reported on the lowest used line		
Example 13	Example 14	Example 15
a. Renal failure	a. Respiratory failure	a. Pneumonia
b. Obstructive lung disease	b. Lung cancer	b. Pulmonary tuberculosis
c. Ischemic heart disease	c. Diabetes mellitus	c. Liver cancer
d.	d.	d. Prostate cancer
Type 5: Only mechanisms of death reported		
Example 16	Example 17	Example 18
a. Cardiopulmonary failure	a. Sepsis	a. Arrhythmia
b. Renal failure	b. Pneumonia	b. Acidosis
c. Bacteriemia	c.	c.
d.	d.	d.

Table 2 Frequencies of the five types of improper cause-of-death (COD) statements among death certificates issued in two medical centers in Tainan, Taiwan, 2009.

	No.	%	(%)
Total death certificates	2520	100.0	
Proper COD statements	1741	69.1	
Improper COD statements	799	30.9	(100.0)
Type 1: One correct causal sequence and only an unspecific COD reported	211	8.4	(27.1)
Type 2: One correct causal sequence and one mechanism of death reported on the lowest used line	145	5.8	(18.6)
Type 3: More than one correct causal sequence and a specific COD on the lowest used line	36	1.4	(4.6)
Type 4: Incorrect causal sequence and one specific COD reported on the lowest used line	46	1.8	(5.9)
Type 5: Only mechanisms of death reported	341	13.5	(43.8)

Table 3 Improper* and major error† rates in cause-of-death statements by specialty of the certifying physician in two medical centers in Tainan, Taiwan, 2009.

Specialty of certifying physician	No. of death certificates issued	Improper rate		Major error rate	
		No.	%	No.	%
Infection	65	45	69.2	23	35.4
Respiratory medicine	115	77	67.0	56	48.7
Nephrology	45	29	64.4	19	42.2
Orthopedics	10	6	60.0	4	40.0
Obstetrics & gynecology	11	6	54.5	6	54.5
Emergency	123	62	50.4	42	34.1
Critical care medicine	433	200	46.2	133	30.7
Cardiology	125	57	45.6	43	34.4
Urology	11	5	45.5	3	27.3
Pediatrics	56	23	41.1	16	28.6
Other internal medicine	64	25	39.1	14	21.9
Neurosurgery	52	20	38.5	13	25.0
Gastroenterology	157	59	37.6	39	24.8
Neurology	44	16	36.4	9	20.5
General surgery	161	51	31.7	24	14.9
Others	19	5	26.3	4	21.1
Cardiac surgery	34	6	17.6	4	11.8
Oncology	995	87	8.7	34	3.4
Total	2520	779	30.9	486	19.3

* Improper denotes a death certificate containing at least one type of improper COD statement.

† Major error refers to death certificates that sustain type 2 and type 5 improper COD statements, in which the mechanism of death would be selected for mortality tabulation.

Figure 1 International form of medical certificate of cause of death recommended by the World Health Organization.

Cause of death		Approximate interval between onset and death
I Disease or condition directly leading to death *)	a).....	.....
	due to (or as a consequence of)	
Antecedent causes Morbid conditions, if any, giving rise to the above cause, stating the underlying condition last	b).....	.....
	due to (or as a consequence of)	
	c).....	.....
	due to (or as a consequence of)	
	d).....	.....
II Other significant conditions contributing to the death, but not related to the disease or conditions causing it	.....	.....
	.....	.....
**This does not mean the mode of dying, e.g. heart failure, respiratory failure. It means the disease, injury, or complication that caused death.*		

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	No missing data
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	No sampling
		(*e*) Describe any sensitivity analyses	No
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	No follow-up
		(b) Give reasons for non-participation at each stage	No non-participation
		(c) Consider use of a flow diagram	No flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	No missing data
Outcome data	15*	Report numbers of outcome events or summary measures	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	No adjusted estimate
		(*b*) Report category boundaries when continuous variables were categorized	No
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	No RR
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	No
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Improper cause-of-death statements by specialty of certifying physician: a cross-sectional study in two medical centers in Taiwan

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Improper cause-of-death statements by specialty of certifying physician: a cross-sectional study in two medical centers in Taiwan

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ABSTRACT

Objective: To determine the frequency of various types of improper cause-of-death (COD) statements reported on death certificates and whether the frequency differed by specialty of the certifying physician.

Design: Cross-sectional descriptive study.

Setting: Two medical centers in Tainan, Taiwan.

Participants: A total of 2,520 death certificates issued by 230 physicians.

Main outcome measures: Four types of improper COD statements based on the criteria of correctness of the COD causal sequence and the level of specificity of underlying COD selected.

Results: Of 2520 death certificates analyzed, 502 (19.9%) had at least one type of improper COD statement. However, only 235 (9.3%) sustained major errors, i.e., 91 (3.6%) reported incorrect causal sequence and 144 (5.7%) reported only mechanism(s) of death (such as respiratory failure, heart failure, sepsis, and acidosis, etc.). The improper reporting rate was highest among nephrologists (53%, 24/45), followed by infectious diseases physicians (45%, 29/65) and was lowest among oncologists (6%, 57/995).

Conclusions: About one-fifth issued death certificates sustained improper COD statements and only one-tenth had noteworthy errors that would threaten the quality of COD statistics. The frequency varied by specialty of the certifying physician, because physicians in different specialties manage different types of diseases and conditions with contrasting complexities in terms of determining the causal sequence and specificity of COD statements.

Article focus

- What's the frequency of various types of improper cause-of-death (COD) statements reported by certifying physician in medical center?
- Do the frequencies of improper COD statements differ by specialty of the certifying physician?

Key messages

- One-fifth of issued death certificates sustained at least one type of improper COD statements.
- However, only one-tenth had noteworthy errors that would threaten the quality of COD statistics.
- The improper reporting rate varied by specialty of certifying physician and was highest among nephrologists and infectious diseases physicians and lowest among oncologists.

Strengths and limitations

- Compared with previous similar hospital-based studies, this study has the largest sample size, which allowed us to stratify the improper rate by sub-specialties.
- The case mix and physicians' certification behaviors in the studied hospitals might differ from other hospitals.

INTRODUCTION

Recording cause-of-death (COD) statements on the death certificate is a common practice of medical physicians. Good quality COD statement is prerequisite for good quality COD statistics. Good quality COD statistics are cornerstones for good quality health policy making and medical researches. The tabulation of COD statistics are based on the underlying COD, which has been defined as (a) the disease or injury that initiated the train of morbid events leading directly to death, or (b) the circumstances of the accident or violence which produced the fatal injury.[1, p.23] This definition is from the standpoint of prevention of death; it is necessary to break the chain of events or to effect a cure at some point, and the most effective public objective is to prevent the precipitating cause from operating.

To facilitate the selection of the underlying COD when two or more COD are recorded, an international standard form of death certificate (Figure 1) has been designed and recommended by the World Health Organization.[1, p.23, 24] Part I of the form is for diseases related to the train of events leading directly to death, and Part II is for unrelated but contributory conditions. It is the responsibility of the medical practitioner signing the death certificate to indicate which morbid conditions led directly to death and to state any antecedent conditions giving rise to this cause.

However, on some occasions, certifying physicians might not report correct causal sequence between diseases or conditions on line a, b, c, or d (please see example 10-12 in

Table 1), the Selection Rules set by the World Health Organization should be used to standardize the process in selection of the underlying COD.[1, p.25-36] Sometimes, the selected underlying COD might not the real intent underlying COD of certifying physician and the derived COS statistics might be biased. Furthermore, if certifying physicians do not provide specific information on the death certificate it is difficult to provide useful information for the prevention of death.

Different classification schemes were used in previous studies to identify different types of improper COD statements (Appendix 1).[2-14] Reporting incorrect COD causal sequence and reporting only mechanism(s) of death are two major errors indicated in every study. Despite many studies demonstrating various types of improper COD statements on death certificates, very few studies have examined the frequency of improper COD statements by specialty of the certifying physician. Information on which specialties have a higher percentage of recording improper COD statements could help to target physicians with a high priority for education and training in how to properly complete COD statements. There were two objectives in this study: 1) to determine the frequencies of various types of improper COD statements on death certificates reported by certifying physicians in two medical centers in Tainan, Taiwan; and 2) to examine whether the frequency of improper reporting differed by specialty of the certifying physician.

METHODS

Setting and data source

This descriptive cross-sectional study was conducted in Tainan, a major city located in southern Taiwan with a population of 1.87 million. There are only two medical centers in Tainan. In 2009, there were 1150 beds in Chi-Mei Medical Center and 1100 beds in National Cheng Kung University Hospital. We retrospectively reviewed all death certificates issued from January 1, 2009 to December 31, 2009 in these two medical centers.

Determination of improper COD statements

We used two criteria—correctness of the COD causal sequence and level of specificity—to define four types of improper COD statements. Examples of proper and four types of improper COD statements are illustrated in Table 1. Determination of the correctness of the COD causal sequence is according to *Decision Table D* in the *Instruction Manual Part 2c* compiled by the US National Center for Health Statistics, which includes all acceptable causal sequences between diseases or morbid conditions.[15]

Level of specificity was classified as specific COD, unspecific COD and mechanism of death. Specific COD is defined as providing specific information on the etiology and body region, such as lung cancer, esophageal varices bleeding, hepatitis B infection, cerebrovascular infarction, etc. Unspecific COD denotes those providing unspecific information on etiology (stroke without specifying whether it is due to infraction or

hemorrhage; tumor without specifying whether is benign or malignant; aspiration pneumonia without specifying whether it is milk or water or other foods) or on body region (gastrointestinal bleeding without specifying whether the bleeding occurred in the esophagus, stomach, intestine or colon). Mechanism of death is defined as a physiologic derangement or a biochemical disturbance produced by a COD, such as congestive heart failure, respiratory failure, various arrhythmias, bacteriemia, sepsis, acidosis etc. The mechanism of death does not provide etiology-specific information and therefore should not be the underlying COD.[16,17]

Proper COD statements include one correct causal sequence and one specific COD reported on the lowest used line (examples 1–3 in Table 1). Type 1 improper COD statements comprise one correct causal sequence and one unspecific COD reported on the lowest used line (examples 4–6 in Table 1). Liver tumor (example 4 in Table 1) without specifying whether malignant or benign and stroke (example 5 in Table 1) without specifying whether it was infarction or hemorrhage. We also included cases in which mechanisms of death (e.g., renal failure, sepsis, heart failure) were reported on the line below some specific COD (e.g., cerebral infarction or acute myocardial infarction) in type 1 improper COD statements (example 6 in Table 1). For example, the true causal sequence might be cerebral infarction resulted in renal failure in example 6 in Table 1; however, the reported causal sequence (renal failure resulted in cerebral infarction) is also acceptable according to *Decision Table D* in the

Instruction Manual Part 2c.[15] Therefore, the underlying COD selected would be the mechanism of death (i.e., renal failure in example 6). In this situation, renal failure was less specific than cerebral infarction and were less useful from the point of view of disease prevention.

Type 3 improper COD statements contain two or more correct causal sequences (examples 10–12 in Table 1). In other words, there were more than one diseases or conditions reported on one line. According to the Selection Rules, the first-mentioned COD will be selected as the underlying COD, i.e., diabetes in example 10, lung cancer in example 11 and sepsis in example 12. However, the intended underlying COD of the certifying physician might not be the first-mentioned COD.

Type 3 improper COD statements comprise one incorrect causal sequence reported (examples 13–15 in Table 1). There were some specific COD (ischemic heart disease in example 13, diabetes mellitus in example 14 and prostate cancer in example 15) incorrectly reported on the line below another specific COD (obstructive lung disease in example 13, lung cancer in example 14 and liver cancer in example 15). Because the specific COD on the lower line could not result in the specific COD on the upper line, therefore the specific COD on the upper line will be selected as the underlying COD according to the Selection Rules. However, the intended underlying COD of the certifying physician might be the specific COD on the lower line.

Type 4 improper COD statements involve only mechanism(s) of death being reported (examples 16–18 in Table 1). This is the most serious error because mechanism of death could not provide etiology-specific information for disease prevention.

Authors TJC and THL reviewed all the death certificates to determine whether the COD statement was acceptable or sustained one of the five types of error. TJC is a senior neurologist and THL is a senior family physician and both are in charge of teaching in how to correctly report COD statements on the death certificate for residents in the two medical centers.

Data analysis

We first calculated the frequencies of the four types of improper COD statements among the death certificates analyzed. We then computed the improper rate (containing at least one type of improper COD statement) and the major error rate (type 3 and type 4 improper COD statements combined) by specialty of the certifying physician. We classified 19 sub-specialties in this study.

RESULTS

In 2009, a total of 2,520 death certificates were issued by 230 physicians in two medical centers in Tainan, Taiwan. There were 502 death certificates that sustained at least one type of improper COD statement, with an overall improper statement rate of 20% (502/2520). However, only one-tenth (235/2520) had major errors, i.e., 91 (3.6%) reported incorrect causal sequence and 144 (5.7%) reported only mechanism(s) of death (Table 2).

The improper rate varied greatly by specialty of the certifying physician, ranging from 53% (24/45) among nephrologists and 45% (29/65) among infectious diseases physicians to 6% (57/995) among oncologists (Table 3). Major errors (type 3 and type 4 combined) were highest among nephrologists (27%, 12/45), followed by cardiologists (25%, 31/125).

DISCUSSION

Main findings

The findings of this study indicate that about one-fifth of death certificates sustained at least one type of improper COD statement. However, only one-tenth had major errors that would have noteworthy threat on the quality of COD statistics. The improper rate varied by specialty of the certifying physician and was highest among nephrologists and infectious diseases physicians and lowest among oncologists.

Interpretations in relation to previous studies

Previous studies have presented different distributions of various types of improper COD statements. The most common error was found to be the reporting of an unspecific COD in four studies,[5–7,9] the reporting of an incorrect COD causal sequence in two studies,[4,12] and the reporting of mechanism(s) of death only in one study.[13] One of the explanations of the above-mentioned variations is the differences in case-mix encountered in different medical settings. Another explanation is that certifying physicians in different medical settings have different COD certification behavior patterns.

Consistent with previous Taiwanese study, unspecific COD statements was the most common improper COD statement.[6] The major error rate was 9% in this hospital-based study, which was similar with previous national study in Taiwan (11%). One possible explanation of lower major error rate in this study was that there were more patients with cancer in two

medical centers in this study, in which the determination of underlying COD was more straightforward.

Despite many studies having examined improper COD statements, few have assessed the improper rate by specialty of the certifying physician. One Canadian study indicated that the overall and major error rates were 61% and 40% in medicine, 65% and 35% in surgery, 50% and 17% in oncology, 27% and 15% in family medicine, 38% and 30% in pediatrics, and 56% and 22% in the critical care trauma unit.[4] Unfortunately, because of the small sample size, they did not further analyze the error rates by sub-specialties. Consistent with the results of that study, the oncologists in this study had the lowest major error rate. Nevertheless, very few family physicians issue death certificates in medical centers in Taiwan.

Physicians of different specialties manage different types of diseases and conditions with contrasting complexities in terms of the determination of the underlying COD. For example, most patients treated by oncologists have cancer, and the determination of the underlying COD is comparably straightforward. Oncologists, who issued largest amount of death certificates; nevertheless, had the lowest improper rate (9% in this study) compared with their counterparts specialists. On the contrary, physicians in department of nephrology, infectious diseases, critical care, cardiology and respiratory medicine work mostly with patients with diseases or conditions lacking a specific etiology, such as renal failure, sepsis, heart failure, respiratory failure or and thus sustained a higher error rate in the COD statements.

As indicated by Kircher and Anderson,[16] most physicians tend to confuse cause and mechanism because medical therapy often attempts to modify or ameliorate mechanisms rather than causes. For example, digoxin is often highly effective in ameliorating the symptoms of congestive heart failure (mechanism) but does nothing to modify the underlying coronary artery disease (cause). It is rather difficult for physicians of infectious diseases, respiratory medicine or nephrology to specify the etiological causes of sepsis, respiratory failure and renal failure.

There were some debates on whether to define pneumonia as a specific COD (see example 3 in Table 1). Ideally, the certifying physician should specify whether the pneumonia was due to which type of virus, bacteria or other etiologies. However, in reality, it was very difficult to get relevant information. Furthermore, pneumonia is a common final pathway to death, which in most occasions was not suitable as the underlying COD. According to *Decision Table D* in the *Instruction Manual Part 2c*, all diseases or conditions could result in pneumonia, similar to other mechanisms of death (such as sepsis, respiratory failure, acidosis, etc.).[15]

In the revision of International Selection Rule 3 in the *Second Edition of the Instruction Manual of the International Classification of Diseases, Tenth Revision* (ICD-10) set by the World Health Organization, which denotes that "any pneumonia in ICD-10 code J12-J18 should be considered an obvious consequence of conditions that impair the immune system.

Pneumonia in ICD-10 code J18.0 and J18.2-J18.9 should be considered an obvious consequence of wasting diseases (such as malignant neoplasm and malnutrition) and diseases causing paralysis (such as cerebral hemorrhage or thrombosis), as well as serious respiratory conditions, communicable diseases and serious injuries. Pneumonia in ICD-10 code J18.0 and J18.2-J18.9, J69.0 and J69.8 should also be considered an obvious consequence of conditions that affect the process of swallowing".[1, p29]

Implications of this study

As there were one-tenth of death certificates analyzed had major errors, i.e., reported incorrect causal sequence and only mechanism(s) of death. Further studies are needed to retrospectively review the medical records for those death certificates to identify the real underlying COD and to estimate the possible effects on the estimation of cause-specific mortality rates.

With regards to intervention, a review study of educational interventions targeted at improving the quality of COD certification suggested that printed educational material alone is the intervention with the least educational impact and interactive workshops are the most effective intervention.[18]

Another way to improve the quality of COD statistics is to query the certifier who reported vague or incomplete information on the death certificate for clarification. A study in the US suggested that fifty-one of the 52 registration areas queried either demographic or COD information, and almost 90% of queries were returned. The underlying COD changed in

approximately 68% of these cases.[19] The Bureau of Health of Tainan city could query death certificates in which only the mechanism of death is reported to obtain more specific information to improve the quality of COD statistics.

Strengths and limitations

Compared with previous similar hospital-based studies, this study has the largest sample size, which allowed us to stratify the improper rates by sub-specialties. This study used very detailed classification of types of improper COD statements, which could provide very practical information for the design of materials for medical education.

One of the limitations of this study was that we analyzed only the death certificates issued in two medical centers, and the case mix and physicians' certification behaviors in the two medical centers studied might differ from those in other hospitals. Another limitation was that we were unable to differentiate whether COD statements were reported by junior residents or senior attending physicians, because of the co-signature system used in the two medical centers studied. The four types of improper COD statements were by no means complete, but were by far the most complete classification as compared with previous studies.

Conclusion

In conclusion, about one-fifth of death certificates sustained at least one type of improper COD statement. However, only one-tenth had major errors that would have noteworthy threat on the quality of COD statistics. The frequencies of improper COD statements varied greatly

by specialty of the certifying physician because physicians with different specialties manage different types of diseases and conditions with contrasting complexities in terms of the determination of a specific COD. Educational intervention and queries should target specialties with a high frequency of improper COD statements.

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REFERENCES

1. World Health Organization. *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision. Volume 2 Instruction Manual the Second Edition*. Geneva: World Health Organization; 2004. http://www.who.int/classifications/icd/ICD-10_2nd_ed_volume2.pdf accessed at September 8, 2010.

2. Leadbeatter S. Semantics of death certification. *J R Coll Phys London* 1986;20:129-32.

3. Zumwalt RE, Ritter MR. Incorrect death certification—an invitation to obfuscation. *Postgrad Med* 1987;81:245-54.

4. Jordan JM, Bass MJ. Errors in death certificate completion in a teaching hospital. *Clin Invest Med* 1993;16:249–55.

5. Peach HG, Brumley DJ. Death certification by physicians in non-metropolitan Victoria. *Aust Fam Phys* 1998;27:178–82.

6. Lu TH, Shou WY, Shih TP, et al. Factors associated with errors in death certificate completion: a national study in Taiwan. *J Clin Epidemiol* 2001;54:232–8.

7. Swift B, West K. Death certification: an audit of practice entering the 21st century. *J Clin Pathol* 2002;55:275–9.

8. Hanzlick R. Quality assurance review of death certificates: a pilot study. *Am J Forensic Med Pathol* 2005;26:63–5.

9. Pritt BS, Hardin NJ, Richmond JA, et al. Death certification errors at an academic

institution. *Arch Pathol Lab Med* 2005;129:1476–9.

10. Lu TH, Walker S, Johansson LA, et al. An international comparison study indicated physicians' habits in reporting diabetes in Part I of death certificate affected reported national diabetes mortality. *J Clin Epidemiol* 2005;58:1150–7.
11. Lu TH, Hsu PY, Bjorkenstam C, et al. Certifying diabetes-related cause-of-death: a comparison of inappropriate certification statements in Sweden, Taiwan and the USA. *Diabetologia* 2006;49:2878–81.
12. Burger EH, van der Merwe L, Volmink J. Errors in the completion of death notification form. *S Afr Med J* 2007;97:1077–81.
13. Katsakiori PF, Panagiotopoulou EC, Sakellaropoulos GC, et al. Errors in death certificates in a rural area of Greece. *Rural Remote Health* 2007;7:822.
14. Lu TH, Anderson RN, Kawachi I. Trends in frequency of reporting improper diabetes-related cause-of-death statements on death certificates, 1985 to 2005: an algorithm to identify incorrect causal sequences. *Am J Epidemiol* 2010;171:1069–78.
15. National Center for Health Statistics. *Instruction Manual Part 2c- ICD-10 ACME Decision Tables for Classifying Underlying Causes of Death, 2008*. Hyattsville, MD: National Center for Health Statistics; 2008. http://www.cdc.gov/nchs/data/dvs/2008Final2C.pdf, accessed at May 1, 2012.
16. Kircher T, Anderson RE. Cause of death: proper completion of the death certificate

JAMA 1987;258:349-52.

17. Hanzlick R. The Medical Cause of Death Manual: Instructions for Writing Cause of Death Statements for death due to natural causes. Northfield, IL: College of American Pathologists, 1994.

18. Aung E, Rao C, Walker S. Teaching cause-of-death certification: lessons from international experience. *Postgrad Med J* 2010;86:143–52.

19. Hoyert DL, Lima AR. Querying of death certificates in the United States. Public Health Rep 2005;120:288-93.

Table 1 Examples of four types of improper cause-of-death (COD) statements.

Proper: One correct causal sequence and one specific COD reported on the lowest used line		
Example 1	Example 2	Example 3
a. Esophageal varices bleeding	a. Coma	a. Respiratory failure
b. Portal hypertension	b. Congestive heart failure	b. Pneumonia
c. Liver cirrhosis	c. Myocardial infarction	c.
d. Hepatitis B	d. Hypertension	d.
Type 1: One correct causal sequence and one unspecific COD reported on the lowest used line		
Example 4	Example 5	Example 6
a. Hepatic failure	a. Sepsis	a. Cerebral infarction
b. Liver tumor	b. Aspiration pneumonia	b. Renal failure
c.	c. Stroke	c.
d.	d.	d.
Type 2: Two or more correct causal sequences reported		
Example 10	Example 11	Example 12
a. Arrhythmia, Heart failure	a. Respiratory failure	a. Gastric bleeding
b. Diabetes, Hypertension	b. Aspiration pneumonia	b. Sepsis, Liver cirrhosis
c.	c. Lung and Bladder cancer	c.
d.	d.	d.
Type 3: Incorrect causal sequence reported		
Example 13	Example 14	Example 15
a. Renal failure	a. Respiratory failure	a. Pneumonia
b. Obstructive lung disease	b. Lung cancer	b. Pulmonary tuberculosis
c. Ischemic heart disease	c. Diabetes mellitus	c. Liver cancer
d.	d.	d. Prostate cancer
Type 4: Only mechanism(s) of death reported		
Example 16	Example 17	Example 18
a. Cardiopulmonary failure	a. Septic shock	a. Arrhythmia
b. Renal failure	b.	b. Acidosis
c. Bacteriemia	c.	c.
d.	d.	d.

Table 2 Frequencies of the five types of improper cause-of-death (COD) statements among death certificates issued in two medical centers in Tainan, Taiwan, 2009.

	No.	%	(%)
Total death certificates	2520	100.0	
Proper COD statements	2018	80.1	
Improper COD statements	502	19.9	(100.0)
Type 1: One correct causal sequence and one unspecific COD reported on the lowest used line	210	8.3	(41.8)
Type 2: Two or more correct causal sequences reported	57	2.3	(11.4)
Type 3: Incorrect causal sequence reported	91	3.6	(18.1)
Type 4: Only mechanism(s) of death reported	144	5.7	(28.7)

Table 3 Improper* and major error† rates in cause-of-death statements by specialty of the certifying physician in two medical centers in Tainan, Taiwan, 2009.

Specialty of certifying physician	No. of death certificates issued	Improper		Major error	
		No.	%	No.	%
Nephrology	45	24	53.3	12	26.7
Infection	65	29	44.6	8	12.3
Cardiology	125	49	39.2	31	24.8
Emergency	125	42	33.6	22	17.6
Others	51	16	31.4	11	21.6
Neurology	44	13	29.5	6	13.6
Other internal medicine	62	18	29.0	7	11.3
Neurosurgery	52	15	28.8	0	0.0
Pediatrics	56	16	28.6	9	16.1
Critical care medicine	433	118	27.3	54	12.5
Gastroenterology	157	42	26.8	22	14.0
General surgery	161	41	25.5	16	9.9
Respiratory medicine	115	18	15.7	6	5.2
Cardiac surgery	34	4	11.8	2	5.9
Oncology	995	57	5.7	29	2.9
Total	2520	502	19.9	235	9.3

* Improper denotes a death certificate containing at least one type of improper COD statement.

† Major error refers to death certificates that sustain type 3 “incorrect causal sequence was reported” and type 4 “only mechanism(s) of death reported” improper COD statements.

Appendix 1: Types of improper cause-of-death statements used by previous studies

Leadbeatter (1986)

1. No cause given
2. Multiple causes given—sequence not clear
3. Single cause given—relevant detail absent
4. Single cause given—error in layout

Zumwalt & Ritter (1987)

1. Only mechanism(s) of death listed in part I
2. Information in part I reversed
3. Only cardiac arrest listed
4. Cause of death listed in part II instead of part I
5. Complications of cause of death listed in part II
6. Inappropriate material included

Weermanthri & Beresford (1992)

1. Mechanism only
2. Reversed logical sequence
3. Illogical sequence
4. Web
5. Underlying cause in part II

Jordan & Bass (1993)

1. Mechanisms without explanation
2. Sequencing errors
3. 2 causes of death
4. No time interval recorded
5. Inappropriate information recorded

Armour & Bharucha (1997)

1. Mode of dying
2. Poor terminology
3. Clinical term or symptom
4. Sequence error
5. Non-existent terminology

Myers & Farquhar (1998)

1. Mechanism only

2. Improper sequencing
3. Competing causes

Lu et al. (2001)

1. Only mechanism(s) of death given
2. Multiple causal sequences given in pat I
3. Single causal sequence given but not specific enough
4. Single causal sequence given but the order was incorrect

Katsakiori et al. (2007)

1. The mechanism but not the cause of death is given
2. Multiple causal statements are given
3. A single but non-precise cause is given
4. A single causal sequence with incorrect order is given

Figure 1 International form of medical certificate of cause of death recommended by the World Health Organization.

Cause of death		Approximate interval between onset and death
I Disease or condition directly leading to death *)	a).....	.....
	due to (or as a consequence of)	
Antecedent causes Morbid conditions, if any, giving rise to the above cause, stating the underlying condition last	b).....	.....
	due to (or as a consequence of)	
	c).....	.....
	due to (or as a consequence of)	
	d).....	.....
II Other significant conditions contributing to the death, but not related to the disease or conditions causing it	.....	.....
	.....	.....
**This does not mean the mode of dying, e.g. heart failure, respiratory failure. It means the disease, injury, or complication that caused death.*		